Tackling Food Insecurity, Air Pollution, Water Insecurity and Associated Health Risks in South Asia

A FUTURE EARTH WORKING DOCUMENT

September 2020

Contributors

A Working Document prepared by:

Report Leads: Smriti Basnett and Anupama Nair

Food Security Group (Part A)

Leads: S. Ayyappan[1], R. Mattoo[2]

P. Choephyel[3], A. Menon[4], A. Nair[2], S. Ram[5], B. Sharma[6], Tshetrim La[7]

Air Pollution and Clean Energy Group (Part B)

Leads: P. Banerjee[2], T. S. Gopi Rethinaraj[2]

Y. A. Adithya Kaushik[2], A. Ajay[2], N. Anand[2,8], K. Budhavant[9], M. R. Manoj[2], H. S. Pathak[2], M.L. Thashwin[2], S. Chakravarty[2]

Water Security Group (Part C)

Lead: R. Srinivasan[10]

R. Prakash[10], S. Bharadwaj[10], K. Madhyastha[10], A. S. Patil[10], S. A. Pandit[10], D. Salim, L. Mathew[10]

Health Sensitization Group (Part D)

Leads: H. Paramesh[10], C. S. Shetty[11]

S. Bharadwaj[2], S. Ranganathan[2], V. Venugopalan[2], P. Sarji[12], R. C. Paramesh[13], Shashikantha S. K.[11]

[1]Central Agricultural University, Imphal
[2]Divecha Centre for Climate Change, Indian Institute of Science
[3] Royal Society for Protection of Nature (RSPN) of Bhutan
[4]K R Puram Constituency Association Welfare Federation
[5]Centre for Crop Development and Agro-biodiversity Conservation, Department of Agriculture, Nepal
[6]Department of Environment, Chandigarh Administration
[7]Department of Agriculture, MoAF,Thimphu
[8]Centre for Atmospheric and Oceanic Sciences, Indian Institute of Science
[9]Climate Observatory-Hanimaadhoo, Maldives Meteorological Services, Maldives
[10]Water Solutions Lab, Divecha Centre for Climate Change, Indian Institute of Science
[11]Adichunchanagiri University
[12]Institute of Public Health and Centre for Disease Control, Rajiv Gandhi University of Health Sciences
[13]Ambedkar Medical College
[14] Future Earth South Asia, Divecha Centre for Climate Change (DCCC), IISc

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1. Food Security in Bangladesh: Challenges, Critical Areas of Intervention for Achieving Sustainable Development Goals

SUMMARY

Current challenges and critical areas of intervention to achieve SDG goals in light of the global pandemic are examined in this report in the context of Bangladesh being one of the most vulnerable countries exposed to extreme climate events and natural disasters. Bangladesh faces a nexus of cascading issues connected to water security (salinity intrusion, tidal bore, river bank erosion, stock depletion, availability of fresh water for irrigation and drinking, crop resilience) that will intricately affect food security, of which Bangladesh has one of the best in South Asia. Even so with the recent pandemic, mass migration of both coastal communities as well as external refugees increase existing stresses exponentially to which the Bangladesh government has been proactively engaging.

Furthermore, the complex nexus of frequent disasters has over time changed long-term production and consumption patterns as more people move towards cities such as Dhaka. Bangladesh currently houses the world's largest refugee camps, providing aid to more than 800,000 refugees as well as approximately 200,000 migrants from coastal Bangladesh. The stresses are especially seen in the complex negotiations of agricultural adaptation in the coastal regions where salinity intrusion and tidal boor make the land unsuitable for rice cultivation. Even with variants of rice that are resilient to salt content, it is seen that the maximum resilience is less than 10 percent of the salt content and sea water. The Global Climate Risk Index ranks Bangladesh seventh for countries where more than 90 percent of the losses were deaths occurred in one year or event, noting that "a special burden also lies in the poor and vulnerable due to unevenly distributed access to proper health care". South Asia hotspots, a World Bank report, identifies reduced living standards in Bangladesh by 2050 due to precipitation and temperature variation on severe hotspots including low lying areas facing flood -related damage, whereas a focus on enhancing opportunities in the non-agricultural sector could see the benefits increased living standards and attenuate the effect of weather changes significantly.

Under the leadership of a very efficient administration, the government of Bangladesh has driven a people-centred development approach and fulfilled sufficient criteria for graduation to a developing country status by March 2018 (announced by the committee for development policy a United Nations panel)--Bangladesh would be transitioning from the list of least developed countries characterised by low income levels and severe limitations to achieving sustainable development goals to a lower middle-income country in 2015 and its final graduation in 2024--a significant impetus towards achieving multiple SDGs.

The agricultural sector (including new and developing aquaculture practices) in Bangladesh requires close attention especially the coastal fisheries industry producing hilsa (fourth largest export of Bangladesh, 12 percent of the total fish production worth US$ 4 billion and constituting 6 percent of inland catch and 44 percent of marine catch employing 0.5 million fishermen and 2.5 million other workers in the value chain). Hilsa, a unique migratory fish that spawns and migrate from the sea to freshwater rivers form the fourth largest export in Bangladesh in and the largest production in Bangladesh amounting to 517,000 tons per year

employing 7 percent of the population directly and contributing to 22.6 percent of the agricultural GDP and 3.69 percent to the total GDP of Bangladesh. The recent stock depletion of hilsa, combined with anthropogenic pollutants, river erosion and silt deposition at river mouth ways, both natural and anthropogenic blockages in inland waterways and rivers are various factors hampering spawning and migratory routes of hilsa. Most recently, the government of Bangladesh's ban on fishing hilsa especially during the ongoing pandemic created extreme stresses among the coastal communities and the fishermen leading to major gaps in access to food security. The coastal fishermen are often the poorest and most vulnerable to the per capita income that is 70 percent lower than the per capita income of the country as a whole.

The coastal regions face further stress from selling intrusion and tidal boor which is a critical water security issue since it affects freshwater access to entire regions both for drinking purposes as well as for irrigation. However, some adaptations in agriculture and shifting to aquaculture through the effective construction of silt and clay barriers termed polders have been and effective opportunity albeit potentially unsustainable in developing shrimp farming. Bangladesh has one of the highest densities of population versus land in the world (approximately 1240 per square kilometer) forming the eighth most populous country in the world with approximately 2.2 percent of the world's population standing at 164.7 comprising of 26.8 percent between the age groups of 0 to 14, 68 percent between the age groups of 15 to 64 and 5.2 percent aged 65 and above respectively.

Poverty has been a critical issue in Bangladesh and the severe limitation in achieving other sustainable development goals, furthermore since the early 2000's approximately 33 million people have been lifted out of poverty, where the poverty rate stood at 40.9 percent and extreme poverty rates stood at 34.3 percent in 2016 they fell to 24.3 percent and 12.9 percent respectively whereas the world extreme poverty rate remained at 13.8 percent the global Hunger Index score for Bangladesh is at 26.1 percent down from 36.0 percent in 2000 with 15.2 percent of the population still considered undernourished with insufficient access to dietary diversity and calories with varied micronutrient deficiencies at a widespread. Various schemes by the government of Bangladesh in the last decade seek to ensure dependable food security system for all people of the country at all times such as the National Food policy, the National nutrition policy, the National plan of action, even the National policy for women's advancement which by empowering women would directly promote and build nutrition security because of the positive association of women empowerment and control of income with food and nutrition.

During the times of COVID the government of Bangladesh has proactively engaged with multiple stakeholders and international organisations including the Food and agriculture organisation to regulate and monitor market prices on grocery items, build access for food security, distribute a wide range of food assistance kits, conditional Cash transfers as well as rehoming homeless and low-income families during the floods while the pandemic was ongoing, supports for the service sector, for the banking sector, for the agricultural sector facing the direct fallout of COVID 19 has seen the GDP stabilise whereas neighbouring countries are still witnessing the onslaught of the pandemic directly on economic activity. The government of Bangladesh effectively tackled 50 lakh poor families through mobile financial assistance programs with special support for coastal areas and fishermen. However with the current conditions of the pandemic with natural disasters and regular flooding as well as consistent onslaught of climate driven events pose massive stresses on water Security, Food Security, long-term health largely mitigated by the various emergency response systems and frameworks that the central, National, district, and local levels-however given the global slowdown the progress towards achieving SDG's could be easily slowed to a halt, even seeing a backward slide in the immediate future.

1.1 INTRODUCTION

The South Asia Region (comprising of India, Bangladesh, Bhutan, Myanmar, Nepal, Maldives, and Pakistan) is at the frontlines of an emerging, climate-driven crisis with massive socio-economic implications that directly impact more than 1/5th of the world's population, occupying little more than 3% of the world's landmass making this region densely populated and highly vulnerable. The World population to landmass per sq km is 59.636 [rounded to 60] (2018) whereas the population of South Asia per sq km is 380 ranking second in population is East Asia whereas the Pacific region is at 95 per sq km - India - 455 people per sq km; Bangladesh - 1240; Bhutan - 20; Myanmar - 82; Nepal - 196; Maldives – 1,719; Pakistan – 275[1,2]. South Asia finds relatively lower representation in the climate negotiations and discussions of on-going climate and impact negotiations in the top organisations of the world formulating climate policy, remaining one of the most underrepresented regions in climate-research and intervention in an area that remains the most vulnerable in the world. The region has multiple coordination and cooperation agencies, trade agreements, and 'collectives and bridges' that represent different nations in the South Asia and Southeast Asia Regions however very little can be achieved without bilateral, multilateral, and transboundary focused interventions. Climate events in particular are trans-boundary in nature and often trans-regional affecting a significant part of the area and population across different countries situated here. The economic outlook of South Asia remains "moderately favourable … [and] highly divergent across countries." Bangladesh, Bhutan and India show largely positive economic conditions and GDP growth is projected to remain robust in the near term, regional GDP is expected to expand by 5.4% in 2019 and 5.9% in 2020 after an estimated expansion of 5.6% in 2018.[3] A significant amount of data however are under review given the ongoing global pandemic.

The proportion of people living on less than $ 1.90 was estimated at 14.7% approximately 249 million people a third of the global poor. The current GDP of South Asia (in 2018) amounted to US$ 3.453 trillion, whereas the real GDP growth in South Asia varies between 1.8 (Afghanistan) to 7.9 (Bangladesh) and notes that about 800 million people in the region live in areas that are vulnerable to climate change impacts.[4,5]

In the period between 1999 to 2018 Bangladesh ranks 7th in the Global Climate Risk Index for countries where more than 90% of the losses or deaths occurred in one year or event. The CRI report ranks Bangladesh "ninth in fatalities among all countries analysed, 37 in fatalities per hundred thousand inhabitants, 17th in losses and 40th in losses per GDP unit" and arrives at the CRI score (1999 to 2018) at 30.00. The CRI report reiterates scientific predictions made by others over the last decade focusing on the interconnected nature and the complex nexus between major risks accentuated, often in a cascading fashion, by climate change noting "heat waves affect human health worldwide leading to increased morbidity and mortality…. A special burden also lies on the poor and vulnerable due to an evenly distributed access to proper health care".[6]

"Our Future on Earth"[7] identifies five main global risks among 30 that will be accelerating and cascading with overlapping effects that are likely to amplify one another and pose the greatest threat to human civilisation in the coming decades. The report conclusively maps these risks namely: the failure of climate change mitigation and adaptation, extreme weather events, major biodiversity loss and ecosystem collapse, food crises, and water crisis among other risks. The complexity of global interlinkages in climate issues can be highlighted in some of the extreme events of 2018 in our region, namely the floods in India and the dust storms covering the entire swaths of North India. Whereas the former has been attributed to excess rainfall, ecological mismanagement and neglect; the latter which is a typical feature of India's weather patterns was made extreme in scale and severity due to abnormally high temperatures in the region resulting in the higher than normal winds carrying debris and affecting structures; with wind speeds almost cyclonic in nature, evolving into thunderstorms with lashing rains. These events are emergent and dependent on a global cycle with more specific regional implications. In temperature ranges, 2014 to 2017 witnessed three severe heat waves and one severe cold wave effectively categorised as extreme; in terms of precipitation 2014 to 2017 witnessed unprecedented hailstorm, heavy rainfall and floods, thunderstorms, resulting in landslides and other incidents that have affected crops, livestock, animals and birds; the period also witnessed cyclonic storms some of which were categorised as very severe; all these severe events have affected different states in different quadrants of the nation regardless of state or national boundaries. Where international boundaries are concerned and since these events do not follow geographical demarcations such as borders and boundaries effectively making this crisis transboundary in nature.

Mani et al., notes "under the climate-sensitive scenario the number of people affected 375 million or 21% of the population … Mitigation efforts can minimise the effects of climate change … can positively affect living standards throughout the region … climate impacts vary from region to region, the hotspots provide for prioritising investments and actions to build resilience." Additionally, "economic implications of … Average weather for households and communities-and their possible thresholds or inflection point- are even less understood". There are emerging patterns and linkages between climate change and economic implications as demonstrated by Mani et al. in South Asia Hot Spots[8] analysing "how average temperature and precipitation-will affect living standards….Changes in average weather will have a clearly negative effect on living standards in Bangladesh, India, Pakistan, and Sri Lanka. In India and Pakistan water-stressed areas will be more adversely affected compared with the national average". The report further states that low-lying Bangladesh and the Maldives are increasingly vulnerable to flooding and cyclones and such events will grow in intensity in the coming decades with cities with over 50 million people-Dhaka, Karachi, Kolkata, and Mumbai-facing severe flood -related damage. The carbon intensive scenario[8] projects reduce living standards in Bangladesh by 6.7% and being a severe hotspot, negative impacts are predicted to be even greater when translated into GDP rendering into a 14.4% reduced income in severe hotspots in Bangladesh by 2050 (under the carbon-intensive scenario and probabilistically in the South East regions -refer figure) - further analysis in the report suggests that enhancing opportunities in the nonagricultural sector by 15% could attenuate the effect of weather changes of -6.7% to

-1.4% and 30% increase would reduce negative effects of changes in average weather while increasing living standards. Notably Bangladesh is one of the few countries in South Asia to tackle the crisis of climate change early on and implement the Bangladesh Climate Change Strategy and Action Plan deployed in 2009[9] and the intended nationally determined contribution deployed in 2015 as part of the pledge to contribute to global emissions reductions under the Paris Agreement.

Average monsoon precipitation in Bangladesh from 1981 through 2010 shows diverse precipitation patterns with portions of the region receiving as little as 100 MM of average annual precipitation and other regions receiving up to 5000 MM or more, the South Asian monsoon-states the report-occurs from June through September with temperatures being the highest pre-monsoon, bringing much of the water facilitating agricultural activities, most water sources are fully used especially in Bangladesh, Myanmar resulting in strong agricultural potential however exposed to a very high vulnerability to changes in access to water (due to lower than expected precipitation in Myanmar in early 2020, most dams will retain water sources for drinking purposes rather than agriculture in the summer of 2021 leading to an increased food security stresses following 2021.)[10] This region demonstrates a wide gap between average received precipitation with one area receiving minimal water and other swaths of the region receiving several catastrophic tropical storms and flooding of which Bangladesh is highly susceptible. As a riverine nation being close to the sea as well as being a delta nation that drains two of South Asia's three great rivers-the the Ganges River and the Brahmaputra River, Bangladesh is extremely prone to heavy natural disasters. Mapping extreme poverty across the region places in context the most vulnerable communities that will be affected by climate change, poorer communities tend to be more exposed to disasters and finds note in the Global Climate Risk Index which uses GDP and PPP with HDI 2018 and the death toll (among other metrics) to arrive at a risk ranking. Bangladesh ranks seventh on the Global Climate Risk Index 2020 and is one of the countries most affected by extreme weather events.[6,11]

The Doha Development Agenda of the WTO from 2001 has been focusing on better integration of trade and implementation of WTO agreements specific to addressing regional problems in developing countries.[12] Doha round in particular saw WTO members negotiating aspects of the link between trade and the environment including discussions on biodiversity, impact of trade policies on the environment, and impact of environmental policies on trade which eventually found mention in the environmental goods agreement. BRICS countries form 42% of the world's population contributing 22% to global GDP, 76.76% of the urban population of Internet subscribers as compared to 14.89% in rural areas, US$ 521.2 billion is India's external debt in December 2018, for every hundred people in India approximately 42% have access to Internet, and globally US$ 153 billion is the official development assistance in 2018 which is the highest ever recorded. Promoting regional integration and collaboration is integral to any mitigation strategy as South Asia remains one of the least economically integrated regions in the world. *A Glass Half Full: the promise of trade in South Asia* [13], notes how the SAARC Arbitration Council, a specialised body under SAARC, "resolves commercial, industrial, trade, banking, investment, and other disputes, but its effectiveness and credibility are yet to be established." The fragility of maintaining trust and credibility points to how SAFTA or the South Asian Free Trade Area is not as effective as it should be at regional integration which is an essential component of SDG 17[14] requires an ambitious and interconnected global development agenda driven by global/regional partnerships. Furthermore, most countries in South Asia import vegetables, fruits, and other food products from each other, interregional imports account for 12% of the total imports of such products by South Asian countries in 2015. Extreme climate change events will have a significant impact on food production, security and internal and regional trade.The South Asia region is divided into approximately four broad climate zones, the northern Indian edge and upper Pakistan have dry subtropical continental climate, the Himalayas have an alpine climate, the far south of India and South of Sri Lanka have on equatorial climate, and most of the peninsula have variations of tropical climate.[15] The International Union for Conservation of Nature (IUCN), a membership Union composed of both government and civil society organisations (1300 member organisations and more than 15,000 experts).[16] As per IUCN program 2017-2020: “South Asia has been considered as a region that requires greatest conservation need among IUCN’s eight Statutory Regions. South Asia is home to a number of protected areas; Transboundary Sacred and Biodiversity Landscapes and Seascapes; Biosphere Reserves; Key Biodiversity Areas (KBA); Wetlands in many shared landscapes and ecosystems. This region has many mega biodiversity hotspots and share several hydro-geological features … Mountain ranges of the Himalayas and Hindukush, Deccan Plateaus, Fertile Indo-Gangetic plain, coastal and marine islands.” [17]

In the areas of policy making, transboundary and international organisations have significant inputs aside from the IUCN; they are environmental governance mechanisms such as the United Nations General Assembly, and multilateral agreements such as the CBD, UNFCCC, UN Convention to combat desertification (UNCCD), the Convention on International Trade in Species of Wild Fauna and Flora (CITES), the Ramsar Convention on Wetlands. Collectively addressing and promoting the role of biodiversity, ecosystem services, gender equality, rights and governance, and environmental law for sustainable development outcomes. IPBES[18] report on biodiversity loss and ecosystem degradation has significant insight into the health and well-being of the entire region-the Asia-Pacific region which includes the South Asia sub-region. The entire region holds 17 of 36 global biodiversity hotspots, nearly 200 million people in the region directly depend on the forest for their non-timber forest products, medicine, food, fuel and other subsistence needs. 7.6% of average annual economic growth has been attributed to biodiversity and ecosystem services, as against a global average of 3.4%.[18] This rapid growth benefited more than 4.5 billion people (of the entire Asia-Pacific region, including South Asia sub-region). The region faces unprecedented threats from climate change induced extreme weather events and sea level rise, invasive alien species, agricultural intensification and increasing waste and pollution.

1.2. TRENDS IN FOOD PRODUCTION AND CONSUMPTION

Bangladesh, previously known as East Pakistan (between 1947 and 1971) and prior to that as East Bengal (before 1947) is one of the highest densities of population versus land in the world (approximately 1240 per square kilometre) forming the eighth most populous country in the world with approximately 2.2% of the world’s population standing at 164.7 comprising of 26.8% between the age groups of 0 to 14, 68% between the age groups of 15 to 64 and 5.2% aged 65 and above respectively[19,20]. However the Bangladesh Bureau of Statistics[21] reports a total population at 2017 at 162.7 million. By 2021 Bangladesh aspires to become a middle-income country and under the dynamic leadership of the Honourable Prime Minister Sheikh

Hasina has adopted a highly adaptable people-centred development approach and fulfilled various criteria's for graduation to a developing country by March 2018[22] announced by The Committee for Development Policy, a United Nations panel. The multi-faceted transition of Bangladesh from list of Least Developed Countries (LDCs)- a category established by the United Nations General Assembly (UNGA) characterized by low income levels and severe limitations to achieving sustainable development requiring special support measures – to a lower-middle-income country in 2015 and its final graduation from the LDC category in 2024 portends a significant impetus towards achieving multiple SDG's. It is notably only five countries that have graduated from this category since 1971 when the UNGA first instituted it[23].

1.2.a. Agriculture and Aquaculture

Bangladesh produces principal seasonal crops and fruits consisting of paddy, jute, wheat, tobacco, pulses, oilseeds, spices, vegetables, Jack-fruit, banana, mango, coconut whereas the principal industries consists of ready-made garment, textiles, chemical fertilisers, pharmaceuticals, T processing, paper and newsprint, cement, sugar, leather goods; principal minerals consist of natural gas, coal, line, white, and glass. However, rice, wheat, mango and jute the primary crops which due to Bangladesh's labour-intensive agriculture has achieved steady increases in grain production despite unfavourable weather conditions (including climatic extreme events and natural hazards). Bangladesh registered record food grain production in 2018 reaching approximately 41.5 million metric tons of food grains achieved particularly through development and adaptation of highly varieties of crop, modern management methodologies, and largely through government policy interventions over the past four decades. The Bangladesh Agricultural Research Institute (BARI) have collectively developed and wheat varieties, 64 tubers, 55 vegetables, 43 fruits, 22 species, 16 flower and seven oil crops-as of 2018.[24]

The food assistance fact sheet[25] effectively documents the extreme stresses on the Bangladesh food security networks, a massive influx of refugees in 2017 into Bangladesh has Cox Bazar district, one of the least developed areas in the country housing more than 34 refugee camps- some of the largest in the known world and exposed to recurring natural disasters such as floods and cyclones exacerbate food insecurity and malnutrition in many parts of Bangladesh reports the USAID as of March 12, 2020; the end of 2019 in Bangladesh witnessed a bumper production of rice that should have regulated prices across Bangladesh however early analysis in February demonstrates a shifting consumption pattern of rice in urban Dhaka households analysed by Dr Iqbal of the Bangladesh Institute of Development Studies examining consumption patterns of urban households and Dhaka estimated using The Household Income Expenditure Survey 2016. The study published early in 2020 is not yet documented the effects of COVID and consumption patterns however given median stresses it can be safely projected that the decrease in a consumer's purchasing power can be correlated to a substitution of cheaper food (substitution effect), Dr Iqbal continues "the results show that, on average, of the total food expenditure, the urban people of Dhaka spent the highest and fish (TK 445.5) consumption followed by rice (TK 388.7) and meet (TK 314.6).… Urban households spend 18.2%, 15.8% and 12.8% of their food budget on fish, rice, meat respectively"[26]. Some of the findings also show that the poorest spends 31% of the food budget on Rice whereas the richer spends 11.4% implying that low income households will be worse it from a rice price hike and the richer households will-according to the Trading Corporation of Bangladesh (TCB) shows a price rise of approximately TK 4.0 as well as TK 6.0, 2.0, 3.0 per KG increase in prices of medium and coarse rice. The fluctuations in price ranges were exacerbated during early stages of COVID.

The fisheries sector in Bangladesh contributes 3.69% to the GDP and 22.6% to the agricultural GDP (as of 2016) up to 7% of the population are engage directly in fisheries, aquaculture and associated activities forming an important contribution also to the diet as a major source of animal protein essential vitamins and other nutrients especially for the poorer groups[27]. Hilsa shad (*Tenualosa ilisha*, Clupeidae) forms the 4th largest export in Bangladesh between 2016 and 2017 and as a culturally important species in the Bay of Bengal and Persian Gulf region, Bangladesh contributes approximately 517,000 tons per year constituting the single largest fishery in Bangladesh, however stocks have been in decline since the 1990s leading the Bangladesh government to establish Hilsa Fishery Management Action Plan (HFMAP) which started its implementation from 2005 furthermore to improve production the Department of Fisheries (DoF) and WorldFish have jointly implemented “Enhanced Coastal Fisheries in Bangladesh – ECOFISH” which is a USAID supported project[28]. Hilsa with a unique migratory fish that migrates from the sea to freshwater rivers and estuaries for spawning but also frequently moves between fresh waters and marine waters for feeding and swimming, it is nutritionally high-protein (18%) and high-lipid (19.5%) and rich in essential micronutrients including phosphorus, calcium, zinc, vitamins a and E, polyunsaturated fatty acids and omega-3 fatty acid remaining the iconic flagship species contributing to approximately 12% of the total fish production worth approximately US $ 4 billion consisting of both England harvest and marine harvest (6% of Indian catch-44% of marine catch respectively) directly employing 0.5 million fissures and 2.5 million ancillary workers connected in its value chain, primarily driven by the small scale hilsa fisheries with the combination of The Hilsa Fishery Management Action Plan and later Eco-Fish there were increase focus on the establishment of sanctuaries to protect the juvenile of the species, protection of brewed in the spawning season, eradication of harmful practices, protection of routes, controlling overfishing, and providing food incentives (40 KG rice per fisher for seven months covering all the band periods) and other supports. From 2005 to 2015 the rigorous management plan demonstrated an increased incremental production. The latter program (ECOFISH) focused on community empowerment involving women’s access to resources and technologies, community resilience and compliance during fishing ban periods, and adaptive co-management and livelihood support activities and other coastal fisheries activities in Bangladesh among others. The International Institute for Environment and Development (IIED) between April 2013 and March 2016 developed innovative ways to tackle overfishing problems and threatened hilsa fish stocks to recover working with the Bangladesh Centre for Advanced Studies in the Bangladesh Agricultural University to create sustainable bottom-up solutions working to preserve hilsa stock as well as enhance livelihoods on a regional level-critical considering fissures are one of the most vulnerable communities in Bangladesh leading an almost hand to mouth existence and consider the poorest of the poor with the per capita income of fishermen approximately 2500 BDT or about 70% lower than the per capita income of the country as a whole.

News reports however document how over half a million Fisher’s in 16 of Bangladesh’s coastal districts are focused on hilsa fishing at sea (amounting to approximately 44% of marine catch) however faced with the combination of the pandemic and consequent fishing bans implemented by the Government of Bangladesh have missed the season and are hardly netting any even in inland estuaries and rivers famous for hilsa (the Padma, Meghna, and Tetulia)-given this hilsa prices have gone skyhigh on local markets and exports have reduced as well making it completely in accessible and out of reach for the average person in Bangladesh with the good catch being exported to North America, Europe, Australia, even India all major markets for the fish-neighbouring Indian markets also have hilsa from the Narmada estuary on the Western coast. Local traders are as badly hit as the fishermen. Since most hilsa this season has been caught in the sea, the news article further claims, expert opined that increasing siltation at the river mouth's has blocked officials migration routes-needing deeper river mouths and freshwater-although the monsoons wash out most of the pollutants from the rivers it cannot mitigate the heavy pollution from cities such as Dhaka on the banks of the Buriganga which flows into the Meghna via the Dhaleswari, notes the article[29]. The various fishing bans instituted by the government have restocked and rejuvenated hilsa stock however they also crippled the fishing communities which depend primarily on hilsa for the daily catch as well as form part of the most vulnerable sections of society in Bangladesh, during times of COVID even when the fishing ban was lifted there were no storage and shipping facilities available due to lockdowns this also means that most of the community will enter extreme debt even with the enormous food security and cash transfers support enabled by the government of Bangladesh. Due to lockdown and logistical disruptions many in the fishing communities especially in the outlying areas could not access the support systems offered by the government of Bangladesh including the 43 KG of rice to each fisherman and other support systems. In the current cycle however even during a productive fishing season with a good catch official family spends more than their earning often using multiple modes of loans and increasingly getting into deeper debt traps without the necessary education and skills to earn alternate income. Multiple NGOs in collaboration with the government of Bangladesh in to be intervening in this space however a broad-based scientific intervention can address the root causes of these problems both at the level of hilsa stock (which is a multilateral intergovernmental issue as well) and at the grassroots community level in building better resilience systems for the survival of an entire community, some of the most vulnerable, dependent on the small scale industry.

1.2.b. Poverty and Human Capital

Poverty however has remained a critical factor in Bangladesh which recently saw over 33 million Bangladeshi people were been lifted out of poverty since the early 2000's. The household income and expenditure survey[30] show the poverty rate for 2016 at 24.3% in the extreme poverty rate for 2016 at 12.9% whereas the international extreme poverty rate for 2016 has remained at 13.8% reduction since 2000 of 48.9% and 34.3% respectively. The World Bank further reports that between 2010 and 2016 poverty fell significantly but in recent years the rate of poverty reduction has slowed down poverty fell faster in rural areas where urban poverty rates decline from 21.3% to 18.9% rural poverty decreased from 35.2% to 26.4% (ibid.). The latest policy brief by the World Bank and its response to Covid-19 are to protect and invest in people-noting that hard-won gains in human capital are at risk the pandemic may permanently damage health and education over the past decade highlighted in the new human capital index 2020 update-the World Bank "calculation for human capital index ranges between zero and one measured in terms of productivity of the next generation of workers relative to the benchmark of complete education in full health."[31] The human capital index numbers for Bangladesh are 0.46 with an upper bound of 0.47 as of 2020-the expected years of school in Bangladesh which remained at an average of six years also managed to cut the gap between the richest and the poorest households in half from 4 to 2 years between 2004 and 2016 with the World Bank noting that a well-designed intervention can contribute to improve educational outcomes for the most disadvantaged.

The economy of Bangladesh is fairly diverse with the service sector accounting for 56% of GDP, while industry and agriculture accounts for 29% and 15% respectively agriculture is a critical and important source of livelihoods representing 42% of total employment[4,32]. Poverty has declined primarily in rural areas more so for those engaged in industrial services rather than on agriculture. As of 2018, the GHI score for Bangladesh is at 26.1 considered serious down from a 2000 GHI score of 36.0 considered alarming, rates of undernourishment, child stunting, and child mortality have all declined since 2000[33].

The Global Hunger Index also notes that 15.2% of the population is still considered undernourished with insufficient access to dietary diversity and calories making access to food and dietary diversity besides rice, vegetables, and fish are significant problem seen in the varied micronutrient deficiencies that are widespread. The health status of children also affects and influences the nutrition and notes the GHI that nearly 30% of children were reported to have consumed soil within the preceding week, other parts of rural Bangladesh also show environmental contamination characterised by poor water, sanitation, and hygiene conditions affecting children. Food production has seen significant imperatives from agricultural and home gardening projects, "Bangladesh was the site of early home gardening and Homestead food production projects that sought to provide women with nutrition education and gardening training enabling households to produce and consume more vegetables and raise their supply of micronutrients". Aquaculture and fisheries projects are fairly widespread in relatively common given the importance of fish in the National diet have provided sufficient nutrients specially to poorer communities. Some key policies and frameworks existent in Bangladesh today are the National development framework titled vision 2021 and the seventh five-year plan which seeks to implement vision 2021 with the objective of achieving adequate food supply for all especially women and children. The National agricultural policy seeks to make the nation self-sufficient in food through increasing production of all crops, including cereals, to ensure dependable food security system for all. The National Food policy focuses on ensuring dependable food security system for all people of the country at all times by meeting three goals to ensure an adequate and stable supply of safe and nutritious food enhancing people's purchasing power for increased food accessibility, and ensuring adequate nutrition for all-this plan has been implemented and monitored by the National Plan of Action. The National Nutrition Policy implemented in 2015 looks to improve the nutritional status of Bangladesh is by ensuring availability of adequate diversified diets, taking a multi-sectoral approach to tackle the school. The National Policy for Women's Advancement seeks to eliminate poverty on women and enhance women's economic integration, the National Women Development Policy promotes women's equality in greater rights in terms of employment, property and inheritance. These policies have a significant potential to increase food and nutrition security because of the positive association of women empowerment and control of income and other resources with food and nutrition security-GHI 2018[33].

1.2.c. Food Security- in context of the COVID-19 Pandemic

the UNDP-climate recently released "Pathways to a Greener, More Resilient Recovery"[34] documenting the deepest global recession since World War II disruption caused by COVID-19 the global pandemic that will push more than 60 million people into extreme poverty while hunger and famine will reach historic proportions. "Two thirds of the SDG's are now under threat or may not be met". UNDP-climate looks to enhancing support for climate governance across integrated initiatives covering forestry, energy, environment, and oceans-insulating vulnerable communities and rebuilding Pathways to achieve SDG goals by 2030. "Field Notes: Bangladesh in times of Covid-19 and food security implications" [35] further documents impacts on food environments, the migration of factory workers back to their hometowns, changes in Food purchasing habits, fear of infection contributing to decreases in consumer demand for food and massively changing purchasing habits with widely varying market hours limiting access to the market for both consumers as well as producers. In terms of availability however Bangladesh has not faced major food shortages other than supply chain disruptions and changing consumption and production patterns decreasing the availability of fresh produce such as fresh, fruits, and vegetables which in turn further reduces consumption patterns. The Ministry of Fisheries and Livestock, documents the note, issued directives to encourage smooth functioning of fresh food supply chains including disruptions in transportation networks. These vast changes in distribution, supply, and purchasing habits have impacted the demand for perishable foods as well as conversely consumption of carbohydrates and legumes such as rice, potatoes and pulses have significantly increased, possibly substituting for animal sourced foods/proteins.

The Food and Agriculture Organisation has issued a wide range of policy advisories with regard to the ongoing pandemic in Bangladesh that covers; in-kind food transfer, to ensure the smooth distribution of rice and flour to residence by the Food card policy and the food friendly program; Price control measures were implemented via the Trading Corporation of Bangladesh (TCB) and Directorate of National Consumer Rights Protection (DNCRP) setup helplines to monitor market prices on grocery items during the virus outbreak, looking at open market sales of essential products, Army deployment for assisting civil administration, food sacks containing 10 KG of rice, five KGF La, two KG of salt, one KG of sugar, 1 L oil, and noodle produce for distribution from the Ministry of Disaster Management and Relief, allocation of 200 to 500 ton of rice and 200,000 to 500,000 BDT for each district for distribution to poor people, and the food friendly program implemented in response to the pandemic; the conditional cash transfer (CCT) focused on low income and homeless people who were plan to reallocate to "Bhashanchar" - an island in Bangladesh under the program "return-to-home" providing for Homestead and six months of food and cash assistance and intervention made directly by the Prime Minister of Bangladesh; stimulus packages of approximately US$ 8 billion or 677.5 billion BDT to provide working capital loan facilities to the affected industries and the government to provide for banks to avail loan facilities to small and medium enterprises, and arrangement of the export development fund increased from US$ 3.5 billion-US$ 5 billion to facilitate further import of raw materials-all functioning as social protection measures and financial support measures through public banks; fertiliser subsidies and vouchers under stimulus package to offer financial assistance to farmers in rural areas for boosting agricultural production facing the fallout of Covid 19, the Prime Minister simultaneously introduces a 9000 crore taka subsidy in fertiliser in the following budget; conditional cash transfers were also enabled to provide cash assistance to mitigate the sufferings of those rendered jobless amid the coronavirus outbreak, the government also declaring the suspension of realising bank entries for two months in the period of May 2020; another conditional cash transfer scheme provided cash assistance among 50 lakh poor families distributed through mobile financial services are targeted 10 lakh people with cash support every single day between May 15 and 18; educational institutions were also further closed providing assistance.[32]

An early rumour that the virus could spread through market produce have negatively impacted the demand for fish and poultry particularly at the beginning of the crisis increasing the demand for dried fish which can be stored without refrigeration. In an effort to counter food security threats the Government of Bangladesh provided food assistance to vulnerable populations including Staples and non-perishable items such as potatoes, rice, oil and subsidised food for around 50 million people and 5 million poor households that received cash assistance through mobile banking, however the relief has not been sufficient, reports Leah Rosen of WorldFish, furthermore local entrepreneurs and politicians have added fish to the relief packages in an effort to increase adequate nutrition for poorer families. A review of the pandemic and its effect in Bangladesh specifically notes the progress of Bangladesh and poverty reduction over the last two decades where the poverty rate has dropped to 23.2% in 2016 from 48.9% in 2000[21], however the remarkable progress Bangladesh has made in food security including areas of food availability, food access, food utilisation, and food stability will face increased stresses from travel restrictions, local lockdowns, social distancing measures over a prolonged period will significantly hamper the country's progress towards achieving food security. The Government of Bangladesh, notes "Covid-19 and food security in Bangladesh: a chance to look back at what is done and what can be done"[36] and further examines the measures by the government to control prices and the food market, develop further access through a web portal title food for nation,[37] created solely to address food supply disruptions in customer access creating in agricultural market place and making a direct connection between producers and customers. Another portal called corona.gov.bd[38] which tracks and reports the pandemic outbreak but also provides food relief measures through which people could request emergency food supplies; however it is unclear whether these online initiatives are helping the food security measures in Bangladesh given that the most vulnerable generally do not have access to devices such platforms. The pandemic has exposed significant stressors and introduced new disruptions in crisis and Bangladesh has made food at the centre of measures towards safety and recovery.

1.3. IMPACT OF ENVIRONMENTAL CHANGES

Bangladesh is a densely-populated, low-lying, mainly riverine country located in South Asia with the coastline of 580 km where between 79% and 80% of the landmass of entire country and occupied by the Ganges (Padma), the Brahmaputra (Jamuna), and the Meghna Rivers their various tributaries which are largely fertile alluvial lowland covering approximately 310 rivers and tributaries and consisting of the world's longest unbroken sandy beach of 120 km[39] facing the Bay of Bengal. Bangladesh has a tropical monsoon climate with wide seasonal variations in rainfall, high humidity and temperature with approximately 10,000 km² of the total area of Bangladesh is covered with water and large areas are routinely flooded during the monsoon season and is a regular occurrence. Forest and woodland cover about 16% of the landmass. Between 1980 and 2008 Bangladesh experienced 219 natural disasters due to its geographical location, multiplicity of rivers, monsoon climate, and other factors that lead to a highly vulnerable position. Bangladesh suffers from a variety of extreme events some of which are linked directly to climate change such as natural hazards suffering from floods, cyclones, storm surge, riverbank erosion, earthquake, drought, salinity intrusion (also tidal boors), fire, tsunamis and other calamities. Bangladesh deals with natural disaster on an almost daily basis and as such has developed a comprehensive disaster management system comprising of regulatory frameworks such as The Disaster Management Act, National Plan for Disaster Management 2010 to 2015, Standing Orders and Disaster (SOD), National Disaster Management Policy, Earthquake Preparedness Measures, Emergency Preparedness Plan for Cyclone and the latest National Plan for Disaster Management 2015 to 2020 form the largest substantive legal governance framework for disaster management in Bangladesh. Institutional mechanisms and arrangements include the National Disaster Management Council which includes The Inter Ministerial Disaster Management Coordination Committee (IMDCC), and the National Disaster Management Advisory Council (NDMAC). The Ministry of Disaster Management in Relief advices the above bodies, The Ministry of Home Affairs operates through law and order protection forces, including fire service, civil defence, police, and others while conducting relief operations, security, rescue and other disaster information management systems. Regional frameworks would include SAARCs Comprehensive Framework on Disaster Management (2006 - 2015) which has been signed by Bangladesh and covers risk reduction strategies and establishing response mechanisms at regional and national levels. Bangladesh is very early on identified the close linkages between climate change and extreme events and designed mitigation plans, being one of the few countries in South Asia to develop and deploy these measures.

The Bangladesh Climate Change Strategy and Action Plan 2008 (BCCSAP) is one such major measure deployed by the Government of Bangladesh recognising the risk posed by climate change and responding to a range of policy and program measures at the National, District, and Community levels. The BCCSAP is a 10 year program (2009 to 2018)-a cross-sectoral policy document-to build the capacity and resilience of the country to meet the challenge of climate change based on six pillars: one, food security, social protection and health; two, comprehensive disaster management; three, infrastructure; four, research and knowledge management; five, mitigation and low carbon development; six, capacity building and institutional measures seeking to eliminate hunger, food insecurity, and malnutrition.[9] The Program Is to Be Implemented under the National Environment Committee financed through the government's own resources and support. The Asian disaster risk reduction documents 25 disasters in Bangladesh according to number killed from 1901 to 2000, it notes that natural disasters in Bangladesh have increased from numbers averaging below 10 from 1901 to 1960 and progressively increasing every decade from 1961 to 2000 culminating in 93 counts of disaster in the final decade with a grand total number of disasters standing at 231 (1901 two 2000)[40]. Bangladesh is a largely riparian country at the cross-section of multiple rivers and estuaries some of the major long-term crises Bangladesh faces are river erosion, climate and extreme event driven migration, Salinity intrusion, natural disasters and other stresses driven by accelerating climate change events. Almost ¼ of the total population of the country live in the coastal areas and face coastal floods, tidal surges, riverbank erosion, Salinity, tropical cyclones specific to the region—Bangladesh could lose up to 15% of its land area under seawater. In many instances riverbank erosion has led many families to lose their homes, in some cases the Bangladesh government through its various departments have rebuilt these homes multiple times, in other cases they have relocated entire families and households to islands such as Hatiya Island under a decade-long feelies under the Bangladesh Forest Department. [41] and islands that is effectively 370 km² located in an estuary where the Meghna River flows into the northern Bay of Bengal, as more families are uprooted by climate change pressures including rising sea and coastal erosion such islands and fallow land formed from river silt are being used to provide housing and living to many families; however being coastal regions and closer to the sea are extremely prone to frequent natural disasters affecting the area. The three-foot rise in sea level would submerge approximately 20% of the entire country and displace approximately 30 million people, some projections look at a 5 to 6-foot rise in sea level by 2100 which would theoretically display up to 50 million people making Bangladesh extremely vulnerable to the vagaries of extreme climate change.

On 14 July after some of the heaviest rains in a decade, followed by monsoon floods in South Asia which are common to the region and crucial to the economy of the subcontinent also causes severe damage and death across the region every year. The heavy rains swallowed 1/3 of the flood prone Bangladesh affecting at least 1.5 million people with homes and roads flooded[42] . However, monsoon events such as these are not limited to one area but effects and entire region and is often are transboundary issue, and our son, north-east India, approximately 2.1 million people have been affected since mid-May as floodwaters surged with thousands of mostly rural households evacuated to relief camps, in a pall more than 50 people died in landslides and floods triggered by monsoon rains. Clearly, monsoon events are regional transboundary issues that affect multiple nations and require multilateral interventions by regional, national, district and local bodies as well. The forces of accelerating climate change are well documented and projections show will increase in both severity as well as frequency and extreme events affecting long-term viability of entire regions; where previously people might have been able to move away during seasonal rains and monsoon flooding, the frequency and regularity of water logging make it impossible for farming, multiple crop varieties such as rice are not tolerant towards saltwater and alternatives in the region are extremely limited.[43,44] In some other cases of saltwater provides an opportunity to shift from rice cultivation to shrimp farms and other forms of aquaculture and although this activity is resilient currently it may not be sustainable to the influx of Salinity over a period of time. Bangladesh has seen a very high penetration of mobile phones primarily being reliant on them for banking seeing 87% of the population approximately using cell phones. With the ongoing recurrence of flooding as well as a massive damage they cause multiple strategies, including resilience strategies, with the support of the Government of Bangladesh are looking at migrating from traditional forms of agriculture to aquaculture which is more resilient to Salinity. An estimated 1 billion tonnes of sand and silt flow downstream every year and settles in the Delta, both counteracting relentless erosion as well as developing new salt formations, However, Polders - designed to carve out farmland from marshland the first built in Bangladesh in the 1960s allowing more intensive farming however over time also creating more issues in the direct flow of silt leading to land inside some of these polders sinking. The sealevel projected to rise between 0.5 and 1.5 m on the Bangladesh coast by 2100 already see episodes of high water driven by storms and tides directly affecting polders and their inhabitants. Efforts to introduce salt resistant crops have largely been limited due to the fact that most of these varieties are tested on waters that contain only up to 10% of the salinity of seawater making its viability limited to upstream estuaries and land.

Often referred to as ground zero for climate change, riverbank erosion in Bangladesh displaces between 50,000 to 200,000 people every year, thousands more flea the region every time a major cyclone reaches the coast. The saltwater incursion leaves millions with little water to drink or food to eat, forming a nexus of water security issues in the coastal regions that simultaneously affects access to drinking water as well as ability to farm leading to a food security crisis in the offing. The International Organisation of Migration, The UN Migration Agency point to a mass exodus of rural Bangladeshis towards the country's cities particularly to its capital Dhaka, approximately 200,000 to 400,000 migrants arrive in Dhaka each year with Salinity intrusion considered a major factor for so many fleeing the coastal and rural regions.[45] The "south-western coast of Bangladesh adjoining the Sundarbans National Park ration remote location with severe freshwater shortages-the region is home to nearly 10 million people with farmers who live in poverty with little water to irrigate their crops or to drink" - the expansion of saltwater aquaculture activity in the region has turned many of the traditional farmers into aquaculture/shrimp farmers since the land is exceptionally is aligned to farm anymore. The transition driven largely by climate change has change the patterns of production as well as consumption and labour activity in the entire region, these regions also face severe water shortages as most sources are high in salt. The influx of migrants into Dhaka, and with 18 million people in the metropolitan area increases the strains on the developing city exceptionally, slums alone house more than a million people according to a 2014 Census[46] which shows the increase in Bangladesh of slum dwellers by 60.43% in 17 years conducted by the Bangladesh Bureau of Statistics[21].

Appendix: Figures, Tables and Graphs

Figure 1: GDP South Asia (early projections)[3]

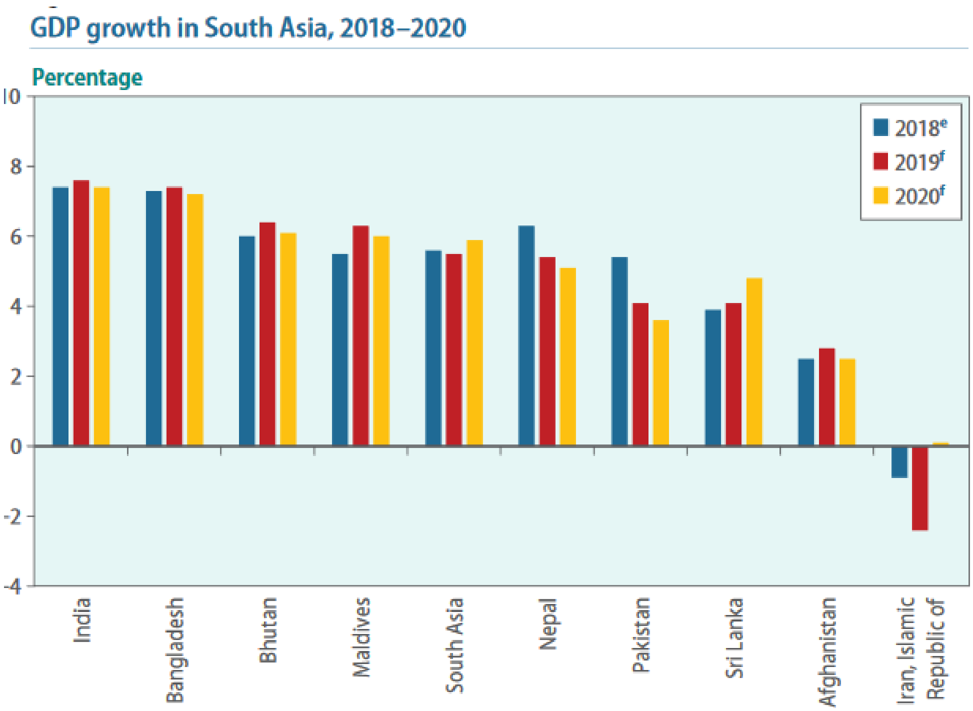


Figure 2: Global Climate Risk Index 2020 (1999-2018) (Note: Bangladesh ranks 7th)[6]

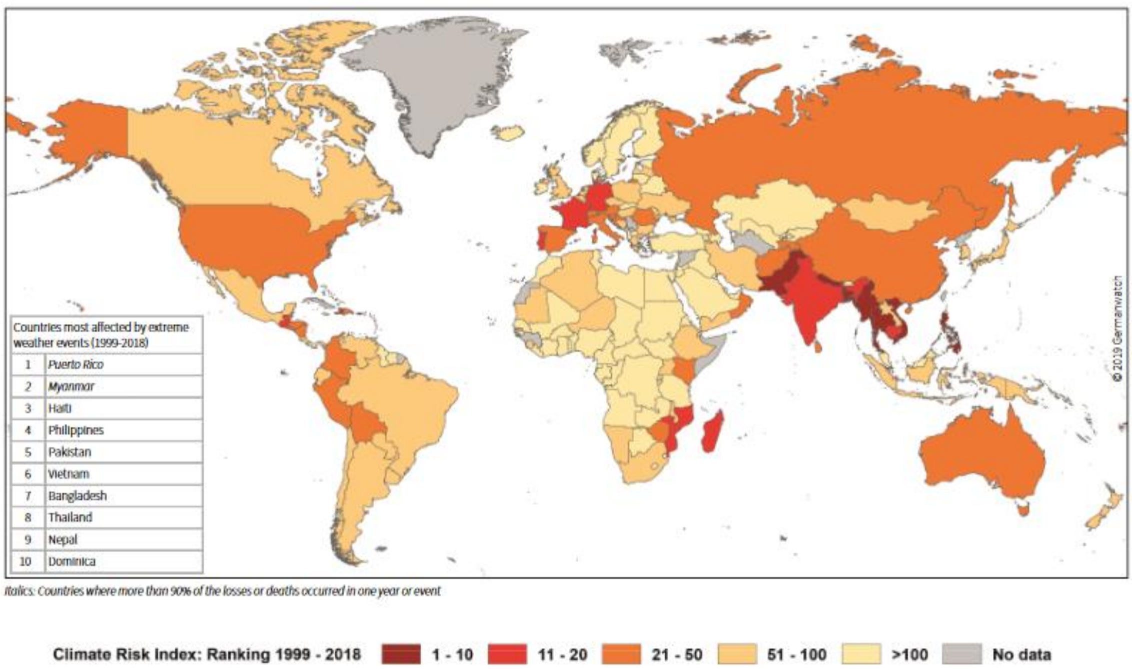


Figure 3: Severe Hotspots 2050 projections [8]

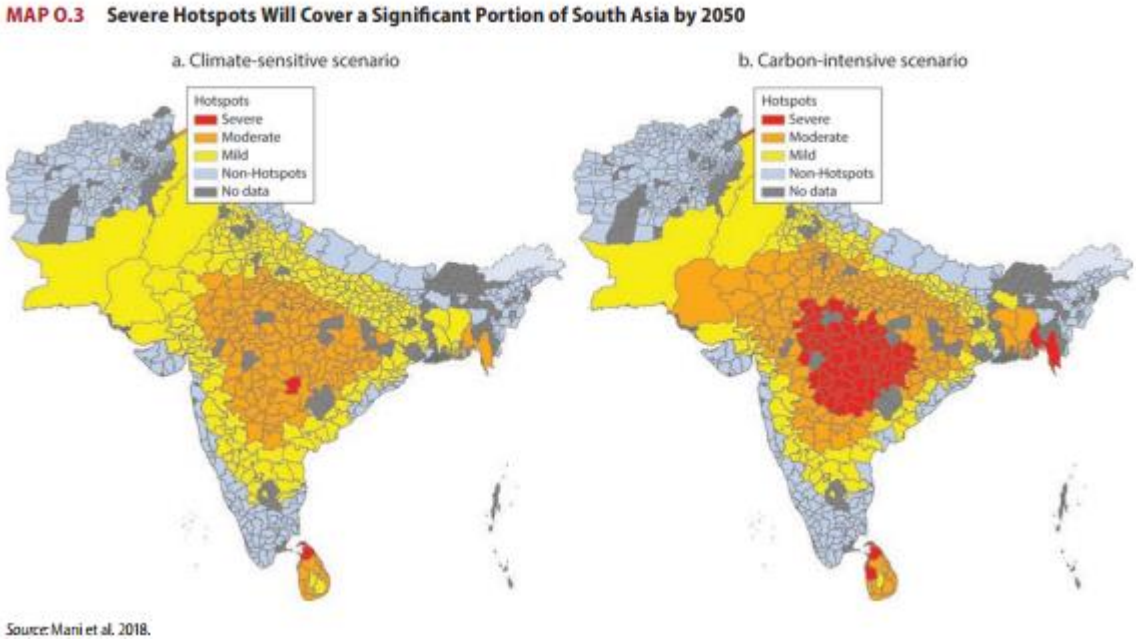


Figure 4: Average Monsoon Precipitation in South Asia[8] and Extreme Poverty Rate in South Asia[8]

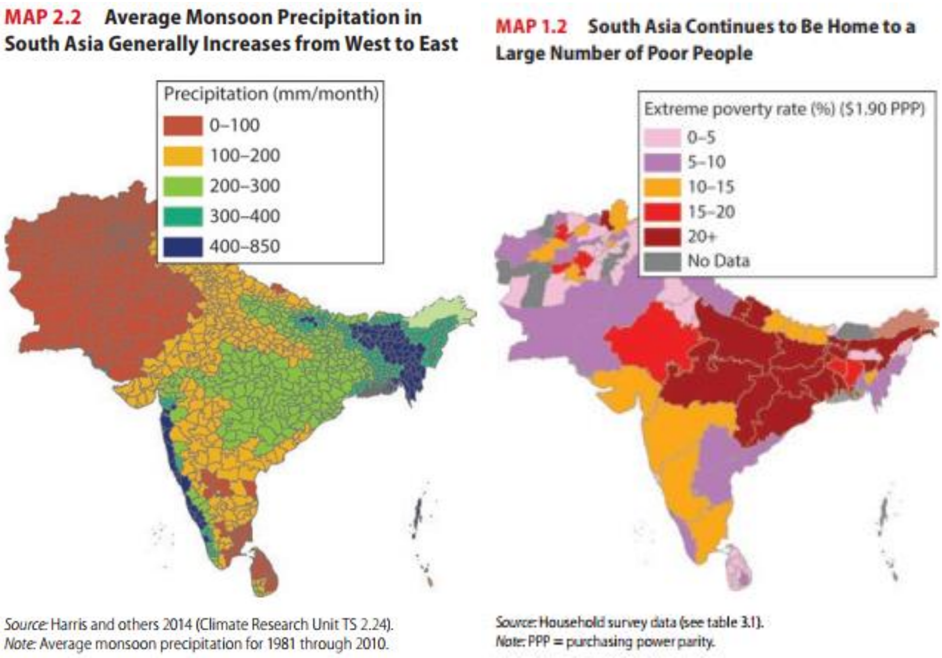


Figure 5: Key Indicators - Bangladesh Bureau of Statistics 2018 [21]

Key Indicators

Demographic and Social Indicators

Indicators	2017
Total Population (Million)	162.7
Male	81.4
Female	81.3
Growth rate	1.34
Total fertility rate (15-49 years)	2.05
Life expectancy at birth (years)	72.0
Male	70.6
Female	73.5
Literacy rate of population (7+ years)	72.3

Source: SVRS-2017

Economic indicators

Indicators	2017-18
GDP at current market price (billion tk.)	17329
GDP at constant market price (billion tk)	8835
Per capita GDP in current market prices (in US$)	1385
Per capita GNI at current market prices (in US$)	1465
Growth rate at constant prices	7.11
Investment at current prices (billion tk)	51.39
Inflation rate (%), General	5.92
Poverty rate for April-June, 2016	23.2
Extreme poverty rate for April-June, 2016	12.9
Total number of establishment	78,18,565
Total persons engaged	2,45,00,850
Total export (Million in TK)	3003837
Total import (Million in TK)	4712495
Share of ready made garments in national export	89.10

2.6 Human Assets Index (HAI) and Economic vulnerability Index (EVI)

	Indicators	Review each Three Year	
		2015	2018
1	**Human Assets Index (HAI)**	**63.8**	**73.2**
1.1	Percentage of Population undernourished	16.7	15.1
1.2	Mortality for children aged 5 years and under	41.1	34.2
1.3	Gross Secondary School enrolment Ratio	53.6	63.5
1.4	Adult Literacy Rate	58.8	72.8
1.5	Maternal Mortality	-	176.1

	Indicators	Review each Three Year	
		2015	2018
2	**Economic vulnerability Index (EVI)**	**25.1**	**25.2**
	Exposure Index	**22.7**	**22.8**
2.1	Population (Million), Ist July	156.59	162.95
2.2	Trade remoteness	36.1	35.7
2.3	Share of population in low elevated coastal area	8.9	8.9
2.4	Merchandise export concentration	0.4	0.4
2.5	Share of agriculture, forestry and fisheries in GDP	17.0	15.4
	Shock Index	**27.5**	**27.6**
2.6	Victims of natural disaster per 100000 popn	4.7	4.0
2.7	Instability of agricultural production	3.1	3.1
2.8	Instability of merchandise exports	6.7	7.1

Source:National Accounting Wing, BBS

Figure 6: extract from the report Bangladesh Bureau of Statistics 2018[21]

5.1 Land Utilization Statistics

(Area in '000' Acre)

Item	2014-15	2015-16	2016-17
Not available for cultivation	8942	8901	36465
Forest area	6368	6368	6368
Cultivable waste area	519	551	8901
Current fallow area	1042	1009	551
Total cropped area	37674	38148	1009

Source: Agriculture Wing, BBS

5.2 Production of Selected Agricultural Crops

(In '000' MT)

Item	2014-15	2015-16	2016-17
Rice	34710	34710	33803
Wheat	1347	1348	1311
Maize	2271	2446	3026
Jute	1399	1371	8247
Potato	9254	9474	10216
Sugarcane	4434	4208	3863
Tea	66	65	82
Pulses	378	378	387
Oilseeds	934	934	974
Onion	1704	1735	1866
Tobacco	94	88	88
Fruits	4635	4765	5019

Source : Agriculture Wing, BBS,
Note : 1Bale=0.1814369 M.ton

12.1 National poverty level of Bangladesh

Duration	Percentage
Poverty rate for 2016	24.3
Extreme poverty rate for 2016	12.9
International Extreme poverty rate for 2016	13.8

Source: Household Income and Expenditure Survey (HIES)

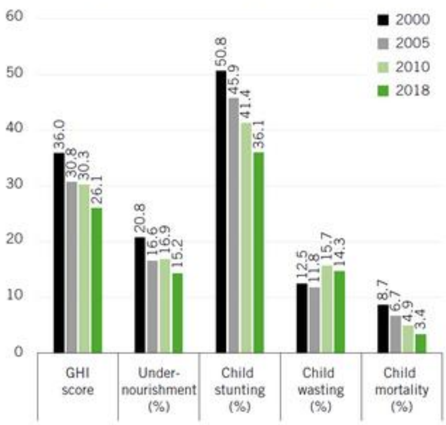
5.3 Species/Group-wise Annual Fish Production

(MT)

SL. NO	Species/Group	2015-16	2016-17
1	Major Carp	750880	811588
2	Other Carp	80647	100730
3	Exotic Carp	357933	409801
4	Pangas (cat fish)	504674	510097
5	Other Cat Fish	65130	66646
6	Snake Head	70106	72991
7	Live Fish	136113	127120
8	Tilapia	377346	370017
9	Other Inland fish	568446	598923
10	Hilsa	394951	496417
11	Shrimp/Prawn	234188	246774
12	Crab	13160	14421
13	Sardine	44386	48704
14	Bombay Duck	58545	69230
15	Indian Salmon	895	775
16	Pomfret	10593	10686
17	Jew Fish	31894	33768
18	Sea Cat Fish	8695	8424
19	Sharks Sjates & Ray	4622	4495
20	Other Marine Fish	165120	132827
Total		**3878324**	**4134434**

Source: Ministry of Fisheries and Livestock, Department of Fisheries

FIGURE 4.2 **BANGLADESH'S GLOBAL HUNGER INDEX SCORES AND INDICATOR VALUES, 2000, 2005, 2010, AND 2018**



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2. Agriculture and Food Security in Bhutan

2. Agriculture and Food Security in Bhutan

SUMMARY

Bhutan is a small landlocked nation located in the Himalayan mountain range with a forest coverage of over 70 percent, and arable land area of 7.8 percent of which only around 3 percent is under cultivation. Despite its challenging topography, Bhutan is predominantly an agriculture-based society. The agriculture sector is dominated by smallholder subsistence farmers, with an average landholding size of 1.2 ha, who produce most of the crop and livestock products. The agriculture sector employs about 53.7 percent of the total population contributing to 13.8 percent of the total GDP.

The country’s size and mountainous terrain has resulted in Bhutan facing a number of constraints especially in the agriculture sector. The renewable natural resources (RNR) sector, which comprises agriculture, livestock and forestry, has been developing relatively slowly mainly due to low levels of technology adoption, predominance of subsistence farming, large tracts of fallows and lack of market access. This has led to heavy reliance on imports of farm products and farm inputs from India and the agricultural trade deficit has been increasing over time. While exports of agriculture and food products grew at an average rate of 15 percent per annum by value over the period 2008 to 2014, imports of agricultural products over the same period grew by 16 percent per annum. This has been exacerbated by significant levels of outmigration from rural to urban areas, as well as increased demand for imported foodstuffs. Further key constraints to reducing the trade deficit have included the shortage of water availability for crop production, low yields and high comparative production costs for many commodities, losses due to human-wildlife conflict, and cultural attitudes towards the production of livestock for meat. Bhutan is also highly vulnerable to climate change-related threats. Since much of the population depends on agriculture and forestry, both of which are sensitive to increasing temperatures and changes in water availability, agriculture in Bhutan is going to be an uphill task if greater efforts and investments are not made in the research and development of climate resilient farming practices and technologies.

Farmers in Bhutan seem to be producing more in response to export opportunities although they are unable to sell a high proportion of their additional output. Weak marketing systems and high post-harvest losses have contributed to this. The domestic market is a small, challenging place to do business. Of the total population, 70 percent live in rural areas and produce most of what they consume. The remaining 30 percent people who live in urban centres are thus the main source of demand. Bhutanese products account for most of the fresh fruit and vegetables sold for the six months from May to October, however, low-priced Indian imports become a major source of competition between November and April. Demand on domestic markets is growing nevertheless, due to rising disposable incomes and an increasing consequent demand for higher value fruit, vegetable and animal products, and for rice.

Household food security continues to be a significant concern, given that UNICEF estimated in 2001 that – despite a significant drop during the 1990s - 40 percent of children in Bhutan still suffered from malnutrition. More recent World Health Organization statistics from national data in 2008 shows further gains, but still records stunting in terms of height for age at nearly 35 percent of children under 5 and weight for age at over 10 percent for the same age

group. The distinction between self-sufficiency and food security, a significant argument in the case of Bhutan's agriculture and food policies, is critical as it determines the types of activities and investments that should be considered in order to achieve them. While there are inevitable risks associated with too great a degree of dependence on imported supplies, including export bans and possible high price volatility, there may be high financial costs to be paid by consumers and the country as a whole as a result of an over-emphasis on self-sufficiency.

The Royal Government of Bhutan (RGoB) has accorded high priority to agricultural development in the 11th Five Year Plan (FYP) and agriculture is featured as one of the five jewels. This comes out of the realisation of the importance of the farm sector to the economy, and its significance in meeting food and nutrition security, poverty reduction, and equitable and sustainable economic development goals. Bhutan has learnt, in the wake of the pandemic, that relying on export markets is not sustainable. The government's strategies had to be moulded to tackle the pandemic as quickly as possible and its first response was to entrust the Food Corporation of Bhutan (FCB) to store the essential food requirements. In order to increase food production, many farmers have been encouraged to take up commercial vegetable farming, focusing on people in the tourism sector who have lost jobs and income after the pandemic brought the tourism to halt. In the long term, it is hoped these measures will help strengthen food self-sufficiency and nutritional security in Bhutan.

2.1. INTRODUCTION

Bhutan is a small landlocked nation located in the Himalayan mountain range with a forest coverage of over 70 percent, and arable land area of 7.8 percent of which only about 3 percent is under cultivation. Despite its challenging topography, Bhutan is predominantly an agriculture-based society. The agriculture sector is dominated by smallholder subsistence farmers, with an average landholding size of 1.2 ha, who produce most of the crop and livestock products. The agriculture sector employs about 53.7 percent of the total population contributing to 13.8 percent of the total GDP.[1,2]

The country's size and mountainous terrain has resulted in Bhutan facing a number of constraints especially in the agriculture sector. The renewable natural resources (RNR) sector, which comprises agriculture, livestock and forestry, has been developing relatively slow in Bhutan, the main reasons being low levels of technology adoption, predominance of subsistence farming, large tracts of fallows and lack of market access. The slow growth of agriculture has led to heavy reliance on imports of farm products and farm inputs from India. The Royal Government of Bhutan (RGoB) has accorded high priority to agricultural development in the 11th Five Year Plan (FYP) and agriculture is featured as one of the five jewels[3]. This comes out of the realisation of the importance of the farm sector to the economy, and its significance in meeting food and nutrition security, poverty reduction, and equitable and sustainable economic development goals.

The agricultural trade deficit has been increasing over time. Increasing hydroelectricity exports to India and a successful high-end tourism industry generate a positive balance of payments for the country[4]. However, the relatively small proportion of land suitable for cultivation, the lack of a well-developed transport and marketing network, and a significant migration of rural populations to urban centers in recent years, among other factors, have all contributed to a significant and growing trade deficit in the agricultural sector. While exports of agriculture and food products grew at an average rate of 15 percent per annum by value over the period 2008 to 2014, imports of agricultural products over the same period grew by 16 percent per annum[5]. This has been exacerbated by significant levels of outmigration from rural to urban areas, as well as increased demand for imported foodstuffs. Further key constraints to reducing the trade deficit have included the shortage of water availability for crop production, low yields and high comparative production costs for many commodities, losses due to human-wildlife conflict, and cultural attitudes towards the production of livestock for meat.

The importance of some imported agriculture and food items in the national diet—particularly rice—has led to concerns, not only in relation to their import costs in foreign currency, but also for the wider food security of the country. This was made clear, following the short-lived ban on rice exports imposed by India (among many producing countries) during the 2008 food crisis. On the other hand, it is worth noting that the area planted to rice has been declining by approximately one percent per annum since at least 2000 yet, as of 2008, cereals (principally rice and maize) still accounted for 65 percent of the total cultivated area[6]. By contrast, it is estimated that for the same year the four major export crops (citrus, potatoes, apples and cardamom) occupied 13 percent of total cultivated area, while the total national area dedicated to the production of these crops for export markets was only 4.3 percent[7].

2.2. AGRICULTURAL PRODUCTION AND FOOD SECURITY IN BHUTAN

2.2.a. Key Aspects of Agriculture in Bhutan

Several characteristics of the agricultural sector in Bhutan are dictated by the location, climate and topography of the country and these factors must be taken into account in formulating any FNS strategy. These include: Labor costs in Bhutan are high in comparison with its main trade partner, India, and labor shortages are increasing due to rapid rates of rural to urban migration; Mechanization is in use in only in an estimated 2 percent of the cultivated area; The landscape renders large-scale production, and hence economies of scale, impossible in most locations. This is of particular importance in relation to the development of irrigation infrastructure; Water supplies are highly seasonal, often located at a considerable distance from production areas, and are apparently declining as a result of reduced winter snowfall; The altitude and climate of Bhutan offers possibilities for counter-seasonal production of some commodities for export to India during the hot season in that country as well as the cultivation of products not suited to many areas in South Asia. As a result, several export products exploiting these characteristics have been successfully developed, including cardamom, mandarin, potatoes, ginger and cordyceps, demonstrating that potentials do exist; The area sown to paddy has declined over the last eight years, although average yields have risen; The relatively poorly developed rural transport and storage infrastructure, combined with low population densities in many rural areas has a major impact on the marketing of agricultural produce.

2.2.b. Recent Patterns in Agriculture and Food Sector Trade

In 2014, Bhutan's overall trade deficit (excluding trade in electricity[8]) was Nu. 31.6 billion (approximately USD526m), or almost 30 percent of total Gross Domestic Product (GDP). The agriculture and food sector contributed close to Nu.6 billion (USD99m) of this deficit, or 19percent of the overall national figure (Figure 1). This is slightly higher than the share of value added by the sector to the national economy (17.1 percent of GDP), according to World Bank statistics. While exports of agriculture and food products grew at an average rate of 15 percent per annum by value over the period 2008 to 2014, imports of agricultural products over the same period grew by 16 percent per annum[9]. Thus, the absolute value of the agricultural deficit increased from Nu.2.3 billion in 2008 to nearly Nu.6 billion in 2014, a 17 percent annual increase. However, the sector share of the total trade deficit has remained fairly constant as other categories of imports have also risen[10].

Using the standard International Trade Classification (ITC) definitions[11], and as shown in Figure 2 below, *Section I* imports (live animals, animal products) accounted for 46percent of the deficit in 2014 (Nu. 2.74 billions), *Section II* (vegetable products plus all crops) accounted for 12percent of the deficit (Nu. 0.74 billions), *Section III* (animal or vegetable fats and oils) accounted for 17percent (Nu. 1 billion), and *Section IV* (prepared foodstuffs, beverages, tobacco) accounted for 25percent of the deficit (Nu.1.48 billions). In light of the serious concern over rice imports, it is perhaps surprising that the deficit on crops and vegetable products is less than one third of that found for animals and animal products. However, significant exports of a number of *Section II* products occur, while almost no *Section I* exports from Bhutan are recorded. More importantly, the decline in the size of the deficit for the crops category in the last two years contrasts strongly with the rapid increase in the deficit for live animals and animal products. This arises from a recent expansion in crop exports. Bhutan has steadily increased its production of vegetables, and only about 10 percent or less of its vegetables are imported. This is not the case with meats. Despite a ramping up of production, chicken import and production was the same in 2018. Pork imported was twice the amount as that produced, and beef and yak combined were less than 20 percent of the amount of bovine meat imported.

2.2.c. Addressing Food and Nutrition Security

The declining share of national production in overall consumption of many agricultural products has led to calls within Bhutan for increased self-reliance and food security in agriculture. The declining level of self-sufficiency in the production of rice has been a particular concern of RGoB, given its importance in the Bhutanese diet. Yet there is still considerable uncertainty as to how food security should best be addressed. The current RGoB priority areas for the agricultural sector are defined very much in production-related terms, comprising: (i) irrigation and water management; (ii) enhanced farm mechanization services; (iii) human wildlife conflict management; and (iv) enhanced production support.

Differentiating the concepts of self-sufficiency from food security, it is essential to clarify the role of agriculture in ensuring the welfare of the population of Bhutan. Food security, in turn, can be viewed from either the national or the household perspective. National food security essentially measures whether domestic production plus imports are sufficient to meet national needs. National production levels thus comprise only part of the assessment, while import availability - the other key factor - is dictated both by the availability of the commodity(ies) on international markets, and the financial ability of the country to cover the resulting import cost.

By contrast, household food security is affected primarily by the income of the household, and hence its ability to purchase the required foodstuffs or products. In the case of Bhutan, household food security is, in fact, *negatively correlated with self-sufficiency* as "households that are more self-sufficient in cereals and in food in general tend to be less food secure"[12], while there is a *strong positive correlation with household income*. This occurs because households with relatively high levels of self-sufficiency market little if any agricultural produce and thus lack the financial resources to purchase key foodstuffs to ensure dietary diversification (e.g. meats and pulses) as well as to supplement food supplies during the 'hungry' period prior to harvest.

Household food security continues to be a significant concern, given that UNICEF estimated in 2001 that – despite a significant drop during the 1990s - 40 percent of children in Bhutan still suffered from malnutrition[13]. More recent World Health Organization statistics from national data in 2008 shows further gains, but still records stunting in terms of height for age at nearly 35 percent of children under 5 and weight for age at over 10 percent for the same age group.[14]

The distinction between self-sufficiency and food security is critical, as it determines the types of activities and investments than should be considered in order to achieve them. While there are inevitably risks associated with too great a degree of dependence on imported supplies (particularly for Bhutan where all imports come through India), including export bans and possible high price volatility, there may well be high financial costs to be paid by consumers and the country as a whole as a result of an over-emphasis on self-sufficiency.

2.2.d. Impacts of COVID-19 on Agriculture

In the wake of the COVID-19 pandemic, Bhutan initially banned food imports. The ban was soon lifted. But with the closure of Bhutan's borders with India, the country's food imports have plummeted. A combination of a shortage of labour to handle the goods, as well as the difficulty of sterilising food products, has meant that imports have slowed to a trickle. The initial closure of the border on March 24, 2020, led to widespread panic buying. The government has since reassured people that the country has enough food stocks to last another six months. Nevertheless, the border closures and limited food supplies have focused the country's attention on food self-sufficiency. To add piquancy to the situation, the Bhutanese national dish is ema datse (chillies and cheese), and with chillies unavailable, it is off the table for many. Bhutan imports most of the food items from India. With the border closure and restriction on imports has given our farmers the opportunity to substitute a large portion of the country's vegetable and meat requirement. The Ministry of Agriculture and Forests has given importance in boosting the agriculture sector and many unemployed youths and farmers were encouraged to do agricultural activities. Even bank loans were provided at the minimum interest rate in order to motivate farming communities.

2.3. ENVIRONMENTAL STRESSES AND AGRICULTURE

Bhutan's RNR sector is one of the most important sectors and it is heavily dependent on biophysical factors and is also vulnerable to environmental stresses like natural disasters and climate change. Bhutan's climatic and altitudinal variability allows cultivation of many crops, including year-round production. Farming in mountainous ecosystems is challenged by inherently low soil fertility along with cold stress and frequent shifts in weather conditions, frequent extreme weather events and natural disasters. Bhutan's rough topography and scattered farmlands in fragmented parcels on mountainous slopes and river valleys limit Bhutan's agricultural capacity as well. These conditions also make the development of irrigation and other modern farm structures very difficult. Many farmlands are being left fallow owing to the difficulty in farming. These are some of the abiotic stresses that pose significant challenges to agriculture in Bhutan.[15]

Bhutan's farmers also find pests, diseases, weeds and other invasive species to be some of the biggest problems they face. Horticulture in Bhutan has experienced worsening situations of fruit loss to diseases and pests. The citrus industry has been devastated by the citrus greening or the HLB disease since 2003. Citrus farmers are also struggling with drop in fruit production caused by citrus fruit flies. In case of apple orchards, woolly aphids, brown rot, collar rots and apple scab diseases have been reported in almost all apple-growing northern districts. Similarly, cardamom production has stagnated due to widespread wilt disease. Stats show apple and mandarin production have started to decline, which could be attributed to both biotic and abiotic stresses.[16]

The intercropping of orchard soils with vegetables and fodder crops has also been getting popular, which increases the pressure on orchard land resources. Owing to topography, plant height and nature of crops, fruit trees are more prone to risk factors such as soil erosion, floods, hail, high-speed winds, nutrient mining and land slips. Another very important issue is that of invasive weed species. It has been observed and reported that alien weed species, such as Lantana camara, Parthenium and Eupatorium have been spreading into both cultivated and forested areas. Farmers have already observed colonization of their pasture lands by invasive weed species that greatly reduce regeneration capacity of grass species.[17]

Although carbon sequestration in Bhutan is much higher than its total greenhouse gas emissions, the country is highly vulnerable to climate change-related threats. Since much of the population depends on agriculture and forestry, both of which are sensitive to increasing temperatures and changes in water availability, agriculture in Bhutan is going to be an uphill task if greater efforts and investments are not made in the research and development of climate resilient farming practices and technologies. Projected impacts of climate change on Bhutan include glacial melting, increased hazards such as flash floods and landslides, and glacial lake outburst floods (GLOFs). Higher discharges of glacial melts in the summer are expected to increase number of mud slides at river bands, leading to increased sediment load.[18]

Simulation models predict mean summer and winter temperature increases of 2.8 degrees C and 2.1 degrees C respectively, over 2040-2069. Winter rains are will be less while summer rains are predicted to increase. Other studies have reported major changes in temperature and precipitation in the range of 2.9 degrees C to 4.3 degrees C and 13 to 34 percent respectively. According to ICIMOD, significant warming has been observed in places situated at higher elevations than lower ones, which would hold true for Bhutan, having experienced fast receding of glaciers in the mountains.[19]

Terraced rice cultivation, commonly known as wetland farming, constitutes 27.86 percent of the country's cultivable land. Rice requires more water than other crops, making it highly vulnerable and dependent on climatic parameters, such as monsoon rains and temperature. In Bhutan, rice is grown under irrigated, rain-fed and upland ecosystems. Under both irrigated and rain-fed systems, rice farming stands out to be highly sensitive to climate change since it requires large quantities of water. Rising temperatures due to climate change might increase the crop growing season but the combined effect of temperature increases and changing rainfall pattern would probably counteract the gains in cropping duration.[20]

Considering carbon fertilization effect of increased atmospheric CO_2 for photosynthesis, some crop yield simulation models have shown positive contribution on the yield of dryland crops (maize, wheat, barley, buckwheat, millets). However, the combined effects of CO_2 fertilization, changing patterns of precipitation and heat stress would likely have negative impacts on crop yields. Climatic suitability gain might not translate to actual increased production areas for Bhutan owing to the country's topography and narrow crop growing seasons due to wide variations in altitude and environmental conditions. The dryland farming system is basically practised on upland mountain slopes, which make it highly prone to the vagaries of climatic and weather events, such as soil erosion, land fragmentation and nutrient loss. Projected high intensity rain in summer and reduced rains in winters in the Himalayan regions indicate massive erosions, crop damage as well as crop loss due to its direct effect on winter crops.[21]

Rising temperatures relate to increasing incidences of pests and diseases in agriculture. This would lead to increasing insecticide usage, affecting ecosystem services and human health. The Bhutanese National Environment Commission warns that a warming climate will spread vector borne tropical diseases into more areas and to higher elevations, and also increase water-borne diseases due to the loss of safe drinking water. Another alarming issue with global warming is its dramatic effect on the chilling requirement of temperate fruits, which will be impacted by increasing temperatures.[22,23]

2.4. SCIENCE AND TECHNOLOGY FOR IMPROVED AGRICULTURE

Bhutan's topography and physio-geography make the usage of certain types of agricultural technology very difficult to adopt. However, Bhutan's Department of Agriculture has placed much focus on farm mechanization over the years, in order to reduce to drudgery of farming and for improving labour efficiency. Measures to promote farm mechanization began in the early 1980s, with the establishment of the Agriculture Machinery Centre (AMC) funded by Japan. Further in 2016, the government has created Farm Machinery Corporation Limited (FMCL), a state-owned enterprise to provide farm mechanization goods and services to the Bhutanese farming community at an affordable price.

Until 2018, the government has procured and distributed close to 6000 power tillers and 23,000 other essential farm machineries including ploughs, seeders, manure spreaders, fertilizer distributors, balers, combine harvesters-threshers, threshing machines, root or tuber harvesting machines, pedestrian controlled tractors & other agricultural tractors (Bhutan RNR Statistics, 2017 & 2018). A small number of complete rice mechanization packages have also been provided comprising transplanters, weeding implements and power reapers for mechanized harvesting. AMC research shows that power tillers can reduce rice production costs by approximately 50 percent, and reduce labour requirements to one quarter or even one fifth of the requirement for cultivation by bullock. When trailers are used, power tillers also improve mobility and transport capacity, a major advantage where farm roads exist. Power tiller use is also spreading on dryland where the slope permits, although intercropping can restrict dryland use.[24][25]

Available data suggest that labour productivity has increased modestly, as measured by real GDP per capita of rural population, reflecting low levels of technology adoption and the predominance of subsistence agriculture. Ownership of power tillers increases among larger farmers who are close to a road head, and who cultivate potatoes and other vegetables. Lower rates of ownership are associated with higher ownership of livestock, the cultivation of maize and irrigated rice and high levels of crop damage by wild animals. Despite the demonstrated reduction in rice production costs, power tillers seem to be less likely to be used on wetland. The AMC attributes this low adoption rate to a lack of spare parts and repair services, and inadequate farmer training, and has set up regional workshops to meet these needs. A quality and safety programme has also been conducted.[26]

The expansion of mechanized cultivation tends to be wider and more sustainable where it is based on increasing access to hire services provided by individual contractors. The current market for machinery hiring services appears to be weak, however, with both supply constraints and irregular demand. According to AMC, there is also a general perception among farmers that power tiller hiring is expensive even though observed hire rates suggest the opposite. There may therefore be greater potential to use mechanization for small-scale food processing. Ultimately, the real nature of demand for farm machinery may become apparent through private sector activity. Indian-made power tillers are becoming available in Bhutan at a price close to that of subsidised Japanese machinery. Transplanters and reapers from Viet Nam, India and Thailand can also be found at affordable prices. Provided that credit is available to finance these machines, farmers and contractors will buy them if they are a viable investment.[27]

A significant problem many farmers in Bhutan report facing is a shortage of labour, which could also incentivise the adoption of certain technologies. Rural-urban migration has had a profound impact on Bhutan. According to the 2005 population census, the rural population grew at an annual rate of only 0.6 percent from 1985-2005, compared to an urban population growth rate of 6.1 percent. This migration alters the gender balance in both urban and rural areas and also alters regional populations. The Population and Housing Census of 2005 showed that internal migration has been characterized by the movement of people from the poorer, eastern regions towards the west and southwest. The main perceived negative effect of rural-urban migration has reportedly been the reduction in agricultural manpower. Urban-rural remittances were seen as an important offsetting positive effect, however, with 54 percent of urban migrants sending a proportion of their income to rural relatives. Some 59 percent of administrations also cited urban-rural remittances as the main positive factor arising from out-migration.[28]

The increased role of female labour and the consequent increase in the labour burden they carry certainly warrants increased attention. A greater emphasis on improving access to mechanized rice threshers and maize shellers has been suggested as a means to reduce the labour burden they face. It also appears that both demand and supply side constraints influence access to paid labour, and that the demand side constraints may be highest for smaller, low income farmers trying to commercialize their operations. Given the topographic factors and small farm sizes, large-scale and complete mechanization in Bhutan is not an achievable goal. However, the various benefits of application of various technologies on agriculture point to their ability to improve agricultural production and productivity in Bhutan. Considering the current objectives of Bhutan to increase food security, mechanization and access to improved technologies could help achieve these goals and increase the competitiveness of farmers in Bhutan.[29,30]

2.5. AGRICULTURAL VALUE CHAIN DEVELOPMENT

Bhutan has made significant efforts to improve road connectivity and commercialization of agriculture over the past few years, although agricultural productivity and growth remains low. Bhutan's small, dispersed rural population, mountainous terrain and subsistence-oriented farming systems do not allow for easily achievable development of competitive production and marketing systems. At the domestic level, market infrastructure and wholesale systems have largely been absent and there is significant potential for commercial agriculture and particularly for exports. Bhutan's climate facilitates the production of off-season fruits and vegetables for sale to India. Second, Bhutan benefits from an almost completely open trade regime with its two neighbours and trading partners, India and Bangladesh, which affords ready access to two huge markets. However, the free trade agreement with India is a double-edged sword in this respect as it assures a stable food supply and ready access to low-cost food, but also results in strong competition.[31]

There has been a gradual shift to commercial crops since 2000, with an increase in the value of cash crops and a decline in the value of cereal production. Production of staple cereal crops still comprises a significant proportion of land use, with most of the country's limited wetland area being used for rice cultivation. Export crops are grown mostly in lower potential dryland. Commercialization of agriculture is higher among richer and better-connected administrative regions, and among larger farmers. A limited number of farmers are engaged in market activity, since a small percentage account for a large majority of crop sales. Market surplus for cereals, fruits and vegetables produced for the domestic market is quite low and a much higher market surplus is observed from major export crops. Production patterns have therefore changed in response to commercialization, with less land dedicated to cereal crops and more to vegetables over time. Rice and maize are both very important crops in terms of area and production, however, their market surpluses remain quite low.[32]

Farmers in Bhutan seem to be producing more in response to export opportunities although they are unable to sell a high proportion of their additional output. Weak marketing systems and high post-harvest losses have certainly contributed to this. The domestic market is a small, challenging place to do business. Of the total population, 70 percent live in rural areas and produce most of what they consume. The remaining 30 percent people who live in urban centres are thus the main source of demand. Bhutanese products account for most of the fresh fruit and vegetables sold for the six months from May to October, however, low-priced Indian imports become a major source of competition between November and April. Demand on domestic markets is growing nevertheless, due to rising disposable incomes and an increasing consequent demand for higher value fruit, vegetable and animal products, and for rice.[33]

The marketing chains for export crops are somewhat better developed. Wholesale markets exist, on or close to border crossing points into India, particularly for potatoes, although the buyers are largely foreign. An assembly process exists for citrus, but it is also driven by foreign buyers who advance seasonal credit as a means to secure supply, then buy the crop on the tree and pick and grade it themselves. Bhutanese market agents have been absent in these activities. Cooperatives and contract farming have been promoted as a means to strengthen market systems through private sector activity and Bhutan’s agricultural sector was opened to foreign direct investment in 2009. A new Land Act allows the leasing of land by foreign companies for a period of up to 30 years, with the possibility of renewal. No internal or export taxes are levied on agricultural production.[34]

2.6. FUTURISTIC POLICY FRAMEWORK FOR AGRICULTURE AND FOOD SECURITY

Bhutan is well known for the importance given to environmental conservation in various policies, including those related to agriculture and food production systems. The Renewable Natural Resources (RNR) concept of the Ministry of Agriculture and Forests (MoAF) in Bhutan works on an integrated and holistic approach to the sector’s development. Farming in Bhutan can be classified as largely traditional with minimal use of external inputs like pesticides and fertilizers.[35]

In order to transform the agriculture sector into cost-effective lucrative business opportunities besides ensuring food security in the country, the RGoB has created various institutions in a phased manner. The Ministry of Agriculture, later renamed as Ministry of Agriculture and Forests (MoAF) by merging forestry sector under one umbrella, has been responsible for providing overall policy guidance and planning to ensure the food sufficiency and economy base of the country. The Department of Agriculture (DoA) is responsible to ensure the attainment of food self-sufficiency and promote income generation through providing appropriate agricultural inputs (technology, machineries, seeds, fertilizers, enterprise development, irrigation, etc). The National Seed Centre (NSC), later renamed as Druk Seed Corporation 9DSC), is responsible for seed and seedling multiplication and distribution, and the procurement and distribution of fertilizer and rice herbicide. The National Plant Protection Centre (NPPC) procures and distributes pesticides and herbicides (for crops other than rice) and also responsible for providing technical backstopping of electric fencing in the villages.

The Agricultural Machinery Centre (AMC) promotes and supports farm mechanization through the procurement and subsidized sale of machinery and spare parts, and through training and research. The Bhutan Agriculture and Food Regulatory Authority (BAFRA) regulate the input supply system and monitors input quality. The National Soil Service Centre (NSSC) co-ordinates soil/land management research activities of the RNR sector. The Rural Development Training Centre (RDTC) organizes capacity development trainings for framers to enhance production of crops and livestock. The Department of Agriculture Marketing (DAMC) facilitates the marketing of agricultural produce and development of cooperative sectors in the country. Bhutan Exporters Association (BSA) provides bridge between exporters and RGoB to facilitate the export of cash crops and spices. The Agriculture Research Development Centres (ARDC) provides agriculture research and development services to the farmers and innovations to improve the farm productions.

The RGoB has developed many policy interventions to improve the agriculture sector in the country through these institutions, including distribution of farm input supply, introducing farm mechanization and irrigation facilities, and facilitating market accessibility. Recognizing the importance of potential impact of climate change on agriculture, the RGoB identified the Climate Smart Agriculture (CSA) as one of the key strategies for adaptation to climate change in 11th five-year plan[36]. However, farmers' awareness of CSA and the associated opportunities and challenges is considerably poor. The availability of CSA technologies is limited and farmers do not have any safety nets or alternative sources of livelihoods if investment activities fail.

The experimental processes to promote organic farming initiated in 2003, followed by preparation of National Framework for Organic Farming (NFOF) in 2006. Organic farming was encouraged and pursued with the vision to become organic by 2020 and to enhance nutrition, health and farm household income, and to become a net exporter of organic agricultural products[37]. In 2007, the Ministry of Agriculture and Forests has developed and launched Bhutan's Policy for Organic Farming[38]. With the organic farming framework and policy in place, the program was institutionalized and up-scaled with the establishment of the National Organic Program in 2007.

However, the government has achieved only about 10 percent in organic agriculture production with just about 545 hectares of crop land (less than 1 percent of total arable land) certified organic in 2020[39]. The limited human and financial resources are major issues that have led to poor progress of the national organic program. The other factors leading to poor advancement in organic production were due to lack of markets and value chains, appropriate supply-and-demand-side mechanisms such as absence of price premiums and low consumer awareness. Emphasizing on the importance of organic farming, the government had prepared and adopted an Organic Master plan in 2012 and had developed a roadmap and organic agriculture development strategies for 2018 to 2023. The vision of 100 percent organic by 2020 was consequently revised to 2035 by the government. Currently, there are 24 farmer cooperatives, three organic retailers and one exporter involved in organic production and marketing in the country.

Bhutan has learnt, in the wake of the pandemic, that relying on export markets is not sustainable. The MoAF's strategies had to be molded to tackle the pandemic in fast and as quickly as possible and its first response was to entrust the Food Corporation of Bhutan (FCB) to store the essential food requirements. These essential items included cereals, particularly rice, oil and sugar. It also took on several steps to combat the effects of the COVID-19 pandemic on food security. In order to increase food production, many farmers have been encouraged to take up commercial vegetable farming, focusing on people in the tourism sector who have lost jobs and income after the pandemic brought the tourism to halt. In the long term, it is hoped these measures will help strengthen food self-sufficiency and nutritional security in Bhutan. Further, the impacts of pandemic have paved way for many innovative businesses initiated by the youth of Bhutan, supported by government and donors. Businesses which were not seen before the pandemic have cropped up, such as vegetables on wheels, dehydration of food resources, scaling up of organic farming, and online transport and services have drastically enhanced. In order to meet essential requirements, shops were identified that would cater to the need of the people in case of a lockdown. Transportation of these items and storage facilities were also created in various locations in the country.

Appendix: Figures, Graphs and Tables

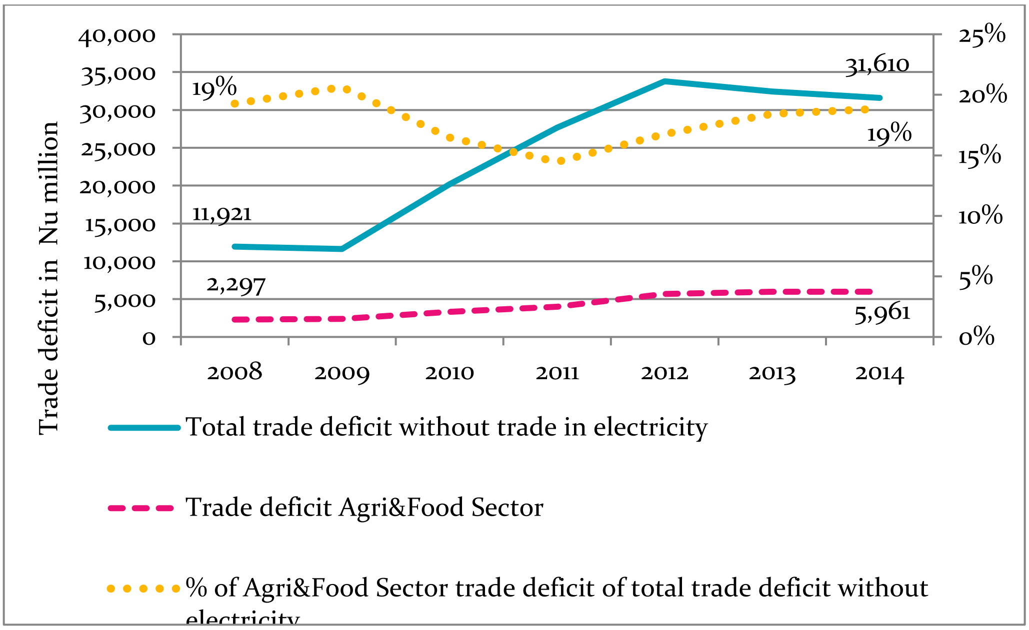

Figure 1: Trade Deficit of the Agri-Food Sector as a Percentage of the Total Deficit (excluding trade in electricity)

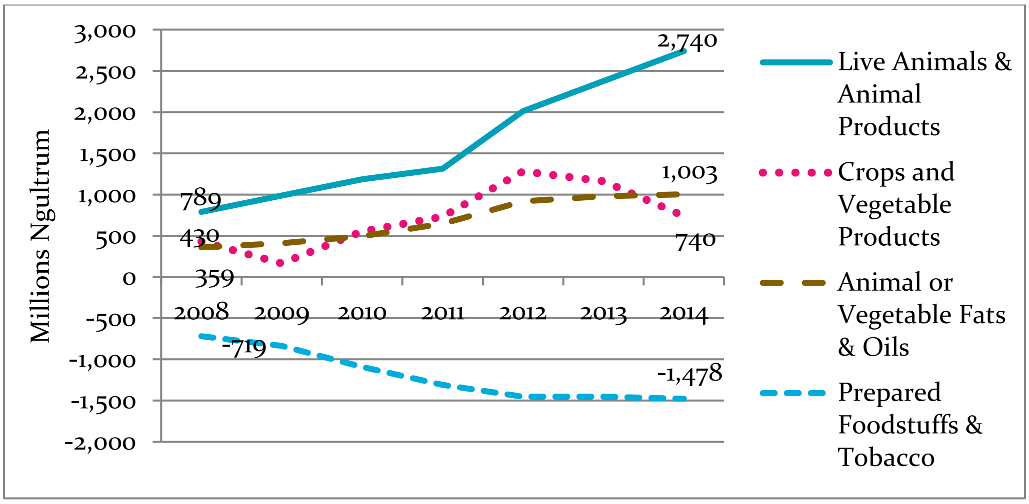

Figure 2: Import Values for Key Agri-Food Sector Categories, 2008-20014

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[9] The use of an annual increase percentage is only indicative since the use of different baseline years would result in a change in the number quoted.

[10] It is worth noting that in the region of one quarter of all imports in 2014 were for equipment and machinery related to hydropower development and were self-financing.

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3. Agriculture and Food Security in India

3. Agriculture and Food security in India

SUMMARY

Eliminating food insecurity has been one of the biggest challenges for India. In the 1960s India faced a severe food shortage and crisis. However due to continued efforts, India has achieved grain sufficiency. Climate change continues to be a threat to Indian agriculture with rising temperature and increasing carbon dioxide levels causing a decline in food production. The rise in carbon dioxide levels decreases nutritional quality of food. According to the 2020, FAO estimates, it is estimated that 189.2 million people still remain under nourished in India. About 50% of women continue to be anaemic.

Increasing floods and climate related disasters, heavy rainfall, different precipitation response, larger periods of drought, rising air, water and soil pollution, increasing population are also of major concern to the agriculture productivity in India since successful agriculture depends on many such factors. Ensuring larger production of nutrient rich foods should be of major importance to India. Increasing the production and distribution of local food crops which have high nutritive and medicinal value needs to be promoted since India is rich with abundant natural biodiversity. Reducing the focus from highly water intensive crops such as rice, sugar cane and wheat to local varieties of food crops such as millets, amaranth, neglected fruits, nuts, legumes which have been neglected need to be revived for sustainability and for food security.

3.1. INTRODUCTION

In spite of our various successful missions on the Earth, banishing food insecurity is one of the biggest challenges which we have yet to overcome. During the early sixties, the most populated South Asian nations experienced a severe food shortage, however, after the mid-seventies, due to a rigorous effort, better growth was achieved in food production. Today, there is rise in food sufficiency especially in South Asian countries, like India, despite their rising population but on the other hand the African countries are experiencing famine like conditions which has created a need to rethink food security.

India is experiencing low/stagnant productivity in major crops, high prices in food, drawbacks in supply of food, lower returns to farmers, land shortage for agriculture diversification and environmental degradation which includes soil, air, water etc. which could be a major crises or threat for ensuring security for provision of safe and nutritious food.

Our aim was to identify major issues and concerns relating to Food security and also provide ideas for policy intervention to overcome the identified problems and improve food security in South Asia.

3.1.a. Major Reasons for the existing food insecurity in India

Climate change and agriculture are strongly co-related, with agriculture being highly dependent on weather. It is clear that the fast pace of climate change would have far reaching impact on agro-ecosystems and their productivity[1]. Hence, it is high time that we prepare ourselves for the up-coming challenges so as to combat the negative impact of climate change and ensure food security not only for humans but other living beings as well. Climate change and insecure food systems are challenges not just to the farmers but to all those who depend on food. Following are some of the major reasons that could affect food availability today and in the near future:

1. Climate Change and Erratic weather pattern

The mean rainfall in India is expected to increase [2], by 10 percent by 2070 [3]. Due to increase in flooding and erratic rainfall conditions, many farmers tend to delay crop planting. Because of this, food price volatility and stress to farmers increases. Also, warming climate causes an increase in pest or pathogen attack [4]. In India, the mean temperature has been projected to increase up to 1.7ºC in *kharif* (July to October) and up to 3.2º C during *rabi* (November to March) season. Since insects are exothermic, they become active in warm weather and estimates show that with a 2^0 C temperature increase, insects tend to possess one to five additional life cycles per season [5], hence possibility of insect attack increases as temperatures rise. The locust attack, annually in South Asia and Africa is one of the most dreaded insect infestations, which causes crop losses. In the last 15 years, there have been reports of ten major invasive pests and weed attacks. Armyworm invasion had led to destruction of India's maize crops.

Increasing temperatures also allows *Salmonella* and other pathogens to thrive and also causes increase in toxin production by fungi which are a threat to food. According to the 2019, IPCC land use report[21], 25 and 30 percent of the food produced globally is wasted, costs $1 trillion per year and accounts for approximately 10 percent of greenhouse gas emissions from agricultural systems. Increase in carbon dioxide levels in the atmosphere account for a decrease in zinc, dietary iron, protein, and other macro- and micronutrients in some crops. According to IPCC's land use report[21], agricultural practices and other land uses are responsible for one-fifth of global CO2 emissions, this creating a chain of circumstances.

2. Irregular Growth in Rural and Urban Areas

Due to lifestyle changes people in India are either overweight or obese [6] even though malnourishment exists. The number of undernourished people in India has declined from 249.4 million in 2004-06 to 189.2 million in 2017-19 [20.] Shortage in access to food supplies in rural areas and tribal areas has resulted in unequal distribution in the quality of food. In urban areas, large proportion of informal workforce has caused unplanned but rapid growth of slums which lack basic health and hygiene facilities. This has led to inefficient distribution of food and hence a correct census of population needs to be carried out. While increased incomes allow households to purchase foods, a diverse range of nutritious food products may not be available in the local marketplace. Moreover, many households often choose to spend increased earnings on other priorities than food, causing no change or even deterioration in food security. Women and children in rural and urban areas have many deficiencies, which can be cured by a balanced and adequate quality of food. In urban areas, although there is affordability but lack of awareness in healthy nutrition and lifestyle change is the cause of many vitamin deficiencies such as Vitamin A, Vitamin D and iron. NFHS-3 has reported that there is severe wasting or severe acute malnutrition in children (0-5 years) and these were at 6.4% for India. Proper implementation of programmes for improving nutrition needs to be done. A complete diet chart of what needs to eaten for obtaining the necessary building blocks for a balanced diet has to be provided so that people can be aware of what needs to be consumed. "Annam Aushadham" according to Ayurveda, the traditional Indian Vedic system of Medicine whose origins are ancient, reveals, “your diet is medicine.” One who knows and understands what to eat, how to eat and how much to eat will obtain good health, well-being and would be free from diseases. According to Ayurveda, a proper diet is an important pillar to support life. Therefore, an emphasis needs to be given to the diverse local foods in each state and their production needs to be encouraged to so that valuable food and medicinal plants are revived. A robust nutrition program needs to be generated.

3. Degrading environmental resource

Long-term ecological effects can be observed, some of which can cause demolishing of whole environments such as many plants and life forms which are evident parts of the environment, but this diverse resource also includes the things these life forms depend upon for example, streams, lakes, soils, pollinators, animals for livestock, beneficial microorganisms etc. Hence, today a lot of plants [7] and animals including birds are endangered. Apart from anthropogenic changes, climate change further aggravates loss of critical pollinators and other microfauna, which are important for ecosystem functions and are essential for nutrient cycling. Excessive use of fertilizers and pesticides during crop production causes disruption in environmental biogeochemical cycles especially nitrogen, phosphorus, iron, sulphur, carbon cycles, also causes aquatic and air pollution and reduces biodiversity. By omitting local food crops, human needs and ecological relationships had taken a backseat. The pests and crops tend to coevolve. Preventing invasive species is also a challenge. By introducing invasive species’ natural enemies — for example, the co-evolved fungi or insects that attack them — their spread can be controlled.

3.2. TRENDS IN FOOD PRODUCTION AND CONSUMPTION

Agricultural science should allow the supply of food for the ever-increasing human population and provide enough nutrition for better health. Due to continuous efforts, agriculture in India has undergone a transformation from severe food shortages in the 1960s to not only achieving grain sufficiency today but also has ensured excess production of some food grains enabling exporting of food grain to other countries.

Agriculture has played a central role in the Indian economy with more than 70 % of the rural households depending on it for their livelihood. Along with fisheries and forestry, agriculture accounts for one-third of the nation's Gross Domestic Product (GDP. Apart from being the largest contributer of India's GDP, the country's exports constitute a fifth of the total exports.

India is world's largest producer of milk, pulses and jute, and comes second in the production of rice, wheat, sugarcane, groundnut, vegetables, fruit and cotton. India also accounts for leading production in spices, fish, poultry, livestock and plantation crops and is the largest producer of pulses (25% of global production). The contribution of agriculture and related sectors is estimated at 13-17% of India's GDP. Although the overall growth in this sector has been fluctuating in recent years, it has been amounting to less than 3% between 2014-15 to 2018-19. However, NITI Aayog, has predicted that the Indian farm sector will continue to grow at 3% this year in spite of adverse conditions and will add 0.5% to the country's GDP in 2020-21, which could play a significant role in preventing the Indian economy from shrinking.

Although, previously, the Green Revolution had helped in increasing the productivity of crops, but adverse practices have led to shifting of sustainable productive practices and natural resource base to a threatening degradation of natural resources. Also, excessive emphasis on rice and wheat has caused reduced production and consumption of jowar, bajra, ragi, maize, and other types of local wheat and rice varieties. Rice and wheat productivity has plateaued especially in India's north-western region[8]. Because the green revolution brought in high yielding varieties of crops, it also led to increased and unregulated use of pesticides and fertilizers. The modern varieties of high yielding varieties of major crops have a narrow genetic base, causing a derailed effort in improving their genetic gains. Continuous monocropping is another burden on land, which contributes to reduced soil health and raises pathogenic attacks or disease outbreaks. With changing climate, the frequency of pest, attacks and long periods of drought would cause more problems in crop production.

It is therefore important to give importance to local Indian varieties of sorghum, other different millets and also drought resistant varieties of crops such as chickpea, groundnuts, legumes, local varieties of rice (including medicinal), drumstick etc. which need to be encouraged to ensure that our diversity does not fade or be lost. We need to also promote grains like amaranth and buckwheat. We now need to revive the traditional food crops, which are not only important for consumption but also broadening the platter to gain the right amount of nutrition.

Since India has achieved grain sufficiency, it is now not only important to sustain our natural resources while paying attention to the food production processes but also advance research into finding new ways to boost our food production process.

The use of conservational and organic agriculture which encompasses the use of low cost inputs such as organic manure, green manure, crop rotation and cover crop can be one such approach to preserve the native strength of our natural resources while also building a sustainable farming system resistant to the harsh variability of the climate. Research demonstrates the efficiency of organic compost applied in different combinations to be at par with mineral fertilizers especially in terms of soil quality, enzyme activity, and available nutrients[9]. For instance, long term application of organic compost in the basmati rice fields of Kaithal, Haryana [10] showed profound improvement in soil health as well as water holding capacity and soil biological activity which is suggestive of the immense benefit that comes from organic farming. There are also studies that indicate an integrated approach of organic farming partly with inorganic fertilizers leads to production of good results in terms of both crop yield and productivity. Organic manure with different components and compost combinations, crop rotation, employing beneficial micro and macro fauna for decomposition processes, cover crops, increasing tree cover are important for integrating into agriculture.

Crop diversification is an effective substitution for mono cropping. This also includes using alternate crops, which are more robust, drought resistant and nutritionally rich. Likewise, other drought resistant varieties of crops include millets, groundnuts, local varieties of rice, sorghum, legumes, chickpeas, buckwheat which can be encouraged for cultivation to promote a diversified farming system in India.

Agroforestry includes the incorporation of multi-purposeful trees into agricultural set-ups with the combined management of the forest reserves in the vicinity and is another means to enhance natural resource. Incorporating fruit trees such as apple, mango, banana, papaya, guava and citrus fruits contribute to 80% of the country's total fruit production. The fruit trees not only serve as a source of income but also produce other commercially important side products like timber, fuelwood, spices, fodder, secondary metabolites for ayurvedic medicines, etc. which add to the livelihood of farmers [11]. Besides adequate revenues generated in the market from the various products, these trees also facilitate farmers to reduce cost-inputs and negate damaging effect of the environment on soil fertility and productivity. For instance, trees function as shelterbelts or wind breaks in agricultural plots inducing micro-climatic changes in the form of reduced wind speed, moderate soil temperatures, reduced soil evaporation losses and improved soil moisture. Additionally, experimental data have also demonstrated agroforestry systems to sequester more carbon than fields with sole crop cultivation [12] which again emphasizes the importance of diversification in agricultural sets up over mono-cropping systems.

More than ever, today, there is also an urgent need to restrict artificial chemical inputs into agricultural soils to facilitate a more effective nutrient cycling system without any risks towards cultivation productivity [13]. In order to create an agricultural system free from these additives, biological agents can be employed as effective replacements. Bio-inoculants is one such resource, recently being advertised as the corner stone of the next green revolution [14] which can be incorporated as a cost cutting solution for agricultural inputs. Microbes have their roles established in supporting mineralization and stabilizing carbon inputs in the soil (as soil organic carbon) thereby facilitating a reduction in net fluxes of greenhouse gases (GHG) into the atmosphere [15]. Besides, research has also depicted how addition of microbial inoculants into degraded soil can help in enhancing rates of carbon sequestration leading to GHG reduction [16]. Additionally, microbes also have recognized roles in nutrient cycling, disease suppression, immunity and growth stimulation in plants which can serve as an advantage towards sustainable and productive farming systems. Microorganisms, which are photosynthetic, utilize atmospheric carbon dioxide, whereas the heterotrophic microorganisms are involved in the decomposition of organic matter, which releases greenhouse gases. This harmonious balance between the two critical processes is an important determining factor of the net carbon flux, which can differ across many ecosystems largely relying on the climatic conditions such as the temperature etc. Hence, this is what makes the microorganisms an important part of the carbon flux on earth [17].

Hence, microbial interactions in nature need to be decoded to engage their activities in overcoming the numerous negative influences of climate change to further enhance plant productivity and carbon storage efficiency of agricultural lands. Beneficial bacteria are important for providing a vital vitamin i.e. Vitamin B12, since its deficiency is present in the Indian population. Urgent action needs to be taken to integrate microbial interplay in agricultural adaptation to climate change to build a fortified agricultural system that is resilient to the extremities of climate vagaries.

3.3. IMPACTS OF ENVIRONMENTAL CHANGES ON AGRICULTURE AND VICE VERSA

Rapid growth of population, misuse and overuse of natural resources, economic development are the primary causes that have led to environmental degradation in India. Rampant economic growth, altered consumption patterns, altered agricultural practices, the rising demand for energy and increase in traffic has led to air, water and noise pollution.

Major and minor environmental impacts include soil degradation, climate change and water shortage, shrinking land resources etc. Although, it is difficult to assess or quantitate how environmental fluctuations will affect agriculture in India it is importance to carefully analyze the current shrinking resources in order to know how much importance must be paid on the mitigation of negative environmental impact. Excessive use of chemical pesticides and chemical fertilizers have caused a deterioration in soil health, therefore, it is important to use biological organic manure which will result in decreased reliance on chemical inputs in agricultural fields. Further, this would allow soil to regenerate, allow reclamation of degraded lands. Biologically enriched compost is known to enhance nutrient cycling, reduce the pest and pathogens in the soil and arrest further soil, air and water pollution. Increasing soil microbial diversity, phytoremediation processes etc., increases soil organic matter which will allow better carbon dioxide fixation in the soil and enhance crop productivity. Afforestation and planned agro-forestry helps in decreasing the level of greenhouse gases which help in mitigating the negative effects of climate change and help in recovering of marginal or degraded land. Deforestation for expansion of agricultural fields and urban development have disrupted the natural balance of carbon cycle which has resulted in increased carbon footprint and led to other adverse effects on biodiversity. Retaining, preserving and nurturing forests with wide diversity of flora are important targets since these forests act as CO_2 sinks and help to reduce greenhouse gases. Even in urban areas tree planting needs to made mandatory as trees improve oxygen levels [18]. Planting local trees such as Neem, Peepal, Banyan trees, Ashoka, could further enhance oxygen levels in the air.

Greenhouse gases including carbon dioxide, methane, ozone, nitrous oxide and chlorofluorocarbons are not only affecting agriculture but also causing increases in atmospheric temperature. The increase in temperature would also lead to increased evapotranspiration. There is need to quantify the specific regional soil-related problems, Saini and Nanda (1986) state that there is a decline of 600–650 grains m−2 in wheat with every 1˚C increase in mean temperatures above 17–17.7ºC especially when the terminal spikelet begins up to anthesis[19]. For every 1˚C rise in temperature during the growing season, it is estimated that wheat production in India could reduce by 4-5 million tonnes and that rice yields may reduce by 6%.

Due to Climate change many sporadic events have been frequently rising. Flash floods, heavy rain, increased drought, melting of glaciers are all examples of this. Kedarnath floods in June 2013 and heavy foods in Kerala, India, in 2018 are examples to showcase that excessive interference with nature could prove disastrous. These floods cause washout of top soil and essential soil nutrients resulting in decline in productivity for several years in future, unless and until rapid, corrective and environmental friendly remediation strategies are not worked upon.

It is now known that more nutrients have been lost than that can be added through chemical fertilizers, and in the current times farmers have to use more fertilizers in order to obtain the same yield than they were getting with lesser fertilizers ~20 years ago. Climate change would further affect soil conditions. Changes in temperature, changes in precipitation patterns and precipitation amount will influence soil water content, run-off and erosion, salinization, biodiversity, and organic carbon and nitrogen content. Extreme weather conditions, such as floods, droughts, heat and cold waves, flash floods, cyclones and hailstorm, are direct hazards to crops. Subtler fluctuation in weather during critical phases of crop development can also have substantial impact on yields. Cultivated areas are subject to a broader range of influences, including changes in commodity prices (seeds, manure etc), costs of inputs and availability of irrigation water. Lesser than normal rainfall can reduce water supplies for crop irrigation, leading to uncertainty in crop yield. During the years of deficit monsoon in India (1966, 1972, 1974, 1979, 1982 and 1987) food grain production had considerably reduced while during the years of excess or normal rainfall (1970, 1975, 1978, 1983 and 1988) crop yields had major gain.

It will be necessary to use advancing in remote sensing and satellite imaging to aid future predictions for the vulnerable agro-ecosystems and hence corrective measures can be applied by involving a multi-disciplinary approach. Such advancements can further aid in working out the appropriate responses, preparedness and planning of managing the agro-ecosystems for extreme events such as water scarcity, heat waves, floods and hence suggest early warnings. Bringing together, educating and sensitizing farmers to sustainable technologies and corrective activities is of utmost importance as the farmers are the ones who can play a major role in implementation of future ecological goals. Climate smart agriculture is also important requirement for enhancing the yields and quality of production.

3.4. SCIENCE AND TECHNOLOGY TO IMPROVE AGRI-FOOD SECTOR

Divecha Centre for Climate Change, Indian Institute of Science, Bengaluru, India along with CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) hosted its first “Asia Regional Workshop titled “Digital solutions to accelerate adaptation to climate change in agriculture” on 13-14th January, 2020. This joint workshop brought together eminent key resource persons from research, industry, civil society, and governments from Asia and other regions to discuss the applications of digital agriculture for climate change adaptation. This successful workshop included discussions on novel frontiers in agricultural practices and state of the art digital solutions to include innovative solutions to food security measures as well.

3.4.a. Science and Technology Solutions to Current Challenges in Food Security

3.4.a.i. Technology Innovations in Irrigation and Water Use

In India, the agriculture strategy for the cultivation of wheat-paddy annual crop cycles has led to conflicting pressures on water resources, with a depletion of ground water, and nutrient loading of potable water. This over exploitation of rice-wheat rotation has led to a plethora of problems. The water productivity of rice, wheat and sugarcane take away almost 80 per cent of the irrigation. These water intensive crops could be grown in hydrologically suitable areas. Local more drought resistant crops need to be given emphasis and their production must be expanded.

Another serious threat is the degradation of environmental quality in the form of pollution of natural water bodies and underground aquifers due to nitrate leaching and phosphates causing irreparable harm to natural ecosystems under high fertilizer use.

Solutions in Water Use and Irrigation for Agriculture

Extensive rainwater harvesting in the urban and rural areas and in agricultural fields to increase the water table.

Building ponds and bunds in every agricultural field so that water is conserved. Few crops could be irrigated during the night so that it prevents evaporation. Ensuring that crops are irrigated using clean uncontaminated water source to prevent diseases.

Using renewable energy sources such as solar power to run desalination plants which could generate fresh water for irrigation. This will enable converting drought affected regions into agriculturally suitable areas.

Better solutions to tap rain water for irrigation. Canals and clean water channels from various river tributaries and rain water to tap excess run of water would be essential. Other regions of India require innovations and catchment management in order to support sustainable intensification of agriculture

Examining past and present water availability with respect to cropping practices during different weathers, surveying to identify water efficient crops suitable to grow in extreme water scarce areas, crop-modelling, identification of water sources and groundwater recharge using stable isotopes signals, assessment of trade-offs between crop yields/income, water consumption along with various other ecosystem services would be essential.

3.4.b. Soil Restoration and Health

As discussed earlier, soil health is critical for food security. As per the United Nations Convention to Combat Desertification (UNCCD) "restoring the soils of degraded ecosystems has the potential to store up to 3 billion tonnes of carbon annually". There is degradation of more than one half of the global agricultural land and crisis associated with disturbance in the nitrogen and phosphorous cycles. This situation is likely to worsen due to climate change. Therefore, a vigorous re-introduction of sustainable land management practices to minimize land degradation would be needed. These practices include crop diversification, use of local adapted species or intercropping in order to maintain soil fertility, carbon sequestration measures, nutrient cycling as well soil erosion control Interestingly, these procedures also help in disease suppression. In addition, sustaining microbial community diversity, structure and composition can help to support ecosystem functions, e.g., by regulating nutrient cycles. The soil health-card scheme, launched by the Government of India in 2015, allows soil testing and analyze any micronutrient deficiency in soil. Such strategies and improvements in these are needed to enhance soil remedial measures.

3.4.b.i. Solutions in Soil Science and Technology for Agriculture

a) Using Drone and satellite imaging technology to map the health status of fields and plan future treatment strategies.

A complete but evolving soil database along with visual analytics would enable us to plan for better soil health.

Incorporating bad quality seeds, chemical fertilizers and pesticides and herbicides, practices are causing degradation and depletion of environment resources. Therefore, natural composting methods, innovative formulations in bio-fertilizers, new mixes of beneficial microbial inoculations, bio-pesticides and new methods in pest and pathogen arrest are needed.

Land degradation is supposed to influence the lives of more than 1.5 billion people and 15 billion tons of fertile soil which is lost every year due to anthropogenic activities and climate change. Land degradation is one of the causes of mass migrations (United Nations Environment Programme in 2017) and due to this 500 million hectares of farmland has been abandoned. Constant drought and desertification, frequently occurring due to climate change, cause low productivity of crops. This also causes immobilization of important nutrients and salt accumulation in soils, in turn making them unhealthy, more dry, highly saline and finally infertile. With time such lands become non-arable leading to farmers abandoning them. Hence suitable solutions to prevent desertification are of urgent need.

3.4.c. Integrating agriculture with other activities

Embracing a synergistic approach of farming with livestock, crop rotation, horticulture, fisheries would help the agriculture in a holistic manner. Integrated farming systems with local diverse crops, flowers, tree vegetables (drumstick etc.), tree fodder, tree flowers (sampige), dairy, poultry, fishery, encouraging insects such as bees, birds for seed dispersal, are necessary.

Thus, models for agricultural enterprises should be designed to achieve higher income and sustainability. Agro industries can produce "Made in India" bio-fertilizers and bio-pesticides. Agroforestry serves to provide forest cover to the agricultural plots and increase carbon sequestration. Aquaculture, along with additional aquatic assets allows generating extra income for farmers. Aquatic plants including water chestnuts, lotuses etc. are used as food and hence need to be encouraged on agricultural fields. Parallel activities such as horticulture, cotton weaving, apiculture, mushroom cultivation, dairy products etc. are important when crops fail due to climatic variability. Moreover, the dung from cattle can be used to generate organic compost to eliminate the overdependence on chemical fertilizers. Agro-based industries like leather preparation from mushrooms, food processing, weaving, dairy processing etc. can be set up for promoting enhanced employment and income opportunities for farming communities. Also, agricultural extension programs can be promoted to enhance the agricultural knowledge of farmers, give education to their children and to expand their problem solving abilities. In India, Agri-Clinics and Agri-Business has been undertaken by the Department of Agriculture Cooperation and Farmers' Welfare to promote awareness on pest diseases and their remedies.

3.4.d. Post-harvest technologies

Improvement and innovations in post-harvest storage of farm produce would be important. Increasing the cold storage capacity and preventing post-harvest losses by grain storage banks etc., could address this. Also addressing food wastage due to many factors such as rodent attack etc., needs to be done. Conversion of food material to value added foods needs to be considered.

3.4.e. Digital technologies

A number of modern technology interventions in agriculture are based on smart phone applications. The government portal, e-NAM, an online trading platform for agricultural commodities, is accessible via smart phones. It is also possible for farmers to access weather tracking services online (IMD), which may allow them to take precautions to protect crops or mitigate losses in case of unfavourable weather conditions.

The use of artificial intelligence has also been recommended to improve agriculture, as these tools can be used to reach solutions-based data such as weather conditions and suitable soil type. The central government-sponsored Pradhan Mantri Fasal Bima Yojana (PMFBY) has used AI tools in a number of pilot studies for optimising crop cutting and yield estimation. Drones are also being used to provide real-time information about crop growth, soil deterioration and pest infections. The use of satellite imagery and animal tracking are suggested as means to improve fishery and livestock respectively, whereas vertical farming is gaining grounds in urban areas where land is scarce. Improvements in agricultural technology especially that is "Made in Inda" that does not require heavy machinery and equipment might be more affordable and be helpful for all those who would want to pursue farming.

3.4.f. Policies that need rethinking and better implementation

a) In India, resources like land, water, and soil health are hugely stressed. Policies should be devised to rejuvenate the barren lands, re-balance the existing health of the farm lands. Also, while mapping new cities or constructions a balance between the business areas/industrial areas, residential areas as well as agricultural lands for region specific cultivation would be important. Areas which have good rainfall and weather conditions should be preserved for agriculture and areas which are not arable need to be allocated for industries.

Policies need to be devised for teaching, awareness building and outreach to relate the importance of farms and agriculture life style for attracting farm-related employment opportunities. Effective communication between scientists, government bodies, public and agricultural personnel needs to be given emphasis.

Policies need to be prioritised for long term goals and strategies oriented towards soil health i.e. maintaining the health of the soil and managing the flora and fauna diversity of the fields, increasing crops with multiple local crops, fruits and vegetables in the same area. Ensuring sustainability in each area would be challenging but important for the future.

3.5. FUTURE PLANNING FOR IMPROVED PROSPECTS OF FOOD SECURITY IN INDIA

Agroforestry: A major shift in incorporating the minor fruit trees along with the major fruit trees within the agroforestry should be encorportated. Minor and major fruit trees are advocated to be incorporated in agroforestry system for self-sufficiency in fruits, conservation of biodiversity, protecting endagered fruit varieties, commericial timber and top feed. Minor fruits are a major source of nutrition to people in rural areas as they have limited access to major fruits. Emphasis on medicinal and aromatic plants/trees which are of pharmaceutical value (including ayurveda, siddha system of health etc) and for commercial purposes are important keeping in mind the health sector of the country.Therefore, emphasis on Agroforestry needs to be seriously considered as it not only contributes to food, sustenance of livelihoods, nutritional and ecological security, reducing poverty and promotion of resilient cropping and farming environments and contribution to mitigation in climate change.

Measures are needed to restrict indiscriminate exploitation of ground water and promote measures to tap rain water.

In-efficient Land Use: The changes in land use patterns need to be carefully observed such as preventing diversion of highly productive, fertile, irrigated land to nonagricultural uses (such as industry, commericial activity etc.)

Measures are needed to resist build-up of diseases/pests- Additional research and local knowledge about preventing plant diseases which affect plant yields.

Climate change and natural hazards: It has been predicted that climate change is expected to reduce precipitation and crop production potential in tropical regions, which could affect food insecurity. It is also expected to increase the frequency of extreme weather events such as droughts, storms and floods, thereby enhancing production risks of farming. These hazards lead to massive losses of human resources and infrastructure. Floods and droughts significantly impact a majority of stated in the country, though they are most common in the north-western and eastern regions and the geophysical hazards affect Northern and north-eastern portions of the country (mainly the Himalayan region). The cyclones influence coastal areas of the country. Hence corrective early warning systems need to be given emphasis to prevent crop losses.

Food contamination/adulteration: Many food items in India have chemicals or adulterants added to them, which make them unsafe for consumption. This will involve a comprehensive process which involves establishing improved and strict testing facilities or laboratories.

Despite significant economic growth over the past few decades, rates of malnutrition continue to prevail which needs to be addressed.

3.5.a. Recommendations:

The need to revise arrangements to ensure affordable delivery of requisite quality food grains in a transparent manner is required.

Improved communication systems using digital platforms may help farmers get a better deal for their produce. Crop insurance schemes can be promoted to protect the farmers when their crops are ruined due to natural calamities.

Enhancing agriculture productivity: The government, through investments in vital agriculture infrastructure, credit linkages and encouraging the use of latest techniques, motivate each district/ block to achieve local self-sufficiency in food grain production. The focus must shift from only rice or wheat to other indigenous local crops. Creation of necessary infrastructure like irrigation facilities will also simulate private investments in agriculture. Emphasis on "Made in India" agricultural goods and involving youth would be a boost to the agricultural security in India. Preserving and advocating traditional food recipes would increase the repertoire of food for consumption.

Targeted Public Distribution System- It is important to distribute food to all the sections of the society and hence measures must be taken in better transport and supply so that food reaches all.

3.5.b. Priority areas

3.5.b. i. Balance food and nutritional security

In order to overcome food shortage, attention had been focused and prioritised on the investment in staple crops such as maize, rice and wheat. However now there is a need to pay attention to the calorie intake and focus on the nutritional balance of the crops grown and consumed. In order to alleviate malnutrition an emphasis on the research and production of not only staple crops but also horticultural crops including local fruits (including dry fruits), legumes and vegetables would be needed. Neglected or underutilized local varieties of fruit and vegetables often offer a good source of nutrition. Famers must be supported to ensure diverse crop varieties and different crop mixes are incorporated in planting regimes. Workshops and incentives for giving them the information they need in order to manage the unfamiliar pests and diseases that may attack their plants would be necessary. The development of a more diverse and competitive seed sector and measures to help farmers improve soil health, are also crucial, since better quality seeds and soil lead to better quality produce. Identify food security gaps and consumer needs first by scientific assessment, and then incorporate this information by using a food security lens to inform value chain selection and analysis. This entails understanding the major factors leading to food insecurity such as poor productivity, availability, access, or utilization. If food insecurity is harboring malnutrition, understanding the key contributing factors (e.g., inadequate calories, unbalanced food plate, lack of protein or micronutrients, poor quality or adulterated food or water) is equally important. For example, if an assessment identifies key macronutrients or micronutrients as a critical contribution to food insecurity, then measures need to be devised so that the food plate should include these micronutrients.

3.5.b. ii. Embrace new technology for knowledge transfer

Agricultural advice through digital technologies especially "Made in India" platforms including that delivered by mobile phone is one of the most effective methods of sharing information. The know-how delivered must cover the information on full food production cycle, from pre- to post-harvest, weather predictions, soil nutrient status, plant diseases, consumer needs must be integrated. For example, the website on Famer's portal run by Department of Agriculture & Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India has been started to provide accurate information on the soil health card. Mobile technologies to link smallholders to markets, to include market information, and microfinance can be expanded.

3.5.b.iii. A balanced and sustainable goal towards agriculture

As the Sustainable Development Goals take shape, certain goals tend to focus on the environment, while others focus on food security but now it is time to integrate them. Farmers must preserve their land for food production and at the same time focus on generating income from tourism and other commercial activities including cash crops. Agriculture should also include beautifying landscapes, reduce wastage of food, promote diversity of interactions among people and their environment, agricultural and non-agricultural systems, animals and plants. The end products after harvesting could be used for fodder and subjected to creating manure. Strategies to reuse and recycle agricultural/farm end products must be adopted.

3.5.b. iv. Create careers in agriculture for young people and women.

Encouraging and supporting employment opportunities for young people and women in agriculture is not a new challenge, but does need reinvigorated attention. In developing countries, the youth are migrating and leaving villages to work in the cities. Nurturing the career of our youth in agriculture is essential so that they become associated with an effective, productive and sustainable food production system that is essential for safeguarding our long-term food security.

3.5.c.v. Analysing and applying a valuable Supply Chain and Demand

Despite many imperfections in the supply chain, block chain based solutions integrated over internet of things or artificial intelligence would be an important addition to creating value in traceability in food produce, its supply to consumers and monitoring its shelf life and storage.

3.6. EFFECTS ON FOOD SECURITY DURING THE CORONAVIRUS PANDEMIC

Although, India did not face any food shortage during the lockdown, due to Coronovirus pandemic, a shortage of labour, shortcomings in safe and suitable transportation facilities and inadequate resources locally to store harvested agricultural food produce posed challenges. However, it led to an awareness for future measures that may need to be implemented during crisis or other pandemics. In addition, measures for production of goods ‘Made in India’ need to be encouraged and implemented.

The central government announced a number of measures taken in response to the consequences of the Coronavirus pandemic. Measures included various activities and infrastructure in agriculture and animal husbandry such as “amendment of the essential commodities act, allowing and facilitating contract farming, allowing private markets to be set up” etc. Introduction of changes in the e-NAM platform and further technological support has been provided to connect farmers to downstream market processes and contract farming has been promoted in some states. As per Second Advance Estimates for 2019-20, India’s food grain production was estimated at a record 291.95 million tonnes (higher by 6.74 million tonnes as compared to 285.21 million tonnes during 2018-19). This is also higher by 26.20 million tonnes as compared to the previous five years’ (2013-14 to 2017-18).

However, with sufficiency being achieved in food production, the major future goals include encouraging more diverse local Indian crops to improve the nutrient uptake by Indians and production of food needs to be carried out under environmentally favourable conditions in order to safeguard our future natural resources.

Appendix: Figures

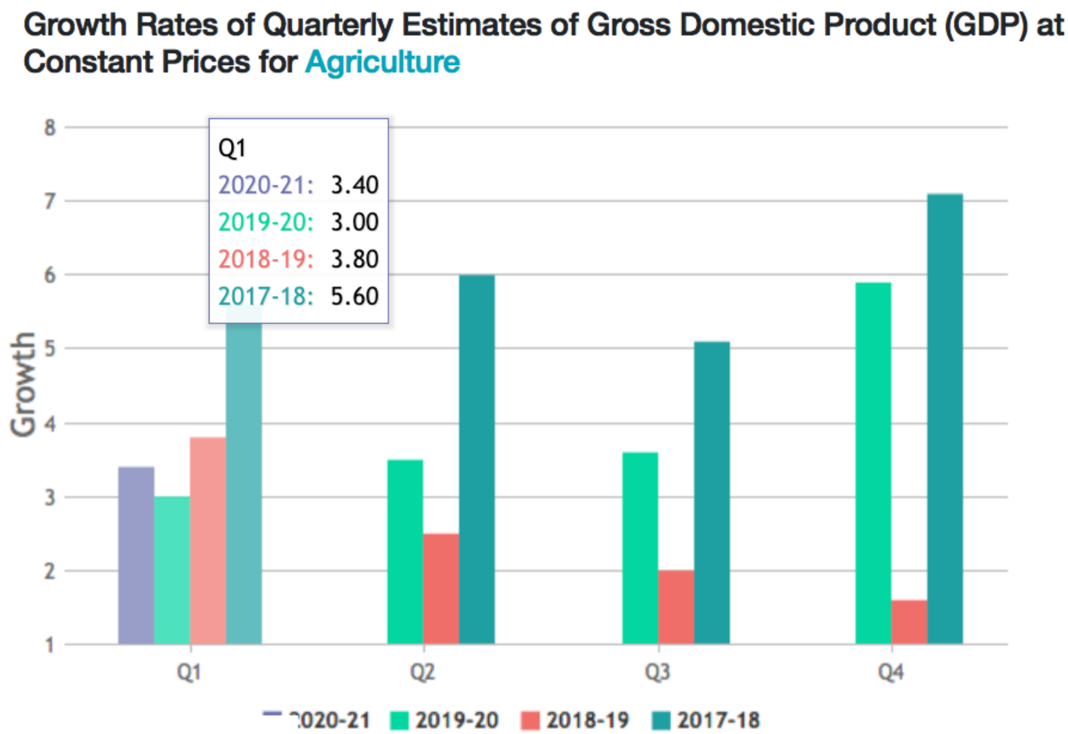

Figure 1 GDP for agriculture in India

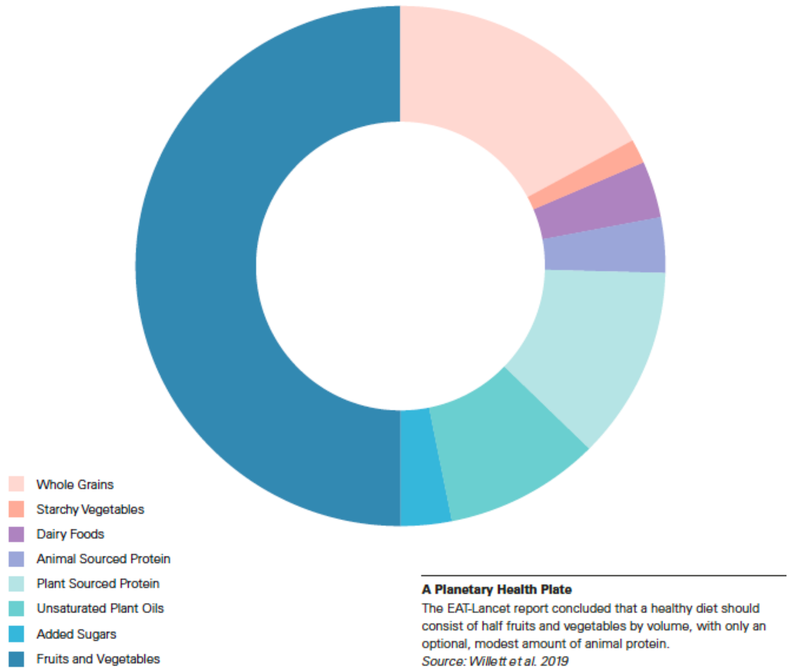

Figure 2 Inclusion of fresh fruits and vegetables as predominant food items need to be encouraged

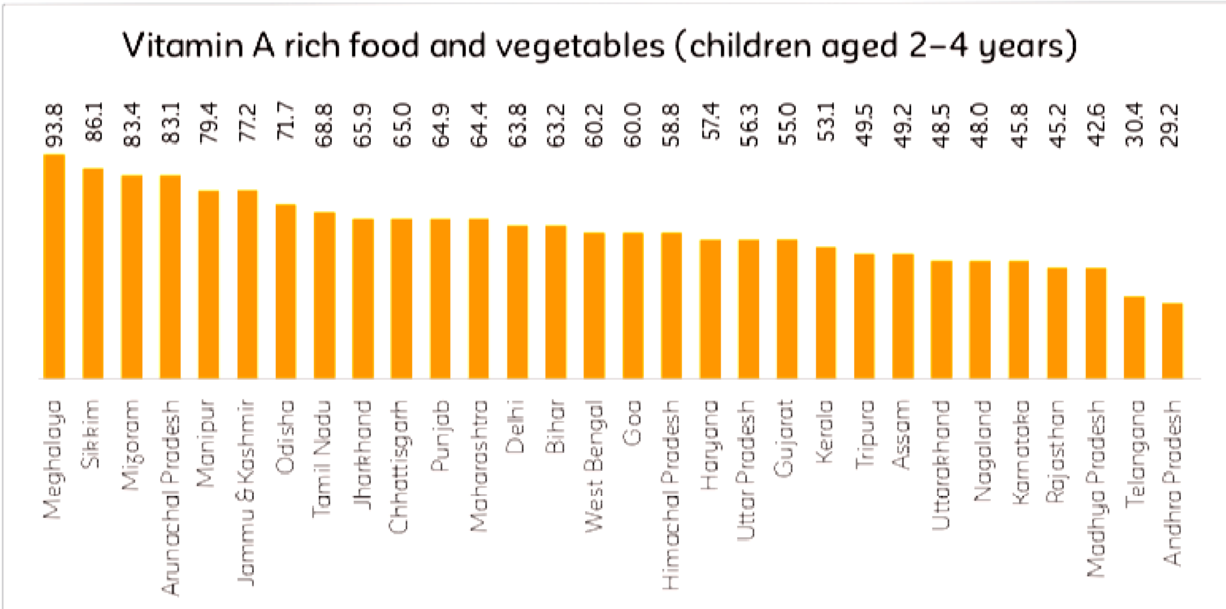

Figure 3 Vitamin A rich foods consumed._Source: Comprehensive National Nutrition Survey_2016-18_Children and Adolescents

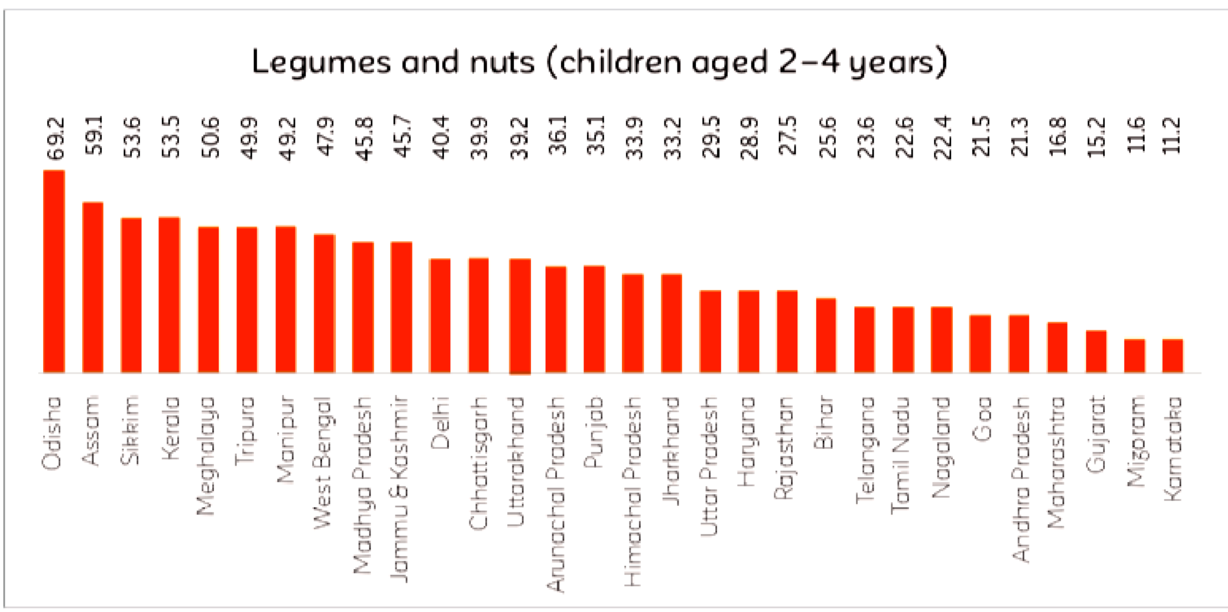

Figure 4 Legumes and nut consumption in India._Source: Comprehensive National Nutrition Survey_2016-18_Children and Adolescents

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4. Agriculture, Fisheries and Food Security in the Maldives

4. Agriculture, Fisheries and Food Security in the Maldives

SUMMARY

The Republic of Maldives is an archipelago of 26 natural atolls, consisting of 1,190 coral reef islands in the Indian Ocean. Around 99 percent of the country's territory consists of ocean. A significant challenge regarding the country's geography is that its population is dispersed across many small islands, which makes service delivery difficult and can limit opportunities for job creation and economic diversification. Along with inclusion issues, this has caused relatively high levels of youth unemployment at 15.3 percent, and low rates of women participating in the workforce.

The natural resources in the Maldives mostly comprise multi-coloured coral reefs, tropical ocean fish of many colours and shapes, crustaceans, turtles, seaweed and shells. The abundance of these natural resources creates the basis of the two most important economic activities in the Maldives, fisheries and tourism. The fisheries sector has traditionally been the biggest contributor to the country's economy although since 1978, its contribution to the GDP has continually declined. This is primarily due to the introduction and rapid growth of the tourism sector and diversification of fishery-related businesses into other economic sectors such as export and labour. The fisheries and agriculture sector account for around 6 percent of the country's GDP, as of latest known figures, and it reportedly employs 10-11 percent of the total working population of the Maldives. The fisheries and agriculture sector are considered to remain important in terms of employment, value added products and export returns.

Maldives is self-sufficient in fish whereas rice, wheat, fruits, vegetables and other food items are largely or entirely imported. The country balances its food requirements through both domestic production and food imports. It is estimated that Maldives produces less than a tenth of its overall food requirements. The majority of food products, including 100 percent of the staples (rice, wheat and sugar) are imported. To cater to the growing population, expatriate community and large number of tourists' visiting the country, the Maldives needs to import large quantities of food every year. The Maldives lack a food security policy, although it is integrating food security into national planning.

Some of the major constraints identified with regards to agriculture, fisheries and food security in the Maldives include lack of proper data and its management, challenges in training and retention of technical capacity, poor institutional capacity, lack of appropriate infrastructure for value chains, low availability and accessibility to finance and credit facilities, poor quality of fish and fisheries products, limited value-added products, undervalued fish exports, lack of seed availability for grow-out farmers in aquaculture, environmental concerns of aquaculture and the unrecognized role of women in fisheries. It has been indicated by the Mauritius Planning Forum that various policy initiatives are being taken up by the government to improve these constraints. Other constraints identified with regards to agriculture in the Maldives include labour shortage and lack of skilled labour, especially with regards to training and extension support capacity, the difficulty

in acquiring credit for agricultural initiatives since it is seen as a low profit sector, the increasing number of pests, diseases and weeds attacking the crops and plantations, and that imported fresh and processed products are cheaper than domestically produced ones.

With regards to the fisheries sector, little sustainability in the industry due to several factors including policy, regulatory and management have severely affected decline in fish catch. A lack of capacity in the current regulatory body to enable and coordinate the sustainable development of the sector has been noted, since this allows for certain parts of the ocean to be exploited as an open access resource. Rapid advancements in the industry have not yet reached all areas nor is there sufficient expertise in engaging in fish business at the international level. Climate change is also regarded as a huge threat to the lives and economy of Maldives since it is quite vulnerable to rising sea levels. 80 percent of its total land area, less than 300 sq. km., is lower than 1 metre above the average sea level. The country's exposure to natural hazards and climate variability poses a large threat to lives and the economy.

As a country greatly dependent on tourism, Maldives is amongst the worst affected countries in Asia due to the impacts of the COVID-19 pandemic. The shock to tourism adversely affects employment and household earnings, as one-third of adult males and a quarter of females are engaged in tourism-related jobs. Lower-income households that depend on fisheries are also affected as exports of raw fish have ceased due to weak demand. The national poverty rate is expected to increase as households close to the poverty line would likely fall into poverty due to the loss of income sources. Moreover, as a country greatly dependent on imports for basic food and medical supplies, any disruptions in international trade can worsen food security in the country. Enhancing the country's ability to produce a greater proportion of its own food requirements might be seen as even more important since the COVID-19 pandemic.

4.1. INTRODUCTION

The Republic of Maldives is an archipelago of 26 natural atolls, consisting of 1,190 coral reef islands in the Indian Ocean. The closest neighbours to the Maldives are India, Sri Lanka and the Laccadives Islands. There are around 200 islands in the Maldives which are inhabited, 89 islands used exclusively as tourist resorts and the rest of the islands are uninhabited and mostly used for industrial and agricultural purposes. The population of the Maldives is estimated to be over 530,000 as of 2019. All islands are grouped into 20 atolls for administrative purposes, and are scattered over an area of 750 km from north to south and 120 km from east to west covering around 90 000 sq. km. Around 99 percent of the country's territory consists of ocean.[1,2] A significant challenge regarding the country's geography is that its population is dispersed across many small islands, which makes service delivery difficult and can limit opportunities for job creation and economic diversification. Along with inclusion issues, this has caused relatively high levels of youth unemployment at 15.3 percent, and low rates of women participating in the workforce.[3]

The natural resources in the Maldives mostly comprise multi-coloured coral reefs, tropical ocean fish of many colours and shapes, crustaceans, turtles, seaweed and shells. The abundance of these natural resources creates the basis of the two most important economic activities in the Maldives, fisheries and tourism. The fisheries sector has traditionally been the biggest contributor to the country's economy although since 1978, its contribution to the GDP has continually declined. This is primarily due to the introduction and rapid growth of the tourism sector and diversification of fishery-related businesses into other economic sectors such as export and labour. The fisheries and agriculture sector account for around 6 percent of the country's GDP, as of latest known figures, and it reportedly employs 10-11 percent of the total working population of the Maldives, although this figure is believed to be underestimated by various sources. The fisheries and agriculture sector are considered to remain important in terms of employment, value added products and export returns.[4]

4.2. AGRICULTURE, FISHERIES AND FOOD SECURITY IN THE MALDIVES

4.2.a. Agriculture Sector

Although the resource base for agriculture is limited, since the coral islands lack sufficient fertile soil and water, agricultural activities play a key role in livelihoods for more than two-thirds of the inhabited islands. The agriculture sector provides a significant proportion of both food and vital non-food items such as timber, betel leaf, cordage, traditional medicines, firewood and so on. Presently, agricultural production is predominantly focused on horticultural crops. In many islands, field crops such as sweet potatoes, taro, cassava, chilies, watermelons, papaya eggplant, green leaves, cabbage, gourds, and pumpkins are grown throughout the year. Seasonal crops such as mango, breadfruit and drumstick fetch good prices in the market and contribute significantly to farmers' income. In some islands, especially those in the South where low lying swampy areas are available, the growing of root crops such as taro is important. Root crops and breadfruit together comprise traditional staple crops that are grown.[5,6]

Agricultural production system in the country can be broadly grouped into three categories: home-garden production, communal plots in inhabited islands leased for farming according to the regulations of the respective island councils on monthly, yearly or seasonal basis, and farming activities carried out on uninhabited islands that are rented for a 5 to 21-year lease. With intensification and commercialization of agriculture, irrigation is now commonly used. Pressure on communal cropping land increased with shortened fallow periods. Consequently, the use of synthetic fertilizers is on the rise. Pesticide consumption has also increased on many islands. Although there is regulation for importing agrochemicals; currently, comprehensive government policy covering the use of fertilizers and pesticides is lacking. Apart from these, various types of conventional hydroponic systems have been widely adopted for growing leafy vegetables such as lettuce and kungkang, and high-value crops like cucumber and sweet melon. The hydroponics production systems have been heavily promoted by MoFA since 2001. These systems are based on conventional imported hydroponics nutrient mixtures.[7]

The livestock sector is limited to goat production mostly due to lack of land and limited feed availability. Chicken farming in cages, containing free range and backyard poultry, is widely practiced throughout the country. Feeding materials for chicken farming are imported and production costs are high. However, there is a high demand for both chicken meat and eggs, as well as goat meat in the country. Information regarding the forestry sub-sector is very scarce. The country's available forest resources have not been surveyed and inventoried, although the same exercise that estimated the total agricultural area reported the total forest area to be 3,716 ha.[8]

4.2.b. Fisheries Sector

The fisheries sector plays a critical role in food supply and economic development in the Maldives and is a major contributor to food availability and access. Since 99 percent of the Maldivian territory is ocean, fish, especially tuna, is the primary source of protein in the local diet. Reef fish are widely used in the local tourism cuisine and communities depend on reef fishery as a source of income. The marine environment, which constitutes a large part of the country's territory, has been used for fishing from time immemorial. In the past ten years, the fisheries sector has modernized and expanded, with new and larger vessels landing catches of tuna. Skipjack tuna is considered to be the most important species in the Maldivian fishery. It contributes about 65-75% of the total fish catch, followed by 10-17% of yellowfin tuna. The two species are caught predominantly by pole and line fishing.[9]

In the Maldives fishing has been the main occupation of the island communities for centuries. Men go out for fishing, while the women fisher folk produce dried and salted fish generally for export to Sri Lanka. The harvesting sector is mainly controlled by individual fishermen, many of whom build their own boats. Income earned by these vessels is distributed evenly amongst the crew on a weekly basis. An extra share is allocated to the master fishermen, to the vessel owner and for vessel repair and maintenance. Fishermen are paid on the spot when they sell fish to the fish collector vessels which operate throughout the country. They are free to sell their fish to any collector vessel. Some of the fishing vessel owners in the yellowfin tuna industry have had agreements with the yellowfin purchasing companies, which stipulated that catches could only be sold to the purchasing company in question. In order to protect the livelihood of the fishermen, and to strengthen their bargaining position vis-à-vis the post-harvest companies, the Maldives Government has enforced a minimum price under section 12 of Skipjack Purchase and Export Regulation 2001. Although the processing companies have never bought at a price close to the base price, the government has resisted pressures to abolish the minimum price. There are no inland fisheries in the Maldives, and aquaculture is in a nascent stage.[10]

The fish-harvesting sector in the Maldives has expanded greatly since the 1960s, with landings increasing from 21,542 MT in 1966 to 180,981 MT in 2006. However, the upward trend in the fish-harvesting sector had reversed after 2006 primarily due to increased fuel costs (making vessel owners less willing to leave port) and higher water temperatures (affecting the aggregation of tuna and reducing their catchability). Overall the fisheries sector continued to be affected by the persistent decline in fish catch, owing to both environmental factors and higher fuel prices.[11] There has been a tendency in the past few years for the vessel owners to build larger vessels with engines of higher horsepower. Modern vessels are equipped with satellite navigation systems, hydraulic line haulers, fish finders, sonars and other technological equipment. These vessels also have a special compartment for crew accommodation and are used mainly for long trips (2-3 days) as opposed to the single day trips that were more predominant in the past.[12]

4.2.c. Food Security and Nutrition

Maldives is self-sufficient in fish whereas rice, wheat, fruits, vegetables and other food items are largely or entirely imported. The country balances its food requirements through both domestic production and food imports. It is estimated that Maldives produces less than a tenth of its overall food requirements. The majority of food products, including 100 percent of the staples--rice, wheat and sugar--are imported. To cater to the growing population, expatriate community and large number of tourists' visiting the country, the Maldives needs to import large quantities of food every year.[13]

Over the past few decades, the health status of children in the Maldives has improved dramatically. In just ten years, rates of undernutrition among children were nearly halved, and rates of exclusive breastfeeding jumped from 10 to 48 percent, and then from 48 to 64 percent over the next decade. In spite of these improvements, malnutrition rates for children under age 5 are still high for a middle-income country. Nearly one in five children is stunted, an irreversible condition marked by low height for a child's age. In some areas of the country, the number of stunted children rises to one in four, illustrating a high level of inequity among certain islands and atolls.[14]

Additionally, 17.3 percent of children in the Maldives are underweight while 10.6 percent are wasted. A Ministry of Health study found 22 percent of first grade students to be overweight or obese. Both under- and over-nutrition are classified as malnutrition and in the Maldives, obesity is largely due to increased consumption of packaged, unhealthy foods and a limited knowledge of proper nutrition. In some island communities, accessing fresh fruits, vegetables and legumes throughout the year can be a problem – and throughout the country, less than 6.5 percent of Maldivians are eating enough healthy produce, according to the Ministry of Health. As a result, there are high rates of micronutrient deficiencies among children under age 5, along with women of reproductive age.[15] Anaemia is common with 52 percent of the children, 55.4 percent of pregnant women and 49.6 percent of non-pregnant women. Micronutrient deficiencies are of concern in all age groups and more prevalent in north and south central regions of the country. Zinc and iodine deficiency, though less severe, is also a public health concern.[16]

The Maldives lack a food security policy, although in response to the current food and fuel crisis, it is integrating food security into national planning. Being a small country, the large service industry created by the tourism sector required continuous importation of large amounts of food, most of which is not feasible to produce in the country due to land and geographical limitations. The Maldivian government has therefore either reduced or removed tariffs on imported food items, agricultural inputs and fuel and is intensifying and diversifying agriculture and fisheries. The Maldives is also promoting and strengthening small and medium enterprises (SMEs) in both these sectors.[17]

4.2.d. Impacts of COVID-19 on the Maldives

As a country solely dependent on tourism, Maldives is amongst the worst affected countries in Asia due to the impacts of the COVID-19 pandemic. The Real GDP of the Maldives is expected to contract by 8.5 percent in 2020, 13.9 percentage points lower than the baseline (pre-COVID-19). This is mostly due to the slump in tourism, which directly and indirectly accounts for two-thirds of GDP, but also due to suppressed construction activity. The shock to tourism adversely affects employment and household earnings, as one-third of adult males and a quarter of females are engaged in tourism-related jobs. Lower-income households that depend on fisheries are also affected as exports of raw fish have ceased due to weak demand. The national poverty rate is expected to increase as households close to the poverty line would likely fall into poverty due to the loss of income sources. A larger impact is expected in the atolls, as there is greater dependence on fisheries and the poverty rate was already higher.[18] Moreover, as a country greatly dependent on imports for basic food and medical supplies, any disruptions in international trade can worsen food security in the country. Enhancing the country's ability to produce a greater proportion of its own food requirements might be seen as even more important since the COVID-19 pandemic.

4.3. CLIMATE CHANGE AND AGRICULTURE IN THE MALDIVES

Climate change is regarded as a huge threat to the lives and economy of Maldives since it is quite vulnerable to rising sea levels. 80 percent of its total land area, less than 300 sq. km., is lower than 1 metre above the average sea level. The country's exposure to natural hazards and climate variability poses a large threat to lives and the economy.[19] The Maldives has, from the very beginning, been one of the most vocal countries in terms of advocacy for climate action. Its first National Adaptation Programme of Action was developed in 2006, where fisheries, agriculture and food security were identified as being particularly vulnerable to various impacts of climate change. These impacts include changes in the movement and abundance of important fish species, coral bleaching and the consequent decrease in availability of live bait, further degradation and erosion of soil that is naturally challenging to cultivate, and increased occurrence and intensity of floods. Falling productivity of the fisheries and agriculture sector would imply a greater dependence on imports for food items, which would lower food security in the Maldives.[20]

4.4. INTERVENTIONS TO IMPROVE AGRICULTURE AND FISHERIES IN THE MALDIVES

The Maldivian government has acknowledged many constraints in the agriculture and fisheries sector and is working towards enhancing the sector. Some of the major constraints identified by them include lack of proper data and its management, challenges in training and retention of technical capacity, poor institutional capacity, lack of appropriate infrastructure for value chains, low availability and accessibility to finance and credit facilities, poor quality of fish and fisheries products, limited value-added products, undervalued fish exports, lack of seed availability for grow-out farmers in aquaculture, environmental concerns of aquaculture and the unrecognized role of women in fisheries. It has been indicated by the Mauritius Planning Forum that various policy initiatives are being taken up by the government to improve these constraints.[21] Other constraints identified with regards to agriculture in the Maldives include labour shortage and lack of skilled labour, especially with regards to training and extension support capacity, the difficulty in acquiring credit for agricultural initiatives since it is seen as a low profit sector, the increasing number of pests, diseases and weeds attacking the crops and plantations, and that imported fresh and processed products are cheaper than domestically produced ones.[22]

With regards to the fisheries sector, little sustainability in the industry due to several factors including policy, regulatory and management have severely affected decline in fish catch, especially skipjack tuna fishes. Live bait is essential for the pole and line fishery in the Maldives, but the excessive use of bait in the fishery raises concerns for the sustainability of live bait resources and needs to be addressed to ensure sustainability in the tuna fishery.[23] A lack of capacity in the current regulatory body to enable and coordinate the sustainable development of the sector has been noted, since this allows for certain parts of the ocean to be exploited as an open access resource. Rapid advancements in the industry have not yet reached all areas nor is there sufficient expertise in engaging in fish business at the international level.[24]

4.5. FUTURISTIC POLICY FOR SUSTAINABLE AGRICULTURE, FISHERIES AND FOOD SECURITY IN THE MALDIVES

The Maldivian Ministry of Fisheries, Marine Resources and Agriculture (MOFA) is the lead agency tasked with fisheries management and development. Its mandates include formulating and enforcing laws, regulations and policies required for sustainable development of fisheries and marine resources, formulating and implementing policies and strategies required for sustainable development of fisheries, agriculture and marine resources of the nation, protecting and conserving the marine and terrestrial biodiversity of the nation, collecting, processing and publishing data and statistics of fisheries and marine resources. It is also responsible for the development and installation of fish aggregating devices (FADs), formulation and implementation of development projects aimed at enhancing peoples' socio-economic standards, monitoring and conducting multi-disciplinary research, and formulating and implementing regulations on scientific exploration and research into the Maldivian waters, seas, seabed, subsoil and soil.[25]

There are various other institutions involved either directly or indirectly in the fisheries sector as well, which play an important role in their respective areas of responsibility. The Ministry of Economic Development (MED) is responsible for the licensing of all commercial fishing vessels and determining the number of licenses to be issued. It also issues export permits for local tuna and reef fish trade. The Ministry of Tourism, Arts and Culture (MTAC) is responsible for ensuring the marine-related interests of the tourism industry, while the Ministry of Defence and National Security Service's Coast Guard monitors vessel positions and enforces EEZ laws and regulations. The Ministry of Home Affairs is responsible for the collection of fisheries-related data and to ensure compliance with the regulations and fisheries laws at island and atoll levels. The Ministry of Housing, Transport and Environment's Transport Division is looks after the registration of fishing vessels and safety checks and training of officers and crew. The Maldives Customs Service is responsible for monitoring export fish trade and quality while the Ministry of Health looks after inspection for food safety and export quality standards. The Maldives also has an Environmental Protection Agency, concerned with the enforcement of the Environment Act of 4/93 and with establishing marine protected areas and reserved diving sites.[26]

The national development agenda for the Maldives is based on medium-term development plans. The Strategic Action Plan (2009–2013) outlines good governance, social justice and economic development as the key themes for development. The country’s economic development policy agenda is based on the diversification of the economy to achieving sustainable growth and reduced vulnerability from external shocks as well as attain greater self-reliance, and its strategic economic development policies are supportive of fisheries and agriculture development. Fisheries sector development is geared towards promoting export and trade, building infrastructure and strengthening research and development whereas agriculture sector development focuses on reducing dependency of import and strengthening food security and enhancing economic benefit from the sector.[27]

Apart from the national policy framework, the agriculture sector has developed several additional policy documents. These include an agriculture development master plan (ADMP) with the assistance of FAO, a commercialization plan assisted by ADB, and a national forestry policy assistance by FAO. Unfortunately, none of these have received required attention. The ADMP envisions a rapid transformation of the country’s agriculture sector and envisages its evolution as the third important driving force in the economy, after tourism and fishery, to expand livelihood options for the rural people, enhance employment and income opportunities, and improve food security and nutritional status of the Maldivian people.[28] The current pandemic might act as a reminder of the importance of increasing agriculture and fisheries operations in order to reduce reliance on exports, and also as a means to create employment and livelihood options alternative to tourism.

Appendix: Figures, Tables and Graphs

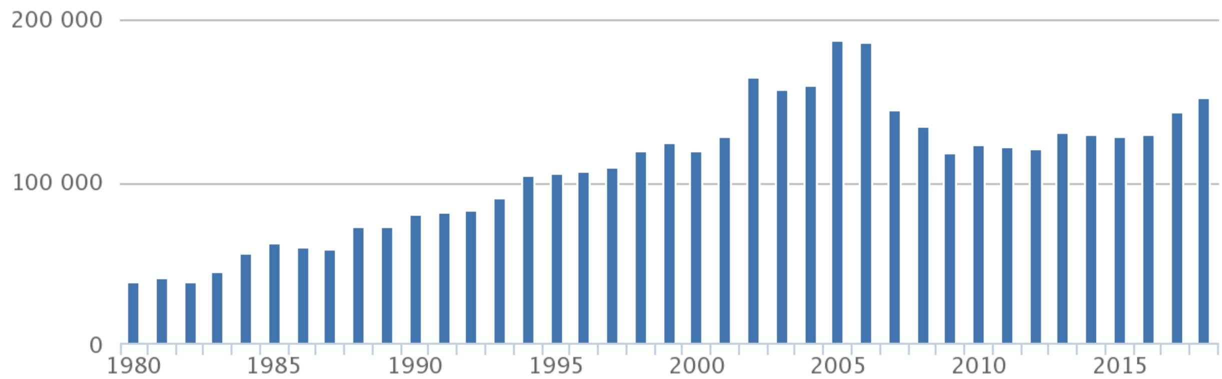

Figure 1: Capture Production by marine waters for the Republic of Maldives (tonnes). Source: FAO FishStat.

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5. Agriculture and Food Security in Mauritius

5. Agriculture and Food Security in Mauritius

SUMMARY

Located off the southeast coast of Africa, Mauritius is an island state composed of the islands of Mauritius, Rodrigues, Agalega, St. Brandon, Tromelin, Chagos Archipelagos and a number of outlying smaller islands. The country's economy has made great strides since independence in 1968 and based on 2019 data, Mauritius was classified as a high-income country by the World Bank for the first time in July 2020, with a GDP per capita of over 11,200 USD current value as of 2019. The GDP contribution of the agriculture, livestock and fisheries sector is down to approximately 3 percent of the country's total GDP. The percentage of people employed in the sector has reduced to around 6 percent of its total working population.

The agriculture sector in Mauritius is dominated by the sugar plantation industry, which had been the backbone of the Mauritian economy until the 1970s. Sugar continues to be the primary agricultural product of Mauritius, most of which is exported to regional markets as well as to Europe and the USA. Mauritius is a net food importer, apart from certain commodities such as eggs, poultry and fresh vegetables. Fisheries and aquaculture play an important socio-economic role in Mauritius. Aquaculture has been practiced in Mauritius for over three decades, but the production was negligible until 2004. Mauritius has since developed into a Seafood Hub and a centre of fishing business in the Western Indian Ocean over the past few years.

As per World Bank data, average dietary energy supply in Mauritius has consistently been above 122 percent since 2000-2002, and average protein supply has been above 85 grams per capita per day since 2008-2010. Food insecurity among the Mauritian population has, however, increased slightly from approximately 5 percent in 2014-16 to 6.5 percent in 2017-19. Factors affecting food security in Mauritius include the impacts of climate change on domestic agriculture as well as agricultural production in the countries that export food to Mauritius, fluctuations in currency and world market prices, piracy and increasing costs of insurance, diversion of land from food production to biofuel production and the decrease of agricultural land in general. Although Mauritius has limited land resources, it produces most of its vegetables and fruits locally. The country still depends heavily on imports, however, as 70 to 75 percent of its food requirements are imported, and the contribution of the agricultural sector to the GDP of the country is steadily declining. These conditions can lead to serious problems of food security in the future.

The COVID-19 pandemic is severely affecting the country's economy through a standstill in tourist arrivals, crumbling export demand in particular for its garment sector, and the temporary lockdown measures adopted in April, May and June. The government put in place a support package to help the private sector cope with the shock, which mitigated the impact on employment, while in combination with declining revenue leading to a large deficit for the fiscal year 2019-20. How the pandemic affects food security in the island nation is yet to be studied in terms of long-term consequences, but international trade and world market prices have certainly been affected

and will likely have consequences on Mauritius. The need for Mauritius to seriously consider problems of food security have therefore become increasingly evident and the government must respond accordingly, while also taking steps to improve the resilience and response of its agriculture and allied sectors in the face of future risks.

5.1. INTRODUCTION

Located off the southeast coast of Africa, Mauritius is an island state of about 1.3 million people. The Republic of Mauritius is composed of the islands of Mauritius, Rodrigues, Agalega, St. Brandon, Tromelin, Chagos Archipelagos and a number of outlying smaller islands. Its GDP in 2019 grew 3.6 percent, driven by construction and services sectors (banking, ICT) as well as a rebound in agriculture. Manufacturing growth remained on a sluggish trend and was negatively impacted by decelerating global demand during 2019. This continued a pattern of structural transformation, with more knowledge intensive services sectors expanding while some of the sectors that have traditionally provided low-skilled employment stagnating or contracting. The country's economy has made great strides since independence in 1968 and based on 2019 data, Mauritius was classified as a high-income country by the World Bank for the first time in July 2020, with a GDP per capita of over 11,200 USD current value as of 2019.[1],[2]

5.2. AGRICULTURAL PRODUCTION AND FOOD SECURITY IN MAURITIUS

5.2.a. Aquaculture and Agricultural Production

The agriculture sector in Mauritius is dominated by the sugar plantation industry, which had been the backbone of the Mauritian economy. Sugarcane was introduced to the island in the 17th century and until the 1970s, sugar production accounted for a third of the country's gross national product and more than 90% of all of its exports. Sugar was the main source of revenue for Mauritius until its economy underwent major structural changes in the late 1970s, characterised by the rapid industrialisation in the form of expansion of the textile production in the export processing zone, and development of tourism.[3]

The GDP contribution of the agriculture, livestock and fisheries sector is down to approximately 3 percent of the country's total GDP. The percentage of people employed in the sector has reduced to around 6 percent of its total working population.[4] Sugar continues to be the primary agricultural product of Mauritius, most of which is exported to regional markets as well as to Europe and the USA. Mauritius is a net food importer, apart from certain commodities such as eggs, poultry and fresh vegetables.[5] Forestry in Mauritius does not operate at a commercial scale and is more oriented towards conservation[6]. Livestock production is undertaken by some 5,000 farmers mainly in cattle, goat, sheep, pig, deer, and poultry farming. Milk and dairy products are also an important component of this sub-sector.[7]

Food crop production is dominated by small scale farming and covers a wide range of crops including potatoes, onion, tomatoes, chillies, crucifers, cucurbits, leafy vegetables, garlic and ginger which are cultivated on commercial scale whereas fruits mainly come from backyard production. Although there are a few irrigated networks, food-crop production continues to be largely rain-fed resulting in surplus vegetable production during the winter months and a shortage in the summer months. Over the last decade, production of selected crops namely tomato, green pepper and cucumber have started under soil-less, protected structures. There is also growing interest for mushroom production.[8]

Around 8,000 small producers cultivating approximately 8,200 hectares of land produce on average 110,000 tonnes of food crops annually, and there is no shortage of fresh vegetables as such on the local market. Except in cases of drought, cyclones and heavy rains, production amply satisfies the local consumption. However, Mauritius imports all its requirements for its main staples, namely some 166,000 tonnes of wheat and 66,000 tonnes of rice. A limited quantity of rice is now produced for the niche market of low-glycemic-index rice for the local market and export whereas wheat production is still at pilot project stage.[9]

Fisheries and aquaculture play an important socio-economic role in Mauritius. Aquaculture has been practiced in Mauritius for over three decades, but the production was negligible until 2004, when total production levels jumped from less than 50 tonnes in previous years to 350 tonnes due to the development of marine cage culture for red drum. In 2017, aquaculture production reached about 1250 tonnes and the two major species produced are red drum grown in marine cages and European seabasses. Mauritius has developed into a Seafood Hub and a centre of fishing business in the Western Indian Ocean over the past few years. The Mauritian government established an independent Fisheries Ministry in 2012. Total fisheries employment was reported as 29,055 people. The country's per capita fish consumption was estimated at 23.2 kg/person/year in 2016. In 2017, capture fisheries production reached about 25,000 tonnes. Catches come from artisanal fisheries around Mauritius and Rodrigues Islands and from semi-industrial operations on Saya de Malha and Chagos fishing banks. These banks have been historically important providers of fish for the Mauritian population, but further increase is unlikely to happen considering already high levels of exploitation.[10]

5.2.b. Food Security and Nutrition

As per World Bank data, average dietary energy supply in Mauritius has consistently been above 122 percent since 2000-2002, and average protein supply has been above 85 grams per capita per day since 2008-2010. Food insecurity among the Mauritian population has, however, increased slightly from approximately 5 percent in 2014-16 to 6.5 percent in 2017-19.[11] Factors affecting food security in Mauritius include the impacts of climate change on domestic agriculture as well as agricultural production in the countries that export food to Mauritius, fluctuations in currency and world market prices, piracy and increasing costs of insurance, diversion of land from food production to biofuel production and the decrease of agricultural land in general.[12]

Mauritius depends on various countries for a range of products. The food crises of 2008 and 2010-2011, increase in prices of some commodities such as fuel and grain, the rising consumption rate over production rate, and extreme weather conditions have proved to be important reasons for the Mauritian government to give serious considerations to food security. Although Mauritius has limited land resources, it produces most of its vegetables and fruits locally. The country still depends heavily on imports, however, as 70 to 75 percent of its food requirements are imported, and the contribution of the agricultural sector to the GDP of the country is steadily declining. These conditions can lead to serious problems of food security in the future.[13]

5.3. ENVIRONMENTAL STRESSES ON THE AGRICULTURE SECTOR

Impacts of climate change cannot be ignored in the context of small island economies like Mauritius. Agricultural activities, especially crop and fish productions, are also likely to be adversely affected by climate change. Mauritius is highly vulnerable to tropical storms and the risk is amplified by climate change. A multi-hazard risk assessment completed in 2017 suggests that Mauritius experiences on average 110 million USD per year in direct losses from tropical cyclones and floods. Mauritius lies within the cyclone area of the Indian Ocean. A large share of the population and productive assets in Mauritius are exposed to multiple risks from cyclones. Flood risk is continuously increasing. The frequency of storms of tropical cyclone strength (winds above 165 km/h) has increased significantly over the past three decades.[14]

Of the environmental stresses that agricultural and fisheries activities in Mauritius could face, the one most evident in the literature is climate change. It is expected that the impact of climate change and increasing variability in weather conditions will cause changes in cropping patterns, crop cycles and cropping calendars. Production may be affected by increasingly frequent and severe droughts and cyclones and heavy rains, especially on coastal lands. Fisheries are also vulnerable to potential impacts of climate change such as coral bleaching. Many steps are being taken by the Mauritian government to consider climate change in its programmes and interventions, however, technical and institutional improvements have been suggested to further strengthen its response.[15],[16]

5.4. INTERVENTIONS TO IMPROVE THE AGRICULTURE AND AQUACULTURE SECTORS IN MAURITIUS

In Mauritius, traditional methods of farming are still quite more common as compared to modern technology. It has been found that the community of farmers in Mauritius is ageing and that the new generation is not particularly interested in joining the sector. Many planters complain that they cannot increase production due to a lack of local workers. One of the suggested solutions to this problem is the promotion of mechanization in the sector. Given that mechanization can be costly, the government has set up a small farmers' mechanical pool so that planters can benefit from mechanization and, to some extent, alleviate the problem of lack of labour in the sector.

Farmers are also being encouraged to move from open farming to protected farming, whereby the impacts of climate change can be reduced to a certain extent. Incentives are being provided so that they may adopt hydroponic culture for food production with an objective to shift from traditional farming to modern farming techniques. This shift can also contribute to increasing food production.[17]

Different incentives have been provided to small farmers to increase food production in Mauritius. Seeds for certain crops like potato, garlic, onions amongst others are being provided to farmers at a guaranteed and preferential price so as to encourage farmers to engage in the production of these food crops. Financial facilities in terms of loan for purchasing of machinery for land preparation, irrigation and harvesting have also been given to planters. Mechanical land preparation has been encouraged among small farmers to increase the yields. Free training is provided to farmers concerning the ways to plant the crop, deal with different diseases, harvesting and storage of different crops. Free compost bags and seeds are given to small planters so that they can restart production after floods and cyclones.[18]

There are periods when there is an excess of vegetables in the market. In such situations, farmers do not harvest their vegetables, since it is not economically viable and this may be wasted. Consequently, the government has been trying to promote agro-processing whereby some vegetables can be used as raw materials for agro-processing firms. The Mauritian government has also been encouraging private initiatives to produce flour from cassava, breadfruit and banana. In addition, farmers are encouraged to produce more fruits and other local vegetables which can be used to manufacture jam and pickles which are mostly imported from other countries.[19]

The Mauritian government has given increased importance to aquaculture by following separate green economy and blue economy strategies, whereby the blue economy focuses on aquaculture. Mauritius has integrated shipping, reefer vessel charter, quay space, cold storage, and seafood processing, marketing and distribution into a special zone, and its fleet was estimated to contain 1,731 vessels.[20] Artisanal fishers have been the main suppliers of fish to the local markets and as of 2012, there were 60 Fish Landing Stations (FLS) around Mauritius that serve as operational bases to the coastal fishing fleet. They are mandated for unloading of fish, data collection and primary sale of fish. A major concern for artisanal fisheries has been the absence of food safety and quality standards along the supply chain, from capture to consumption. Preservation of fish on board is rudimentary or non-existent. Traditional boats are not equipped with fish holds and ice is not used nor is it available around the island, particularly at the FLS.[21]

Agricultural research and development (R&D) in Mauritius has been well-staffed and funded, primarily by the national government. The national government realizes the important role that agricultural R&D plays in the development of the agricultural sector and the economy more generally, and has various well-functioning policies and funding mechanisms in place to support the sector. The Mauritian government is also aiming to diversify crop production in the country, which has also been reflected in its R&D staff capacity.[22]

5.5. FUTURISTIC POLICY FOR SUSTAINABLE AGRICULTURE, AQUACULTURE AND FOOD SECURITY

The Mauritian government has developed three strategic plans in order to deal with the problem of food security since 2008. The first one was set for 2008-11 and the second one was set up for 2013-15. The strategic plan 2008-11 was launched by the Ministry of Agro-Industry and Food Security to increase production of priority crops, maintain self-sufficiency level in poultry meat and fresh vegetables, introduce new protein-rich crops, provide more land for production of foodstuffs, encourage the regrouping of small-scale farmers, achieve a higher self-sufficiency level in the production of fresh milk and meat, sensitize the population on the benefits of eating healthy foods, mitigate the marketing constraints encountered by small food crop farmers, and partner with regional countries for the production of selected commodities (potato, maize, rice, onion and pulses). It is noted that the plan was successful to a certain extent since both crop and livestock production increased during the period. Crop production increased by 23.7 percent while meat production increased by 53 percent between 2008-2011. Potato production increased by 45 percent in the same period whereas milk production increased by 37 percent, and these can be attributed to the implementation of the plan.[23]

The Food Security Strategic Plan 2013-15 was prepared as a continuation of the previous plan. It had been developed after analyzing shortcomings of the previous plan and the lessons learnt from past experiences in the sector. It also took into consideration all challenges facing the agricultural sector and the trends observed in the agro-industry at the time. The plan recognizes that it is unrealistic to achieve 100 percent self-sufficiency in food production due to scarcity of land and targets a realistic 33 percent self-sufficiency in food production.[24]

Building on the achievements of past strategic plans and based on lessons learned, the Ministry of Agro-Industry and Food Security has developed its new strategy for the period 2016-2020 using a participatory approach. The Plan is inspired broadly by the Government Programme 2015-2019, and has been formulated to take Mauritius to a higher level of food security whilst respecting the need for safe food and better nutrition of the population. It takes on board the need for sustainable agricultural development in a climate-friendly mode as well as safeguarding farmers livelihoods. The areas of intervention identified in the Strategic Plan for 2016-2020 include enhancing food and nutrition security, improving competitiveness, promoting food safety and efficient and sustainable production practices, promoting strong value chains, developing resilience to climate change, exploring agri-business potentials for international and regional markets, promoting the emergence of agro-entrepreneurs, creating and enabling environment for risk management, facilitating the emergence of agri-business clusters, and further research and development.[25] It is evident, therefore, that the Mauritian government has already incorporated many suggestions to improve the state of agriculture, fisheries, livestock, forestry sector and food and nutrition security in the country, and seems likely to make further changes in response to future trends and suggestions.

The COVID-19 pandemic is severely affecting the country's economy through a standstill in tourist arrivals, crumbling export demand in particular for its garment sector, and the temporary lockdown measures adopted in April, May and June. The government put in place a support package to help the private sector cope with the shock, which mitigated the impact on employment, while in combination with declining revenue leading to a large deficit for the fiscal year 2019-20.[26] How the pandemic affects food security in the island nation is yet to be studied in terms of long-term consequences, but international trade and world market prices have certainly been affected and will likely have consequences on Mauritius. The need for Mauritius to seriously consider problems of food security have therefore become increasingly evident and the government must respond accordingly, while also taking steps to improve the resilience and response of its agriculture and allied sectors in the face of future risks.

Appendix: Figures, Tables and Graphs

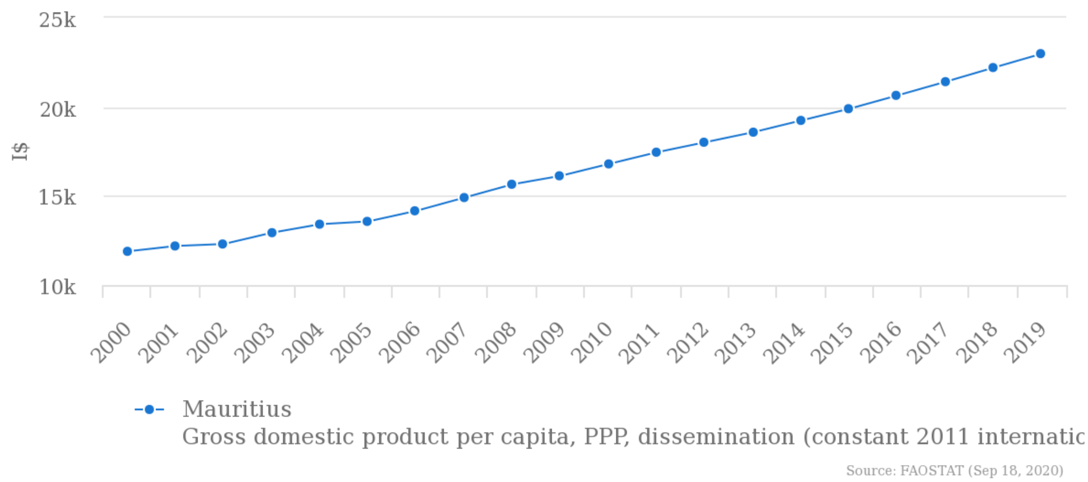

Figure 1: GDP per capita, PPP (constant 2011 international dollar).

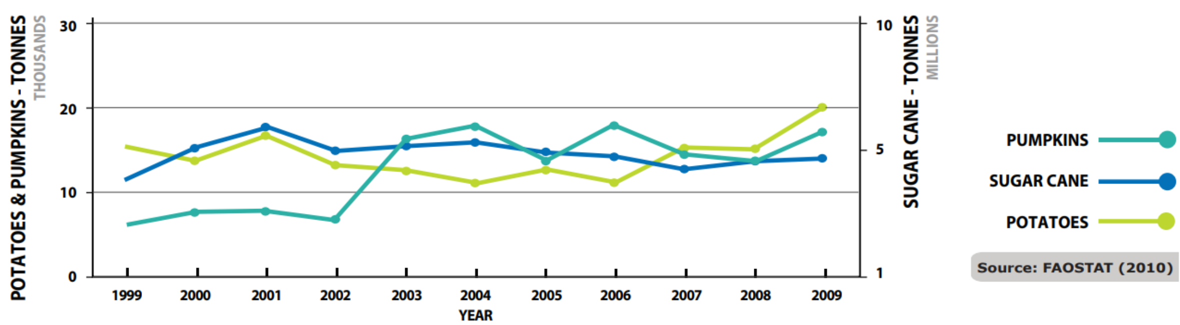

Figure 2: Crop Production in Mauritius in tonnes

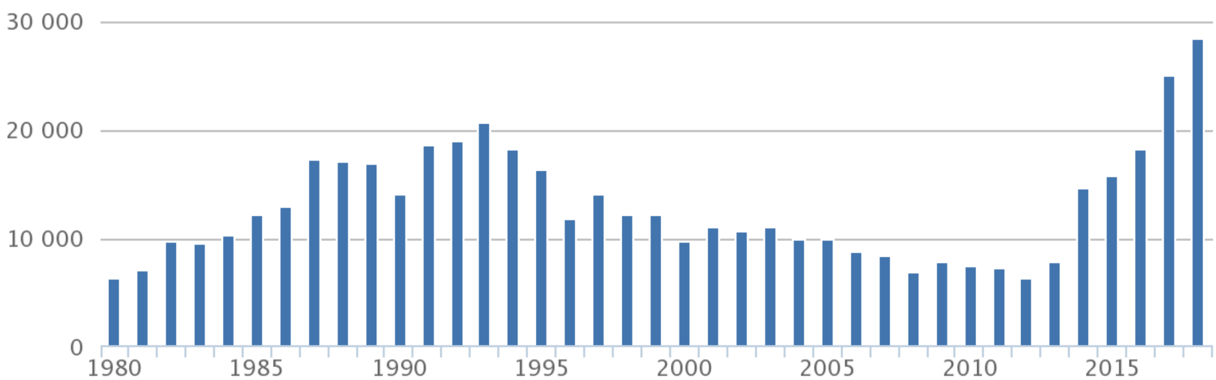

Figure 3: Total capture of fish for the Republic of Mauritius (tonnes). Source: FAO FishStat

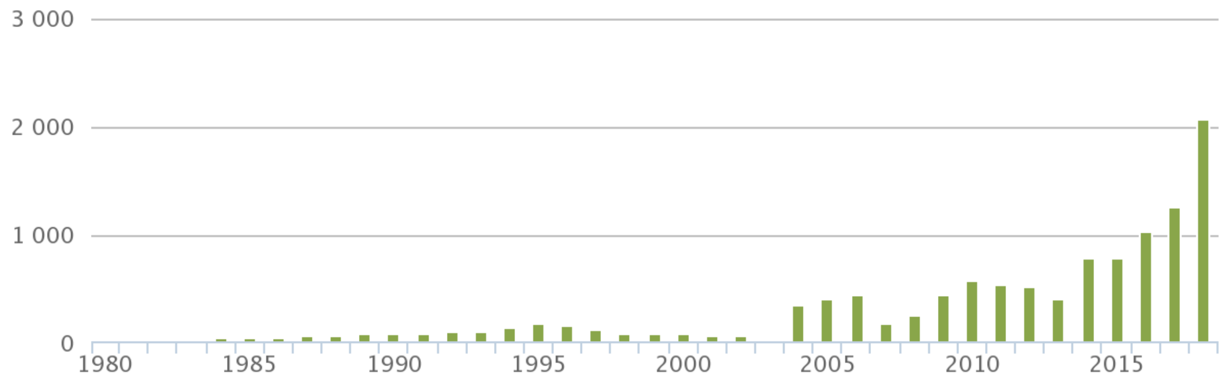

Figure 4: Total aquaculture production for the Republic of Mauritius (tonnes). Source: FAO FishStat.

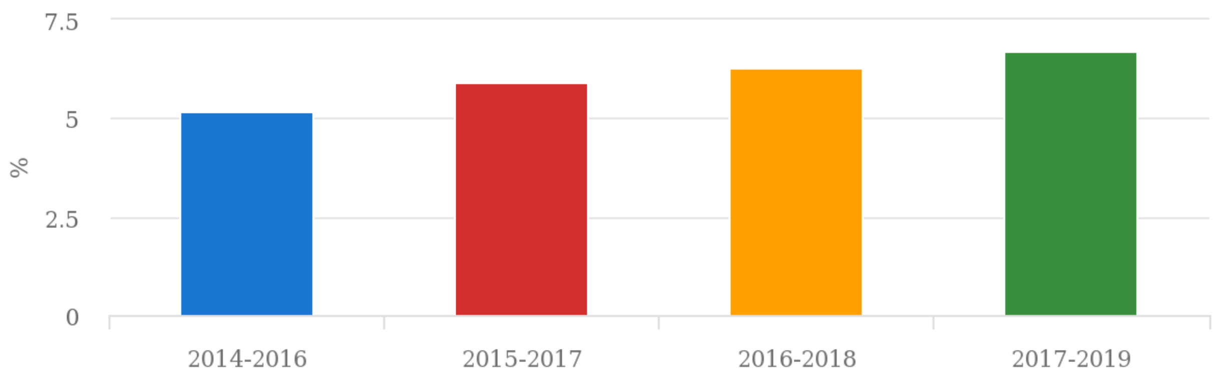

Figure 5: Prevalence of severe food insecurity in the total population (percent) (3 year average). Source: FAOSTAT (Sep, 2020)

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6. Agriculture and Food Security in Myanmar

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SUMMARY

Closed off for decades from the global economy, the Republic of the Union of Myanmar's topographical features are dominated by a horseshoe-shaped mountain complex and the valley of the Ayarwaddy (Irrawaddy) River system. Myanmar relied heavily on the agriculture sector until recent large scale structural changes, although the sector remains a high priority for the Government of Myanmar. According to the Myanmar Agriculture Development Strategy, agriculture contributes to 30 percent of national GDP, although other sources place it at 25 percent, and about 68 percent of the rural population relies on crop farming and livestock for their livelihoods and income. More than fifty percent of all jobs in the country are in agriculture. In rural areas, the sector accounts for more than two-thirds of total jobs, and about half of rural workers are women. Moreover, many non-farm jobs are also linked, directly or indirectly, to the agriculture sector, including in areas of food processing, food services, and agricultural trade.

Even though half of Myanmar jobs are in agriculture, the sector only accounted for about 29 percent of the country's GDP in 2015-16, implying that the returns to agricultural labour are low compared to those of labour in the services and trade sectors. One major contributor to Myanmar's low agriculture productivity is found to have been the prevalence of mono-cropping and the overwhelming dependence on rice production. The use of irrigation and water management systems need to be expanded as well. A second contributor to low productivity is the fact that the Myanmar agriculture sector is far less mechanized than those of other countries in the region. Skills training in irrigation systems—including their maintenance, operation, and construction, as well as the rehabilitation of canals—should be prioritized. In order to reach its full agricultural potential, issues of quality, market inefficiency, inaccessibility, and lack of education in its fertilizer sector must also be addressed. Seed technology, fertilizer, research, mechanization, and irrigation are interdependent and should be developed together. Efforts to deliver new seed technology to rural areas should be supported by effective extension if the new variety requires different management practices. Support for the agriculture sector is suggested to be underpinned with policies that create a national business, institutional, and regulatory environment that enables agro-value chain growth.

Despite making important socio-economic strides in recent years, Myanmar is faced with a multitude of challenges which hinder ongoing development efforts. An estimated 24.8 percent of its 54 million population live near or below the poverty line. Many struggle with inadequate physical, social and economic access to sufficient, safe and nutritious food, with women, girls, and persons with disabilities and minorities particularly affected. Malnutrition is a major challenge, and wasting rates prevail at 6.5 percent nationally. With restrictions on movement and limited access to livelihoods, many conflict-affected people urgently need food assistance.

Although Myanmar is self-sufficient in food production at the national level, food and nutrition insecurity exists at the household level in some areas due to low income, constraints in food production, transportation, poor knowledge in feeding practices and poor care-giving. Myanmar's food and agriculture systems determine the quantity, quality and diversity of food available for consumption. Therefore, food and nutrition security should focus on availability, accessibility, utility and stability. In addition to agriculture and food policies, the efficiency of agricultural production, markets and trade in Myanmar shape the relative prices of different food commodities. Currently, the rural poor suffer from inadequate food, nutrition and essential non-food items. Micronutrient deficiencies account for 4 to 6 percent of all deaths under five years old. Although Myanmar is a net food exporter, about 10 percent of the population is estimated to be below the official food poverty line, with many pockets of high level food and nutrition insecurity across various states, regions and villages. Frequent human and natural crises affect food availability, adding to the existing structural limitations of the agricultural sector, including inadequate productive infrastructure, poor quality of inputs, high costs of production, low acceleration in modernization of agro-techniques, limited knowledge of agricultural practices and market information, and significant post-harvest losses. Recurrent climate shocks put communities at high risk of displacement and loss of productive assets and livelihoods. Natural disasters impact particularly the agriculture sector, affecting standing crops, livestock, fishery and productive infrastructures.

There has been much improvement since liberalization in Myanmar, but many of the measures taken thus far are not sufficient to underpin full, potential long-term growth of agriculture as a driver of economic development. The COVID-19 pandemic has negatively impacted Myanmar's economy directly and indirectly, and it has also had negative impacts on the agriculture sector owing to disruptions in the movement of goods and services. One study estimated a decline in Myanmar's agricultural GDP by 14 percent during the two-week lockdown period in April, 2020. The pandemic has also had strong negative impacts on income-based poverty among both rural and urban households, primarily due to loss of jobs or other sources of income. In response to income losses associated with COVID-19, the Government of Myanmar introduced a series of emergency measures to provide basic assistance to vulnerable households. It is critical to assess the effectiveness of such assistance in reaching food-insecure populations and maintaining basic food security. Job creation must be at the heart of economic recovery strategies, and the agriculture sector must be closely monitored and supported.

6.1. INTRODUCTION

Myanmar, officially known as the Republic of the Union of Myanmar, is bounded on the north by China, on the east by China, Laos, and Thailand, on the south by the Andaman Sea and the Bay of Bengal, and on the west by the Bay of Bengal, Bangladesh, and India. The coastal region is known as Lower Myanmar, while the interior region is known as Upper Myanmar. The total area of the country is 676,578 square km. A horseshoe-shaped mountain complex and the valley of the

Ayarwaddy (Irrawaddy) River system are the dominant topographical features of Myanmar. Most of the mountain systems have northern to southern axes. The ArakanYoma range, with peaks reaching more than 2740 meters, forms a barrier between Myanmar and the subcontinent of India. The Bilauktaung range, the southern extension of the Shan Plateau, lies along the boundary between southwestern Thailand and southeastern Lower Myanmar. Generally narrow and elongated in the interior, the central lowlands attain a width of about 320km across the Ayarwaddy-Sittaung delta. The delta plains, extremely fertile and economically the most important section of the country, cover an area of about 46,620 sq. km. Both the Arakan (in the northwest) and the Tenasserim (in the southwest) coasts of Myanmar are rocky and fringed with islands.[1]

6.2. AGRICULTURAL PRODUCTION AND FOOD SECURITY IN MYANMAR

Agriculture is an important sector as it contributes significantly to the socioeconomic development of Myanmar. According to the Myanmar Agriculture Development Strategy, agriculture contributes to 30 percent of national GDP, although other sources place it at 25 percent, and about 68 percent of the rural population relies on crop farming and livestock for their livelihoods and income.[2] The Myanmar jobs market is broadly agriculture dependent. More than fifty percent of all jobs in the country—a figure that includes all income earning activities, including both wage-earning and farm and non-farm self-employment—are in agriculture. In rural areas, the sector accounts for more than two-thirds of total jobs, and about half of rural workers are women. Moreover, many non-farm jobs are also linked, directly or indirectly, to the agriculture sector, including in areas of food processing, food services, and agricultural trade. Even though half of Myanmar jobs are in agriculture, the sector only accounted for about 29 percent of the country's GDP in 2015-16, implying that the returns to agricultural labour are low compared to those of labour in the services and trade sectors.[3]

6.2.a. Physiography and Climate

The highland regions of Myanmar are covered with highly leached, iron-rich, dark red and reddish brown soils. When protected by forest cover, these soils absorb the region's heavy rain, but they erode quickly once the forest has been cleared. The lowland regions are covered with alluvial soils—mainly silt and clay. Low in nutrients and organic matter, they are improved by fertilizers. In the dry belt of the central region are found red-brown soils rich in calcium and magnesium. In the same region, however, when the soil has a low clay content, it becomes saline under high evaporation and is recognizable by its yellow or brown colour.[4]

Although Myanmar is located in the monsoon region of Asia, its climate is greatly modified by its geographic position and its relief. The cold air masses of Central Asia bring snow to the northern mountains for two months of the year, but this mountain wall prevents the cold air from moving farther south, therefore Myanmar lies primarily under the influence of the monsoon winds. The north-south alignment of ranges and valleys creates a pattern of alternate zones of heavy and scanty precipitation during both the northeast and southwest monsoons. Most of the precipitation, however, comes from the southwest monsoon. The west coast is subject to occasional tropical cyclones.[5]

Myanmar has three seasons: the cool, relatively dry northeast monsoon (late October to mid-February), the hot, dry inter-monsoon season (mid-February to mid-May), and the rainy southwest monsoon (mid-May to late October). The coastal regions and the western and south eastern ranges receive more than 5,000 mm of precipitation annually, while the delta regions receive about 2,500 mm. The central region is not only away from the sea but also on the drier, lee side—in the rain shadow—of the Rakhine Mountains. Precipitation gradually decreases northward until in the region's dry zone it amounts to only 500 to 1,000 mm per year. The Shan Plateau, because of its elevation, usually receives between 1,900 and 2,000 mm annually. Elevation and distance from the sea affect temperature as well. Although Myanmar generally is a tropical country, temperatures are not uniformly high throughout the year.[6]

6.2.b. Agricultural Performance and Food Production

Closed off for decades from the global economy, Myanmar has heavily relied on the agriculture sector which continues to employ more than 60% of the population. Hence, the agriculture sector remains a high priority for the Government of Myanmar. While this sector accounted for a third of the Myanmar economy in 2011, it has steadily declined to a quarter of the economy in 2018. Myanmar produces both annual crops (including oilseeds and vegetables) as well as industrial crops (including rubber, sugarcane, cotton, oil palm, coffee, tea). It also has promising abundant natural resources, including fertile and diverse agro-ecological land areas, water, forests, and a coastline of over 2,000 kilometres. Historically, rice has been the country's top export commodity. Myanmar was once the world's largest rice exporter accounting for a third of the global rice trade between 1934-35. In the post-independence era, however, rice exports from Myanmar were deemed uncompetitive due to rising international standards and Myanmar's poor production quality. Reforms implemented by the Government of Myanmar over the past decade have accelerated the revival of rice exports, coupled with aggressive targets set by the Myanmar Rice Federation to achieve four million tons of rice exports by 2020-21.[7]

The most common crops in decreasing order are rice, beans and pulses, and maize. In general, farmers grow rice and maize during the monsoon season and beans and pulses during the dry season, although farmers in the temperate highlands often aim for a second harvest of rice and maize if there is enough water left after the rains. Rice (including Myanmar's most famous variety, Paw San) and beans and pulses (especially chickpeas, green gram and black gram) are grown throughout the country. However, the Ayeyarwady Delta Region accounts for the highest share of rice production while the central dry zone region primarily accounts for the largest share of beans and pulses. Unlike beans and rice, maize thrives in the temperate highlands, especially in Shan State, Sagaing Region and Chin State. Other crops produced in a significantly lower amount compared to rice, beans and pulses or maize include groundnut, sesame and sunflower, and fruits such as watermelons, oranges and chillies in the central dry zone. In Shan, Kachin and Chin States, which are higher altitude regions, farmers also plant soy, coffee, tea and strawberries. Additionally, onions, potatoes, pumpkins, carrots and other vegetables are planted in the foothills in these regions. Rubber plantations are commonly found in Kayin and Mon States.[8]

A number of agricultural workers do not own land, especially in the Dry Zone, where around 40% of rural households were found not to own or operate on their own land. The average landholding size among those who owned land was 6.8 acres, with the smaller farmers owning between 1 and 2 acres and the larger farmers owning upwards of 14 acres.[9]

With rice being the staple food for Myanmar people, the country only exports the surplus amount after local consumption has been met. Meanwhile, beans and pulses are consumed relatively less in the domestic market, leaving a large volume for exports. Myanmar is the largest beans and pulses exporter in Asia and ranks second after Canada in the world. In Myanmar, many rice farmers grow beans in between rice-growing seasons to gain additional income. India is the largest single market for Myanmar beans traders. India mainly purchases mung beans and pigeon peas while China and the EU countries import green gram. China has also been buying maize from Myanmar. Currently it accounts for over 90% of Myanmar maize exports, with the remaining portion being shipped to Singapore, Malaysia, the Philippines, Vietnam, Taiwan and Hong Kong via sea freight. Myanmar exports fishery products such as fish, prawn and crab to over 40 countries and regions including China, Saudi Arabia, Japan and Thailand.[10]

Fish serves as a major source of animal protein of its people who largely consume rice and fish in their daily meals. With a population of 51.5 million in 2016, the country's average fish consumption was 68 kg/person/year. Most people in the delta and hill regions prefer to consume freshwater fish and coastal people prefer the marine fishes. The fisheries sector is one of the major components of the country's economy supporting thousands of households who are dependent on fisheries for their livelihoods. A total of 3,220,000 of the county's population are employed as full time and part time fishers, where 57% are engaged in freshwater fisheries and 43% in marine fisheries. The fisheries sector of Myanmar is divided into marine and freshwater fisheries sub-sectors. While marine fisheries sub-sector includes inshore and offshore, the freshwater fisheries sub-sector includes aquaculture, as well as leasable and open fisheries sub-sectors. [11] The forestry sector is also an important source of employment. In 2015-16, it provided more than 886,000 jobs, accounted for 4.1 percent of national employment, and generated up to US$93.7 million. Rural households depend on forests for a range of material benefits, ecosystem services, and cultural values. There appears to be strong correlation between poverty and forest cover at the township level, particularly in ethnic majority upland states. This is because a large majority of all rural households rely on fuelwood, and 63 percent of rural land is either forest or woodland.[12]

3.2.c. Food Security and Nutrition

Despite making important socio-economic strides in recent years, Myanmar is faced with a multitude of challenges, including armed conflict, displacement, widespread poverty and food insecurity and more recently the COVID-19 pandemic, which hinder ongoing development efforts. An estimated 24.8 percent of its 54 million population live near or below the poverty line. Many struggle with inadequate physical, social and economic access to sufficient, safe and nutritious food, with women, girls, and persons with disabilities and minorities particularly affected. Malnutrition is a major challenge, and wasting rates prevail at 6.5 percent nationally. Likewise, Myanmar is one of the world's 20 high tuberculosis (TB) burden countries. It is also among the 35 countries accounting for 90 percent of new HIV infections globally. Ethnic conflict exacerbates an already fragile situation. Over 1 million people have been displaced from their places of origin since June 2011. With restrictions on movement and limited access to livelihoods, many conflict-affected people urgently need food assistance.[13]

Food dominates the expenditures of the majority of households. Dietary diversity is more limited among the poor and in rural areas. Individuals who live in the poorest quintile households spend on average 538 kyat per day per adult equivalent on food, compared to 1814 kyat among the richest quintile of the expenditure distribution. The share of spending from rice and pulses drops as one climbs the food expenditure distribution, while the share of expenditure devoted to more protein and fat intensive foods, such as fish, meat, dairy and eggs, rises. Dietary diversity is lower in rural areas than in urban areas. Households in rural areas spend more on rice and pulses than those in urban areas—both in absolute terms and as a percentage of total expenditures – and less on meat, dairy, fish and eggs. Food away from home is also an important share of expenditure for urban households, where it accounts for 13 percent of total spending. Rice is the calorie staple in Myanmar for rich and poor. While richer households can afford to eat a diverse set of foods while maintaining this staple, poorer households focus more spending to meet this basic food need.[14]

Calorie consumption of rice, pulses, beans and nuts is remarkably stable throughout the expenditure distribution in Myanmar at approximately 1400-1500 calories per adult equivalent per day. Individuals living in poor households devote a third of their food expenditures to meet their rice needs. There is also a clear wealth gradient in the type of rice consumed, with higher value aromatics consumed by better-off households. The low food expenditures in the bottom quintile in Myanmar is mirrored in calorie consumption. Within households in the bottom quintile, individuals consume an average of 1959 calories per adult equivalent per day, compared to an average of 2463 calories nationally. The lowest calorie consumption occurs in the hills and mountains, where individuals consume an average of 2255 calories a day. Approximately 41 percent of households consume less than 2238 calories per adult equivalent per day, the calorie norm used to define the poverty line. Calorie consumption in urban areas is lower than that in rural areas, reflecting multiple factors, including higher physical activity levels in rural areas linked to manual labour.[15]

Myanmar is self-sufficient in food production at the national level. However, food and nutrition insecurity exists at the household level in some areas due to low income, constraints in food production, transportation, poor knowledge in feeding practices and poor care-giving. Myanmar's food and agriculture systems—including livestock and fisheries—determine the quantity, quality and diversity of food available for consumption. Therefore, food and nutrition security should focus on availability, accessibility, utility and stability. In addition to agriculture and food policies, the efficiency of agricultural production, markets and trade in Myanmar shape the relative prices of different food commodities. At the same time, nutrition education influences knowledge and food preferences. Currently, the rural poor, who constitute 35% - 53% of the rural population, suffer from inadequate food, nutrition and essential non-food items. Micronutrient deficiencies account for 4-6% of all deaths under five years old. Although Myanmar is a net food exporter, about 10% of the population is estimated to be below the official food poverty line, with many pockets of high level food and nutrition insecurity across various states, regions and villages.[16]

Frequent human and natural crises affect food availability, adding to the existing structural limitations of the agricultural sector, incuding inadequate productive infrastructure, poor quality of inputs, high costs of production, low acceleration in modernization of agro-techniques, limited knowledge of agricultural practices and market information, and significant post-harvest losses. Recurrent climate shocks put communities at high risk of displacement and loss of productive assets and livelihoods. Natural disasters impact particularly the agriculture sector, affecting standing crops, livestock, fishery and productive infrastructures.[17]

6.3. ENVIRONMENTAL STRESSES AND AGRICULTURE

Shocks and stresses play key roles in food insecurity and poverty in the context of agricultural livelihoods. A number of these shocks and stresses depend on the environment, including land degradation, erratic rainfall and climate change, pests and plant disease. The primary drivers of desertification are deforestation, erosion, and salinization. Increasing deforestation is largely attributed to demand for fuelwood and agricultural land. Soil erosion, particularly severe in upland areas of the Dry Zone, is largely as a result of high intensity rainfall and rapid surface runoff. Wind erosion is widespread throughout the Dry Zone as well, as evidenced by sandy soils, which are very common. All types of erosion are exacerbated by deforestation. Increased soil alkalinity is primarily caused by the use of saline groundwater for irrigation. Additional causes of reduced soil productivity include fertilizer and pesticide misuse, and over cropping.[18]

Highly variable rainfall is a significant stress to farming in Myanmar, which is primarily rain fed. As a result, farmers are highly susceptible to climatic variability, particularly the beginning and end of the monsoon season and the duration and timing of the mid-season rain gap. Farmers report a shortage of water that affects crop production approximately every three years on average. The result is recurring shocks in the form of both drought and floods. Low seasonal rainfall totals limit crop selection, production yields, and quality, particularly towards the centre. In recent years, a statistically significant reduction in June rainfall totals has also occurred, which has increased the risk of drought conditions during the primary planting season. Exacerbating the situation is insufficient crop water management. The management of existing irrigation water systems is inadequate with little capacity to equitably, sustainably, and efficiently provide water to farmers. As a result, few farmers take advantage of small-scale supplemental irrigation techniques and technologies and existing large-scale irrigation systems reach a small number of intended users.[19]

Farmers in Myanmar are also exposed to several types of plant diseases and pest infestations that can reduce or completely destroy a season's worth of income. Infestations occur in various agro-ecological zones when favourable conditions exist. As a result, farmers use pesticides and fertilizer, which can be challenging to access, increase input costs, and reduce profits. Common pests of crops included trichogramma, rice leaf roller, yellow stem borer, brown planthopper, case worms, rice gall midge, rice hispa, rice blast, rice sheath blight, rice bacterial leaf blight, heath rot, pot borers (chickpeas), aphids (sesame), army works (nuts, beans, sesame), and boll works (cotton).[20],[21]

Climate change will also be causing adverse effects to the industry and adding more burdens to the farmers. Late or early onset of monsoon season, longer dry spells, erratic rainfall, increasing temperature, heavy rains, stronger typhoons and flooding are common climate events that have been occurring more frequently in the recent decade. Deforestation, industrialization and increased greenhouse gas emissions are just some of the factors that cause climate change. Some agricultural practices, likewise, contribute GHG to the atmosphere. Myanmar's population and the calorie intake, which expectedly will increase between 2015 and 2050 due to greater affluence rising demand on land for the generation of food and fuels, will require significant increases in agricultural productivity in the context of more constrained availability of resources. With agriculture contributing about 30% of the country's GDP and providing employment to approximately 60% of the population, the impacts of climate change on agriculture would have repercussions on the livelihoods, food production and the overall economy of Myanmar. While at the same time, the agriculture sector holds significant potential to mitigate climate change through reduction of GHG emissions and enhancement of agricultural sequestration.[22]

In response to climate change, the Ministry of Agriculture, Livestock and Irrigation developed the Myanmar Climate Smart Agriculture (CSA) Strategy in 2015. Myanmar's CSA strategy has been designed socially, culturally and politically appropriate, environment-friendly and economically feasible to promote sustainable agriculture with maximized food security and nutrition, development, climate change adaptation and mitigation. The Government of Myanmar is trying its best to cope with the adverse effects of climate change with a National Adaptation Program of Action (NAPA) covering eight sectors, namely: 1) agriculture, 2) early warning systems, 3) forests, 4) public health, 5) water resources, 6) coastal zones, 7) energy and industry, and 8) biodiversity. Agriculture, early warning systems and forests have the highest priority. [23]

There are a number of different ways to improve farmers' and agriculture systems' resilience to climate change, and to adapt to the threats it poses. While many of these will be in terms of scientific and technological improvements, other means such as improving provision and access to crop insurance and credit, enhancing agricultural value chains and marketing will also be very important.

6.4. SCIENCE AND TECHNOLOGY FOR IMPROVED AGRICULTURE

Even though half of Myanmar jobs are in agriculture, the sector accounts for less than a third of the country's GDP, implying that the returns to agricultural labour are low compared to those of labour in the services and trade sectors. This is due to a range of factors, including an over-abundance of agricultural workers and a corresponding over-reliance on labour in the sector. Overall, Myanmar's agriculture sector remains largely non-mechanized, and its agricultural labour intensity is one of the highest in Southeast Asia. Accordingly, the high labour supply in agriculture, particularly in rural areas, also fuels high rates of underemployment, unpaid or voluntary employment, and employment in subsistence farming.[24]

High labour force participation is often a feature of an economy dependent on an under-developed and non-mechanized primary sector. About 70 percent of the rural labour force, or 53 percent of the total labour force, is employed in the agriculture, forestry and fishing sectors. Men are slightly more likely than women—at 55 percent compared to 50 percent—to identify "agriculture, forestry, or fisheries" as their main sector of employment. The high share of agricultural employment explains the high seasonality pattern we observe in the labour force participation rates in rural areas. Many agricultural workers leave the labour force in the lean season and join the workforce during the monsoon season.[25]

One major contributor to Myanmar's low agriculture productivity is found to have been the prevalence of mono-cropping and the overwhelming dependence on rice production. Rice paddy cultivation in Myanmar uses 70 percent of total arable land and accounts for 30 percent of agricultural output and 95 percent of total cereal output. The country's policy of rice self-sufficiency has led farmers to make rice one of the cultivated crops in all irrigated areas, even when conditions are not appropriate for this task. This has been done to such an extent that rice is the only crop produced in many areas of Myanmar. Other important crops include corns, pulses, onions, and peas, which are grown largely during the second season of rice-based farming systems. Livestock is a relatively small sector, and contributes only to about 7.5 percent of the agriculture GDP, while the contribution from fisheries is even lower. Rice is a low productivity, low value crop, and an important component of developing Myanmar's agriculture sector should be encouraging increased crop diversification.[26]

A second contributor to low productivity is the fact that the Myanmar agriculture sector is far less mechanized than those of other countries in the region. Mechanization is important for modernizing agricultural production techniques and for increasing farm labour intensity and productivity. Myanmar's low mechanization rate is not surprising given the country's low wages and the surplus labour found in rural areas. Furthermore, poor infrastructure and electricity distribution make powering machines difficult, and raise the initial investment costs of mechanization. While mechanization is important for increasing agriculture labour productivity, its greatest benefits come from the indirect effect it has in freeing up labour to engage in other, more productive forms of employment. While the mechanization of rice farms reduces their demand for labour by 10 percent, the fact that labour costs are already so low that profitability does not increase by much when less labour is hired. Mechanized farms, hiring fewer people, saw net profit margins of $121 per hectare whereas non-mechanized farms earned $94 per hectare. Nevertheless, the labour that mechanization frees can be dedicated to more lucrative off-farm activities, particularly if nascent agro-value chains develop enough to generate more jobs. Since mechanization reduces demand for labour, this process must be complemented with an expansion in the number of non-farm rural job opportunities that will absorb the labour that will leave farming.[27]

The use of irrigation and water management systems need to be expanded as well. Skills training in irrigation systems—including their maintenance, operation, and construction, as well as the rehabilitation of canals—should be prioritized. The government should also support investments in irrigation, both for small-scale projects to make water management more efficient, as well as for large-scale irrigation delivery systems (such as lining irrigation, drainage canals, and the associated structures of each). These projects will not only help increase production yields, but will also create wage jobs in rural areas.[28]

Modern agricultural research in Myanmar focuses on increasing productivity while enhancing the sustainability of agricultural practices through resource management with an emphasis on making policy recommendations based on research results. Consequently, much of Myanmar's agricultural research centers on crop improvement trials and variety development. Agricultural management techniques like multi-cropping systems have not been paid much attention to. Limited funding compounds these problems of limited research scope. The lack of resources and direct communication between researchers and farmers hamper research infrastructure.[29]

According to findings and analysis by the Agricultural Science and Technology Indicators, investment in agricultural research in Myanmar is grossly inadequate and based on the structural characteristics of its economy and agricultural sector, the country should be able to invest 0.61 percent of its Agricultural GDP in agricultural research. To have reached this target, Myanmar would need to have spent 141,720 million kyat in 2017, instead of the 13,705 million kyat it actually spent. It is not only the quantity, but also the quality of agricultural R&D investment that is important. Myanmar has set the goal of diversifying its agricultural production and increasing its exports. It will therefore need to invest proportionally less in research on cereals and more on high-value commodities, such as fruit and vegetables, cash crops, livestock, and fisheries.[30]

It has been suggested that Myanmar's government expand research in the public agricultural sector so that it can focus on topics that are responsive to farmers' needs, including crop productivity and diversification. This will require reliable two-way information pathways between farmers and researchers, research institutions interested in rural livelihoods, and the incorporation of farmer advocates into policy conversations. Establishment of cooperatives could facilitate collabouration between researchers, extension agents, and farmers on a regional scale, and could allow local needs to guide research questions.[31]

Understanding the importance of the agricultural economy, the Myanmar government has placed a significant emphasis on improving the agricultural infrastructure and enhancing access to clean, affordable, and high-yielding seed in order to improve agricultural productivity more rapidly. Myanmar's primary crops consist of upland and lowland rice, maize, beans, pulses, and oilseeds. Of these, only maize and some pulses are regularly grown from certified seed and most farmers reuse a portion of their own crop or source seed from neighbouring farmers or villages. Smallholder farmers must be included in the evolving seed production system to ensure the proper distribution of economic gains across the agricultural economy as well as close the large gap between supply and projected demand for certified seed.[32]

In order to reach its full agricultural potential, issues of quality, market inefficiency, inaccessibility, and lack of education in its fertilizer sector must be addressed. Across all channels of fertilizer distribution in Myanmar, there is reportedly a severe lack of quality testing at the farmer level. Combined with the large-scale quality issues throughout both domestic and imported fertilizer distribution channels, this poses a significant problem for farmers. It has been suggested that the government of Myanmar assist in establishing laboratories and a testing service to ensure the consistently high quality of products being developed and entering domestic markets. This would not be an insignificant task for a single lab to undertake, but will instead require country-wide coordination and cooperation.[33]

Current challenges in water and irrigation include the lack of a unified policy, overlap in formal duties among ten ministries, an overemphasis on rice system irrigation, and dangers related to overexploitation and environmental pollution. Irrigation projects that are currently being developed in Myanmar in collaboration with other countries and research programs require considerations about their social impact on the community. There is, therefore, a need to prioritize local community empowerment. Cooperatives have an important role to play in both, coordinating management plans that account for local variability and being an advocate for rural people's interests. [34]

Seed technology, fertilizer, research, mechanization, and irrigation are interdependent and must be developed together. Efforts to deliver new seed technology to rural areas must be supported by effective extension if the new variety requires different management practices. Upgrades in mechanization also require the local capacity for farm equipment maintenance. Governments and NGOs should help strengthen farmer-led rural institutions such as cooperatives to coordinate development efforts. They could act as intermediaries between farmers, agencies, and business interests, advocate for the interests of rural people, and connect farmers to markets. An aggregated approach that employs the use of farmer cooperatives has the potential to enhance the effectiveness of each agricultural upgrade recommendation and support an overall more equitable, sustainable, and resilient agricultural system.[35]

6.5. AGRICULTURAL VALUE CHAIN DEVELOPMENT

The development of a dynamic rural sector that ties together on-and off-job activities is vital for job growth in Myanmar. Since Myanmar is in a pre-transition phase of agricultural development, many of those employed in rural trade and manufacturing sectors are likely mainly involved in primary processing and in the trade of agricultural products. Agro-value chains consist of interdependent enterprises that generate value added throughout a food system, and have the potential to create many rural jobs tied to agriculture both on and off-farms. Beyond farming and other agriculture production, agro-value chains include upstream jobs—such as seed and fertilizer input suppliers—and downstream jobs—such as in wholesale, retail, food processing, and food services.[36]

To support the integration of rural jobs into agricultural value chains, policies are needed to improve the skills and ease the financial constraints of the rural workforce. People without formal schooling are employed largely in on-farm jobs, while workers with at least a tertiary education work primarily in non-farm jobs. Training support should be given to small business owners through extension services to increase their knowledge of markets, sustainable business practices, international production standards, facilitating client decisions, best practices implementation, and vertical integration opportunities. This training is especially important for agro-industries which will need to adopt good practices and standards to increase their competitiveness and productivity. Community-based rural enterprises, namely farming cooperatives, are ideal recipients for this training support, as they are well equipped to distribute learning material. Farming cooperatives can also act as intermediaries to increase access to financial services, meaning that these organizations must also be able to access loans from a wider range of financial institutions.[37]

Evidence from agricultural and rural development interventions shows that rural populations engage in non-farm activities more when given access to finance and links to markets. Policy support is also needed to increase the use of vertical integration to mitigate risk in the supply chain. This would create forward and backward linkages between small enterprises, farms and larger firms in the value chains. Financial support should be given to firms in the services and manufacturing sectors that support agro-business with the on-the-job training of their rural workforce. Support for the agriculture sector must be underpinned with policies that create a national business, institutional, and regulatory environment that enables agro-value chain growth. Furthermore, a regulatory and institutional system could be established that sets, enforces, and certifies food standards, ideally enabling businesses along agro-value chains to meet international standards and export to foreign markets where profits are highest. Testing, certification, and labeling facilities ideally could be established near cultivation zones, and be complemented with improved infrastructure. Farmers will need to be provided with technical support to improve their farming practices and adopt techniques to meet international standards.[38]

6.6. FUTURISTIC POLICY FRAMEWORK FOR SUSTAINABLE AGRICULTURE AND FOOD SECURITY

Myanmar's agriculture sector finds itself at the initial stages of an accelerated but partially completed policy liberalization. Tight state control over agricultural land rights, crop choice, and production decisions, as well as marketing, trading, and pricing, initiated during the socialist period (1962–1987) resulted in diminished incentives and poor agricultural performance. This has lingered despite partial liberalization starting with pulse marketing and exports in 1988 and with rice in 2003.[39]

The Ministry of Agriculture, Livestock and Irrigation noted its Missions, namely: to attain market share in regional and global markets for agro-based value-added agriculture and specialty food products, to improve food security and poverty alleviation especially in rural areas, and to manage green growth. Accordingly, the recognition of the importance of agriculture to Myanmar's economic development is reflected in a number of its reform initiatives in the past decade. The 2011 National Strategy on Poverty Alleviation and Rural Development identified eight priority areas for agriculture and rural development, and the 2012 Framework for Economic and Social Reform identified 10 priority areas, including food security and agricultural growth, while many of the other areas indirectly relate to agriculture and rural development as well. The 2011–2030 National Comprehensive Development Plan laid down three targets for the agriculture sector and five short term objectives to achieve them.[40]

The Ministry developed the Agricultural Development Strategy (ADS) with the consensus of all stakeholders involved and officially launched it in June 2018. Food and Nutrition Security is one of the 12 principles laid down in ADS.[41] Other important policies and legislations relevant to improving agriculture and food security in Myanmar include the Law of Protection of the Farmer Rights and Enhancement of their Benefits, Farmland Law, National Land Use Policy, National Strategy for Rural Water Supply, Sanitation and Hygiene (WASH), Climate Change Strategy and Action Plan, Myanmar Plant Health System Strategy, Myanmar Action Plan on Disaster Risk Reduction, and Multi-sectoral National Plan of Action on Nutrition, and National Food Policy.[42]

Notably, Myanmar's parliament recently enacted a suite of laws intended to bolster private sector involvement in seed production through incentives and intellectual property protections. Such laws are a necessary first step for a country transitioning from a centrally planned agricultural system to one that encourages private-sector contributions. However, because of both a deficit in investment in the marketing and production of quality certified seed and an infrastructural system that excludes access to small-holder farmers in remote villages, the benefits of these contributions are not universally enjoyed.[43]

There clearly has been much improvement since liberalization in Myanmar, but many of the measures taken thus far are not sufficient to underpin full, potential long-term growth of agriculture as a driver of economic development. The underperformance of agriculture in Myanmar is both a challenge and immense opportunity, as much of the underperformance has resulted from constraints that can be further addressed with straightforward interventions and reforms. This means that targeted investments in institutions, policies, and infrastructure have enormous potential to lift the sector's performance.[44]

The COVID-19 pandemic has negatively impacted Myanmar's economy directly and indirectly, and it has also had negative impacts on the agriculture sector owing to disruptions in the movement of goods and services. One study estimated a decline in Myanmar's agricultural GDP by 14% during the two-week lockdown period in April, 2020.[45] The pandemic has also had strong negative impacts on income-based poverty among both rural and urban households, primarily due to loss of jobs or other sources of income. In response to income losses associated with COVID-19, the Government of Myanmar introduced a series of emergency measures to provide basic assistance to vulnerable households. It is critical to assess the effectiveness of such assistance in reaching food-insecure populations and maintaining basic food security. Job creation must be at the heart of economic recovery strategies, and the agriculture sector must be closely monitored and supported.[46] Improving the agri-food sector in Myanmar over the next few years through targeted investments in institutions, policies and infrastructure will also play a crucial role in making the sector more resilient to future crisis situations, and it is therefore imperative that all of Myanmar's goals and targets are met through active policy and ground-level interventions.

Appendix: Figures, Graphs and Tables

Figure 1: Agriculture, Forestry and Fishing Output and GDP Share. Source: World Bank - World Development Indicators, 2018.

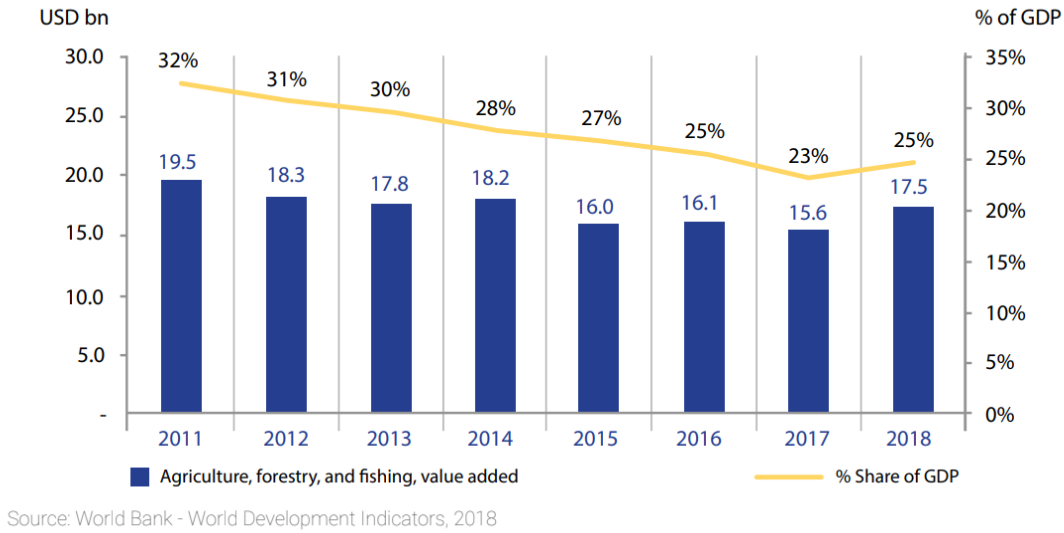
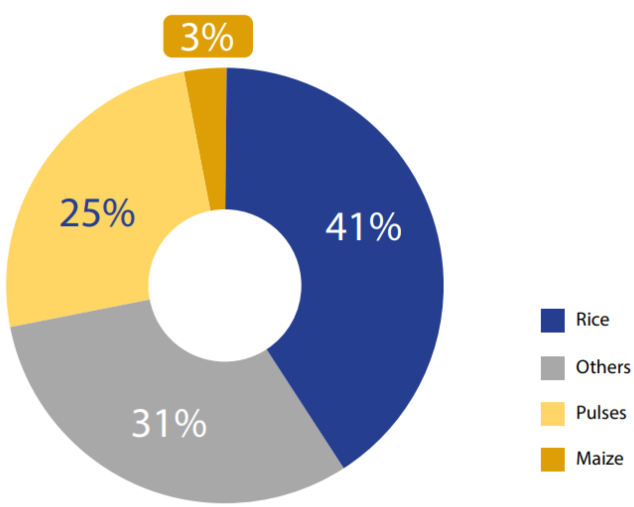


Figure 2: Sown Acreage Split by Selected Type of Agriculture Product Nationwide (2017-18). Source: Central Statistical Organization, 2018. Note: Others include wheat, oilseeds, spices, tobacco, beverage crops, vegetables and fruits, fibre and miscellaneous



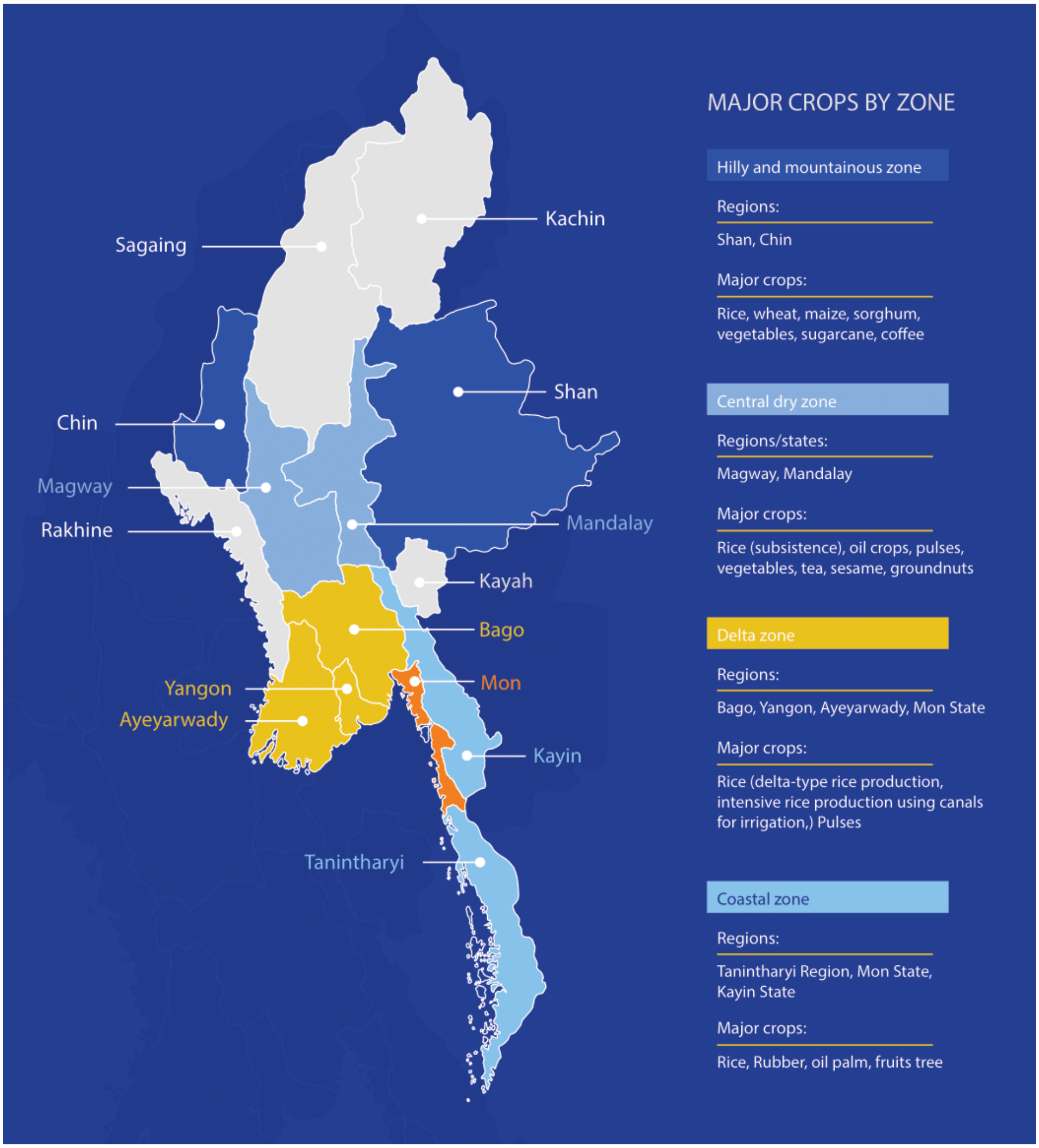


Figure 3: Major Crops by Zone on the Map of Myanmar. Source: EuroCham Myanmar, 2020.

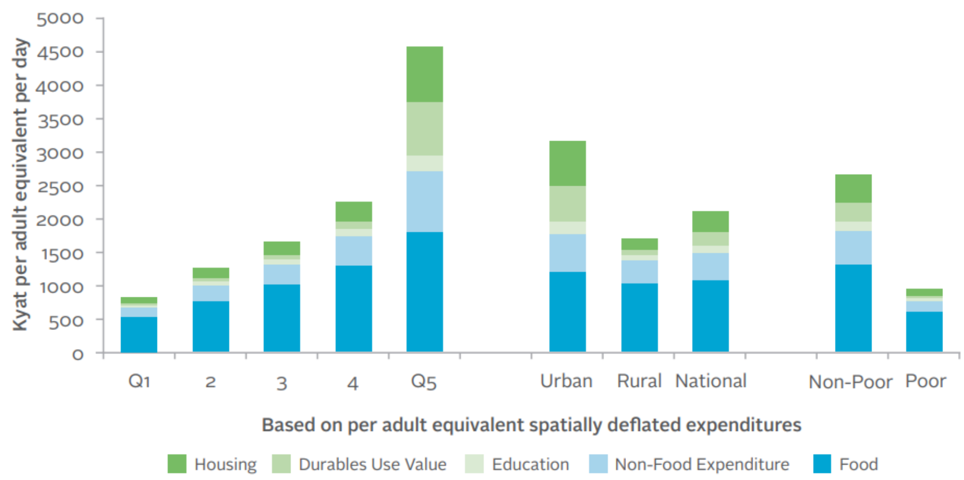


Figure 4: Total consumption and consumption share per adult equivalent, by components. Source: World Bank Group, 2017.

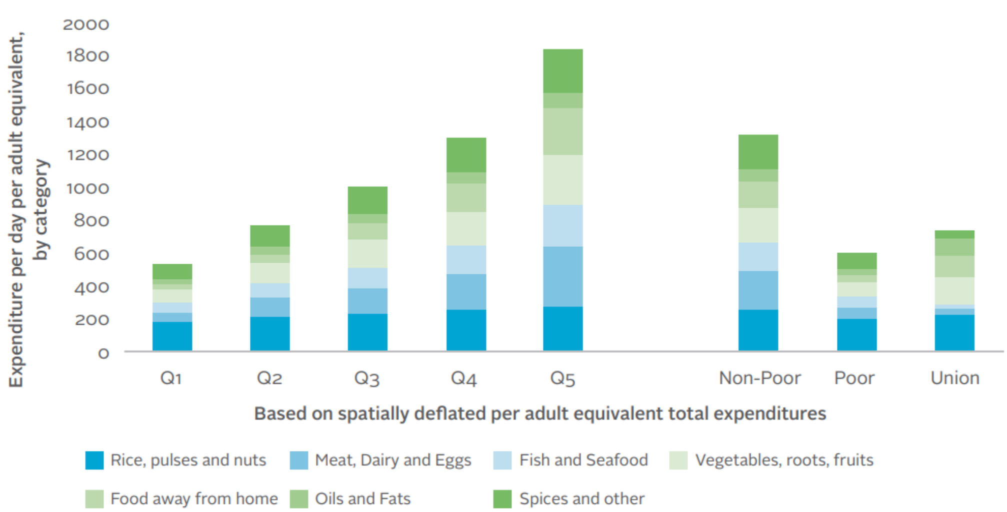
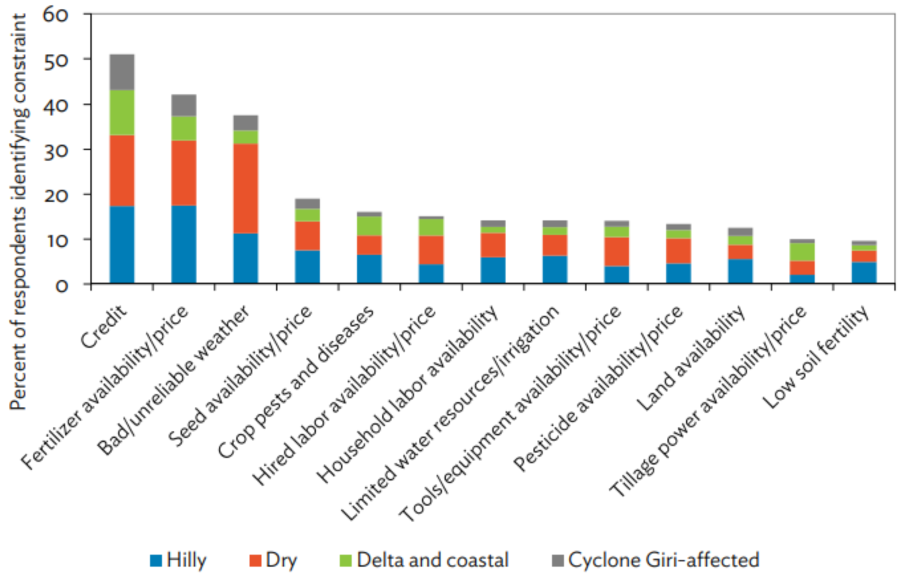


Figure 5: Food expenditures by item. Source: World Bank Group, 2017.



Note: There were 240 respondents identified by LIFT baseline survey respondents in 2011 in the Cyclone Giri-affected zone, 319 respondents in the delta and coastal areas, 632 in the dry zone, and 807 in the hilly areas.

Figure 6: Constraints to Agricultural Production, Survey Results. Source: Livelihoods and Food Security Trust Fund, 2012.

Mission

- Attain maximum market share in regional and global markets for agro-based value-added agriculture and specialty food products
- Improve food security and poverty alleviation, particularly in rural areas
- Manage green growth

Strategy

- Secure linkages among research and development, extension, and markets
- Develop an efficient supply chain and industry clusters
- Assure sustainable land tenure
- Establish efficient systems of:
  - Inputs (seed, fertilizers and chemicals, and machinery)
  - Credit
  - Guaranteed purchase and price
  - Insurance on crops and climate
- Establish an efficient buffer policy and system
- Promote contract farming
- Develop infrastructure:
  - Small and medium-sized enterprise laws and regulations
  - Wholesale markets
  - Rural access roads
  - Rural electrification and bioenergy

Policies

- Production and utilization of high-yielding and good quality seeds
- Training and education activities for farmers and extension staff
- Research and development activities for sustainable agricultural development
- Transformation from conventional to mechanized agriculture, production of crops appropriate to climate, and extension of irrigated area
- Amendment of existing agricultural laws and regulations to reflect current situation

Box 1: Mission, Strategy and Policies for Myanmar's Agriculture Sector Development. Source: Ministry of Agriculture and Irrigation, 2013.

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7. Agricultural Production and Food Security in Nepal

7. Agricultural Production and Food Security in Nepal

SUMMARY

Nepal is a small landlocked country surrounded by India and China. The country is divided into three ecological regions, namely; mountains, hills and Terai with 35 percent, 42 percent and 23 percent of the total area respectively. The agriculture sector in Nepal contributes around one third of Nepal's GDP. It is a major source of food security, trade earnings and an important driver of pro-poor growth and social welfare as it employs around 65 percent of the total working population. Although the contribution of agriculture to the GDP has been declining over time, it is still the single largest economic sector with nearly 27 percent contribution to GDP. The sector is employs around two-third of Nepal's economically active population. The agriculture sector in Nepal is in a low development stage since productivity and competitiveness of the sector are low and adoption of improved technology is limited.

Nepal, like many other developing countries, is struggling to ensure food and nutrition security. Nepal Demographic and Health Survey (NDHS) 2016 found the national household food security to be 48.2 percent and severely food insecure households to be about 10 percent. Despite some growth in the yield of major staples, food insecurity is still very high primarily due to population pressure and changes in dietary patterns. Zero Hunger Strategic Review (ZHSR) conducted in 2017-18 also concluded that the country was still suffering from severe food insecurity and malnutrition. Malnutrition has also been a serious socio-economic problem in the path of the rapid economic development in the country. According to the NDHS Survey, Nepal has a very high rate of child malnutrition as 36 percent and 27 percent of children under five are stunted and underweight, respectively. The stunting, wasting and low weight in children contribute to 52 percent of child mortality in Nepal. Likewise, one in five (21 percent) children is born with low birth weight, reflecting malnutrition in the womb. About 17 percent women of reproductive age have chronic energy deficiency and 41 percent of this population is anaemic. Similarly, women and children also suffer from some of the world's highest levels of vitamin and mineral deficiencies. Moreover, overweight and obesity have been growing rapidly in recent years due to high intake of high amounts of fat, sugar and salt, and inactive lifestyles leading to a growing incidences of high blood pressure, diabetes and other non-communicable diseases.

There exists an adequate framework for agriculture and food related public policy. However, components of national food system are less integrated. Climate change is likely to be the single largest factor shaping the food system in Nepal. Much scope exists for meeting technological gaps in food value chains for a more sustainable and resilient food system. There is a need to focus more on nutritious and safe foods besides meeting calorie requirements. Increasing investment in agriculture and agriculture research and development, in particular, and strengthening linkage between research, extension and teaching are critical for the overall growth in agriculture sector. A framework for the engagement of federal, provincial and local governments vis-à-vis building

sustainable and resilient food system is urgently needed. For this, capacity building of governments and stakeholders is equally important.

Since the COVID 19 crisis looks far from over, agriculture will continue to suffer as every other sector of economy has. Efforts are being made to lessen the damage and revive the sector through various initiatives and schemes by the central and lower governments. However, revival and rehabilitation from government efforts alone are not sufficient to deal with this scale of unprecedented impact on and damage to the sector. Farmers' representative bodies, civil society organizations, private sector entities and farmers themselves need to join hands to deal with the situation and continue and put extra efforts to increase production. In this regard, maximum yet sustainable utilization of available resources should be the first strategy and get top priority. Young farmers and entrepreneurs and returnee migrant workers should be encouraged and motivated to till abandoned fallow land to turn into a well-managed modern agriculture farm by providing needed technical and financial supports and incentives.

Digitalization of activities in every possible stage of value chain is another suggested strategy in order to make the entire value chain more efficient as well as to help all value chain actors adopt health and safety measures in this pandemic situation. E-learning sessions and virtual meetings should be encouraged in technology and knowledge transfer. There is an urgent need for developing and executing a comprehensive plan of action for the rescue, relief and rehabilitation of farmers and small and medium agribusinesses with the involvement of all the three levels of government. The Ministry of Agriculture and Livestock Development is better placed to initiate and lead such a process. The importance of food security and achieving self-sufficiency, at least in major staples and consumables, is probably one of the biggest lessons from this crisis. It has provided an opportunity for us to look back and reconcile our past efforts and build a sustainable and resilient food and agriculture system locally as well as globally.

7.1. INTRODUCTION

Nepal is a small landlocked country surrounded by India and China. The country is divided into three ecological regions, namely; mountains, hills and Terai with 35 percent, 42 percent and 23 percent of the total area respectively. Two third of terrain is mountainous, and the climate is wet in summer and dry in winter. Nepal has five Physiographic regions, namely; High Himalayas, High Mountains, Middle Mountains, Siwalik and Terai (Plains) (Fig. 1). The agriculture sector in Nepal contributes around one third of Nepal's GDP. It is a major source of food security, trade earnings and an important driver of pro-poor growth and social welfare as it employs around 65% of the total working population[1]. Any improvements made to this sector, therefore, will likely have equally important effects on the welfare of the people of Nepal, especially in the aftermath of the COVID-19 pandemic.[2] Major soil orders of Nepal according USDA taxonomy are: Entisols, Inceptisols, Mollisols, and Alfisols. Spodosols, Histosols, Utisols, and Aridisols are occasionally found. Agricultural cultivated land is 21 percent of total area with 35 percent of the cultivated land under year-round irrigation facilities. The total number of holdings is 12,000,000 with average holding size of 0.68 ha[3].

7.2. AGRICULTURAL PRODUCTION AND FOOD SECURITY

7.2.a. Agricultural Performance and Food Production

Although the contribution of agriculture to gross domestic product (GDP) has been declining over time, it is still the single largest economic sector with nearly 27 percent contribution to GDP[4]. The sector is employs around two-third of Nepal's economically active population. The agriculture sector in Nepal is in a low development stage since productivity and competitiveness of the sector are low and adoption of improved technology is limited[5]. Nepal's agricultural growth has been slow (about 3.2 percent between 1995-96 and 2015-16) with high annual variation. Nepali agriculture production continues to depend heavily on monsoonal rains. Nepal was a net food exporter until the early 1980s, however, from the 1990s, its population growth outpaced cereal production growth, causing sporadic food shortage at the national level. Nepal has therefore turned to a net food importer, with food import bills and trade deficit growing every year. Other major factors contributing to overall food deficit include adverse weather conditions like drought, floods and inundation, landslides, hailstorm etc., but the magnitude of food deficit is usually less than one percent of the total food requirement.

The major food grains produced in Nepal are paddy, maize, wheat, millet and barley cultivated in 3.5 million ha of land. Among these, cereals paddy alone covers about 42 and 50 percent of the total cereal area and production respectively. Production of major staples (rice, maize and wheat) has increased by more than a three-fold in the last fifty years (Fig. 2). However, due to high population growth, nearly stagnant yield or meagre growth and change in food habit of the majority of the population who increasingly favour fine rice has led to the rapid increase of rice imports in recent years. The value of rice imports has doubled in the last six years (Fig. 3).

7.2.b. Food Security and Nutrition

Nepal is among the world's poorest countries, ranking 148th out of 189, with a Human Development Index (HDI) score of 0.574 in 2019[6]. Per capita GDP was estimated to be 1085 USD in 2019 whereas 18.7 percent population was estimated to live below the national poverty line of less than US$0.50 per day[7]. Reducing hunger and malnutrition is probably the biggest development agenda of developing countries in the contemporary world as hunger and malnutrition are often the root cause of multiple health and wellbeing consequences and negatively impact not only an individual and the family but the society and the nation as a whole[8].

Nepal, like many other developing countries, is struggling to ensure food and nutrition security. Nepal ranked 73th out of 117 countries in Global Hunger Index (GHI) in 2019. Similarly, it ranked at 79th (out of 113 countries) in Global Food Security Index, 2018. Nepal Demographic and Health Survey (NDHS) 2016 found the national household food security to be 48.2 percent and severely food insecure households to be about 10 percent[9]. Geographically, the mountain region was suffering more from food insecurity compared to terai because of the terai region having higher percentage of cultivated area than the mountains. Despite some growth in the yield of major staples, food insecurity is still very high primarily due to population pressure and changes in dietary patterns. Moreover, a strictly calorie-based approach is incompatible with the definition of food security. The food has to be safe, healthy and nutritious with appropriate balance of carbohydrate, protein, fat, macro-nutrients, micro-nutrients and vitamins in order to achieve the final goal of ensuring a healthy life. Zero Hunger Strategic Review (ZHSR) conducted in 2017-18 also concluded that the country was still suffering from severe food insecurity and malnutrition[10].

Malnutrition has been a serious socio-economic problem in the path of the rapid economic development in the country. According to the NDHS Survey, Nepal has a very high rate of child malnutrition as 36 percent and 27 percent of children under five are stunted and underweight, respectively. The stunting, wasting and low weight in children contribute to 52 percent of child mortality in Nepal. Likewise, one in five (21 percent) children is born with low birth weight, reflecting malnutrition in the womb. About 17 percent women of reproductive age have chronic energy deficiency and 41 percent of this population is anemic[11]. Similarly, women and children also suffer from some of the world's highest levels of vitamin and mineral deficiencies. Moreover, overweight and obesity have been growing rapidly in recent years due to high intake of high amounts of fat, sugar and salt, and inactive lifestyles leading to a growing incidences of high blood pressure, diabetes and other non-communicable diseases.

To achieve the goal of sustainable nutrition security the Government of Nepal has adopted a multi-sector Approach (MSA) to nutrition. The MCA aims at improving the nutritional outcome with achieving improvement in agriculture productivity and household income. This approach stresses on the interconnectedness between agriculture and nutrition sector to consider food diversity as an important aspect of food security. A number of related government agencies, NGOs and donor-supported projects are working in the field of food and nutrition security. At the functional level, the MCA brings together respective units of related government institutions and other stakeholders for the better coordination in program implementation in order to realize ultimate nutritional outcomes. However, with three levels of government in place, cascading MSA to lower level governments and bring all the government together and work under the one national framework for food security and nutrition has been a challenging task.

There have been significant changes in food consumption pattern in Nepal over the years[12,13]. Food budget share of a household has declined over time with a shift of household food budget from cereals and pulses towards fruits, vegetables, meat, dairy products and other miscellaneous food items. The diversity in dietary pattern has become more apparent over time and the dietary diversity depicts a positive impact on nutritional outcome[14].

While shift of dietary pattern towards more diverse foods in the diet is a positive change from the perspective of general health and wellbeing, increasing trend of consuming junk foods has offset the potential nutrition gain of dietary diversity. In recent years, there has been an exponential growth in the trend of consumption of high-calorie junk foods including packaged foods, carbonated soft drinks, fast foods, and ultra-processed foods with unhealthy fat, sugar and salt in excess, especially among the youth. Such unhealthy dietary pattern has become a leading cause of malnutrition and a challenge to improve nutrition of people of all ages, but particularly mothers, infants, children and adolescents[15].

7.2.c. Impacts of COVID 19 on Agriculture and Food Security

With increasing number of COVID 19 cases in the country, the Government of Nepal imposed a nation-wide lockdown starting 24 March, 2020, in a bid to contain the spread of the virus. While this might have helped in curbing the rapid transmission of the disease from person to person by restricting movement, the lockdown also brought almost all businesses and economic activities to a complete halt. The government has revised the GDP growth rate to be 2.3 percent as against the original estimate of 8.5 percent for the fiscal year 2019-20 due to the impacts of COVID 19 and consequent economic slowdown[16]. However, further shrinkage in national economy is on the cards due to COVID-19, and GDP growth in Nepal could stand at meagre 1.8 percent in FY2020, compared to 7 percent in FY2019[17]. The national economy is estimated to bear a loss of over four trillion Nepali rupees in the fiscal year 2019-20 as estimated by Asian Development Bank. As per World Bank projections, the remittance earning of Nepal could slide by 14 percent in 2020[18]. Although the numbers are not the biggest ones compared to other countries in the region, it will impact overall national economy significantly given the fact that remittances represent more than a quarter of the country's economic output.

Based on a rapid assessment survey of 700 businesses and 400 individuals, and consultations with over 30 private sector organizations and government agencies conducted during the lockdown, the UNDP found that the COVID-19 pandemic has disrupted supply chains, and caused to shut or threatened the survival of small and informal enterprises. The survey also concluded that the COVID 19 crisis has made people highly vulnerable to falling back into poverty through widespread loss of income and jobs. UNDP Nepal estimates agriculture, forestry and fishing sector of Nepal to be at medium risk[19]. Moreover, during COVID-19 lockdown smallholder farmers are impacted more in Nepal due to the disruption in supply of agricultural inputs, access to markets as well as delays in harvest and planting[20].

The start of lockdown had coincided with the wheat harvesting season, partially impacting the otherwise good harvest due to acute labour shortage resulted from imposed restriction on the movement. Moreover, producers of perishables including fresh vegetables and dairy products suffered the most due to a complete disruption of supply chain following the imposition of lockdown and restriction of vehicular movement. While major cities saw an irregular supply of farm fresh produces, farmers had to waste their vegetables and milk for failing to transport up to the market. Although the federal and lower level governments vowed not to restrict the movement of transport vehicles ferrying farm produce in the lockdown, farmers hardly benefited from the governments' decision of allowing movement of agriculture goods. Such circulars were often found defied by the local security personnel deployed on the highways and market centres. Higher officials from the Ministry of Agriculture and Livestock Development (MoALD) often had to approach a high level COVID Crisis Management Committee (CCMC), formed by the government, to mobilize the law enforcing mechanism in facilitating the movement of essential goods. Farmers also faced a shortage in supply of fertilizers at the time of paddy planting and nitrogen top-dress.

7.3. AGRICULTURE AND ENVIRONMENTAL STRESSES IN NEPAL

7.3.a. Impacts of Climate Change

Nepal ranks 4th under Climate Vulnerability Index and 30th in terms of water-induced disaster. Weather station data indicates an increase in temperature trends across Nepal in the period 1975-2009. Nepal's average annual mean temperature has increased by 0.060 degrees C between 1977 and 2000, and these increases are more pronounced at higher altitudes and in the winter. For the last few years, a recurrent trend of late monsoon has been observed, with subsequent impact on summer crops. A study conducted by Nepal Country Vulnerability Study Team in 2009 projected that Nepal's mean annual temperature may rise by 1.4 degrees C by 2030, 2.8 degrees C by 2060 and by 4.7 degrees C by 2090[21]. Nepal produces only 0.027 percent of total global greenhouse gas emissions but due to the rise in atmospheric temperature and its fragile geology and geographic condition, Nepal is impacted disproportionately by the change in climate. Extreme high precipitation, increase in temperature, extreme low precipitation, and increased climatic variability are major climate change event risks faced by all regions in Nepal.

Evidence suggests that the observed changes in temperatures and soil moisture are negatively affecting agriculture in many parts of Nepal. The Terai region, Nepal's prime agricultural belt along the entire southern region of the country, is most at risk from flooding. This could lead to inundation or depositing of sediments on agricultural land. Similarly, drought–both during winter and summer–is affecting crop production. A recurrent trend of late monsoon has been observed in the recent past, with subsequent impact on summer crops. Therefore, food production in Nepal is highly sensitive to climate risks. More than 1.9 million people are estimated to be highly climate vulnerable and 10 million increasingly at risk in Nepal. Agriculture is also at risk of increased water scarcity due to growing demand from other sectors. Threats to food security will also increase due to loss of local crops and landraces owing to rapid loss of habitat as a result of climate change. As there is a dominance of small and marginal farmers in the country, such groups are more vulnerable to climate shocks. The ability of Nepal's agriculture sector to adapt to these changes is limited.

Various government and non-government agencies have been promoting Climate Smart Agriculture (CSA) practices in a bid to help empower the farming communities become more climate resilient. Some of the CSA practices being adopted include cultivation of stress tolerant crop varieties, water use efficient and water harvesting practices, energy saving technologies, adjusting in the agronomic practices and crop calendar, in-situ and ex-situ conservation of crop landraces and local varieties and promotion of cultivation of such crop and varieties, organic and ecological farming, minimum tillage and crop residue management, weather-based crop advisory and crop insurance.

7.3.b. Conservation of Agro-Biodiversity

Nepal ranks the 49th position in the world in biodiversity. The country is rich in landraces, but only 37 landraces of 19 local crops have been utilized in breeding to develop 41 crop varieties so far[22]. Nepal became a member of the Convention on Biological Diversity (CBD) in 1992 and of ITPGRFA in 2009. It is also a party of other international protocols including The Cartagena Protocol on Bio-safety-2000 and Nagoya Protocol-2014. A number of policy and regulatory frameworks for conservation of agrobiodiversity are in place in the country including Agrobiodiversity Policy, Seed Act, National Seed Vision 2013-2025, among others. A number of government and non-government institutions have been working in the field of agrobiodiversity conservation.

A rapid loss of agriculture plant genetic resources (APGRs) has threatened food and nutrition security nationally and globally, mainly due to the mono-cropping of modern varieties and poor utilization of landraces and indigenous cultivars in modern farming practices. The negative impact of climate change has aggravated the situation. The situation has warranted strategic interventions for the conservation of agrobiodiversity.

The common methods of conserving agrobiodiversity are seed bank for orthodox crops and field gene bank for recalcitrant and vegetatively propagated crops[23]. At the on-farm level, community seed bank (CSB) and community field gene bank (CFGB) are the main methods operated at local levels and run by the community. There are strong evidences that community seed bank (CSB) could play an instrumental role in conserving and utilizing the endangered species[24]. Some other methods being used for the conservation of plant genetic resources include providing incentive and award for custodian farmers, image bank, seed and crop herbaria and agro museum, diversity fair, food fair landraces catalogue, ownership documentation, registration of local crop and landraces maintaining Community Biodiversity Register, and diversity field school, among others.

Despite the country being rich in agrobiodiversity and various policy frameworks for conservation in place, conservation and utilization of native agrobiodiversity is something that not getting adequate priority. Use of landraces in crop varietal development and improvement has not received due attention and priority. More than 90-95 percent germplasms used in crop varietal development are exotic ones. There is an urgent need of policy shift to facilitate the utilization of in-country landraces for varietal development and contribution to the global genetic pool.

7.4. IMPROVING TECHNOLOGY FOR SUSTAINABLE AGRICULTURAL PRODUCTION

Agriculture absorbs the majority of the labour force (more than 60 percent), but this sector contributes about 27 percent to the GDP[25] which clearly indicate low productivity of the labour force. The estimate of labour productivity in agriculture in Nepal is about one fourth of the productivity in the rest of the economy[26].

7.4.a. Agricultural Mechanization

As per the sample agriculture census conducted in 2011-12, less than 1 percent farms were using power tillers, indicating low level of farm mechanization in Nepal[27]. The same census also found that only 22.04 percent farm households used tractors and 20.96 percent used thrashers. There has been more than eight times increase in number of tractors registered in the Department of Transport Management in twenty years between 1989-90 and 2010-11 with total number reaching to more than 64,000[28]. A sharp rise in the number was observed after 2007-08, which could be due to the increased government subsidy on the purchase of tractors. Over the years, the use of diesel pump sets commonly used for pumping water and 4-wheel tractor and 2-wheel power tiller used for tillage operation and transportation have been increasing mainly in the plains of Nepal. Likewise, the increased use of thresher has been seen for threshing operation. Farm mechanization in Nepal is mostly concentrated in the plains, which get benefited from the spill over of mechanization drives in bordering Indian states.

With increasing shortage of farm labour due to outmigration of the youth, mechanization is becoming a compulsion. As a response to farm labour shortage, farm mechanization is also important in lowering the cost of production, and in reducing women's drudgery in Nepali context. The Government of Nepal has been giving priority to mechanization in its agriculture and farm sector related policies and programs. The Agricultural Mechanization Promotion Policy, 2014, has been an important milestone in promoting mechanization in the country. Likewise, the 20-year Agriculture Development Strategy (ADS) has recognized mechanization as an important area to intervene for higher productivity as it blames lower rates of mechanization together with lower rates of inputs and irrigation for much lower cereal yield as compared to China which has about the same arable land per capita[29]. Similarly, mechanization has been one of the main thrust areas of Prime Minister Agriculture Modernization Project (PMAMP), a national flagship project for the modernization of agriculture sector in the country.

Moreover, the use of machinery for the promotion of Conservation Agriculture based Sustainable Intensification (CASI) is becoming popular in the plains of Nepal with the help of various donor funded projects including DFAT Australia funded Sustainable and Resilient Farming System Intensification (SRFSI). Despite the wide spread recognition and promotion for agriculture commercialization and modernization, mechanization drive in Nepal has been marred by a number of constraints and challenges including small and fragmented holdings, lack of adequate repair and maintenance facilities and workshops, lack of machinery testing and standardizing services, poor after sales service, lack of small machineries suitable for small farmers and reducing women drudgery, poor local fabrication and heavy dependence on import, and poor research and development in developing farm machinery, among others.

7.4.b. Potential for Digital Technology

Future agriculture will have to be more efficient in terms of water, energy, farm inputs, labour, time etc., while also giving higher yield and higher profit in the face of negative impacts of climate change and increasing demand for food. Digitalization will have to play a critical role to achieve these goals. The agriculture sector has benefited from the rapid expansion of mobile technology and internet and Nepal has adopted a Digital Nepal Framework. Agriculture is one of the eight thematic areas of the Framework. Nine intervention areas have been identified in agriculture under the Framework, namely; eHaat Bazaar, Precision Agriculture, Agriculture Tools Sharing, Digital Payment of Subsidies, Specialty, Food Program, Digitalization of Land Records, Smart Irrigation Project, Education and Training Programs for Farmers, and State of the Art Knowledge Centers. However, the Framework is yet to be fully implemented in those intervention areas.

Use of digital technologies in agriculture has been growing rapidly in recent years in Nepal, especially online platforms and social media to access new digital technologies and for marketing. However, majority of small farmers have not been introduced to digital technologies, and many continue to use basic mobile phone services, with only a few using smart phones and internet based applications and services.

With the increasing use of digital technologies in agriculture, some issues have cropped up. Since small farmers have not been able to make best use of digital technologies, there is a danger of digital divide and the risk of smallholders being left out given the fact that small farmers in rural areas generally face problems of limited access to infrastructure, networks and technologies. Similarly, there are issues of affordability and general farmers' low level of e-literacy. There are also issues of coverage, quality and reliability of telecommunication and internet services in remote parts of the country. Moreover, lack of standardization of digital technologies and quality of content and services, availability of disaggregated data and regulatory framework for data access and protection, and ownership of data and protection of privacy are some other issues becoming increasingly evident.

7.5. AGRICULTURE VALUE CHAIN DEVELOPMENT IN NEPAL

One of the main reasons for the Nepali agriculture sector's poor level of commercialization and competitiveness could be poorly developed value chains of major traded produce. There are problems in almost every stage of value chain, right from inputs management through production to postharvest and marketing practices. Highly fragmented and poorly organized value chains have also denied the just sharing of ‘value’ accrued to the different value chain actors across a value chain.

Timely availability of major inputs such as seeds and fertilizers are still an issue. There are often complaints of timeliness of supply (more so with imported fertilizers), quality and price of the farm inputs. To address the issue with supply of inputs, the government has planned several policy interventions. With the implementation of National Seed Policy, 2000, paving a way for the involvement of the private sector in seed business, seed supply and demand have increased remarkably. National Seed Vision (2013-2025) has clearly outlined a roadmap to strengthen the seed value chain in the country. Although seed value chain has developed more compared to the past, issues persist with varietal choice and quantity and quality of seeds available in the market. Since Nepal does not have own fertilizer factory, it has to depend on imports from the international market. Timely import of fertilizers in Nepal is often marred by price fluctuation in the international market, mainly due to embargo prevailed in exporting country, long shipping time coupled with congestion in Kolkata-Haldia port, which is the nearest see port for Nepal. Nepal also purchases fertilizers mainly from India under Government to Government arrangement but this arrangement too has not been regular and effective in ensuring smooth supply.

Failing to harvest at the right time and improper harvesting of crops by farmers for various reasons often results in poor produce quality at harvest. Inadequate and improper threshing techniques and other post-harvest operations such as drying and storage are often responsible in reducing output quantity and market quality. Poor cleaning, sorting and grading practices is common to most produce. Improper pre-cooling, cooling and storage practices often cause quality deterioration and big losses to farmers and entrepreneurs of horticultural products. Contract farming and buy back arrangements are prevalent in some crops and commodities, but due to lack of contract farming act and any other legal provision, there are often cases of contract breaching and other malpractices by both parties for the sake of self benefit.

7.5.a. Current Value Chain Support Systems

Existing value chains are characterised by relatively poor support services. Extension services for teaching farmers improved production and post-harvest technologies have been less efficient and effective. Farmers and agribusiness operators often receive insufficient training and finances for improving post-harvest management. Access to finance and market information is often difficult for small farmers, who form the majority of agriculture output volume. Markets are generally highly unpredictable and fluctuating, coupled with a lack of adequate market structures and facilities in and near the major production pockets. Use of information and communication technologies in marketing of produce is on the rise but common farmers are not able to make best use of cutting edge ICTs, and at times are victim of the ‘digital divide’.

7.5.b. Storage Infrastructure and Facilities

Limited market and storage infrastructure is more common in case of cereal crops. Small farmers are often forced to sell their harvest to traders and middlemen at low prices for failing to manage the storage of the produce due to insufficient storage facilities in the vicinity. There is a limited number of warehouses and go-downs operated by the private sector, but these are often not within the reach of small farmers. There are some community storage structures and facilities built by using government funding support but their capacity is small and is disrupted by management inefficiencies. In recent times, all three levels of the government have given priority to constructing various storage structures mainly for the storage of cereals, but these are usually small in size and not established in strategic locations. There is a need to set up big silos and warehouses in strategic locations in the public-private partnership model. This should be preceded by a comprehensive study to map the existing storage facilities and locate the strategic place or market to build the big storage structures mainly in the plains, which are the food basket of Nepal.

7.6. FUTURISTIC POLICY FRAMEWORK FOR AGRICULTURE AND FOOD SECURITY IN NEPAL

7.6.a. Agricultural Extension

The public agricultural research and extension system has undergone several changes in terms of organizational restructuring and program approach since the establishment of *Krishi Adda* (Agriculture office) in 1921. In the early days, it largely served the interest of the regime with limited work in agriculture research and development, and technology dissemination. After 1950, systematic efforts were started to provide extension service to the common people albeit at a limited scale, along with the introduction of exotic genetic materials. A vibrant and more productive phase was started after 1970, when separate institutions for agriculture research and teaching were set up with the influx of donor-supported agriculture projects. Opening up of government agriculture farms and resource centres also become more evident during this phase before a massive political change in 1990 through a popular movement. In the aftermath of the political change, which also coincided with worldwide trend of liberal and market economy, various new approaches in agriculture technology generation and dissemination came to the forefront by virtue of donor-funded projects and international agriculture development organizations. Distribution of free inputs and other handouts and subsidy for the adoption of new technology became institutionalized[30]. However, several issues cropped up regarding the quality of services, which deteriorated due to the decade-long armed conflict, political instability, increasing handouts culture, and lack of good governance, among others[31]. Domination of handouts and subsidies in recent years has put the extension on the back foot in many regards.

The constitution of Federal Republic of Nepal in 2015 prompted a number of changes in political, economic and bureaucratic system in the country. The constitutional provision has transferred agriculture related rights to lower levels of government. Basic extension functions have been vested on local and provincial governments, leaving agriculture research and development functions mainly under the jurisdiction of federal government. While this has been a positive development, there is a concern that some clients may be denied extension support and services owing to potential lack of institutional capacity and low priority of agriculture compared to other sectors. In fact, although farmers have started getting extension services from local government units, many general farmers have been struggling in accessing extension services due to disruption of the existing system of extension service delivery. Moreover, with cessation of previous functional linkages and technical line-of-command between central, regional and district level units, negative impacts on extension service delivery have already become evident[32].

Revitalizing agricultural extension is necessary to address current problems faced by farmers and agribusinesses. The revitalized system is expected to develop extension workers, farmers and entrepreneurs as experts rather than merely agents of free handouts and subsidy administration which, if continued, would further compromise the quality and effectiveness of the extension service and continue defaming the extension system. There is an urgent need of a national agricultural extension policy and legal framework for overall management of extension services in the country[33]. Moreover, revitalizing the extension system should also be supported by reforms in other related areas including national agricultural research system, cross-border agriculture trade, irrigation, credit, road and infrastructures, and staff motivation, among others, to have a visible impact in agriculture growth and development.

7.6.b. Major Policy Framework for Agriculture and Food Security

The constitution of Nepal has enshrined the 'right relating to food' as one of the fundamental rights for Nepali citizens. Accordingly, 'Right to Food and Food Sovereignty Act' had been enacted in 2018 and the 'Right to Food and Food Sovereignty Regulation' is being drafted to operationalize the Act. National Agricultural Policy has been in implementation since 2004. A number of sub-sector policies have been formulated based on this umbrella policy. Since a lot has been changed in terms of overall socio-economic conditions, technological development, and agrarian system and practices in the country and internationally, the government has initiated the process of making amendments to policies to fit the changed context. Agriculture Development Strategy (ADS), 2015–2035 is a vision of Nepali agriculture sector for the next 20 years. It is based on a comprehensive analysis of contemporary issues and constraints regarding agriculture performance and has suggested actions to solve the problems and resolve the issues. The beginning of implementation of ADS coincided with federal restructuring of the country. Since the strategy was formulated in pre-federal context, it is now being reviewed and being cascaded to lower government levels. The successful implementation of ADS is expected to transform the Nepali agriculture sector from one being unattractive and less profitable to a vibrant sector. However, its mainstreaming in policy and programs of provincial and local governments and its implementation in the collaboration and coordination of all the three tiers of governments is quite challenging.

Some other policies and plans directly or indirectly related to food and agriculture include: Agro-biodiversity Policy, 2007; Trade Policy, 2009; Multi-sectoral Nutrition Plan (MSNP) II; National Seed Policy, 2000; Agri-business Promotion Policy, 2006; National fertilizer policy 2002; Irrigation policy 2003; Climate Change Policy 2019; Food and Nutrition Security Plan of Action (2013-2022); Fifteenth Periodic Plan (2018/19-20222/23); Agro-biodiversity Policy, 2007; Trade Policy, 2009; Forestry sector policy 2000; NARC Vision (2011-30)p; National Seed Policy, 2000; Agri-business Promotion Policy, 2006; Minimum Price Support (MSP) Policy (2012) in Crops; Agriculture Insurance Policy (2013); Food Act (1966) and Food Regulations (1970); and Consumer Protection Act (1998) and Rules (2000), among others.

7.6.c. Major Institutions associated with Food and Agriculture

As per the constitutional rights divided between the three tiers of government, much of the responsibility of implementing agriculture development programs falls on provincial and local level governments whereas rights related to formulating national policy, standards and regulation are with the central government. The National Planning Commission (NPC) is an apex and advisory body for formulating development policy and plans. The NPC is also responsible for the overall coordination of food and agriculture related programs of the central government.

The Ministry of Agriculture and Livestock Development (MoALD) is the main government agency responsible for executing the programs related to food and agriculture in the country. Major institutions working under MoALD in the area of agriculture and food security are Nepal Agriculture Research Council (NARC), Department of Agriculture (DoA), Department of Livestock Services, Department of Food Technology and Quality Control. Other associated government agencies are Department of Irrigation, Agriculture Input Company Ltd., Salt Trading Company Ltd., Nepal Food Management and Trading Company Ltd. Besides these, various donor supported projects and NGOs work in the area of agriculture development, and food security and nutrition as well.

Major areas of public sector investment in food and agriculture include technological and socio-economic research or study and development, extension, training and capacity building, irrigation, agriculture road, market, warehouses and other infrastructure development, subsidy on improved seeds, fertilizers, farm machineries, interest on credit, subsidy on transport of farm inputs in remote areas, Minimum Support Price (MSP), support in the case of pest and disease outbreak, crop and livestock insurance, and distribution of foods on subsidy in food insecure remote areas.

7.6.d. Agriculture Policy Changes since COVID-19

MoALD unveiled a COVID 19 recovery plan amidst growing concerns over losses in the farm sector and in an attempt to thwart the looming food crisis situation. The plan details actions to be accomplished with immediate effect, interventions for one to three months, and the long term strategy for more than six months, along with the mode of action for the implementation of the plan. However, the plan is yet to be implemented in its entirety. The Ministry also issued guidelines on performing farming activities following COVID 19 safety precautions. It was also engaged with provincial and local level governments for carrying out pandemic related relief and rehabilitation moves in coordinated fashion involving all the three levels of government.

Additionally, provincial and local governments are implementing some relief initiatives to ease negative impact of the production and marketing of farm produce. Many local governments have distributed seeds and planting materials for free or at subsidised rates. Some have initiated to set up 'Grain Banks' to deal with potential food crisis. Some have started a campaign to provide cash and technological support to local farmers and returnee migrant workers to till their fallow land. Provincial governments and some local governments also ran an 'agriculture ambulance' service to transport the fresh farm produces to the nearby markets during the lockdown. Soft loan and collateral free credit schemes have also been initiated by provincial governments and local governments.

7.6.e. Conclusion and Suggestions

In general, there exists an adequate framework for agriculture and food related public policy. However, components of national food system are less integrated. Climate change is likely to be the single largest factor shaping the food system in Nepal. Much scope exists for meeting technological gaps in food value chains for a more sustainable and resilient food system. There is a need to focus more on nutritious and safe foods besides meeting calorie requirements. Increasing investment in agriculture and agriculture research and development, in particular, and strengthening linkage between research, extension and teaching are critical for the overall growth in agriculture sector. A framework for the engagement of federal, provincial and local governments vis-à-vis building sustainable and resilient food system is urgently needed. For this, capacity building of governments and stakeholders is equally important.

Since the COVID 19 crisis looks far from over, agriculture will continue to suffer as every other sector of economy has. Efforts are being made to lessen the damage and revive the sector through various initiatives and schemes by the central and lower governments. However, revival and rehabilitation from government efforts alone are not sufficient to deal with this scale of unprecedented impact on and damage to the sector. Farmers' representative bodies, civil society organizations, private sector entities and farmers themselves need to join hands to deal with the situation and continue and put extra efforts to increase production. In this regard, maximum yet sustainable utilization of available resources should be the first strategy and get top priority. Young farmers and entrepreneurs and returnee migrant workers should be encouraged and motivated to till abandoned fallow land to turn into a well-managed modern agriculture farm by providing needed technical and financial supports and incentives.

Digitalization of activities in every possible stage of value chain is another suggested strategy in order to make the entire value chain more efficient as well as to help all value chain actors adopt health and safety measures in this pandemic situation. E-learning sessions and virtual meetings should be encouraged in technology and knowledge transfer. There is an urgent need for developing and executing a comprehensive plan of action for the rescue, relief and rehabilitation of farmers and small and medium agribusinesses with the involvement of all the three levels of government. MoALD is better placed to initiate and lead the process. The importance of food security and achieving self-sufficiency, at least in major staples and consumables, is probably one of the biggest lessons from this crisis. It has provided an opportunity for us to look back and reconcile our past efforts and build a sustainable and resilient food and agriculture system locally as well as globally.

Appendix: Figures and Tables

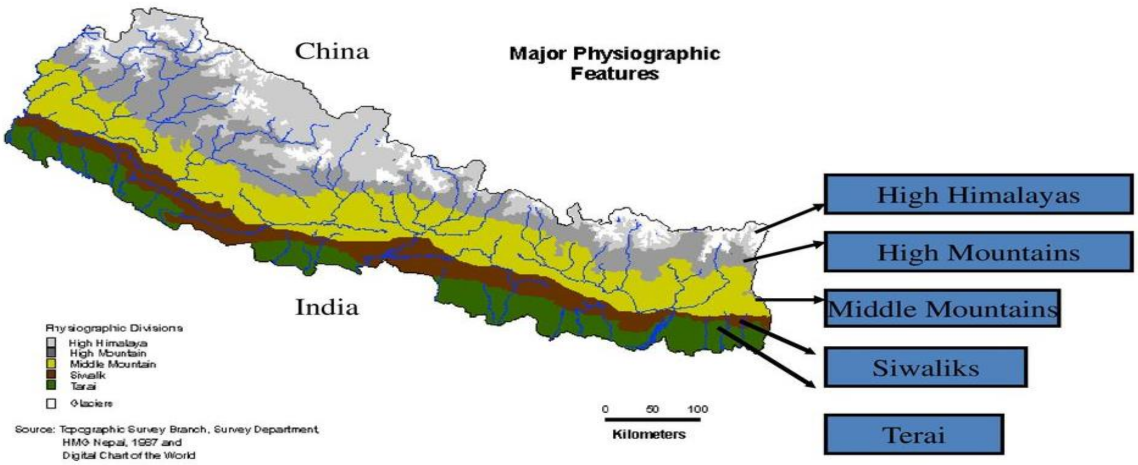

Figure 1: Physiographic regions of Nepal

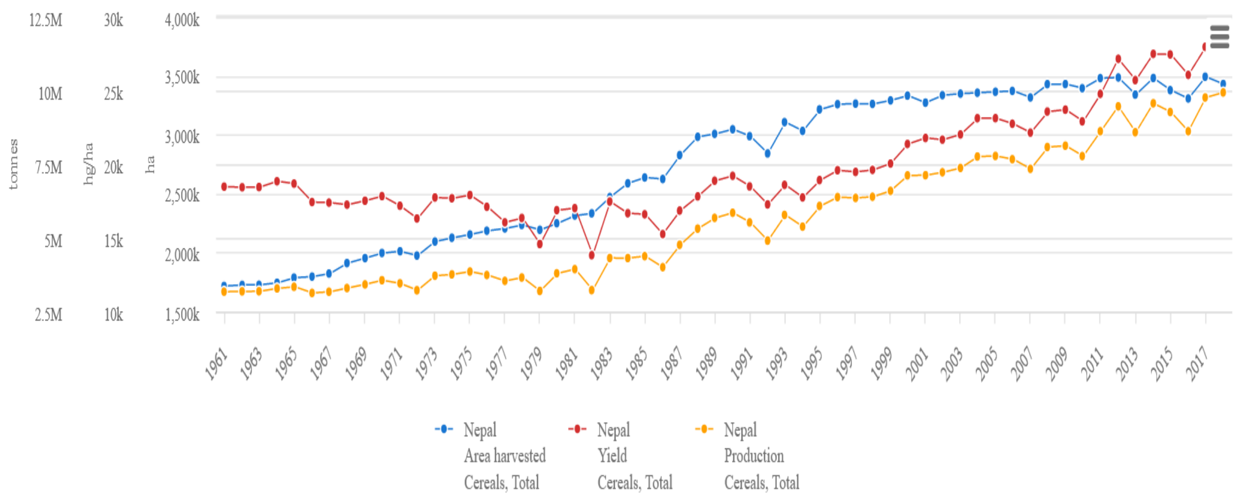

Figure 2: Area, production and yield of major cereals (1961-2017) (Source: FAO STAT)

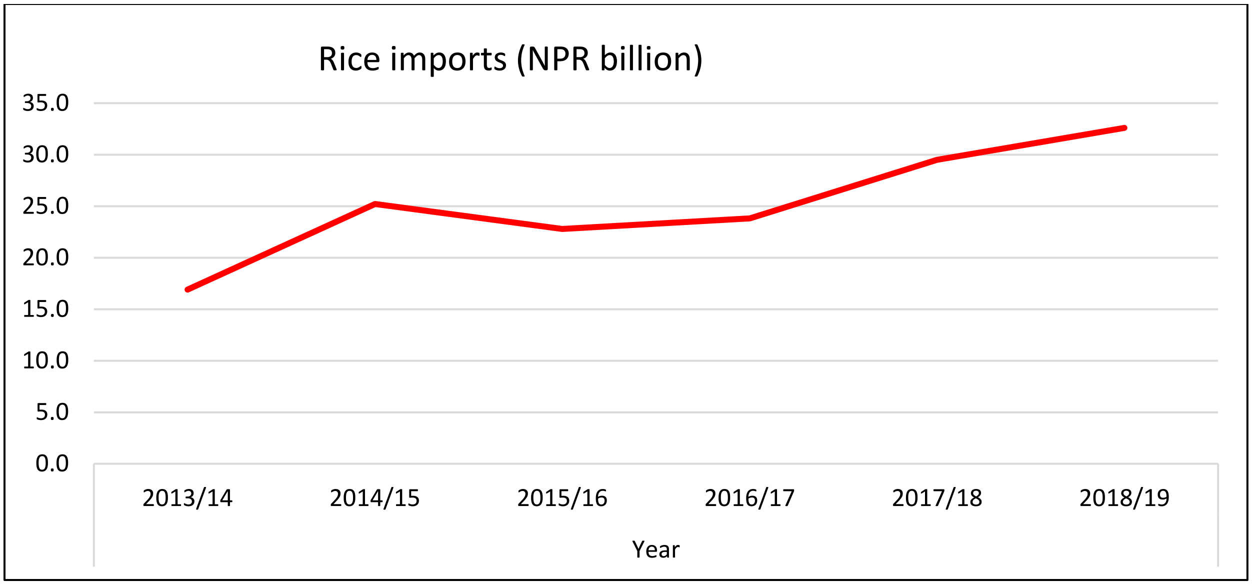

Figure 3: Rice import value in recent years (Source: Department of Custom, Nepal)

Table 1: Major Acts, Rules or Regulations related to Agriculture and Food in Nepal.[34]

Major act, rule or regulation	Main objective
Land (Survey and Measurement) Act of 1963 (Tenth amendment 2010 and Rules 2001)	Surveying, measuring and grading land based on its quality
The Land Act and Rules of 1964 (Sixth amendment in 2015)	Fixed the upper ceiling of landholding, made provisions for acquisition of excess land, and provided for equitable distribution of cultivated land
Food Act 1967	To maintain proper standards of foodstuffs
Land Acquisition Act 1977 (Fourth amendment 2010)	Provides power to the government to acquire lands for public purpose or for institutions, with compensation for losses to the previous owners
Land Revenue Act 1978 (Third amendment 1998) and Regulations 1979.	Provisions for registering land and collecting and recovering land revenue

Nepal Standards (Certification Mark) Act 1980	Provides a mechanism for determining the standard of any goods for the welfare of the public and issues standard certifications
Soil and Watershed Conservation Act 1982 (Second amendment 2010)	Made legal provisions for land and watershed conservation by controlling natural calamities and maintaining convenience and economic interests of the general public
Pesticides Act 1991 and Rules 1993	Guides the import, export, production, purchase, sale, and use of pesticides, whereas the Chemical Fertilizer Order regulates the provisions and procedures for imports, manufacturing, and quality control
Cooperatives Act 1992 (First amendment 2000)	Guides the formation and operation of various types of cooperative associations and societies for economic and social development, including agriculture
Water Resources Act1992 and Irrigation Rules 2000	To regulate the utilization, conservation, management, and development of water resources, including irrigation
Value Added Tax Act 1995and Rules 1996	To increase the mobilization of revenue needed for the economic development of the country by systematizing the processes of recovering the value added tax on all transactions, including sales, distributions, transfers, imports, and exports of goods and services
The Seed Act 1988 and Rules 1997	Guides the production and distribution of seeds based on quality standards
The Chemical Fertilizer (Regulatory) Order 1998	Regulates the provisions and procedures for imports, manufacturing, and quality control

Animal Health and Livestock Services Act 1998 and Regulations 1999	To systematize and develop animal husbandry businesses and the healthy production, sale, distribution, export, and import of animal products
Contracts Act 2000	Regulates the contracts or agreements between two or more parties for performing or not performing work, which is relevant to developing the contract farming system
Competition Promotion and Market Protection Act 2007	Supports a more open liberal market and competitive enterprises for the production and distribution of goods and services
The Local Government Operation Act (LGOA) 2017	Authorizes a number of functions with respect to agriculture development by local parties

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8. Agriculture and Food Security in Pakistan

8. Agriculture and Food Security in Pakistan

SUMMARY

Pakistan is a South Asian country that has the fifth most populous country, a little over 60 percent of which resides in rural areas. Agriculture is the largest sector of the economy of Pakistan in terms of labour participation, and the livelihoods of a majority of the population depends on it directly or indirectly. However, during the last few decades, its contribution to GDP has gradually decreased to 19.3 percent. Being the sector engaging the largest workforce and providing raw material to most manufacturing sectors, its development not only contributes towards achieving poverty alleviation but can also uplift socio-economic conditions of a large segment of the population. The performance of the agriculture sector improved between 2019-2020 and it performed better than other sectors. However, challenges due to climate change, pest attacks, shortage of water etc., kept agricultural production far less than its potential.

One key issue related to agriculture is that the farmers have limited direct access to the market due to which the role of middlemen remains crucial. And farmers normally do not receive fair market prices for their produce. In terms of potential, the agriculture sector has the capacity not only to produce for the domestic population but to have surplus production for exports, which can ensure food security as well as contribute towards foreign exchange earnings. Pakistan's agricultural productivity also depends greatly on the timely availability of water.

Pakistan, along with other developed and under developing countries, suffers from high rates of malnutrition. The National Nutrition Survey (NNS) 2018 revealed that almost 18 percent (38 million) of the country's population is severely food insecure. It also found that 40 percent of under-five children are stunted, 18 percent wasted, and another 29 percent are underweight. Over-nutrition in the form of excess weight also prevails among children both in rural & urban settings, and among women. About 24 percent of the women of reproductive age are overweight, while 14 percent are obese, with a high ratio of 17 percent in urban and a lower ratio of 12 percent in rural areas. The economic costs of malnutrition are high and persistent, with approximately 3 percent of loss of GDP every year in Pakistan. This loss is reportedly due to low productivity from the poor physique, cognitive development, schooling, and increased health care costs.

Recent trends in agriculture and food policy in Pakistan include producer-oriented decisions such as enhancing access of small and marginal farmers to formal credit, strengthening disaster risk management, scaling up fertilizer subsidies, and ensuring wheat price support through public procurement. Some of the consumer-oriented policy decisions include enhancing social assistance programmes, scaling up cash transfer programmes and addressing malnutrition and pushing forward integrated nutrition interventions, and finally, in terms of trade-oriented macroeconomic policy, there have also been attempts to stimulate export growth and competitiveness. More recent policies have not been able to be included in this report owing to inaccessibility. Many of the policy interventions mentioned, however, need strengthening and improvements. They also need

to address concerns such as mainstreaming climate change into development agenda, maximise the efficiency of water resource management and minimize inequalities, especially with regards to gender, in order to make agriculture more sustainable and food and nutrition security more achievable in the long-term.

Additionally, the recent pandemic COVID-19 poses extraordinary challenges for almost all sectors of the economy of Pakistan. The need for maintaining food security and livelihoods has also gained more importance. The cereal markets are expected to remain balanced and comfortable despite uncertainties over the impact of COVID-19. As logistical issues may pose challenges to food supply it is important to take measures for boosting agriculture production which will contribute in mitigating the socio-economic impact of COVID-19.

8.1. INTRODUCTION

Pakistan is a South Asian country bordering the Arabian Sea, between India on the east, Iran and Afghanistan on the west, and China in the north. It is the fifth most populous country, a little over 60 percent of which resides in rural areas.[1] Agriculture is the largest sector of the economy of Pakistan in terms of labour participation, and the livelihoods of a majority of the population depends on it directly or indirectly. However, during the last few decades, its contribution to GDP has gradually decreased to 19.3 percent. Being the sector engaging the largest workforce and providing raw material to most manufacturing sectors, its development not only contributes towards achieving poverty alleviation but can also uplift socio-economic conditions of a large segment of the population. The performance of the agriculture sector improved between 2019-2020 and it performed better than other sectors. However, challenges due to climate change, pest attacks, shortage of water etc., kept agricultural production far less than its potential.[2]

8.2. AGRICULTURAL PRODUCTION AND FOOD SECURITY IN PAKISTAN

8.2.a. Agricultural Performance and Food Production

Pakistan has a diverse climate, from northern arid high desert at 5,000 metres altitude to southern coastal subtropical region. It has a large dry desert in the south-east and south-west and a temperate region in the northwest. Its total geographical area is 79.6 Million hectares, nearly 50 percent of which is reportedly agricultural land. Further 50 percent of agricultural land in Pakistan was reported to be irrigated as per FAO estimates.[3] Pakistan has two cropping seasons."Kharif", the first sowing season, starts from April to June and is harvested from October to December. Rice, sugarcane, cotton, maize, moong, mash, bajra and jowar are “Kharif" crops. "Rabi", the second sowing season, begins from October to December and is harvested from April to May. Wheat, gram, lentil, tobacco, rapeseed, barley and mustard are "Rabi" crops.[4]

One key issue related to agriculture is that the farmers have limited direct access to the market due to which the role of middlemen remains crucial. And farmers normally do not receive fair market prices for their produce. In terms of potential, the agriculture sector has the capacity not only to produce for the domestic population but to have surplus production for exports, which can ensure food security as well as contribute towards foreign exchange earnings. Pakistan's agricultural productivity also depends greatly on the timely availability of water.[5]

The recent pandemic COVID-19 poses extraordinary challenges for almost all sectors of the economy of Pakistan. The need for maintaining food security and livelihoods has also gained more importance. The cereal markets are expected to remain balanced and comfortable despite uncertainties over the impact of COVID-19. As logistical issues may pose challenges to food supply it is important to take measures for boosting agriculture production which will contribute in mitigating the socio-economic impact of COVID-19.[6]

8.2.b. Food and Nutrition Security

Good nutrition plays an important role in a healthy and prosperous life. Pakistan, along with other developed and under developing countries, suffers from high rates of malnutrition. According to the National Nutrition Survey (NNS) 2018 of Pakistan, 40 percent of under-five children are stunted, 18 percent wasted, and another 29 percent are underweight. Overnutrition in the form of excess weight also prevails among children both in rural & urban settings, and among women. About 24 percent of the women of reproductive age are overweight, while 14 percent are obese, with a high ratio of 17 percent in urban and a lower ratio of 12 percent in rural areas. The economic costs of malnutrition are high and persistent, with approximately 3 percent of loss of GDP every year in Pakistan. This loss is reportedly due to low productivity from the poor physique, cognitive development, schooling, and increased health care costs.[7]

NNS 2018 revealed that almost 18 percent (38 million) of the country's population is severely food insecure. Moreover, since malnutrition in Pakistan primarily affects women, improving nutrition, and lowering dietary risks would advance gender equality. Reducing dietary risks would also help reduce-out-of-pocket payments on health care, which in turn can help reduce poverty. Pakistan produces enough food for its domestic dietary requirements. The trends of food availability of essential food items are assessed annually by using Food Balance Sheets. During 2019-20, the availability of staple food items has been estimated as adequate and almost remained the same with slight variations compared to the previous year, 2018-19. The availability of calories through major food commodities is 2,325 in 2019-20 as compared to 2,319 in 2018- 19. The cost of a minimum food basket providing 2,100 calories and 60gm protein/day is being calculated on a monthly basis by using Consumer Price Index Data from the Pakistan Bureau of Statistics.[8]

8.3. ENVIRONMENTAL STRESSES AND AGRICULTURE IN PAKISTAN

Land degradation causes huge reduction in land productivity. Soil salinity, waterlogging, soil nutrient deficiency and soil erosion hugely degrade the land's productive capability. Over 4.5 Mha area of land in Pakistan has been reported as salinized because of saline groundwater lying close to land surface and cropland irrigation with poor quality tube well water. Secondary salinization is taking place due to use of poor quality groundwater for irrigation. Estimates of losses due to salinization are 28,000 to 40,000 ha of land and about US$ 230 million of revenue per year because of low crop yield due to salinity problems.[9]

Waterlogging is another environmental problem which degrades land productive capability. According to one study, rise in the water table from 1–2 m to less than 1 m resulted in 27 and 33 percent yield loss for wheat and sugarcane, respectively. For cotton, a rising water table from 2–3m to less than 1 m caused 60 percent yield loss. In Pakistan, low fertilizer use efficiency causes low soil fertility which results in low land productivity. Every crop harvest results in depletion of more nutrients from soils compared to addition of nutrients to soils due to imbalanced use of fertilizers. In rain-fed and mountainous areas, soil erosion results in huge soil nutrients depletion causing low soil fertility which results in low agricultural productivity.[10]

Unfavourable climatic conditions such as heavy rains, floods and droughts adversely affects agricultural productivity. Modelling of climate change scenarios for Pakistan shows that if agriculture and water management in the Indus River Basin continue in a BAU mode, increasing temperatures and changes in precipitation will pose serious threats to the future livelihoods of farmers and to the Pakistani agricultural sector. Due to rise in temperatures, an overall increase of 1000 Growing Degree Days (GDDs) between historical and late century extreme scenarios has been observed in case of wheat, implying that the South Eastern side of Pakistan is likely to become unsuitable for wheat production due to temperature extremes after 2050. Results from studies about changes in wheat and maize production using the Agricultural Production Systems Simulator (APSIM) model and Aqua crop model suggest that the aggregate impact of climatic parameters, i.e., changes in temperature and rainfall, exert an overall negative impact on cereal crop yields, given that the management practices and use of technology remain unchanged.[11]

The agriculture sector also happens to be the second largest sector contributing to GHG emissions in Pakistan. To manage the situation, FAO, under the general oversight of the Ministry of Climate Change, is going to undertake a project on "Transforming the Indus Basin with Climate Resilient Agriculture and Water Management in Pakistan." The project objective is to transform agriculture in the basin by increasing resilience among the most vulnerable farmers and strengthening the government's capacity to support their communities to adapt. About 1.3 million rural people are expected to be direct project beneficiaries, including women farmers, as well as professionals involved in project capacity development. Increased land productivity could help mitigate the impact of climate change on agriculture, with the adaptation of modern and clean technology.[12]

8.4. Science and Technology for Improved Agriculture in Pakistan

As a result of population increase and land division, land holdings in Pakistan have become very small. About 81 percent of Pakistani farmers own less than 5 hectares of land and about 58 percent of the total farms in Pakistan are 2 hectares or less in size. Small land holdings are linked with inefficient and uneconomical use of land and are also a big impediment for adoption of modern agriculture technology. Many small farmers use traditional methods of cultivation, which result in relatively low crop yield in spite of increasing investments on inputs such as fertilizers. Lack of awareness about modern farming practices and technologies, difficulty in accessing credit and high prices of modern technologies are the main reasons for the widespread prevalence of traditional methods of cultivation.[13]

Accelerated farm mechanization is an important element to accelerate growth in the agriculture sector, however, mechanizing small and non-contiguous groups of small farms is against 'economies of scale' for individual ownership of farm machinery. So far, Pakistan has only experienced selective farm mechanization as this concept has remained limited to use of tractors only and at the country level, the temporal analysis shows that an increase in tractor population from 1975 -1984 was about 341 percent while it was 61 percent from 1984-1994. At present there are about 0.94 million tractors in Pakistan, which alone provides 0.84 horsepower/acre. Land preparation is the only operation that is nearly 100 percent mechanized in the country for almost all crops, with 901 thousand chisel ploughs and 108 thousand Mouldboard ploughs. The market of planting and spraying machinery has grown from 70 and 21 thousands in 2004 to 295 and 1438 thousands in 2014 respectively, due to the inclination of the farming community towards mechanized sowing and spraying. The thrasher's market in Pakistan is estimated at 20,000-30,000 units annually by sales resulting in nearly 100 percent mechanized threshing operation for cereal crops. By increasing the available horsepower per hectare and by the proper management of agricultural machinery, the average crop yield can be enhanced.[14]

In Pakistan, inadequate supply of improved quality seed is also a big constraint for enhanced agricultural productivity. During 2012-13, only 24, 24, 81 and 39 percent of wheat, cotton, rice and maize seed requirement, respectively, was made available to farmers. Fertilizer usage is imbalanced owing to high costs of various fertilizers and the inability of poorer farmers to purchase them in adequate amounts. Pests and plant diseases also cause low crop yields in Pakistan. Rice, wheat, cotton and sugarcane are often attacked by pests and insects and lack of proper use (doze and timing) of good quality pesticides results in low crop yields.[15]

Though some modern agriculture technologies such as laser land leveling, zero tillage, bed-furrow, high efficiency irrigation technologies and precision surface irrigation have shown considerable increase in land productivity, these technologies have not been up-scaled. High costs, lack of access and timely availability, lack of machinery, small landholdings, lack of adequate training and advice, and preference for traditional practices have been some major constraints to accelerate the adoption of new technologies especially among small farmers.[16]

Although Pakistan has a large number of federal and provincial agriculture research institutes, their research projects have reportedly lacked a need, demand and economic benefits based focus. Lack of coordination between research and extension organizations has also been a major constraint to increasing agricultural productivity. Consequently, improved quality inputs, new agriculture and irrigation technologies, practices and strategies do not reach farmers and they therefore continue to apply inefficient methods resulting in low crop yield.[17]

8.5. AGRICULTURE VALUE CHAIN DEVELOPMENT IN PAKISTAN

Problems have been identified in terms of the value chains of horticultural products in Pakistan, and some of these have been addressed in a few projects undertaken in the past. On average, cereal crops like wheat, rice, maize, jowar, bajra, and barley accounted for about 57 percent of total cultivated land during 2001– 2015. During the same period, the average share of vegetables and fruits in total cultivated land was about 6 percent, and the remaining 37 percent was used by other crops including oil crops, fiber crops, sugarcane, etc. However, not much information was found regarding the value chain of other agricultural products, and the focus of this section is therefore on horticultural products.[18]

A needs assessment carried out by CABI as part of a project to improve vegetable value chains in Pakistan showed that supplying consistently good quantity vegetables to the market remains challenging. Structural constraints such as poor storage, handling, transportation and processing, are big issues. These, coupled with production constraints (such as seed quality, price of inputs, and pests and diseases) and economic constraints (such as mechanism of access to capital, credit, land tenancy) means that consumers are not being supplied with enough good quality vegetables. Overarching socio-cultural factors such as the lack of knowledge to address these constraints, including inadequate extension services, and restricted opportunity for women and youth also act as barriers to working collaboratively within some communities.[19]

A majority of the farmers sell their produce at wholesale markets. Most farmers contract out fruit orchards during the flowering stage to middlemen, commission agents, or wholesalers who provide loans to the farmers over the course of production. Vegetables and fruits are transported by the same cart or truck from farms to the main markets in the absence of specialized vehicles for specific products. Recently however, reefer trucks have been introduced on a limited scale in some parts of Pakistan. In the absence of direct access of carrier vehicles to the farms, farmers gather their products in a convenient spot along the roadside for pickup. When middlemen or contractors are involved, it is their responsibility to collect and transport the produce. The unsold or un-auctioned produce in one market is sent to other markets in the same locality. Fruits and vegetables are packaged using local materials before shipment. In most cases such packaging fails to preserve the freshness and quality of the products. Another problem is absence of cooling and packaging centers, and inadequate cold storage facilities to preserve the produce at or near the wholesale markets. More than 555 cold storage units have been identified in Pakistan with about 0.9 million MT storage capacity, against more than 15 million MT of production of fruits and vegetables.

There are no available cooling and packaging houses, and cold storage facilities close to the farms that can be used by the producers.[20]

The negative impacts of the current value chain can be assessed in terms of the low share of farmers in consumer prices. Usually producers get 15 percent to 20 percent of the retail price. Producers do not get price dividends when production is low, shooting the retail price. Benefits of high retail prices are disproportionately expropriated by the middlemen. When there is a market glut where perishables and their prices fall, producers suffer as their share in retail prices also falls significantly.[21]

Both seasonal and spatial price fluctuations of fruits and vegetables are high in Pakistan. The annual cost of price fluctuations of fruits and vegetables is estimated to be about $825 million. Postharvest losses in fruits and vegetables due to mishandling of the perishable product, poor transportation, and inadequate storage facilities and market infrastructure account for about 30 percent–40 percent of total production. Due to low economies of scale, lack of synergies and collaboration among traders, high loading and unloading time, and high transportation cost, overall marketing cost is very high. It is difficult to comply with food safety, sanitary, and phytosanitary standards with the current value chain. The income and corporate tax revenues foregone due to the current value chain and marketing structure are also potentially high.[22]

The COVID-19 pandemic and consequential lockdown in Pakistan led to disruptions in the supply chain of agricultural produce, owing mostly to difficulties in transportation facilities and access to labour. It had earlier been observed that food storage capacities, especially of grain and rice, would be sufficient to meet the country's needs for a few months, however, there were concerns that if current conditions extend for longer than a few months, then there could be a shortage of unpreserved food items followed by staple food items. Extensive disruptions in agricultural supply chain and price fluctuations could result in large negative consequences in terms of livelihoods and food security for vulnerable communities in Pakistan.[23]

8.6. FUTURISTIC POLICY FOR SUSTAINABLE AGRICULTURE AND FOOD SECURITY IN PAKISTAN

During the last few decades, Pakistan has undergone a considerable shift from an agrarian to a service-led economy, and the agricultural share of GDP has experienced a declining trend over this period. Nonetheless, agriculture is still the mainstay of Pakistan's economy. Overall, the main challenge for agriculture development in Pakistan is the rural sector, which suffers from increasing poverty and other social, economic and technological factors.[24]

In 2014, the Government of Pakistan (GoP) adopted a long-term development strategy, which aims at transforming Pakistan into an upper middle-income country by 2025 and a top ten economy by 2047. The vision focuses on macroeconomic stability through the promotion of inclusive growth, and envisages a hunger-free Pakistan by adopting innovative and cost-effective strategies. Most of the goals of Vision 2025 are being implemented through the Federal Public Sector Development

Programme (FPSDP) 2014. In 2013, the GoP drafted the new Agriculture and Food Security Policy (2013), which sets out a vision and goal for agriculture and food security, with the objective of halving malnutrition by 2030 and bringing food insecurity down to zero by 2050. An essential part of this policy is to achieve food security and to raise overall rates of economic growth for the benefit of all social classes of society.[25]

In 2015, the Ministry of Food Security and Research (MNFSR) drafted the National Agriculture and Food Security Action Plan (2015), which will be a part of the comprehensive National Agriculture and Food Security policy. In view of Pakistan's high vulnerability to the adverse impacts of climate change, in 2013 the GoP formulated the Framework for the Implementation of Climate Change Policy (2014–2030), which was developed for mainstreaming climate change concerns into decision-making so that it creates enabling conditions for integrated, climate-compatible development processes.[26]

Trends in agriculture and food policy in Pakistan that have been identified include producer-oriented decisions such as enhancing access of small and marginal farmers to formal credit, strengthening disaster risk management, scaling up fertilizer subsidies, and ensuring wheat price support through public procurement. Some of the consumer-oriented policy decisions identified include enhancing social assistance programmes, scaling up cash transfer programmes and addressing malnutrition and pushing forward integrated nutrition interventions, and finally, in terms of trade-oriented macroeconomic policy, there have also been attempts to stimulate export growth and competitiveness. More recent policies have not been able to be included in this report owing to inaccessibility. Many of the policy interventions mentioned in this section, however, need strengthening and improvements. They also need to address concerns such as mainstreaming climate change into development agenda, maximise the efficiency of water resource management and minimize inequalities, especially with regards to gender, in order to make agriculture more sustainable and food and nutrition security more achievable in the long-term. [27]

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9. Agriculture and Food Security in Sri Lanka

9. Agriculture and Food Security in Sri Lanka

SUMMARY

Sri Lanka, an island nation of around 65,610 sq. km. in the Indian ocean, was elevated to lower middle income status in 2019, with a GNI per capita of between USD 3,996 and 4,060, and an average GDP growth rate of 5.3 percent between 2010 and 2019 following a period of civil war. The Sri Lankan economy is transitioning from being primarily rural-based to a more urbanised economy oriented around manufacturing and services. The contribution of the agriculture and allied sectors has decreased slowly over time to 7 percent of Sri Lanka's GDP as of 2018, although the sector is still very important as it employs 25 percent of its working population. It accounted for 17.8 percent of total exports between 2013-2016 and the total value of agricultural exports in 2018 was estimated at USD 2,579 million, or 21.7 percent of total national exports.[1,2,3]

Of the 7.0 percent total GDP contributed by the agricultural in 2018, the crops subsector contributed 4.6 percent, fisheries 1.2 percent, animal production 0.6 percent, and forestry and logging 0.6 percent. Monsoon and inter-monsoon rainfall patterns shape agricultural seasons and irrigation patterns in Sri Lanka, with two thirds of the agricultural land in the dry zone where the bulk of Sri Lanka's irrigation infrastructure is located. The majority of farmers cultivate both lowland rice and other food crops, such as cereals, pulses, condiments, fruits and vegetables, on higher ground. The plantation crop segment is dominated by tea, rubber and coconut but also includes cashew, oil palm and sugarcane. The production of minor export crops, such as cinnamon and pepper have been on an upward growth path in the period 2008 to 2017. The floriculture industry in Sri Lanka has developed rapidly and now earns substantial foreign exchange and generates direct and indirect employment. Animal production systems are dominated by small producers who engage in a range of animal production systems but primarily poultry and dairy production and some small ruminants and pigs. The fishery segment comprises coastal and deep-sea marine fishery and aquaculture practiced in coastal waters and large inland reservoirs and ponds, producing finfish, prawns, and ornamental fish, among others. Fisheries are dominated by small producers with half of the over 30,000 fishing fleet comprising small traditional crafts.[4]

Between 80 and 85 percent of Sri Lanka's annual food consumption is produced domestically and the remaining amount is imported. Much emphasis has been placed on increasing domestic production of rice, resulting in inadequate agricultural diversification, especially with regards to animal products, fruits and vegetables. Although rice is an important component of Sri Lanka's staple diet, all cereals including rice were found to comprise only 11 and 16 percent of total household expenditure on food in urban and rural households respectively. Furthermore, data demonstrate that the demand for rice in Sri Lanka is declining with income rise. There is, therefore, a significant gap between what is available for consumption and what is needed to ensure proper nutrition.[5,6]

A significant problem with regards to food security in Sri Lanka is post-harvest losses, which occur at all stages of the supply chain. The FAO estimates that Sri Lanka loses nearly 30 percent

of food before it reaches consumers.[7] Post-harvest infrastructure in Sri Lanka, as in many developing countries, is poor and results in losses in all agricultural production sub-sectors, including 15 percent loss in rice, 16-40 percent loss in fruits and vegetables, and 30-40 percent losses in fisheries. Although food processing is the largest manufacturing industry in Sri Lanka, traditional channels of food processing are not considered to be consistent and reliable sources of supply. This is due to many factors, including lack of transport facilities, low returns, problems in marketing, part-time engagement, dependency on external support schemes for investments, and small scale of production.[8]

Data on household income and expenditure indicates a rise in income, although food still comprises between 38 and 50 percent of total household expenditure, indicating sensitivity of food and nutrition security to income and price fluctuations. The status of dietary energy consumption in Sri Lanka has also remains very poor, with almost half of the population consuming below the minimum level required and marginal improvement since 1990. Two categories of households in Sri Lanka seem to be most vulnerable in terms of food and nutrition security, which are the urban poor and the rural poor. Existing vulnerabilities in terms of agricultural production and food security are further threatened by the impacts of climate change.[9,10]

Activities involving the agriculture sector in Sri Lanka operate within a framework of national policies, including sectoral and sub-sectoral policies that recognise the need to facilitate improvements in production, strengthen markets and value chains, find solutions to connectivity and logistics issues and strengthen private sector participation in service delivery. Concerns of sustainability, climate change, labour shortages, fragmentation of land holdings and land degradation are also recognised. A draft Overarching Agricultural Policy was developed by the Government of Sri Lanka in 2019, which covers issues that need to be addressed on a topic-by-topic basis, in response to evolving priorities and challenges at the global, national and sectoral levels. The various topics that are focused on include natural resources, land administration, land degradation, land use planning, agricultural water management, climate change, food security, trade, governance, production support and service delivery, education, research and extension, and development subsidies to supply and value chain actors. The draft policy was developed using an evidence-based approach based on the observation of best practices from Sri Lanka and elsewhere.[11]

The Sri Lankan government is on the right track in terms of creating an enabling and effective policy framework to enhance agricultural production and food security. How the policies translate to effective ground-level action will need to be addressed, especially since the COVID-19 outbreak has substantially exacerbated an already challenging macroeconomic situation of low growth rates and significant fiscal pressures. Although the agriculture sector has been less affected as compared to others, there have been disruptions in the sector's activities due to labour shortages, cessation of markets and price collapse. Many households stand to lose their sources of income, leading to worsened food insecurity. Meanwhile, import restrictions will also impact food and nutrition security at the national level. Issues of self-sufficiency, and food and nutrition security must not go unaddressed during this period, and the government's response must consider the minimization of damages and building of resilience in the sector and overall food security.[12]

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B: Air Pollution - Clean Air and Energy in South Asia

Contents: Tackling Air Pollution – Clean Air and Energy in South Asia

Part I: The Status of Air Pollution over South Asia

SUMMARY

On average about 70% of the population of countries covered by Future Earth South Asia are exposed to air pollution levels exceeding the World Health Organization Interim-1 target. While island nations experience comparatively better air quality, the countries of mainland South Asia have been consistently lagging in this aspect. Adverse effects of exposures to high levels of pollution have been observed not only with respect to high mortality and morbidity, but also in terms of the economic costs that can be quite substantial. Thus, while aspiring towards economic development, it is important that a gradual shift is made towards clean energy use. The primary sources of air pollution in this region are from biofuel and biomass burning, transport, power generation, industrial activities, and from soil dust emanating from degraded land. As far as general tendencies go, there has been a decreasing trend in share of mortality due to indoor air pollution in all these countries between 1990 and 2017, while the share of mortality owing to outdoor air pollution has been rising.

Fortunately, different countries have adopted a wide range of measures to combat air pollution. However, as a region we have a long way to go to ensure air qualities that adhere to World Health Organization guidelines. Our report identifies three levels at with actions can be taken to tackle air pollution while taking account of regional diversity in pollution sources as well as varied economic situations and priorities. At the same time, it is important to recognize that, since air pollution is a trans-boundary problem, regional co-operation is essential to arrive at solutions that will have a measurable and lasting impact. At the individual urban scale, steps to curb air pollution should be firmly based on source apportionment studies that would inform area-specific reduction measures. This would lead, for example, to measures adopted varying from city-to-city as well as across different zones of a city. Nonetheless, at the regional-level, there are common themes across countries, and tackling two important sources of air pollution will be important for almost all the countries examined here. The first is transitioning to higher Euro emission standards for vehicles, which will contribute to a significant improvement in urban air quality across countries. The second is transitioning out of biofuels use to employing clean fuels for household purposes, which has the potential to give rise to a significant reduction in mortality associated with indoor air pollution exposure. Additionally, our report highlights the importance of long-range transported air pollutants, which can contribute to more than 30% of total air pollution in some regions and is especially relevant across much of the Indo-Gangetic plain. The two most important contributors to trans-boundary air pollution are biomass burning and soil dust from degraded land, each of which poses serious health risks during the respective peak seasons when they are highest. While tackling the first source of pollution requires a multi-sectoral approach, an important part of which is

providing lucrative alternatives to crop burning, addressing and reducing pollution from soil dust requires improved and sustainable land management practices. Such efforts, taken up wherever they will have the largest impact but also involving regional coordination, can not only help in reducing regional air pollution, but also contribute markedly to improving land use as well as food security.

1.1. INTRODUCTION

The countries covered by the Future Earth South Asia together comprise 24% of world population. The diverse and contrasting geographical features along with high population density, rapid economic development, urbanization and industrialization makes South Asia highly susceptible to the adverse impacts of climate change[1-6]. Air pollution is one of the most serious environmental problems confronting this region. In general, an excess amount of aerosol or gas which has detrimental effect on the environment is considered as a pollutant. The sources of the pollutants can be natural (e.g., volcanic eruption, sea salt, dust storm, wildfire) or anthropogenic (e.g. emissions from industries, transportation, biomass burning). Here we define air pollution as: "when gases or aerosol particles emitted anthropogenically, build up in concentrations sufficiently high to cause direct or indirect damage to plants, animals, other life forms, ecosystems, structures, or works of art''[7]. That is, our focus here is on the solid, liquid or gaseous particles in the atmosphere which are present as a result of anthropogenic perturbations and have direct impact on health and environment; and the build-up of which can be controlled through proper policy interventions. In contrast, greenhouse gases (GHGs) impact the radiation budget of the earth and may or may not have an immediate effect on health and environment.

The majority of the GHGs reside in the atmosphere for several years (few years to a several hundred years). The most important GHG, carbon dioxide (CO_2) has varied atmospheric lifetime, which can go up to thousands of years based on removal processes. On the contrary, particulate matter or aerosols have relatively shorter tropospheric lifetime of few days, but once they reach the stratosphere they can remain airborne for a few months to even years [8,9]. Together with pollutant gases, aerosols from anthropogenic sources pose major risks to cardiovascular and respiratory health of the population. Based on the location and type of emissions from different economic activities, different countries have defined their respective 'criteria pollutants'. The most commonly used 'criteria pollutants' are particulate matter (PM), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO) and lead (Pb). PM includes those having aerodynamic diameter less than 10 µm (PM_{10}) and 2.5 µm ($PM_{2.5}$). The primary sources of these pollutants and their residence times are indicated in Table 1. The pollutants with the strongest links to adverse health effects are PMs, O_3, NO_2 and SO_2. Different air pollution indices are used to communicate to the public the level of severity of air pollution. The most popular index is the Air Quality Index (AQI). AQI includes data relating to concentrations of PM and other pollutants (e.g., NO_2, SO_2, O_3, CO) for different time intervals (1-hour, 8-hour, 24-hours). Different countries use different point scales and also different pollutants to report AQI. An example of this is shown in Figure 1 for $PM_{2.5}$.

1.2. AIR POLLUTION IN SOUTH ASIA

At the outset, getting a full picture of air pollution over South Asia requires an understanding of atmospheric circulation over this region. The most important characteristics of the climate of South Asia is the seasonally reversing monsoon wind, which impact different aspects of the meteorology, and by extension, air pollution emission, residence time, transport and removal (see Figure 2). The atmospheric concentration of PM/aerosol is highest during the spring and summer months due to soil dust emission and transport from the arid and semi-arid regions of the Middle East and South Asia. In general, soil dust is the most important contributor to PM_{10} over this region. Aerosol levels are reduced drastically during the southwest monsoon period due to the washout of aerosols and soluble gases by rain. The deep convection prevailing during monsoon season helps in transporting pollution to the tropical tropopause layer, the gateway to the stratosphere. On the contrary, the shallow boundary layer during winter months traps aerosols and keep their near-surface concentrations high. The near-surface flow is northeasterly during winter and the regional pollution forms a thick haze layer in the lower troposphere which spreads out over a large area between South Asia and the Intertropical Convergence Zone(ITCZ), located ~10^oS latitude over the Indian Ocean. During the monsoon transition periods, the flow across the northern Indian Ocean is mainly zonal, and pollution plumes originating from both Southeast Asia and Africa spread across the central Indian Ocean[10]. The conditions are entirely different in Mauritius, located in the southern hemisphere, where easterly winds prevail throughout the year.

Rapid economic growth has made environmental degradation a matter of serious concern in South Asia. A quick overview of this can be obtained by looking at the Environmental Performance Index (EPI), which ranks 180 countries based on their environmental performances. For example, the best performing country is 1 and the worst performing country is ranked 180. Figure 3a shows that all countries except Mauritius have overall EPI rank below 100. This indicates that in general the South Asian countries have a long way to go to tackle the problem of environmental degradation. With respect to air quality, except the island nations, countries of South Asia have not performed well (Figure 3b). Although there is some relation between overall EPI rank and total population, we do not see much relation between EPI and the level of urbanisation (Figure 3c). There is a large spread in the National Ambient Air Quality Standards that have been adopted by different countries of South Asia. These have been mostly decided based on locations and the type of dominant economic activities. These limits are indicated in Table 2. Note that different time averaging has been used for different pollutants in Table 2, based on data availability, to facilitate comparison between different countries.

One of the striking features of this region is the immense diversity in fuel consumption for energy production. Unlike the rest of the northern hemisphere where fossil fuel burning and industrial processes dominate, in South Asia biofuel and biomass burning play a large role in the emissions of pollutant gases and aerosols. The use of biofuel is more in South Asia compared to the western countries. Although the per capita consumption of energy is much lower compared to the industrialised western countries, the size of the region, the large human population and inefficient burning of fuels result in the emission of large amounts of pollutants into the atmosphere including: greenhouse gases like CO_2 and methane (CH_4); CO, O_3 precursors such as nitrogen oxides (NOx = NO + NO_2), non-methane volatile organic compounds (NMVOCs); aerosol particle precursors such as SO_2; and primary particles comprised of soot and other organic compounds.

1.3. CLIMATE, HEALTH AND ECONOMIC IMPLICATIONS OF AIR POLLUTION

Air pollutants influence the climate through their interaction with the incoming solar radiation, clouds and cryosphere. They can influence the energy balance of the Earth, the hydrological cycle, atmospheric circulation[12]. Apart from this, they also affect the abundance of greenhouse and reactive trace gases in the atmosphere by heterogeneous chemical reactions and other multiphase processes[9,13]. Some of the more direct effects of air pollution over South Asia are briefly described below.

The deposition of carbonaceous aerosols (associated with anthropogenic activities) on the Himalayan glaciers as well as the Tibetan Plateau has seen a striking rise of almost 200% from 1998 to 2005[14]. These carbonaceous aerosols are almost equally contributed from fossil fuel burning and biomass burning, which is in line with source fingerprints of black carbon (BC) from the Indian region, especially the Indo-Gangetic plain. The deposition of BC on snow has been estimated to reduce albedo by 6-10% with respect to clean snow and can lead to instantaneous radiative forcing of~75-120 W m^{-2} [15]. Between 2000-2016 and 1975-2000 there has been a doubling in the rate of ice mass loss across the Himalayas[16]. Atmospheric deposition of pollutants can have large impacts on water quality of River Ganges by supplying heavy metals like Cd, Cr, Cu, Pb, Ni[17]. Similarly, atmospheric deposition of phosphate and nitrate are important sources of these inorganics in the Ganges water[18]. The emissions of sulphate and nitrate from industry and transport sectors can lead to increased acidity of rainwater[19,20].

The global distribution of death rates from air pollution in 2017 shows that countries in South Asia are leading in terms of adverse health effects from air pollution (Figure 4).

Ultrafine particles (diameter < 100 nm) are particularly hazardous to human health, because they are sufficiently small to penetrate the membranes of the respiratory tract and enter the blood circulation or to be transported along olfactory nerves into the brain[21]. However, the physical and chemical properties of aerosols (e.g., particle size, number, mass concentration, composition) which determine their adverse health effects are not well known, especially the relations between allergic diseases and air quality[9].

An analysis of the global burden of diseases[22] estimated that outdoor $PM_{2.5}$ caused around 3.2 million deaths (3% of all deaths) and around 76 million years of lost healthy life on a global scale in the year 2010. In South Asia, $PM_{2.5}$ emitted both from household combustions and outdoor pollution contributes around 6% and 3%, respectively, to Disability-Adjusted Life Year (DALY) mainly via cardiovascular and circulatory diseases[22]. Between 1990 and 2015, increases in population, population ageing and increased exposure to poor air quality have led to ~40% increased mortality attributable to $PM_{2.5}$pollution over India and Bangladesh[23]. According to 2018 Global Burden of Disease study, most significant increases in death (1990-2017) due to air pollution in South Asia is in Nepal, followed by Bangladesh and India. The least increase has been over Maldives. Over different regionsof the world there is relative importance of different sources of air pollution contributing to mortality (see Figure 5). Over Pakistan and northwest India, soil dust from degraded land is the most important contributor to mortality from air pollution[24]. Pollutants emitted from residential and commercial energy use impact mortality rate in the rest of India, Sri Lanka and Bangladesh. Biomass burning emissions are the most important contributor to air pollution-related mortality in Mauritius and Myanmar. Finally, emissions from road traffic are the highest contributor to mortality from air pollution over Nepal and Bhutan. Furthermore, with continuing business as usual scenario, the urban centres of South Asia will globally dominate pre-mature mortality due to $PM_{2.5}$ and O_3 during 2050 with the highest impact being felt on Kolkata, Mumbai and Dhaka[24].

The economic burden of air pollution goes well beyond the costs incurred due to effects on health because of multifaceted consequences for the ecosystem, agriculture and buildings among others. The most important non-health-related effects of air pollution are deteriorated environment for residents, tourists and visitors; visual intrusion and decrease in the aesthetic value of scenic views and landscape; lower land and property value damage to crops and agricultural products and damage to buildings. For instance, the impact on tourism is determined by estimating the change in revenues stemming from visitors, whereas damages to agriculture are valued at the relative market price for crops[25]. The financial implications for air pollution-related diseases for the Asian region has been estimated to be between 180 million to 2.2 billion US Dollars[26].

1.4. CURRENT STATE OF UNDERSTANDING OF AIR POLLUTION OVER SOUTH ASIA

In the following sections we will focus on specific topics relevant to air pollution over South Asia. These topics are:

1. Anthropogenic aerosols in South Asia
2. Pollutant gases over South Asia
3. Perturbation of natural aerosols by human activities
4. Air pollution in the COVID world

Air pollution being a trans-boundary problem we generally maintain a regional approach. However, in each of the sub-sections wherever possible, we describe the state of air pollution with respect to individual countries.

Table 3 gives an overview of the main sources of air pollution in different countries of Future Earth South Asia. The table also provides an overview of the status of clean energy use, which is particularly relevant to air pollution levels in South Asia. In general, most of South Asia economies are service-based. Apart from that, industrial activities are important contributors to the total gross domestic product in Bhutan, Myanmar and Sri Lanka. More than half of the gross domestic product of Maldives can be accounted for by tourism. Compared to other countries, general dependence on industry or per capita vehicle dependence, that are important sources of air pollution, is less for the South Asian countries. On the other hand, for most of the countries, there is a high dependence on solid fuel use and low/no emission standards for vehicles.Transitioning to clean fuel use and having higher emission standards for vehicles are important steps to combat air pollution in this region. For example, Maldives and Mauritius, the two best performing countries with respect to air quality EPI, have more than 90% of population using clean fuel.

1.4.a. Anthropogenic aerosols in South Asia

Although globally aerosol load is mainly from natural sources, regionally the anthropogenic species dominate in areas of high population density, industrialization and urbanization, or regions of extensive biomass burnings[27].One of the most important and widely used parameter to quantify the concentration of aerosols in the atmosphere is the Aerosol Optical Depth (AOD) which is the vertical integral, through the entire height of the atmosphere, of the fraction of incident light scattered and/or absorbed by aerosolsas a function of wavelength. Studies have shown that over South Asia anthropogenic aerosols can contribute to 50% of the total AOD with greatest contribution from sulphate aerosols (~36%) followed by organic carbon (OC, 13%)[28].

1.4.b. Anthropogenic aerosols in India

India is the second most populated country in the world with total population estimated at 1.37 billion as of 2019. The average population density of India is 382 persons km^{-2}, while that in the most densely populated state West Bengal is at 903 persons km^{-2}. In the highly populated cities of Mumbai, Delhi and Chandigarh the population densities are greater than 20 times the national average. Thus, anthropogenic emissions of aerosols and gases are prominent over the urban regions, mainly due to power consumption, transport and industrial activities. The major contributors to the total AOD over India are inorganic aerosol (41–64%), OC (14–26%), and dust (7–32%)[29]. The inorganic aerosols, which include sulphate, nitrate, ammonium and other water soluble aerosols, are produced from both natural and anthropogenic sources. Carbonaceous aerosols are mainly produced during combustion, but direct emissions of biogenic aerosols (from plants) and chemical reactions in the atmosphere also contribute to the carbonaceous aerosol load in the atmosphere. The AOD over the Indian region has been found to increase at a rate of ~4% per year during the period 2000 to 2012 (see Figure 6) which is due to a corresponding increase in anthropogenic fraction, as is evidenced by the trend in the AOD spectral index[30]. It is also found that the AOD spectral index does not show any statistically significant trend during the last decade.

BC is one of the most important aerosol species in the atmosphere, which has strong potential to affect regional climate due to absorption of solar radiation and consequent atmospheric warming. Total BC emissions from India have been estimated to be 0.41 Teragram year^{-1} (Tg y^{-1}), with0.17 Tg y^{-1} from biofuel burning, 0.14 Tg y^{-1} from open biomass burning, and 0.1 Tg y^{-1} from fossil fuel burning. Compared to the other parts of the world biofuel burning contributes significantly more (in the form of CO and NMVOC) to the BC emissions in South Asia. Most emissions inventories indicate a total BC source from India of approximately 0.5 Tg y^{-1} (or ∼0.7 Tg y^{-1} from South Asia, with an upper limit of ∼1 Tg y^{-1}). It has been observed that BC mass concentration over India is decreasing at an average rate of ~242 ± 53 ng m^{-3}y^{-1} during the period 2007-2016[32]. This is largely due to the effective control measures on industries and vehicular emissions and improvement in the combustion efficiency over the years. The vertical transport of aerosols is also believed to play a part in reducing the near surface aerosol concentrations, although the reasons are not yet completely understood.

Since the implementation of Mass Emission Regulation in 1991, the government of India has brought in statutes aimed at regulating and monitoring industrial and vehicular pollution in the country. The increasing number of vehicles has been significantly contributing to the atmospheric pollution and the dramatic increase in the last two decades has posed a serious problem (Figure 7). The stringent steps taken by the government to control the emissions has played an important part in keeping the rising pollution levels under check. The nationwide implementation of India 2000 emission standard was followed by more stringent standards like Bharat Stage II (BS-II), BS-III, and BS-IV. The emission standards BS-II to VI are based on Euro 2 to 6. Central government has mandated that from 2020 onwards only BS-VI vehicles are to be manufactured and sold skipping BS-V altogether. Simultaneously, steps have also been taken to improve the fuel quality. Current steps to meet the BS-IV standards, which significantly reduce sulphur, lead, and benzene content, improve the octane/cetane number for petrol/diesel. The sale of BS-III vehicles were banned since April 2017, along with the completion of nationwide implementation of BS-IV. The regulations of pollutant emissions from industries and transportation led to a significant reduction in SO_2 and NO_2. Studies in this regard indicate that improvement in combustion technology and fuel quality in India has resulted in an increase in fuel use efficiency, and a consequent decline in BC emission intensities from industries, residential sector, and transportation[33].

1.4.b.i. Anthropogenic aerosols in Bangladesh

Bangladesh is located in the south-eastern part of the Indo Gangetic Plains, through which pollution from the rest of South Asian mainland reaches the Bay of Bengal. The population of Bangladesh is 161.4 million, with a high population density of 1265 person km^{-2}. The primary sources of emissions are transportations and brick kilns[34]. Along with that, the air quality in Bangladesh is also controlled by the long-range transport of pollutants, emissions of industrial pollutants, and biomass burning from surrounding areas[35]. The region is dominated by mostly three types of absorbing aerosols: BC, OC and dust, and their concentrations are continuously increasing. During the period 2002-2016 AOD values >0.5 were observed all over Bangladesh except over a small region to the east. This indicates that generally high levels of aerosols are present throughout the country. Based on satellite observations, AOD is also found to be increasing significantly (at 95% level) at 0.012 y^{-1} over the region[36] (Figure 8).

1.4.b. ii. Anthropogenic aerosols over Pakistan

Pakistan has a population of 212.2 million, with population density of 287 person km^{-2}. Among the major cities, Karachi and Lahore are the most populated ones with population crossing 10 million. In general, Pakistan experiences highest aerosol load during spring and summer months[37] associated withdust transport[38]. With respect to anthropogenic aerosols, higher values of CO, NO_2 and SO_2 are recorded during the winter months and O_3 levels increase during the summer months[39] (see also Figure 9). Rapid industrialization, large population and heavy traffic are responsible for elevated levels of gaseous and particulate pollutants. Road traffic is the primary source of $PM_{2.5}$ in Pakistan. The city of Lahore, being densely populated and located withina semi-arid region, undergoes a large seasonal cycle of aerosol load with minimum AOD of 0.47 ± 0.26 in February and maximum AOD of 1.02 ± 0.41 in July[40]. The main sources of air pollution in Lahore include emissions from diesel, biomass burning, coal combustion, two-stroke vehicle exhaust, and industrial sources. Diesel and two-stroke vehicles contribute about 36%, biomass burning about 15%, and coal combustion sources around 13% to the $PM_{2.5}$ mass. Nearly two-thirds of the $PM_{2.5}$ mass is carbonaceous material. Secondary particles (e.g., sulphate, nitrate) contribute about 30% of $PM_{2.5}$ mass[41]. Measurements in Karachi have shown that fossil fuel burning is the main source of carbonaceous aerosol. The concentrations of these carbonaceous aerosols peak during winter and fall seasons and are lowest during spring and summer[42]. Over Lahore and Karachi, the ranges of different aerosols are given in Table 4. In general, Lahore records higher values of different pollutants compared to other cities.

1.4.b. iii. Anthropogenic aerosols over Sri Lanka

Sri Lanka is an island nation in South Asia with a population of 21.7 million, and a population density of 341 person km^{-2}. Colombo and Kandy are the two megacities of the Sri Lanka. Ambient air pollution, especially in urban areas, results from a spectrum of different sources. Vehicular emissions and biomass burning are the major contributors to air pollution in Sri Lanka, while, dust aerosols and sea salts have the lowest contribution. On average, PM and BC concentration in Colombo are 29 $\mu g\ m^{-3}$ and 12.2 $\mu g\ m^{-3}$ respectively[45]. Several measures have been taken to reduce outdoor air pollution due to vehicular emissions which contribute to over 60% of total emissions in Colombo. The National Policy on Urban Air Quality Management was adopted in 2000. The phasing out of leaded gasoline in June 2002, the introduction of low sulphur diesel in January 2003, banning the import of two stroke three-wheelers in 2008, and the initiation of vehicular emission testing programme in year 2008 are some of the key steps that have been taken to control urban outdoor air pollution in Sri Lanka. The acceptable ambient air quality standards for selected air pollutants were for the first time enacted under the National Environmental (Ambient Air Quality) Regulations in 1994. With the publication of World Health Organisation air quality guidelines in 2005, air quality standards for Sri Lanka, including standards for PM_{10} and $PM_{2.5}$, were amended and gazetted in August 2008[46].

1.5. Pollutant Gases Over South Asia

In this section we will look into the gaseous pollutants which impact health and the environment. The major gaseous pollutants of concern to human health are CO, SO_2, NO_2, O_3 and volatile organic compounds (VOC). Although O_3 in the stratosphere acts as a shield from the harmful ultraviolet radiation of the sun, their presence in the lower atmosphere is hazardous[47]. Continuous emissions of these gases have been linked to several health issues such as pulmonary diseases, asthma, lung cancer, and respiratory infections in children (https://www.who.int/airpollution/).

Human activities since 1750 have produced a 48% increase in the atmospheric concentration of CO_2 (from 280 to 414 ppm), the highest concentration ever over the last 14 million years, mainly due to the burning of fossil fuels and to deforestation[48]. CO_2 emissions from fossil fuel combustions and industrial processes have contributed to about 78% of the total greenhouse gas emission increase from 1970 to 2010, with a similar percentage contribution for the period 2000–2010[49]. There are substantial overlaps between the sources of CO_2 and other air pollutants which points to the co-benefits of mitigating air pollution. While emissions of different GHGs and pollutant gases in South Asia have been historically low, the increasing population and fast-growing economies are pushing the region towards a more carbon-intensive development path. Such expansion in energy use results in increased fossil fuel consumption with associated emissions of pollutants. Also, present-day tropospheric O_3 has increased by 42% since pre-industrial times, and the increase results from atmospheric reactions of short-lived pollutants emitted by human activity.

Although, there are small variations resulting from the local emissions, the major contributions to air pollution over this region are from transportation, industrial emissions, biomass burning, and energy sectors. Table 5 shows the contributions from different sources to pollutant gases over South Asia. Fossil fuel and biofuel burning are the leading sources for most of the trace gases.

India, Nepal, Bhutan, Sri Lanka, Myanmar, Bangladesh, Maldives, Mauritius, and Pakistan together contribute about 17.5% for BC, 16.4% for $PM_{2.5}$, 16.6% for PM_{10}, 6.6% for NOx, 5.3% for SO_2, and 10.7% for CO, respectively (https://edgar.jrc.ec.europa.eu/) to the global total during 1970 to 2015. This percentage contribution is showing an increasing trend (Figure10), which is a point of concern for the local governments. The increase is most steep for SO_2.

In general, O_3 concentrations are mostly NOx-sensitive in India. Reductions in NOx emission bring down the disease burden associated with O_3 exposure[50]. Regional transport contributes 10% to this reduction in the disease burden[51]. Long-term exposure to surface O_3 is a risk factor for human health in India. The highest production of O_3 over India is during April-May due to a combination of summer heat and biomass burning, while during the southwest monsoon months O_3 concentration is minimum due to upward transport via monsoon convection[52]. Although, emissions of NO_2 and SO_2 are reducing over Europe, North America and East Asia, there is a positive trend of these gases over South Asia. For example, during 2005-2015, there has been 50% and 200% increase in NO_2 and SO_2 columns, respectively, over India. The SO_2 and NO_2 sources are mostly coincident with coal-fired power plants over east central India and most of the increases in NO_2 and SO_2 have also been seen there[53]. At the city level, the top 3 cities with largest concentrations of NO_2 are Durgapur, Asansol and Kolkata. The top 3 cities with largest SO_2 concentrations are Jamshedpur, Firozabad and Shillonging[54]. Based on the Ozone Monitoring Instrument (OMI) data, over India highest increase in NO_2 during 2004-2014 have been over Chennai (25%) and Bengaluru (23%). Interestingly, there have been decline of NO_2 observed over Mumbai, Surat and Ahmedabad. A large increase of NO_2 during 2004-2015 has been observed over Dhaka (79%), Lahore (53%) and Islamabad (47%)[55]. Additionally, biomass burning is also an important source of NO_2 mainly during the months of March-April over northeast and central India[56].

The trends in emissions of CO, SO_2, and NOx for different South Asian countries are illustrated in Figure 11. In general, India and Pakistan are leading in the emissions of all the three gases. Interestingly, Maldives shows the highest rate of increase in emissions of these gases. Energy consumption in various sectors constitutes a major share of emissions in the Maldives. As an example, the contribution of SO_2 from energy, manufacturing and construction industry have gone up from 52% in 1970-1979 to 82% in 2010-2015 (https://edgar.jrc.ec.europa.eu).

1.6. PERTURBATION OF NATURAL AEROSOLS BY HUMAN ACTIVITIES

Natural aerosols have been present in the atmosphere throughout historical time. The most important natural aerosols are sea salts, dimethylsulphide (DMS) from marine phytoplanktons and mineral dust from arid and semi-arid regions. Often episodic volcanic eruptions add to the total aerosol burden, although, their impact on the climate generally subsides within a year. These naturally occurring aerosols have important impact on the climate, mainly, via interacting with incoming solar radiation. It is being increasingly observed that human activities are perturbing the production of these aerosols, which can have regional and global climate implications. Here, we will focus on mineral dust aerosol, which is the most important natural aerosol over land and has adverse impacts on air quality, visibility and human health. While other natural aerosols impact the climate of a region they do not have a direct bearing on air quality and health.

Mineral dusts are small soil particles that are emitted under dry conditions by the wind. These are highly variable in space and time and vary in size between 100 nm to 100 µm[57]. Based on the size distribution and the removal process, dust can have lifetime in the atmosphere ranging between minutes to few weeks. The finer size dust particles, which have longer lifetimes, can be transported to places far removed from their sources and have range of impacts on health, air quality, radiative forcing, atmospheric heating etc. The coarser particles, on the other hand, are deposited near the source.

1.7. SOURCES OF SOIL DUST IN SOUTH ASIA

Asia is the second largest global dust source with different climate models estimating annual dust emission ranging between 54-873 Tg[58]. Within the domain of South Asia (considered as 60^{o}E-100^{o}E longitude and 5^{o}N-30^{o}N latitude) total annual dust emission is estimated as 62 Tg with almost 45% contribution from anthropogenic sources[59]. The two countries in South Asia which are important dust sources are India and Pakistan. The rest of the countries over mainland South Asia receive significant deposition of dust emitted from India and Pakistan, although, wind erosion lifting local dust is also reported. Additionally, about 50% of dust over the Indo-Gangetic plain in South Asia is transported from sources like the Middle East and Northeast Africa[60]. Mauritius located in the Southern Indian Ocean receives dust mainly from South African and Australian dust sources with a minor contribution from Middle East and North Africa[61].

Based on the Aridity Index, more than 57% and 93% of the land area of India and Pakistan are under the dryland category respectively. More than 6% and 71% of India and Pakistan, respectively, are arid regions[62]. Dust emission starts increasing from March onwards to reach a peak during the months of May-June and subsides after that as the southwest monsoon season sets in. During the peak dust, around 59% of the area within Pakistan experiences arid climate, which reduces to 41% during the winter period[63]. Notably, more than 90% of anthropogenic dust sources in the region are associated with fine sediments exposed due to the drying of water bodies. The Thar Desert in the India-Pakistan border and coastal Pakistan are characterised by natural dust emission from bare soil (Figure 12). The rest of Pakistan and India are characterised by anthropogenic emissions associated with agricultural land-use with the Indo-Gangetic plain being the most important contributor. Over India, wind erosion is the second most important cause of land degradation after water erosion. Rajasthan bears the burden of most of the wind erosion followed by Jammu and Kashmir, Gujarat, Haryana and Tamil Nadu[64]. Rajasthan also has the maximum area experiencing desertification followed by Maharashtra and Gujarat. In Pakistan, wind erosion is the second most prominent form of land degradation after water erosion with nearly 50% of the area impacted by wind erosion comes under the category of “Severe to Very Severe”. Punjab and Sindh provinces bear the greatest brunt of wind erosion[65].

Apart from dust from disturbed soil, over the urban and semi-urban areas there are additional dust sources, which contribute to both fine and coarse particulate matter load. These include dust from combustion and industrial sources, road and construction sources, wear and tear of tyres and brakes from vehicles. However, different studies have different definition of what constitutes anthropogenic dust in urban regions and use different methods to distinguish urban dust sources. In general, dust is the dominant component of PM_{10}. This is mostly based on the composition of crustal dust along with dominant anthropogenic pollution sources expected in a city. In general, elements such as Al, Ca, Si, Mg and Ti are among the common elements used as tracers of dust. Along with that, Ni and V for residual/fuel oil combustion, K for biomass burning in fine particulate matter, Zn, Cr for refuse burning/incineration and Zn, Cr, Pb, Ni, Cu etc are used for vehicular/industrial emissions[66].

1.7.a. Dust pollution in India

In general, Indian cities have some of the highest percentage contribution of road dust to PM pollution.The Central Pollution Control Board (CPCB) released air pollution status and source apportionment report for 6 Indian cities in 2010[67]. These cities are Bengaluru, Chennai, Delhi, Kanpur, Mumbai and Pune. It is seen that Delhi consistently records the highest levels of both PM_{10} and $PM_{2.5}$. Only in summer months PM_{10} and $PM_{2.5}$ concentrations in Kanpur exceeds that of Delhi. Year-round PM_{10} and $PM_{2.5}$ values in Delhi exceeded the recommended national standards set by CPCB. A study conducted in Delhi showed that about 71% of PM_{10} is from crustal (soil) dust, 3.5% from tyre wear dust and 3.9% from brake wear dust[68]. Bengaluru and Chennai consistently record low PM_{10} and $PM_{2.5}$ values throughout the year. In general, industrial areas consistently show high levels of PM10, while unpaved surfaces show high levels of PM2.5.

Road dust contributes significantly to the total PM_{10} load for the 6 cities covered by CPCB 2010 report. The highest contribution of road dust to total PM10 is in Chennai (73%) followed by Pune (61%) and Delhi (53%). Kanpur (14%) has the least contribution of road dust to the total PM_{10}. A separate study using CPCB data for 2010 also demonstrated the importance of road dust to PM_{10} with road dust due to vehicle movement contributing between 24 to 46 % of the total concentration[69]. However, within these cities studied by CPCB, different zones display large heterogeneity.

With respect to road dust contribution to $PM_{2.5}$, a study done for 20 Indian cities using CPCB $PM_{2.5}$ data for 2015, showed, that Chennai is leading in road dust contribution (23.5% including on-road resuspension and construction) to $PM_{2.5}$. Additionally, cities like Pune, Bengaluru, Indore and Bhubaneshwar also showed greater than 20% contribution[70].

1.7.b. Dust pollution in Bangladesh

In Bangladesh soil dust is an important contributor to the coarse mode fraction. Air mass back trajectory analysis shows that increased soil dust is mainly associated with the northwesterly wind coming from the Indo-Gangetic plain. Studies in 4 major cities of Bangladesh (Rajshahi, Dhaka, Khulna and Chittagong) during 2010-2012 have shown that Rajshahi leads in term mean of $PM_{2.5}$ and $PM_{10-2.5}$ (size between 10 µm and 2.5 µm) concentration[71,72]. Chittagong has minimum $PM_{10-2.5}$, but higher values of $PM_{2.5}$, possibly, due to traffic at the port. Khulna shows the lowest $PM_{10-2.5}$ value among the 4 cities. The capital city of Dhaka holds an intermediate position. Data collected during 2010-2012 show that in $PM_{2.5}$ size range soil dust contributes 9%-2% and road dust contributes 9%-1% with soil dust mostly dominating compared to road dust. There are some indications of a slight decline in road dust contribution to $PM_{2.5}$ for Rajshahi (2001-2002 to 2010-2012) and Chittagong (2006-2007), while the total mass of road dust has gone up. Opposite trends are seen between these two cities so far as soil dust is concerned. Rajshahi has experienced an increase in both mass and percentage contribution of soil dust to total $PM_{2.5}$. On the contrary, Chittagong has experienced a decrease in both mass and percentage contribution of soil dust to total $PM_{2.5}$. Based on different measurement periods, it is seen that in Dhaka soil dust contributes much more than road dust. In coarse mode soil dust can contribute up to 50% of PM_{10}[73]. Although, data are not continuous, overall, road dust has shown a decreasing trend in Dhaka, while, soil dust has shown a slightly increasing trend[74].

1.7.c. Dust pollution in Nepal

Most of the air pollution studies in Nepal are focussed on Kathmandu Valley. There is overall dominance of $PM_{2.5}$ in all seasons. Generally $PM_{2.5}$ and PM_{10} are seen to peak during late winter to summer, just before the monsoon precipitation sets in[75]. During this time, dust constitutes on average 29% of $PM_{2.5}$ mass fraction (average ~22 $\mu g\ m^{-3}$). During summer months, in PM_{10} size group, dust concentration can exceed 100 $\mu g\ m^{-3}$. Later measurements in 2014 along major roadways in the Kathmandu Valley have shown that crustal element concentration in $PM_{2.5}$ have gone up during the monsoon season compared to spring, possibly, due to resuspension of crustal materials due to poor road conditions[76]. Soil dust was found to contribute 33% and 42% of $PM_{2.5}$ and PM_{10}, respectively, during monsoon and the second most important PM source after exhaust from vehicles[77]. Also during winter measurements in Kathmandu Valley have found soil dust to be the second most important contributor to PM_{10} (26%) after motor vehicles (51%)[78]. The average soil dust concentration in PM_{10} in Kathmandu Valley was found to be around 32 $\mu g\ m^{-3}$.

1.7.d. Dust pollution in Pakistan

Although, there is a lack of systematic long-term measurements, in general particulate and soil dust pollution in Pakistan is the highest among the 9 South Asian countries. Considering the annual average aridity index, between 1901-1950 and 1967-2016, as a whole, about 9% of the area changed from arid to semi-arid over Pakistan[63]. However, during the winter season, there is a shift from arid to hyper-arid over the regions, mainly coinciding with anthropogenic dust sources.

Measurements conducted during March-April showed that the northern cities of Peshawar and Rawalpindi have very high levels of PM_{10} with a 24-hour average concentration of 540 and 448 $\mu g\ m^{-3}$ respectively. Coarse-mode PM is dominant in these cities with $PM_{2.5}$ consisting of around 30% of PM_{10}. The coastal city of Karachi also has very high levels of PM (ranging between 88 and 461 $\mu g\ m^{-3}$) with almost 50% contribution from $PM_{2.5}$[37]. Source apportionment studies in Karachi during the spring of 2009 showed that mineral dust is the most important contributor to PM with a contribution of 46% and 78% to $PM_{2.5}$ and $PM_{10-2.5}$ respectively[79]. The second most important contribution is from elemental carbon and organic matter originating from combustion and bioaerosol sources (21% $PM_{2.5}$ and 6.5% $PM_{10-2.5}$). A year-round study in Karachi showed that road dust can contribute about 16% and industrial emissions about 53% to $PM_{2.5}$[80]. Source apportionment studies in Peshawar, showed that road and soil dust including dust from under construction and unpaved road contributed to ~36% of the PM_{10} followed by contribution from vehicular emission (27%)[81]. Springtime measurements in Lahore showed $PM_{2.5}$ and PM_{10} concentration of 91 and 198 µg m^{-3} respectively with almost equal contribution from fine mode fraction to the total PM[37]. Another study that measured PM in Lahore for a year during 2007-2008, however, showed a much higher annual average value of 194 µg m^{-3} for $PM_{2.5}$ and 336 µg m^{-3} for $PM_{10-2.5}$[82]. PM_{10} concentration in Lahore peaks during April-May and October-November, while dust concentration and its contribution to PM_{10} are conspicuous during May-June and October-November. Source apportionment studies showed that dust dominated $PM_{10-2.5}$ constituting about 74% of the mass. Dust accounts for 14% of $PM_{2.5}$ mass, second to carbonaceous aerosol which accounts for 37% of $PM_{2.5}$ mass.[73]

1.7.e. Dust pollution in Sri Lanka

Source apportionment study in Colombo, Sri Lanka has been carried out at 2 sites during 2000-2005 and 2003-2008. The study shows that, for both PM_{10} and $PM_{2.5}$, road dust is the second most important contributor to PM concentration after vehicular emissions[45]. The contribution from road dust to $PM_{2.5}$ varies between 27% and 9%. Seasonally, dust concentration over Colombo is high during the dry months, which stretches from October to April with March experiencing the highest dust concentration. In general dust concentration is below 4 µg m^{-3} except for the strong signatures of elevated soil dust (exceeding 10 µg m^{-3}) in Colombo following dust storms in the Middle East. For the period 2000 to 2007, an overall reduction in soil dust is clear with the highest dust concentrations being measured during the years 2003-2004[45]. A separate study in Colombo has shown that road dust is impoverished of lithogenic components and is more polluted than road deposited sediment with high concentrations of Zn, Cu, Pb, Cr: indicating contribution from vehicle tyres, exhaust and parts[83].

1.8. TREND IN SOIL DUST AND FUTURE PROJECTION

Understanding the trend in dust requires long-term continuous measurements, which is particularly lacking in South Asia. Since the beginning of the 21st century ground-based measurement stations and satellites have started monitoring atmospheric aerosols and their properties. From these, an indirect understanding of dust load and its variability can be obtained. At the very outset, it is important to note that dust emission undergoes natural variability due to global teleconnections (like El Nino/La Nina or Pacific Decadal Oscillations) which modulates wind speed and precipitation over dust source regions. However, anthropogenic activities have high potential to modify the trend and relation between dust and large-scale teleconnections. Over South Asia, several studies have reported a decrease in dust aerosol since the beginning of 21st century and have attributed this to the increase in monsoon precipitation and reduced westerly wind speed[84,85]. However, a recovery in dust activity since 2013 has also been noted[86]. Observations have shown that dust over South Asia is associated with reduced vegetation cover and increased precipitation during spring[87].

In general, there are strong indications from climate model simulations that dust load over the dust belt of South Asia will increase significantly by the end of 21st century by ~30%[88]. At seasonal scale, most of the increase in dust is projected to be during the pre-monsoon and monsoon months. The Coupled Model Intercomparison Project 5 (CMIP5) models attribute this increase to a decrease in precipitation and an increase in wind speed over dust source regions[87]. Furthermore, CMIP5 model simulations also predict more than 10% decrease in soil moisture during 2080-2099 compared to 1980-1999 levels over South Asian dust belt which will push northwest India and entire Pakistan into severe drought[89]. In fact, under Representative Concentration Pathway (RCP) 8.5 scenario, as years will progress more of the arid and semi-arid regions will be pushed into hyper-arid category and humid areas will change to sub-humid category over western Indian, Indo-Gangetic plain and entire Pakistan[90].

1.9. AIR POLLUTION IN THE COVID WORLD

The worldwide spread of the coronavirus disease 2019 (COVID-19) has resulted in unprecedented disruptions to daily life and socio-economic activities. In December 2019, COVID-19 disease was first identified in Wuhan China[91]. Within 3 months more than 100 countries have been infected with the virus. As on 02 September 2020, according to the World Health Organization the deadly COVID-19 has spread rapidly throughout the world, killing 861,667 people, and infecting over 25,884,895. The first confirmed case of COVID-19 in India was on 30 January 2020 and since then caseloads have gone up rapidly. The trajectories of COVID-19 caseloads for the 9 Future Earth South Asian countries based on data from the World Health Organization is shown in Figure 13.

To tackle the spread of the virus the Indian government announced international travel restrictions starting from 04 March when the country saw a sudden increase in COVID-19 cases. The first nationwide lockdown was imposed for 14 hours on 22 March 2020. This was followed by 21 days (lockdown Phase 1 or LD1) nationwide lockdown starting from 25 March with total ‘Stay at Home approach’. There was a complete cessation of vehicular traffic except for emergency services. Industries, commercial establishments, places for entertainment, places of worship and educational institutions remained closed. Public gatherings were banned. International Energy Agency data shows a nearly 28% decrease in electricity demand during the first week of lockdown (https://www.iea.org/reports/covid-19-impact-on-electricity). Subsequently, the Indian government extended the lockdown, with certain relaxations, in following phases: LD2 (15 April to 03 May), LD3 (04 May to 17 May) and LD4 (18 May to 31 May) phases. The first phase of opening up the economy started on 01 June 2020 (that is, Unlock 1.0).

An unexpected result of the lockdown was the manifold impacts of halting economic activities on the environment. As emissions from different anthropogenic activities reduced significantly, clear skies were visible after many years. An example is shown in Figure 14, where the effect of reduction in anthropogenic emissions on visibility is depicted. The conditions associated with lockdown provide a natural laboratory to understand the impact of air pollution mitigation on the environment and as such demonstrate that, unlike CO_2, cleaner air can be achieved via short term policy interventions. Furthermore, calculations have shown that in different parts of the world reduction in air pollutants during COVID-19 lockdowns can lead to large reductions in air pollution-related mortality[92,93].

At the very outset, it is important to remember that apart from anthropogenic activities, the concentration of air pollutants also has large dependencies on naturally occurring climate modes. Weak El Nino conditions characterised the winter of 2019-2020. With the progress of the year 2020, the El Nino slowly transitioned to La Nina conditions during the southwest monsoon period. The Indian Meteorological Department data showed that till 11 September 2020, 49% of districts in India received normal rainfall and 19% of districts in India received excess rainfall. As such, winter El Nino conditions are associated with wet conditions over northwest India and southwest Asia[94]. This leads to reduced residence time and quick removal of aerosols[95]. Similarly, summer-time La Nina is also responsible for increased precipitation and enhanced removal of pollutants. However, even with the wet conditions favourable for the removal of aerosol, the decrease in the levels of air pollution associated with the lockdown is unprecedented.

The CPCB monitoring sites across India registered significant reductions in $PM_{2.5}$, PM_{10}, NO_2, and CO concentrations[96]. This reduction in air pollutants peaked during the morning traffic hours and late evening hours. The largest reductions were recorded for PM_{10} and $PM_{2.5}$ (more than 50%) over the Indo-Gangetic plain and northwest India (Figure 15). The largest decrease of NO_2 (~70%) was seen over northwest India and the largest decrease of CO (~40%) was over central India. On the contrary, while there was a day-time decrease in O_3 over most regions, night-time O_3 increased by 20-30% over the Indo-Gangetic plain, possibly due to reduction in NO_2 at night. The values of SO_2 also showed a mixed behaviour with slight increase over central India and a ~20% decrease over the Indo-Gangetic plain and southern India.

Figure 16 shows a drastic reduction of satellite-retrieved AOD over India during different lockdown phases as compared to climatological AOD values (2000-2019). Overall, during the entire lockdown period in India (25 March to 15 May, 2020), a 45% reduction in AOD was observed compared to the long-term mean AOD (2000-2019) for the same time of the year[97]. Four metropolitan cities (that is, NCR: National Capital Region of Delhi, Mumbai, Kolkata and Bengaluru) showed negative AOD anomaly with NCR having the highest negative AOD anomaly (−36.5%) during the entire lockdown period (25 March to 15 May 2020) followed by Mumbai (Figure17). Another study noted 50% reduction in air pollution over New Delhi[98]. Additionally, large reductions were noted in NO_2 (-53%) and CO (-30%) levels in Delhi with About 61% reduction in the value of AQI[99], indicating, a large improvement in air quality.

The impact of lockdown on air quality is evident in Bangladesh, which also witnessed an improvement in air quality. For example, Chittagong went into lockdown from 26 March 2020. One month since then, there were 40%, 32% and 13% reductions in $PM_{2.5}$, PM_{10} and NO_2, respectively[100]. An overall 26% improvement in air quality index was recorded.

1.10. Key Takeaways

World Bank data shows that more than 85% of the population of different countries in South Asia lives in regions where $PM_{2.5}$ levels exceed the World Health Organization Interim-1 target. The exceptions are Sri Lanka, Myanmar and Bhutan, where, 3%, 43% and 55% of the population, respectively, are exposed to $PM_{2.5}$ levels greater than the World Health Organization Interim-1 target. No such data are available for Maldives and Mauritius. The implications of such exposures are serious and manifold, as has been discussed in Section 2. Estimates suggest that more than 7.4% of gross domestic product in South Asia is lost to air pollution[101]. Mitigating air pollution has the additional benefit of reducing CO_2 emissions, the main greenhouse gas, since they have several overlapping emission sources. The relation between economic growth and air pollution can be viewed through the lens of what is known as the Environmental Kuznets Curve (EKC). EKC embodies the hypothesis that along with economic development first there is a degradation of the environment followed by subsequent improvements. This can be seen via the relation between gross domestic product and death due to outdoor pollution in Figure 18a, where middle income countries bear the greatest brunt of air pollution. Two of the most important pollutants that are directly associated with increase in economic activities are SO_2 and NO_2. These show a steady rise in India, but decline in the higher income countries (Figure 18b).

There are steep and immediate costs of not mitigating air pollution. Thus, it is important to get out of the trap of EKC curve in middle-income economies. Based on our current understanding we shed light on major areas that need to be addressed to reduce air pollution in this region. We see that ultimately tackling the problem of air pollution requires actions at city, country and regional levels.

1) Indoor pollution due to solid fuel burning for cooking and heating dominates $PM_{2.5}$ exposure over South Asia. This is particularly true for the Indo-Gangetic plains where more than 30% of population is exposed to $PM_{2.5}$ from indoor pollution, with largest contribution (20-50%) coming from residential cooking (see Figure 19)[102,103]. In fact, studies have shown that residential energy use contributes between 25% and 50% of mortality associated with $PM_{2.5}$ exposure. A study over India shows that replacing solid fuel with clean fuels will result in approximately 30% reduction in $PM_{2.5}$ exposure and will form an important foundation towards achieving clean air indoors [103]. Although, World Bank data shows that there has been significant decline in the percentage share of death from indoor pollution for all the 9 Future Earth South Asia countries, it is important to point out that except Maldives, Mauritius and Bhutan, as of 2016, all other countries have less than 50% of their populations having access to clean fuel. Bangladesh has only 18% of its population having access to clean energy and the highest death rate due to indoor air pollution. Thus access to clean fuel for domestic purposes is an important step to combat indoor air pollution and its adverse effects.

2) Although, there are indications of reductions in percentage share of all deaths from indoor pollution over time, World Bank data shows significant increase in percentage share of death due to outdoor pollution. The steepest rises in percentage share of all mortality attributed to outdoor pollution are for India and Nepal, where this percentage in 2017 was the highest at 8.3 and 8.7% respectively (Figure 20). In contrast, Maldives and Sri Lanka have seen decreases in percentage share of mortality due to outdoor pollution.

Studies on outdoor pollution have mostly focussed on urban areas. Typically, they are based on measurements carried out across several locations in a city and provide an estimate of variation in concentrations of different pollutants together with source apportionment analysis. Different studies have put forth mitigation measures for different urban regions of South Asia to tackle air pollution. These mitigation measures can be categorized broadly as:

a. Emission standards for industries, brick kilns and vehicles and enforcing checks on emissions. Transition to higher Euro emission standards.
b. Vehicle inspection, maintenance and promoting electric vehicles.
c. Encouraging public transport

d. Managing residential waste burning and waste management.
e. Managing open burning.
f. Shifting to clean energy use.
g. Repairing unpaved roads and increasing green spaces in urban areas.

For each urban area, some of these measures are more relevant than others but all of them are likely to play some role. It is, therefore, very important that the measures that are adopted in urban areas should be soundly based on source apportionment studies. Thus, ideally the measures that are adopted will vary from city to city and country to country and will depend on local conditions and patterns of energy use and emissions, in order to be most effective. As an example, implementation of higher Euro emission standards will have to be done country-wide, while increasing green spaces have to be city-specific. Keeping the above city-to-city and region-to-region variations in air pollution sources in mind, it is important to recognize that to ultimately improve air quality across the region, regional co-operation is essential, because the combination of topography and meteorology have resulted in long-range trans-boundary transport of pollution across much of the region from various sources. Regional sources of air pollution lying outside individual urban air sheds have large influences on local air quality, making a regional approach to air quality control necessary. Regional influences are especially prevalent for the cities located along the west coast of India and the Indo-Gangetic plain, where more than 30% of pollution arises from trans-boundary sources (see Figure 21).

The two most important contributors to trans-boundary air pollution are biomass burning and soil dust from land degradation. Based on the ^{14}C content of aerosol particles in the Asian outflow, it has been concluded that biofuel burning and biomass burning are the two most important sources of black carbon in this region followed by fossil fuel[104]. Thus, tackling biomass burning is going to be a key challenge for improving air quality. Furthermore, tackling biomass burning will lead to lower levels of other pollutants such as SO_4 and CO. Forest fires mainly occur during the spring and summer months and peak during April-May, whereas cropland burning is prominent during April-May and October-November months[105]. State-wise, Uttar Pradesh, Haryana, Punjab and Maharashtra are the main contributors to crop-residue burning with the largest share from rice, wheat and sugarcane residue burning[106]. The northwesterly wind over the Indo-Gangetic plain is the most important medium of transporting air pollutants from the main crop-burning regions into the northern Indian Ocean. The main challenge here will be diverting farmers from burning agricultural fields in preparation for the new cycle of seeding, when alternate options are either time consuming or too expensive. One way forward is to develop methods to reuse agricultural waste, for example, as fertilizer for the next cropping cycle.

The second trans-boundary aerosol with the potential to influence air quality at remote locations is soil dust emitted from degraded land, which is the largest constituent of PM_{10}.

As discussed earlier in this report, dusts from anthropogenic sources are mainly associated with water bodies, such as the Indus and the Ganges rivers. These regions are characterized by intense agricultural activities and irrigation, which although initially leading to increased agricultural production, ultimately results in land degradation. The leaching of nutrients from soil and salinization of land owing to excess irrigation, and their consequent abandonment has given rise to desertification over time. Classic examples of these are: the Sistan Basin around the Iran-Afghanistan border[107]and the Indira Gandhi Nahar Project in northwest India[108]. These regions were once characterized by sprawling agricultural activities. Many of the important dust sources over South Asia have been caused by land degradation arising from excess irrigation. Thus, an important step towards combating dust pollution would be to work towards restoration of the land surrounding the water bodies and adopting sustainable agricultural practices. This, in turn, would not only help in reducing soil dust emission, but also contribute to improvements in soil quality, water and food security.

Appendix: Figures and Tables

Table 1. Sources and residence times of major air pollutants

Pollutants	**Examples of major sources**		**Residence time**
	Natural	**Anthropogenic**	
$PM_{2.5}$	Atmospheric reaction of gaseous pollutants.	Combustion processes (power plants, gas and diesel engines, wood burning, industrial processes).	Days-weeks
PM_{10}	Sea salt and soil dust.	Re-suspended dust, construction and demolition, industrial processes, residential burning.	Minutes-days
O_3	Chemicals emitted from vegetations.	Reaction of chemicals emitted from industries, electric utilities, vehicles.	Weeks-months
SO_2	Volcanoes	Fossil fuel combustion.	2 year
NO_2	Intrusion of stratospheric nitrogen oxides, bacterial and volcanic action, and lightning.	Road traffic, electric utility, industrial boilers.	100 year or more

Table 2. Emission standards for different countries of South Asia.

Pollutant	Period	WHO	India	Bangladesh	Bhutan	Mauritius	Nepal	Pakistan	Sri Lanka
$PM_{2.5}$ (μg m^{-3})	1 y	10	40[d,e]	15	-	-	-	15	-
	24 h	25	60[d,e]	65	-	-	-	35	-
PM_{10} (μg m^{-3})	1 y	20	60[d,e]	50	50[a], 120[b], 60[c]	-	-	120	-
	24 h	50	100[d,e]	150	75[a], 200[b], 100[c]	100	120	150	-
O_3 (μg m^{-3})	8 h	100[×]	100[×,d,e]	157[×]	-	-	-	-	-
	1 h	-	180[d,e]	235	-	100	-	130	200[f]
NO_2 (μg m^{-3})	1 y	40	30[d], 40[e]	100	15[a], 80[b], 60[c]		40	40	-
	24 h	-	80[d,e]	-	30[a], 120[b], 80[c]	200	80	80	100[f]
SO_2 (μg m^{-3})	24 h	20	80[d,e]	365	30[a], 120[b], 80[c]	200	70	120	80[f]
CO (mg m^{-3})	8 h	-	2[d,e]	10	1[a], 5[b], 2[c]	10	10	5	10[f]

Maximum permissible limits for **a** sensitive targets **b** industrial area **c** residential area;

Standard for **d** ecologically sensitive areas **e** industrial, residential and other areas;

f maximum limit value; **+** 99th percentile; × daily maximum

No data were available for Maldives and Myanmar.

Table 3. Main sources of air pollution and other relevant information.							
COUNTRIES	**MAIN SOURCES OF POLLUTANTS**	**INDUSTRY SHARE OF GDP (%) (2019) a**	**MAIN POLLUTING INDUSTRIES**	**MOTOR VEHICLE/ 1000 POPULATION (2014) b**	**VEHICLE EMISSION LIMIT**	**HOUSEHOLDS WITH SOLID FUEL (2010) c (%)**	**CLEAN FUEL FOR COOKING (2016) d (%)**
BANGLADESH	Industry & vehicle emissions, brick kilns, trans-boundary transport.	30	Cement, brick making, construction, metal smelting	3	Euro 1 for diesel vehicle; Euro2 for patrol vehicle	91	18
BHUTAN	Industry & vehicle emissions, solid fuel, forest fire, crop burning	38	Cement factories; dust from Calcium carbide & Ferro silica industries.	57	Euro 2	40	53
INDIA	Vehicles, power, manufacturing, road dust, biomass & biofuel burning	25	Petroleum refining, chemicals, textiles, steel, cement, mining, basic metal industries.	18	Euro 6 since 2020	58	41
MALDIVES	Land & sea vehicles, power, trans-boundary pollution.	12	Incinerator plant, construction	28	None	No reliable data	94
MAURITIUS	Power generation s & industrial activities	17	Food processing (mainly sugar milling), textiles, metal products,	175		No reliable data	93

			transport equipment.				
MYANMAR	Road dust, biomass burning, vehicles, trans-boundary pollution	38	Manufacturing, mining, energy.	7	To meet Euro 4 norms by 2023.[c]	92	18
NEPAL	Road dust, brick kilns, soild fuel burning.	13	Metal manufacture; construction; brick kilns	5	Euro 3, although pre-Euro vehicles are also used	82	28
PAKISTAN	Soil & road dust, biomass burning, vehicle, industries.	1	Cement; fertilizer; sugar; steel; power plants; brick kilns.	18	None	64	43
SRI LANKA	Road dust, vehicle, power plants, biomass burning, open waste burning.	27	Processing agricultural goods, textiles, cement, petroleum refining.	76	Euro 1	75	26

[a] **https://data.worldbank.org**

[b]**http://www.nationmaster.com/country-info/stats/Transport/Road/Motor-vehicles-per-1000-people**

[c]**Solid Fuel Use for Household Cooking: Country and Regional Estimates for 1980–2010**

[d] https://data.worldbank.org

Table 4. Range of measured concentrations of different pollutants in urban areas of Pakistan

Concentration (µg m^{-3}) City	SO_4^{2-}	NO_3^-	BC	$PM_{2.5}$
Lahore	0.5-141	0.3-74.5	17.3-21.7	15.1-476
Karachi	0.9-53.2	0.6-15.4	2-10	46-116.97
Peshawar	-	-	-	70.2-160
Islamabad	-	-	-	73-140

Quetta	-	-	-	47.1

Source: Table taken from REF[43]and references therein.

Table 5. Source-wise contributions (%) to different trace gas emissions from South Asia.

Trace gas	Fossil fuel	Industry	Biofuel burning	Biomass burning	Agriculture/waste
CO_2	67	3	8	22	0
NOx	61	4	21	13	1
CO	12	1	65	20	2
NMVOC	33	7	49	8	2
SO_2	77	10	12	1	0

Data taken from REF[10]

Figures

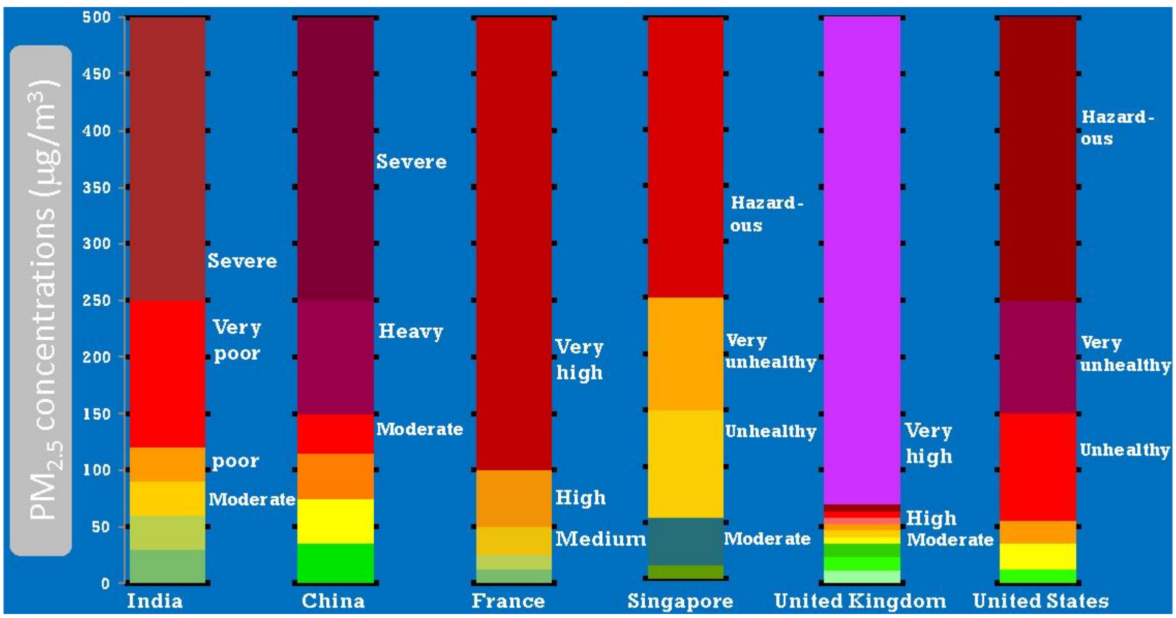


Figure 1. Comparison of $PM_{2.5}$ concentrations used by different countries to define Air Quality Index break points. Source: https://urbanemissions.info.

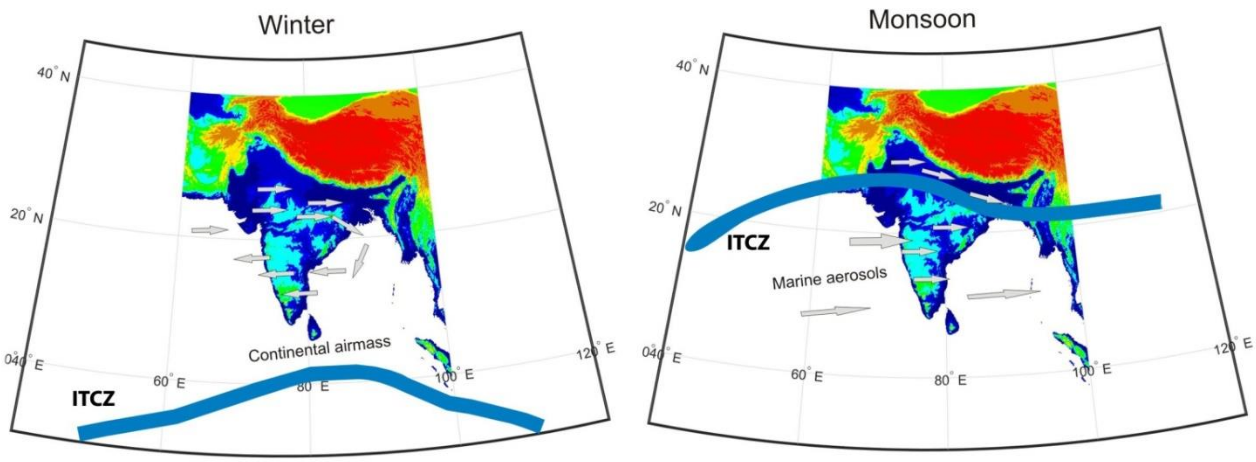


Figure 2. Synoptic wind over South Asia and the northern Indian Ocean. Figure taken from REF[10]. During the winter months the polluted continental air mass reaches the southern tropical Indian Ocean, while during the southwest monsoon season the clean maritime air mass prevails over large part of South Asia. This entire change is due to the north-south migration of the intertropical convegence zone (ITCZ). Position of the ITCZ is adapted from the REF[11].

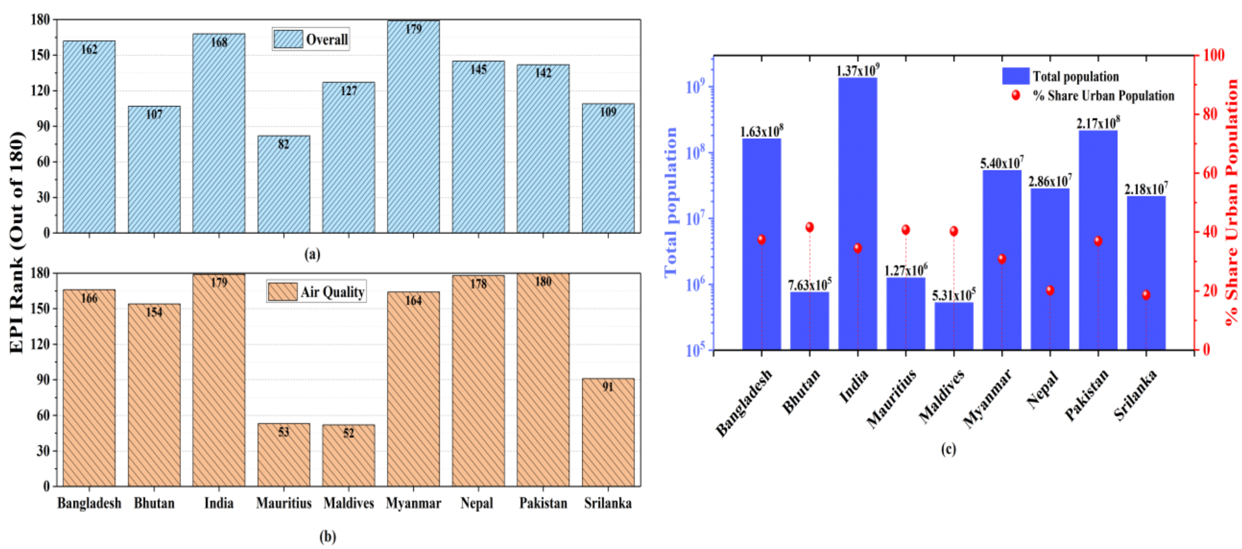


Figure 3. (a) Country rank based on overall Environmental Performance Index (EPI) for 2018 and (b) country rank based on EPI for air pollution. (c) The blue columns show the total population for 2019 and the small red circles show the percentage share of urban population. Population data source: World Bank (*https://data.worldbank.org*).

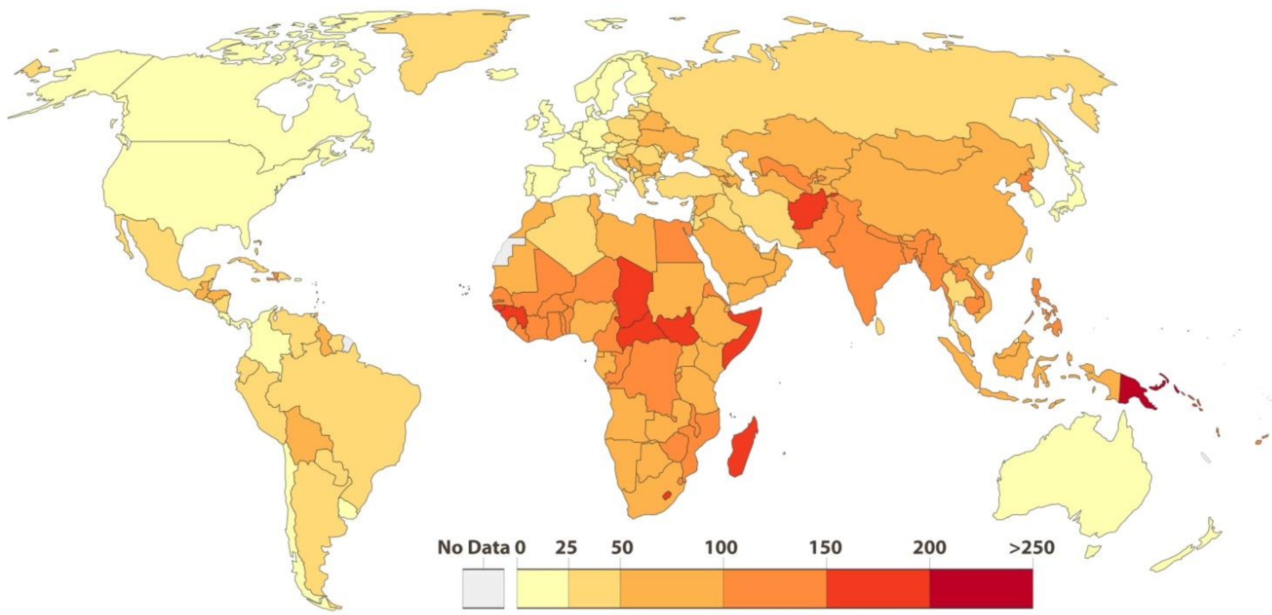


Figure 4. Death rates from air pollution in 2017. Source: https://ourworldindata.org/air-pollution

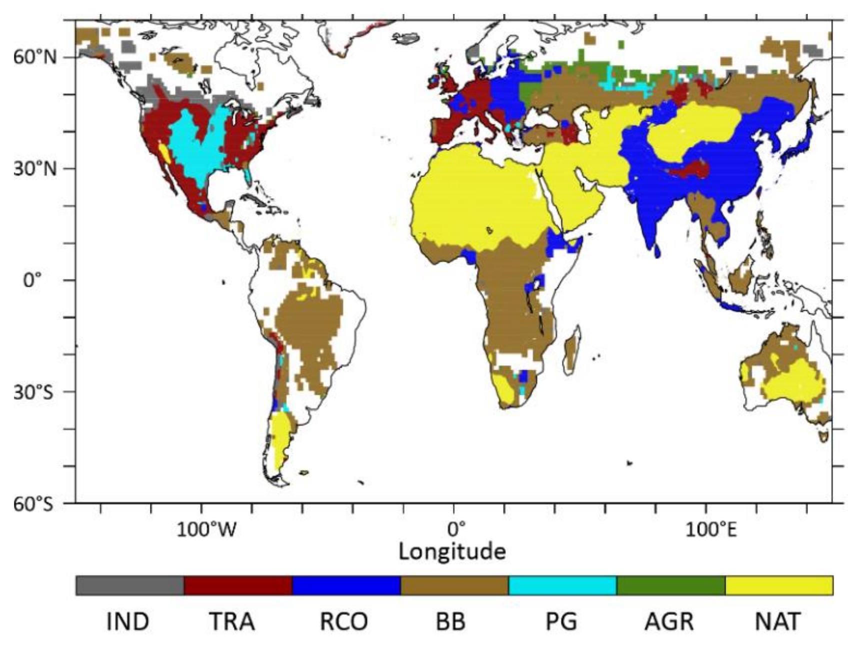


Figure 5. Main sources of air pollution responsible for mortality during 2010. IND: industrial sources, TRA: land transport; RCO: residential energy use; BB: biomass burning; PG: power generation; AGR: agriculture; NAT: natural sources. Figure taken from REF[24].

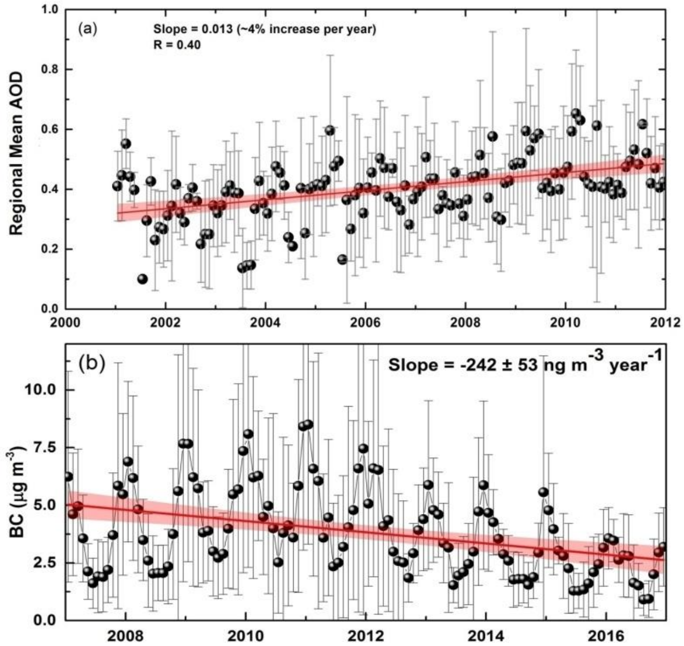


Figure 6. Trends in (a) AOD (b) and BC over India. The top panel (a) is the modified version of AOD trend over India from REF[31]and (b) is adopted from REF[32].

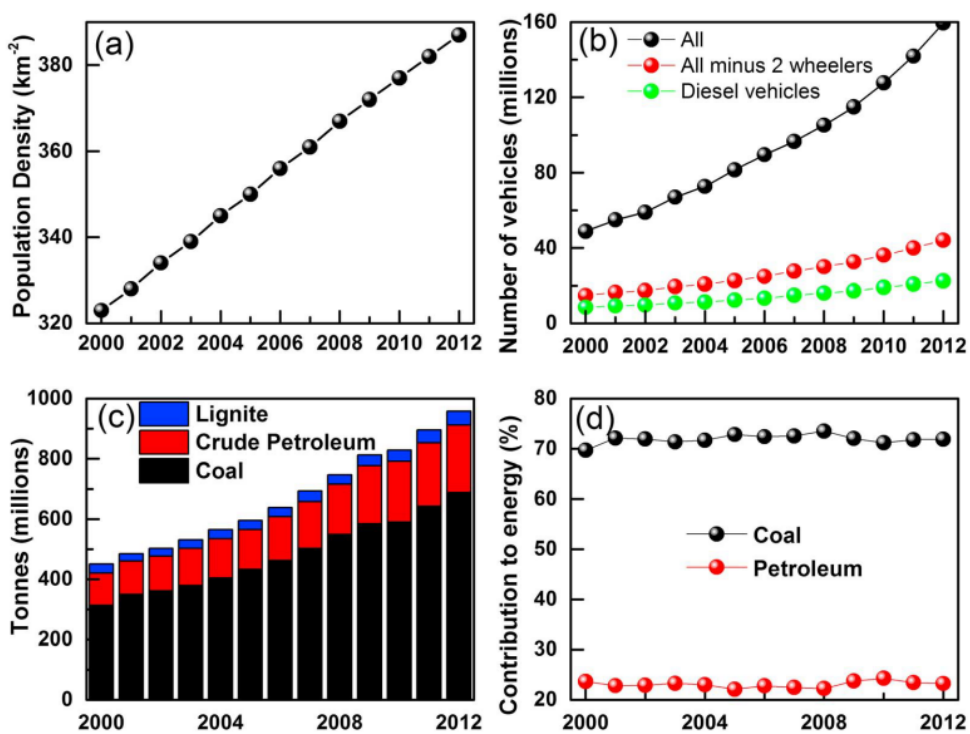


Figure 7. Changes in Population (a), number of vehicles (b), energy consumption (c) and role of coal and petroleum (d) over India. Figure taken from REF[32].

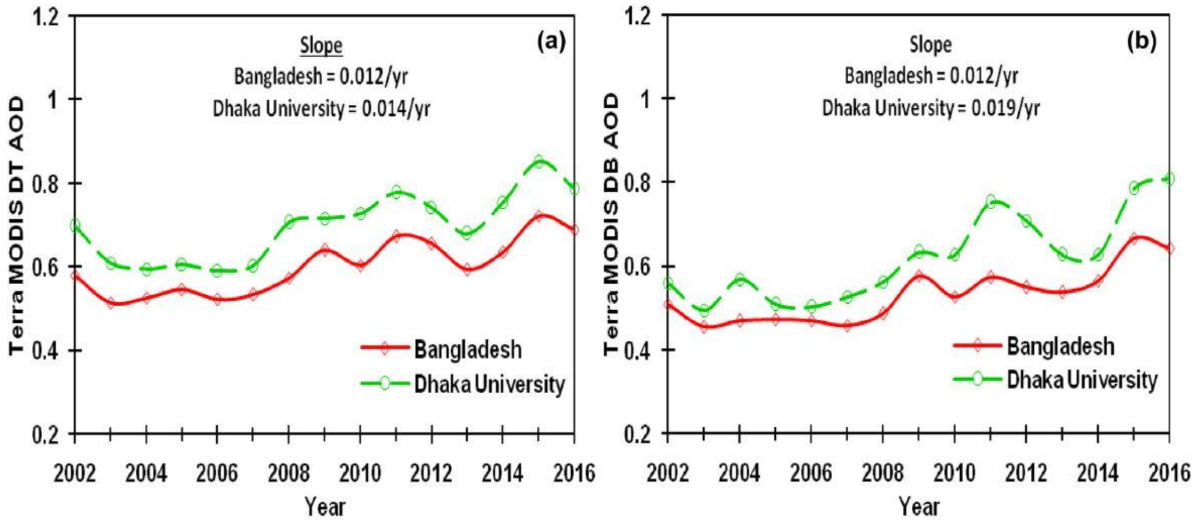


Figure 8. Annual variations in satellite-observed aerosol optical depth over Bangladesh and Dhaka University. Figure taken from REF[36].

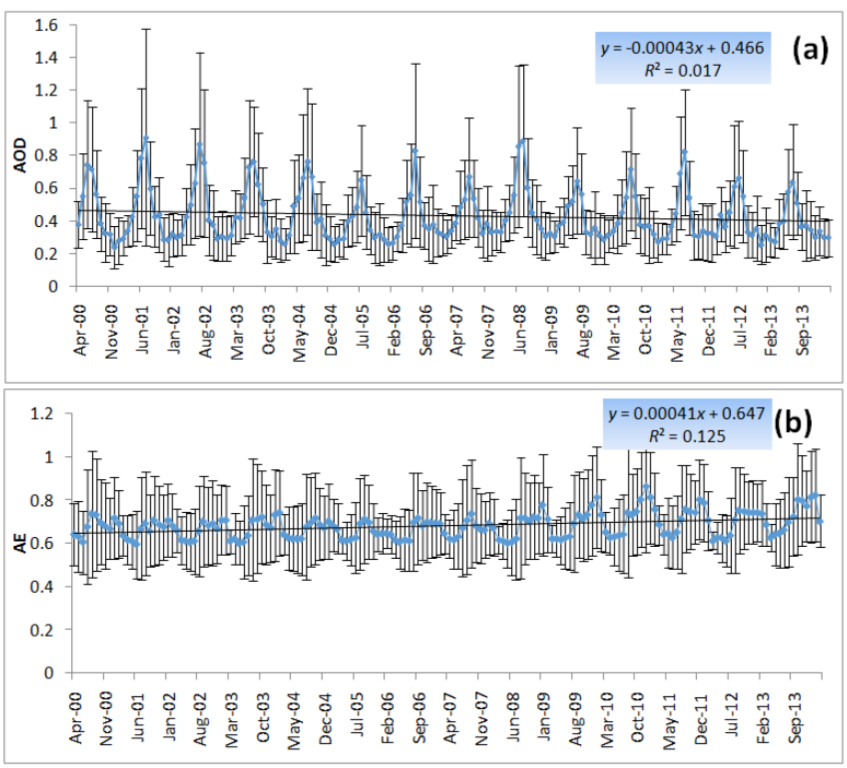


Figure 9. Long term variations in AOD and Angstrom exponent over Pakistan (Figure taken from REF[44]). Greater is the value of Angstrom exponent greater is the load of fine mode/ anthropogenic aerosols.

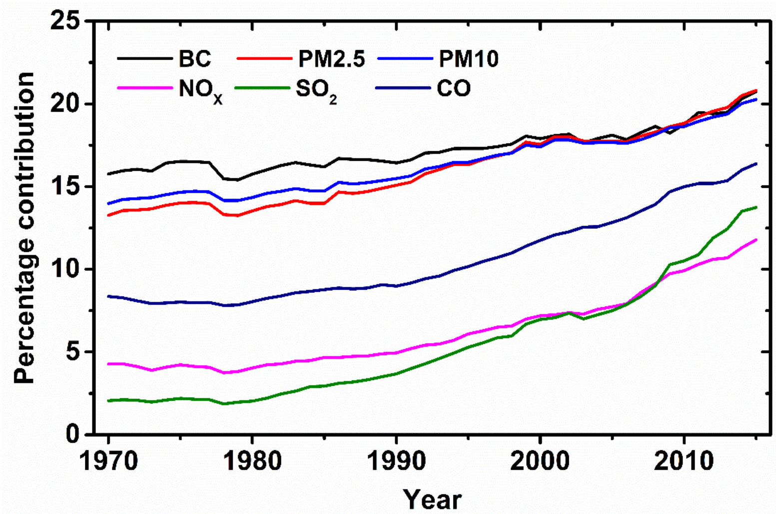
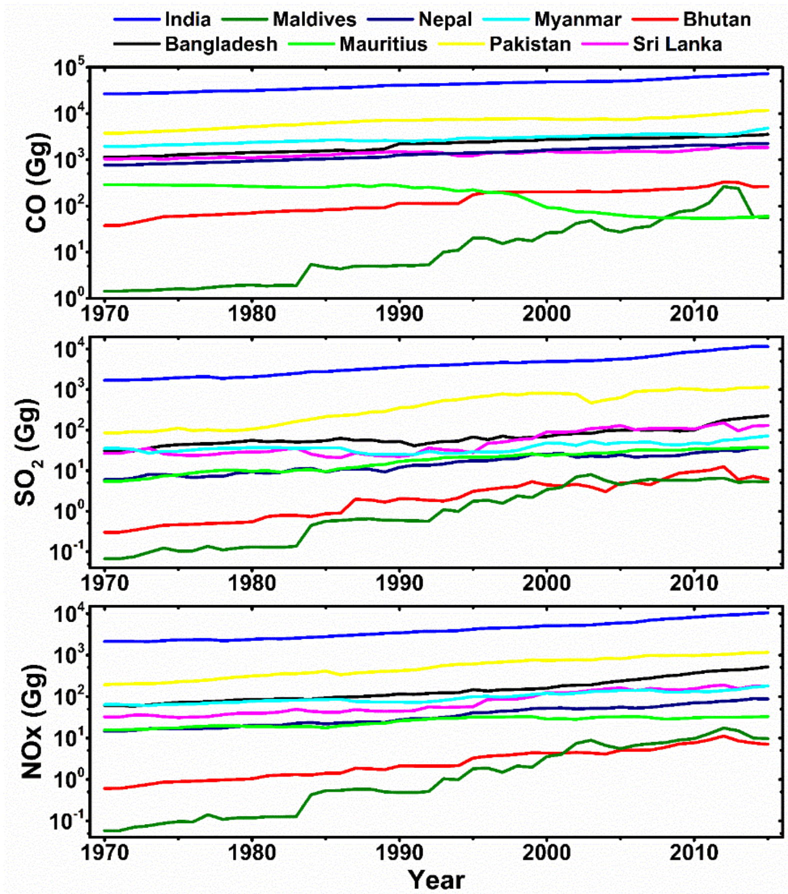


Figure 10. The long-term trend in the percentage contribution of air pollutants from South Asia to the global total during 1970-2015. Data from EDGARv5.0,



https://edgar.jrc.ec.europa.eu.

Figure 11. Long-term trends in CO (top panel), SO_2 (middle panel), and NOx (bottom panel) for different South Asian countries. Data from EDGARv5.0 air pollutants, https://edgar.jrc.ec.europa.eu.

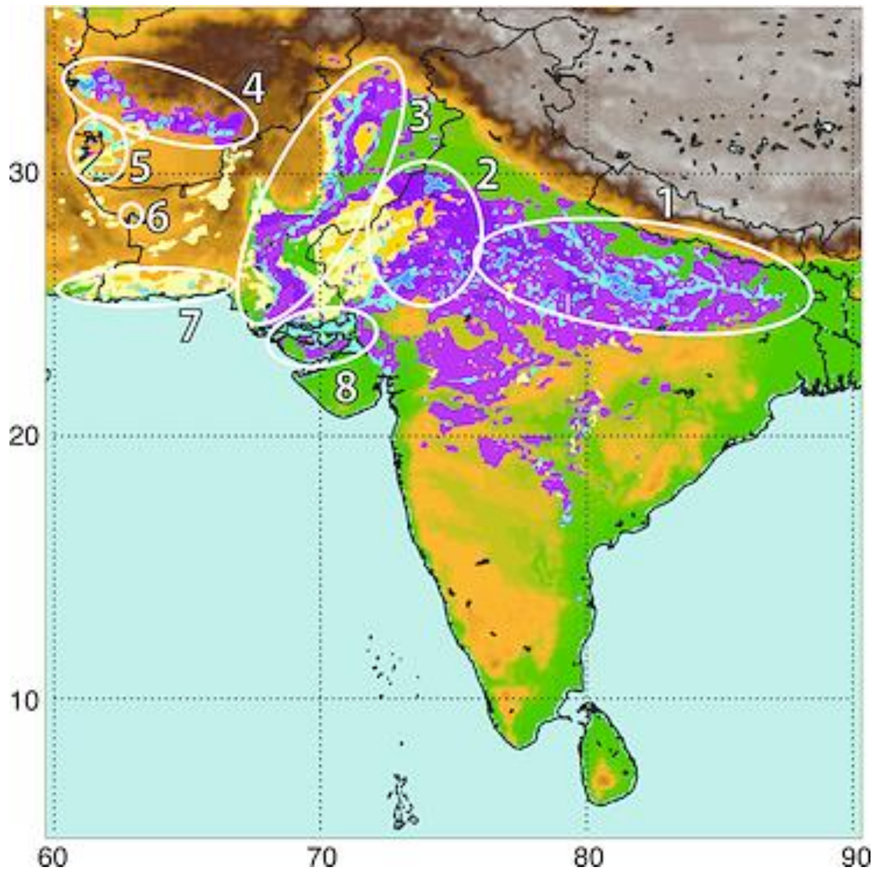


Figure 12. Distribution of main dust sources in South Asia. These are:1. the Ganges basin in India; 2. the Thar Desert; 3.the Indus basin in Pakistan; 4.Helmand river basin in Afghanistan; 5.Sistan lake; 6.Hamun-i-Mashkel, Pakistan; 7.The Makran coast; and 8.The Rann of Kutch in India. Blue is for dust sources associated with water bodies, yellow is for natural sources, magenta is for anthropogenic, Figure taken from REF[59].

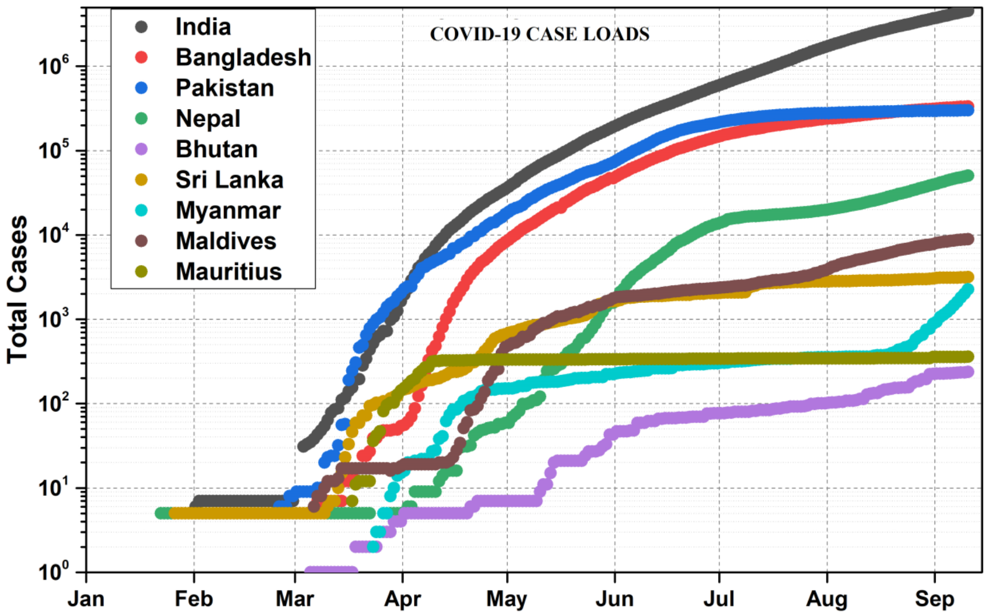


Figure 13. Evolution of COVID-19 caseloads for the Future Earth countries under South Asia. Source: World Health Organization.

Figure14. An illustration of clear sky due to lockdown. (left)The Dhauladhar ranges of Himachal are visible after 30 years, from Jalandhar (Punjab) after pollution drops to its lowest level. Source: https://indianexpress.com, 04 April 2020. An image of the India Gate in Delhi before (middle) and after (right) lockdown. Source: https://www.insider.com, 15 May 2020.

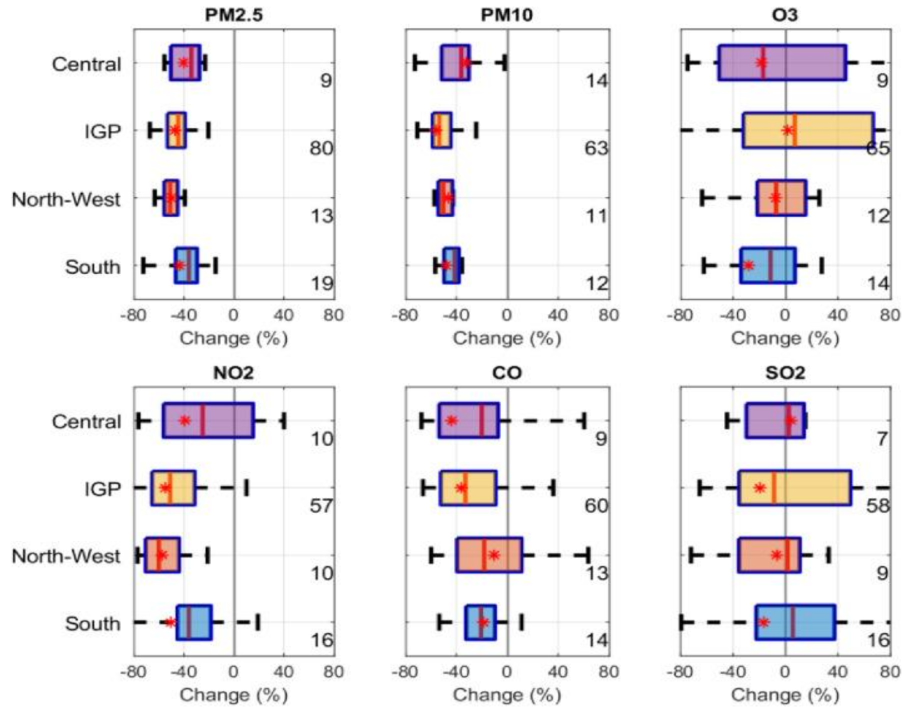


Figure 15. Figure showing the percentage change in different pollutants during the lockdown. The red star shows the mean, the vertical red line in each box shows the median value, and the box shows the inter-quartile range. The numbers to the right are the number of stations used. Figure taken from REF[96].

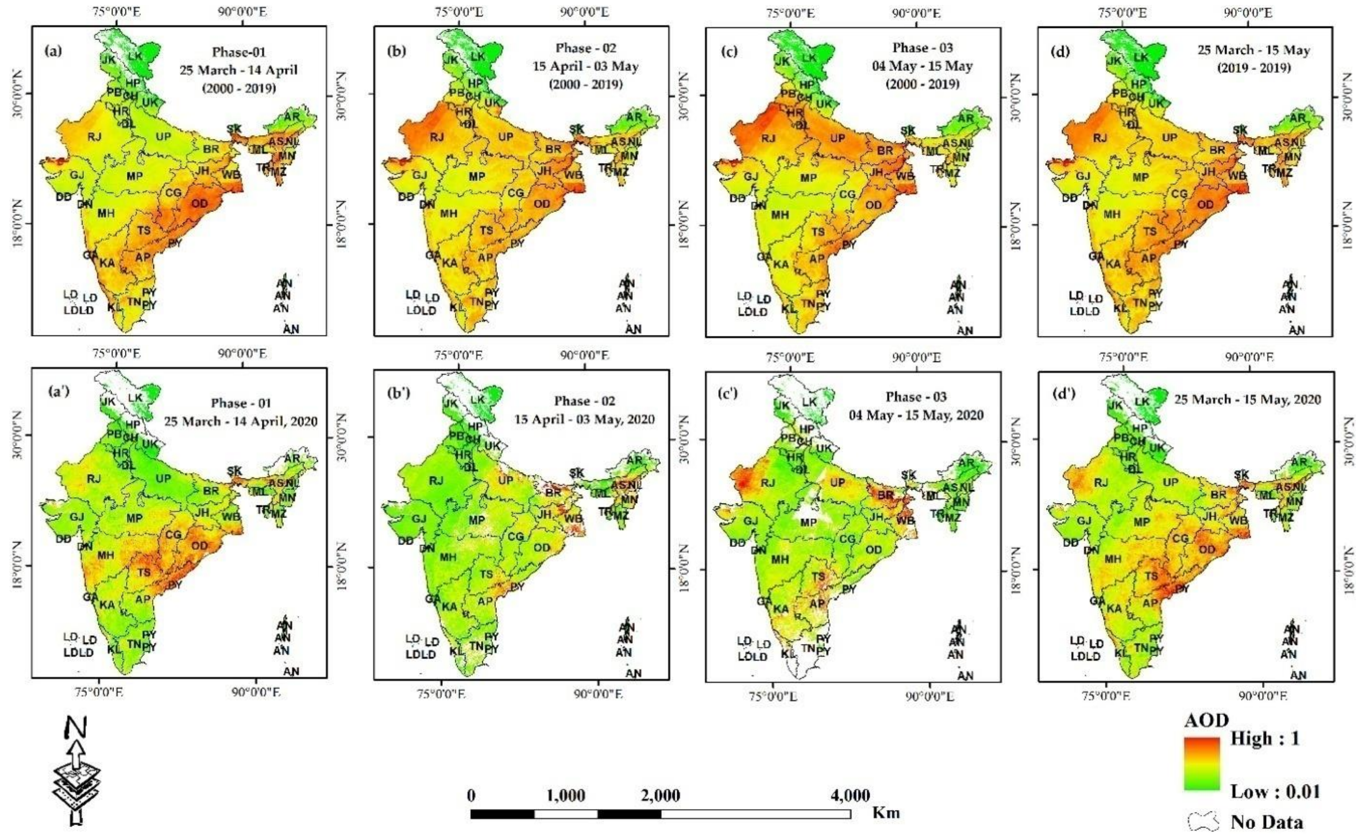


Figure 16. AOD maps for different phases of lockdown in India. Upper panels are showing long-term mean AOD during 2000-2019 and the lower panels are showing the mean AOD for the same time periods during the year 2020. Figure taken from REF[97].

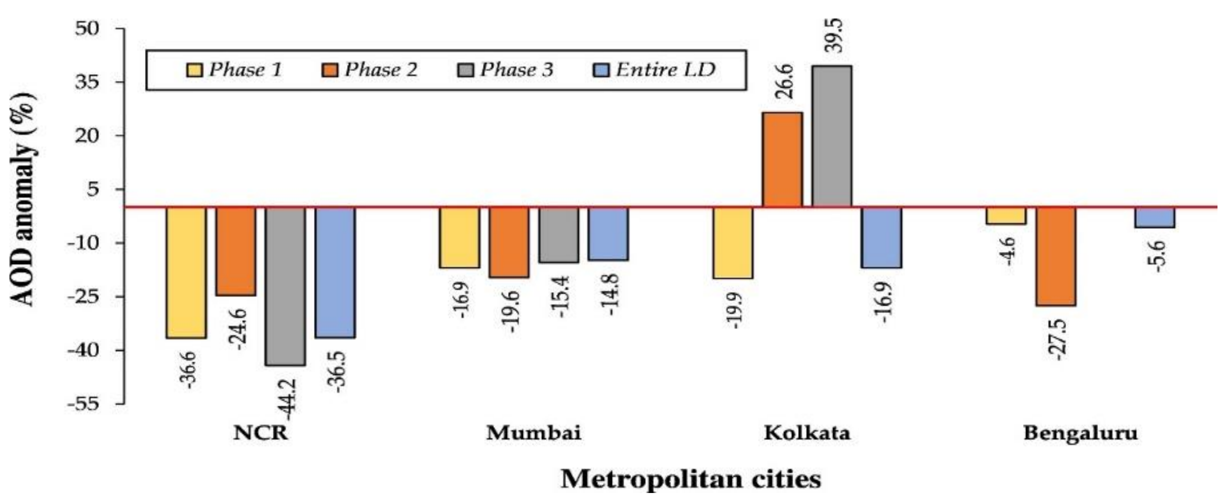


Figure17. AOD anomaly over different metropolitan cities of India during the different phases of lockdown.Figure taken from REF[97].

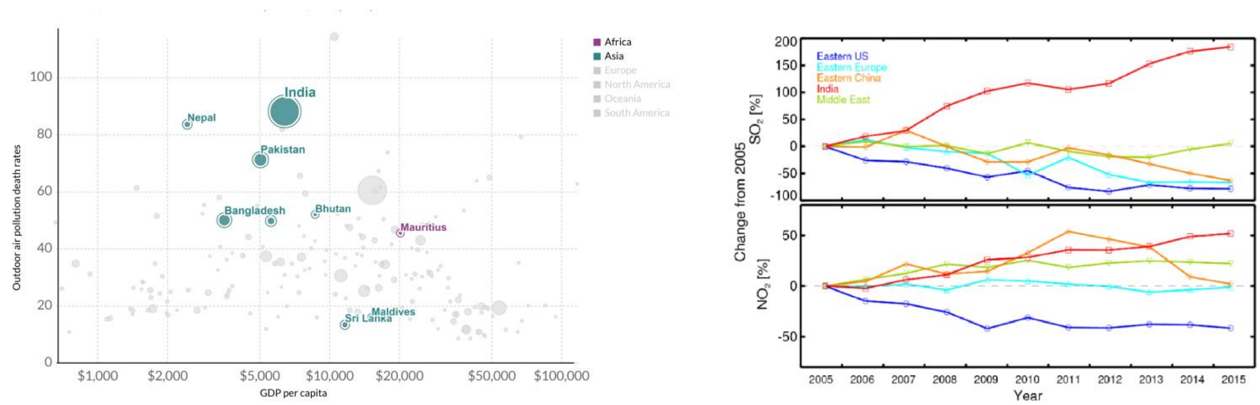


Figure 18. (left) Date rates due to outdoor air pollution versus per capita gross domestic product for 2017. Source: ourworldindata.org (right) Percent change in satellite-observed column SO_2(top) and NO_2(bottom) concentrations since 2005 for some regions, Figure taken from REF[53].

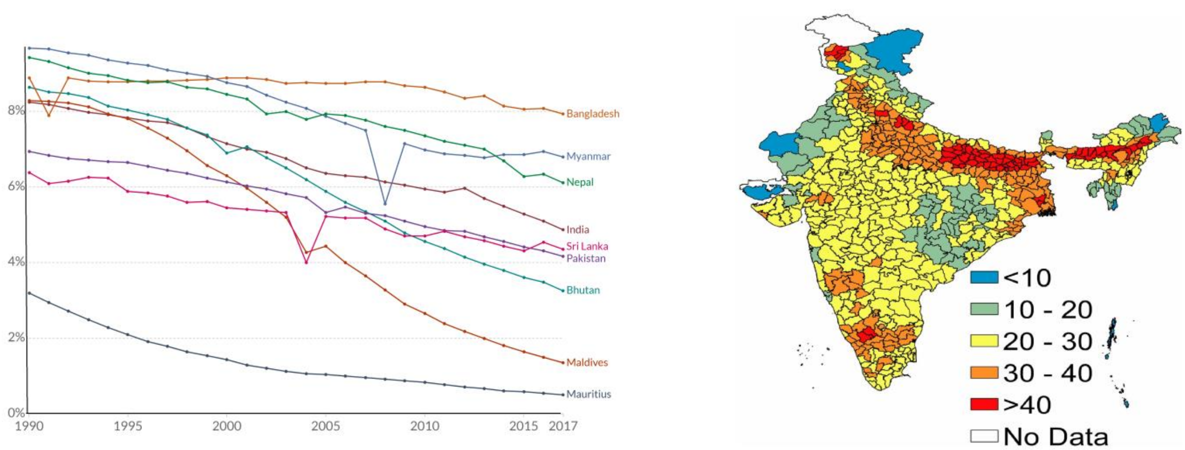


Figure 19. (left)Share of deaths (%) due to indoor air pollution in South Asian countries. Source: ourworldindata.org. (right) Percentage of population with ambient $PM_{2.5}$exposure that can be attributed to household sources, Figure taken from REF[103].

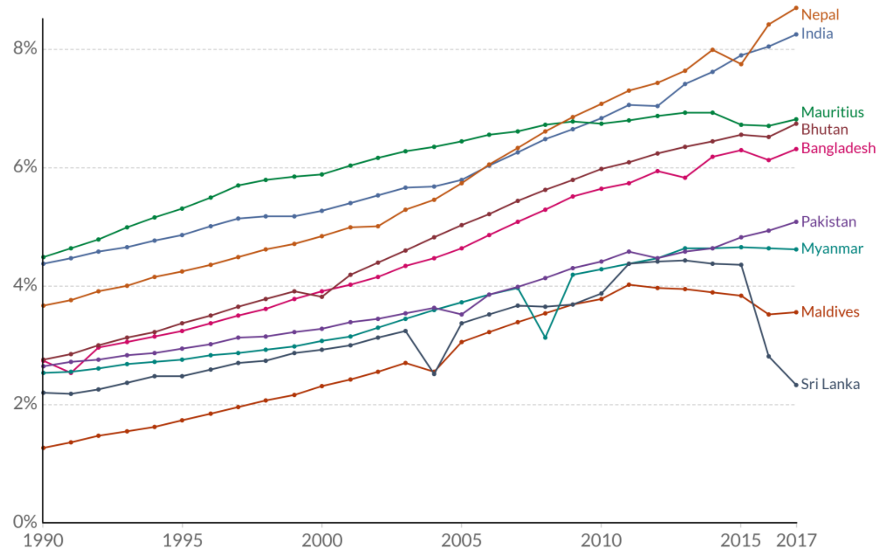


Figure 20. Share of deaths (%) due to outdoor air pollution in South Asian countries. Source: ourworldindata.org.

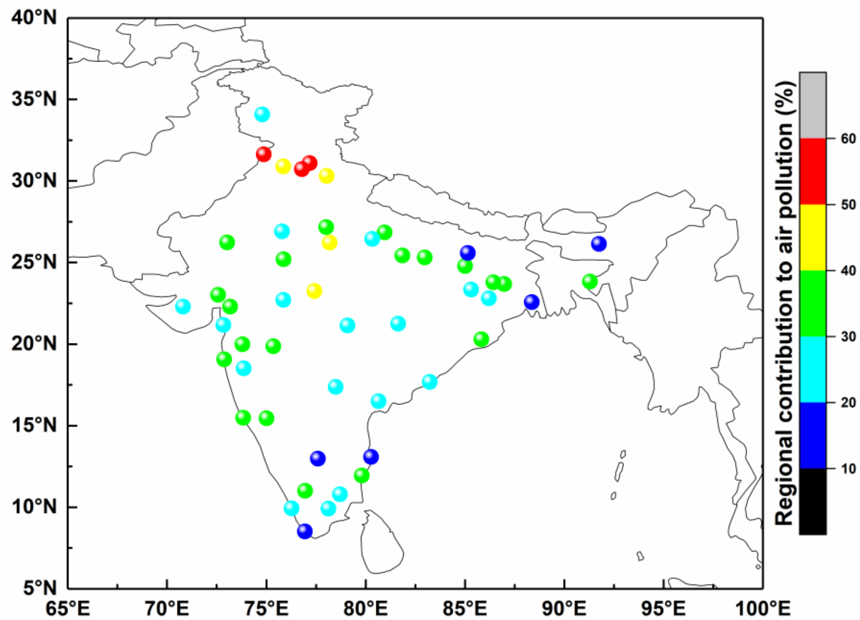


Figure 21. Contribution to air pollution (%) from regional sources to different cities of India. Figure taken from REF[70].

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B. Air Pollution: Clean Air and Energy in South Asia

Part II: Overview of Energy Sector in South Asia

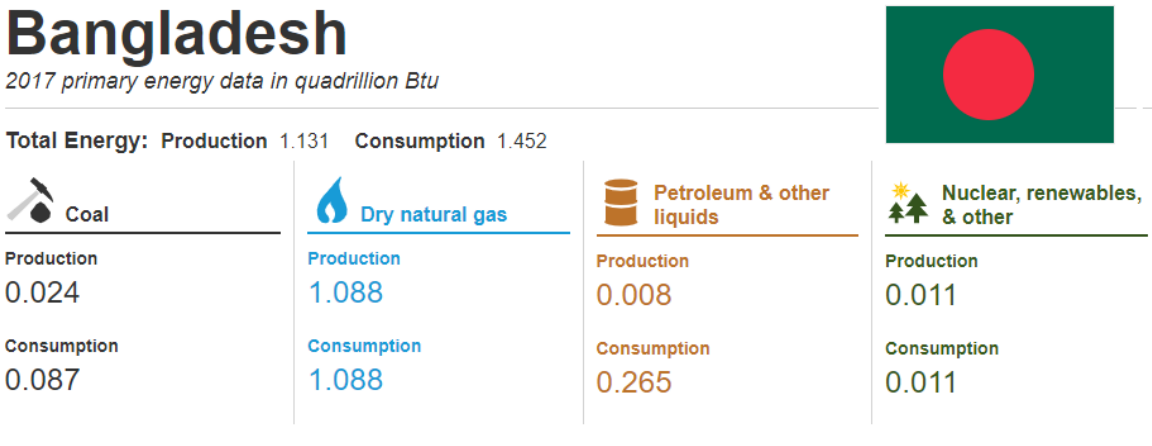
1. Summary of Energy Sector in Bangladesh

With a population of 163 million, Bangladesh is the third most populous country of South Asia and a major energy consumer in the region. The country's total primary energy consumption in 2017 was 1.45 quads (quadrillion BTU) as against the total domestic primary energy production of 1.13 quads. Bangladesh's per capita primary energy consumption is very low at 9.1 million BTU. Its energy intensity of economic output is 2.17 thousand BTU per US$ at purchasing power parity.

Natural gas and traditional biomass and waste account for most of Bangladesh's total primary energy consumption. Even though Bangladesh is a major producer of natural gas in the region, only a small fraction of the population (less than 10%) has access to natural gas, mainly in urban areas. Most households in the rural areas as well as urban areas use biomass sources such as wood, cow dung, jute sticks or other agricultural wastes for cooking purposes. Some of the major energy problems faced by the country is unreliability of power supply, persisting gap between peak demand and supply, inefficient use of available energy, heavy dependence on kerosene lamps for lighting in rural areas, and over 90% dependence on traditional biomass for cooking fuel.

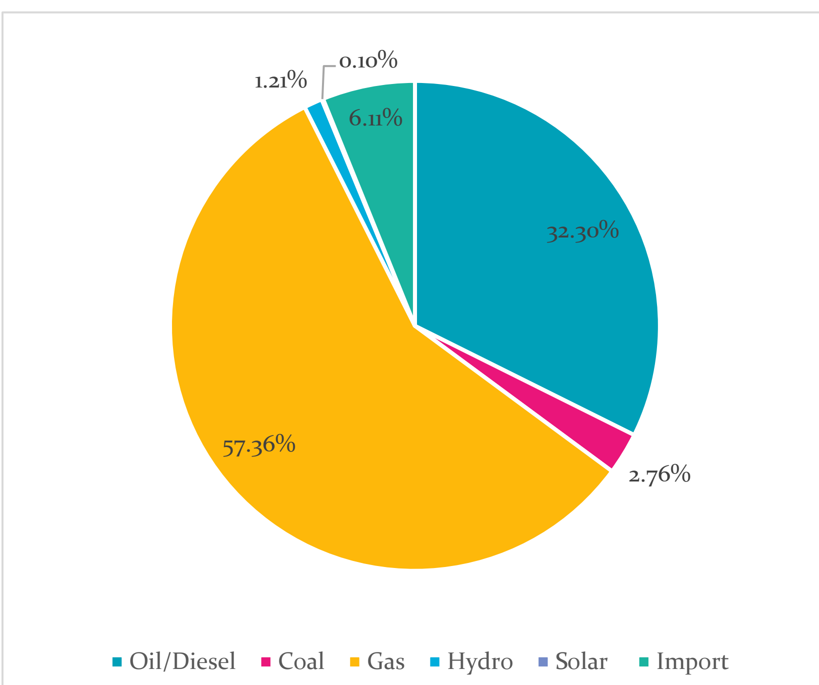
As of 2016, the total number of consumers connected to the grid represent roughly 50% of all Bangladeshi households excluding 15% of the households that have access to off-grid electricity. Even with total installed generation capacity of 19 GW, including 1.2 GW import from India, the quality of power supply is suboptimal. Major expansion of the grid infrastructure and electrification programs are underway. Bangladesh is also adding a sizeable nuclear power capacity to its grid with Russian and Indian assistance. Two 1.2 GW Russian designed VVER light water reactors are under construction in Ruppur on the banks of river Padma, and the first unit is expected to come online by 2023 and provide reliable baseload power for urban and industrial consumption. This will be the first commercial nuclear power plant in Bangladesh.

Current electricity supply is heavily based on limited domestic natural gas production and oil and diesel generators. Plans to expand supply using imported coal and LNG is likely to be very expensive and add financial stress to utilities. Renewable electricity generation is yet to take off in a major way and accounts for just one tenth of a percent of total installed capacity and generation. A 2019 study found Bangladesh has 16 GW of onshore wind potential, 134 GW of offshore wind potential, and over 150 GW of solar potential for utility scale generation. Although land requirement to tap these renewable energy options is large for a population dense country like Bangladesh, it is likely to be attractive compared to expensive import of coal and LNG. There is some evidence that there are suitable sites available in the country than previously thought for expanding wind and solar power generation. With India well on its way for a substantial increase in renewable energy production, increasing import of electricity could be part of long-term energy portfolio choice in Bangladesh.



Source: United States Energy Information Administration

Share of Electricity Generation Capacity by Source in Bangladesh



Bangladesh's Electricity Market Composition in 2019				
	Installed Capacity		**Electricity Generation**	
Source	***MW***	***% Share***	***GWh***	***% Share***
Oil/Diesel	6140	32.30%	13448	19.10%
Coal	524	2.76%	1230	1.70%
Gas	10877	57.36%	48306	68.50%
Hydro	230	1.21%	725	1%
Solar	30	0.10%	39	0.10%
Import	1160	6.11%	6786	9.60%
Total	**18961**		**70534**	

References:

The statistical data and information summarized in this section are drawn from the following sources:

1. United States Energy Information Administration, Department of Energy. https://www.eia.gov/international/analysis/country/BGD
2. Bangladesh Energy Situation, Energypedia. https://energypedia.info/wiki/Bangladesh_Energy_Situation
3. Simon Nicholas and Sara Jane Ahmed. Bangladesh Power Review. May 2020. https://ieefa.org/wp-content/uploads/2020/05/Bangladesh-Power-Review_May-2020.pdf

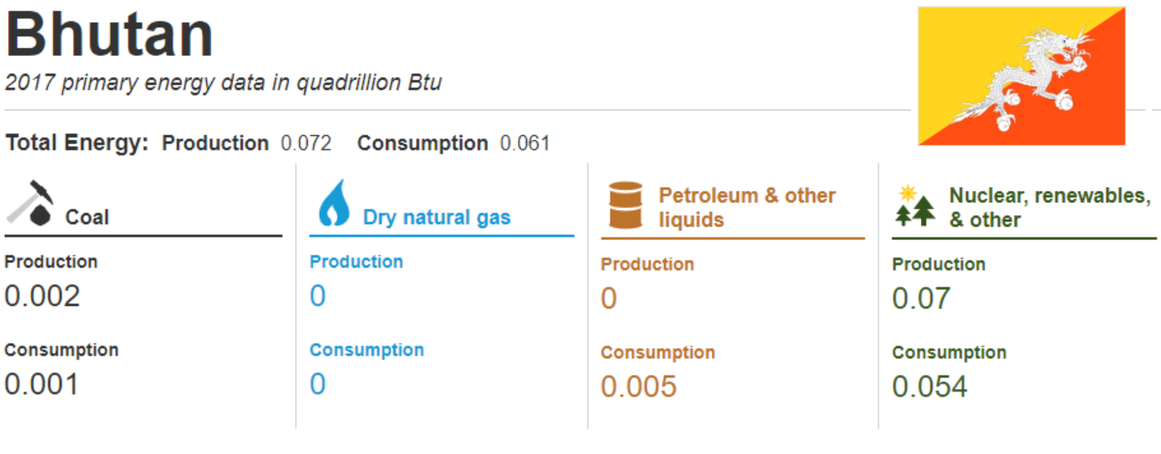
2. Summary of Energy Sector in Bhutan

With a population of less than a million, Bhutan's total primary energy consumption in 2017 was 0.061 quads (quadrillion BTU) as against the total domestic primary energy production of 0.072 quads. Land-locked Bhutan is thus a net primary energy producer and exports the surplus production to India. Bhutan's per capita primary energy consumption is 81.87 million BTU, and energy intensity of economic output is 9.1 thousand BTU per US$ at purchasing power parity.

Bhutan's electricity sector is almost entirely hydropower based, which accounts for 99.4% of installed capacity and the rest comes from fossil fuel and solar and wind plants. The total installed electricity generation capacity of Bhutan is 1623 MW of which 1614 MW capacity is hydropower. Almost entire population (99.8%) has access to electricity and 76% have access to clean cooking fuels while the remaining rely on traditional biomass fuel. The country's primary energy supply is dominated by renewables and accounts for 84% share, while oil and coal accounts for 11% and 5% respectively. Of renewables, 63% comes from biomass and the remaining 37% from hydropower.

Small countries with large potential for hydropower generation like Bhutan and Nepal can benefit by expanding hydropower generation and export the surplus to neighboring countries using transboundary power grids. Bhutan exports its surplus electricity from hydropower plants to India which has resulted in significant economic benefits for a landlocked country.

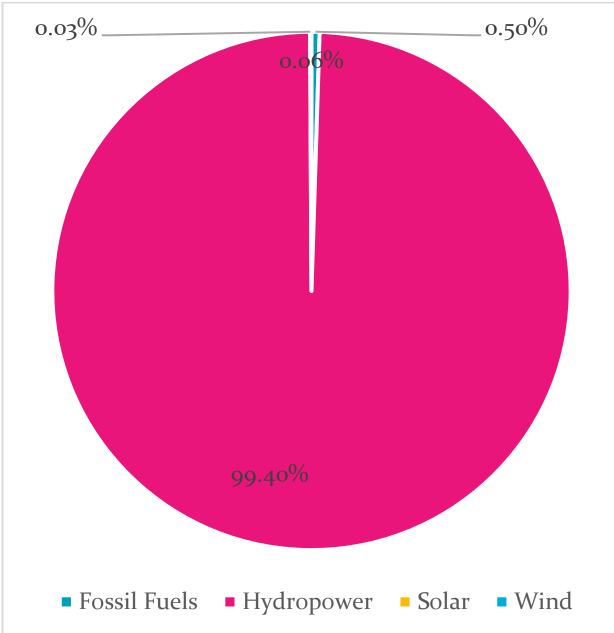
Compared to Nepal, Bhutan has greatly increased its hydropower capacity despite having a small land area and population. With increasing electricity exports to India, Bhutan has also accelerated its own electrification program and achieved near universal access (99.8%). It also has one of the cheapest power tariffs in South Asia. Bhutan has effectively used India's bilateral assistance for hydropower development which has resulted in major economic benefits.



Source: United States Energy Information Administration

Bhutan's Electricity Market Composition in 2017		
Source	***Installed Capacity (MW)***	***% Share***
Fossil Fuels	9	0.50%
Hydropower	1614	99.40%
Solar	0.5	0.03%
Wind	1	0.06%
Total	1623	

Share of Electricity Generation Capacity by Source in Bhutan



References:

The statistical data and information summarized in this section are drawn from the following sources:

1. United States Energy Information Administration, Department of Energy. https://www.eia.gov/international/overview/country/BTN
2. Kaoru Ogino, Mikiyasu Nakayama, and Daisuke Sasaki. Domestic Socioeconomic Barriers to Hydropower Trading: Evidence from Bhutan and Nepal. *Sustainability* 2019, 11, 2062.
3. https://www.irena.org/IRENADocuments/Statistical_Profiles/Asia/Bhutan_Asia_RE_SP.pdf

3. Status of Energy Sector in India

With the second largest population of 1.37 billion, India was among the fastest growing economies until the outbreak of Covid-19 pandemic in early 2020 was an important player in global energy markets. India's total primary energy consumption in 2017 was 30.5 quads (quadrillion BTU) as against the total domestic primary energy production of 17.7 quads. Although India is the third largest consumer of primary energy globally, per capita primary energy consumption is very low at 22.7 million BTU. Its energy intensity of economic output is 3.27 thousand BTU per US$ at purchasing power parity.

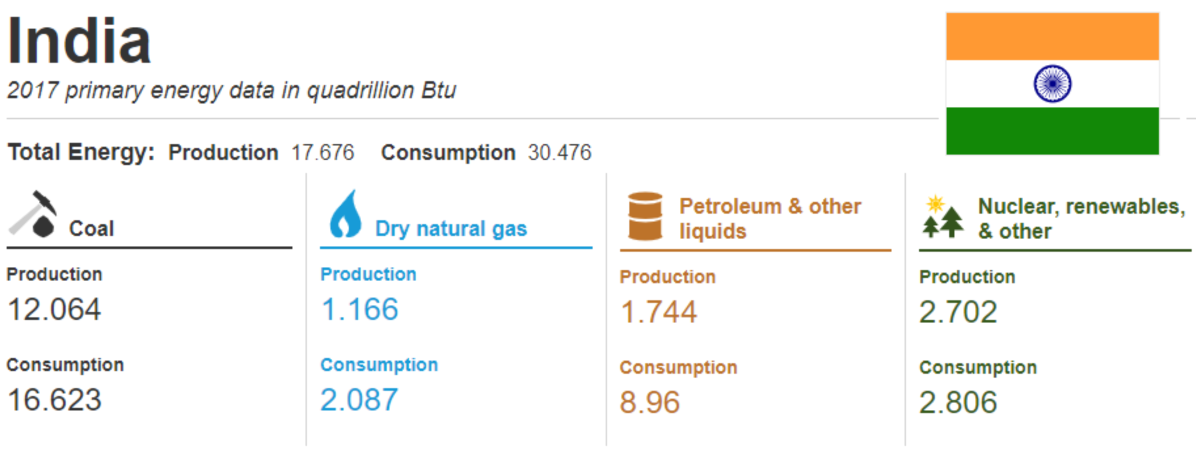
India has large domestic coal reserves and has seen significant domestic production of coal and natural gas in the past 20 years. Domestic oil production is limited and a large share (over 85%) of demand is met through imports. The government plans to reduce its import dependency for various energy sources by developing domestic options, especially renewable sources while also emphasizing efficiency improvements in energy production and end use. The electricity sector has seen the largest growth in terms of energy demand. There has been significant progress in expanding access to electricity, however 15-20% of the population still lack access to electricity and more than 50% of the population lack access to clean cooking fuels.

It is estimated that more than 700 million people in India gained access to electricity over the past two decades. India's primary energy supply and electricity generation is dominated by coal plants. coal supply has increased rapidly since the early 2000s, and coal continues to be the largest domestic source of energy supply and electricity generation. However, the government has also launched an ambitious program to expand the use of renewable sources like solar and wind for electricity generation with the target of achieving 175 GW renewable capacity by 2022 and 450 GW in the long run. Fall is renewable energy costs in recent years has helped India to make significant progress toward this goal. India also has an ambitious civilian nuclear power program with 22 currently operable reactors with a capacity of 6.8 GW with plans to add at least 20 GW by 2030. The composition of India's electricity generation capacity is summarized in the figure and table provided below.

India's energy system is dominated by coal for electricity generation, oil for transport and industrial applications, and traditional biomass for residential heating and cooking. While a major share of coal consumption is based on domestic production and biomass entirely domestically sourced, oil and natural gas used in the country is predominantly imported. Industry accounted for the largest share of final energy use followed by residential use, transport, and services including agriculture.

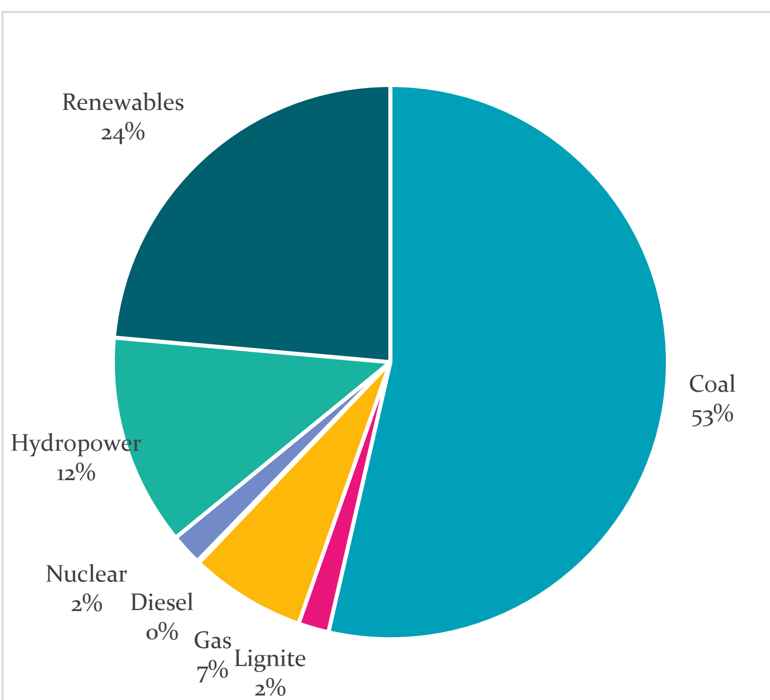
At the Conference of the Parties (COP) 21 meeting in Paris in 2015, India committed to deep cuts in carbon emissions even though its per capita emissions are among the lowest in the world. Building on the earlier commitment made at the climate summit in

Copenhagen in 2008, India submitted its Intended Nationally Determined Contribution (INDC) to reduce the emissions intensity of its economic output by 33-35% from 2005 levels by 2030 and have 40% of the installed electric power capacity from non-fossil sources. The composition of India’s current installed power generation capacity reveals that it is already compliant with the goals of national commitment made at the 2015 Paris climate summit.



Source: United States Energy Information Administration

Share of Electricity Generation Capacity by Source in India



Electricity Generation Capacity (MW) in India								
Ownership	*Coal*	*Lignite*	*Gas*	*Diesel*	*Nuclear*	*Hydro*	*Renewables*	*Total*
State	65362	1290	7155	236	0	26959	2357	103358
Private	74173	1830	10599	274	0	3394	83395	173664
Central	58990	3490	7238	0	6780	15347	1632	93477
Total	198525	6610	24992	510	6780	45699	87384	370499

References:

The statistical data and information summarized in this section are drawn from the following sources:

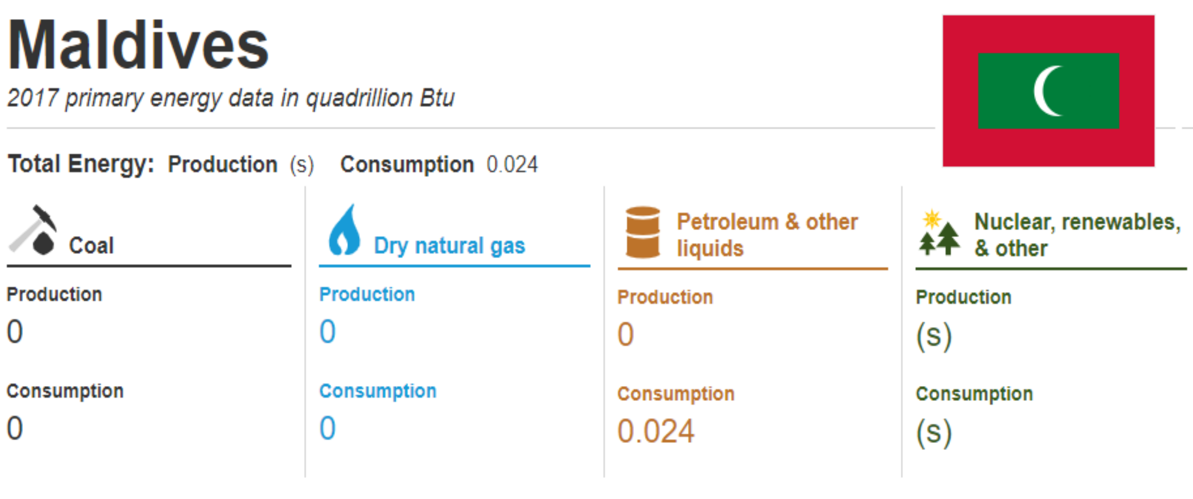
1. United States Energy Information Administration, Department of Energy. https://www.eia.gov/international/overview/country/IND
2. Central Electricity Authority (CEA). Government of India. http://www.cea.nic.in/reports/monthly/installedcapacity/2020/installed_capacity-05.pdf

4. Summary of Energy Sector in the Maldives

With a population of a little over half a million, Maldives' total primary energy consumption in 2017 was 0.024 (quadrillion BTU). Maldives imports almost all of its primary energy needs and fuel for electricity generation. Per capita primary energy consumption of Maldives is 49.1 million BTU, and its energy intensity of economic output is 3.48 thousand BTU per US$ at purchasing power parity.

Due to geographical constraints, all islands of Maldives have their own electric power systems where each island functions as an independent mini grid powered by diesel generators. The main energy supply are various refined petroleum products with a small solar and wind capacity. The Greater Male region has several solar energy installations in residential and commercial buildings. As shown in the figure and table below, fossil fuel power systems (entirely comprising diesel generators) account for 96.4% of total installed capacity and the remaining solar and wind. Out of the 280 MW of installed capacity, diesel gensets account for 270 MW capacity and solar and wind 9 MW and 1 MW respectively. However, 99.42% of total electricity generated in 2017 came from diesel generators.

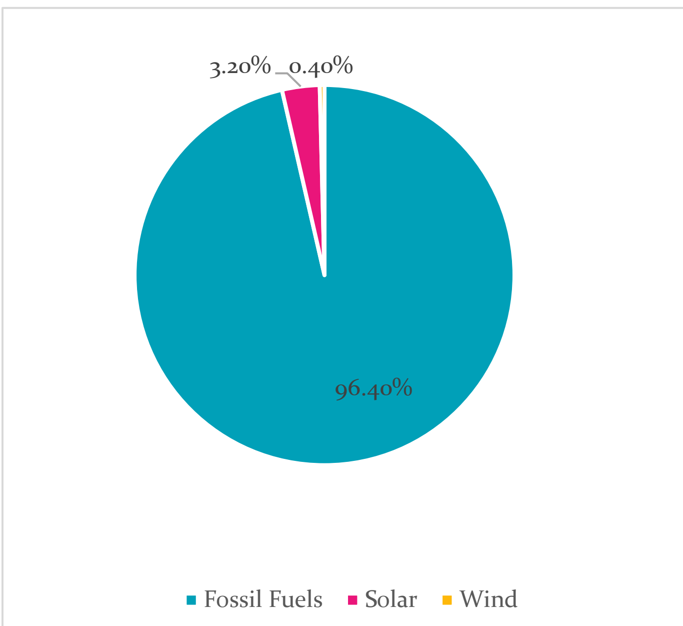
Diesel accounts for 80% of imported fuel and the remaining petrol, kerosene and jet fuel. Power generation in the main island of Maldives and other atolls are relatively efficient. The main source of energy for cooking and other domestic use in smaller islands in the periphery has been traditional biomass comprising dried branches from trees and shrubs, coconut shells and husks. But with the depletion of these traditional resources and government restrictions many of households even in these remote islands have switched over to LPG and kerosene.



Source: United States Energy Information Administration

Maldives Electricity Market Composition in 2017		
Source	***Installed Capacity (MW)***	***% Share***
Fossil Fuels	270	96.4%
Solar	9	3.2%
Wind	1	0.4%
Total	**280**	

Relative Shares of Power Generation Capacity by Source in Maldives



References:

The statistical data and information summarized in this section are drawn from the following sources:

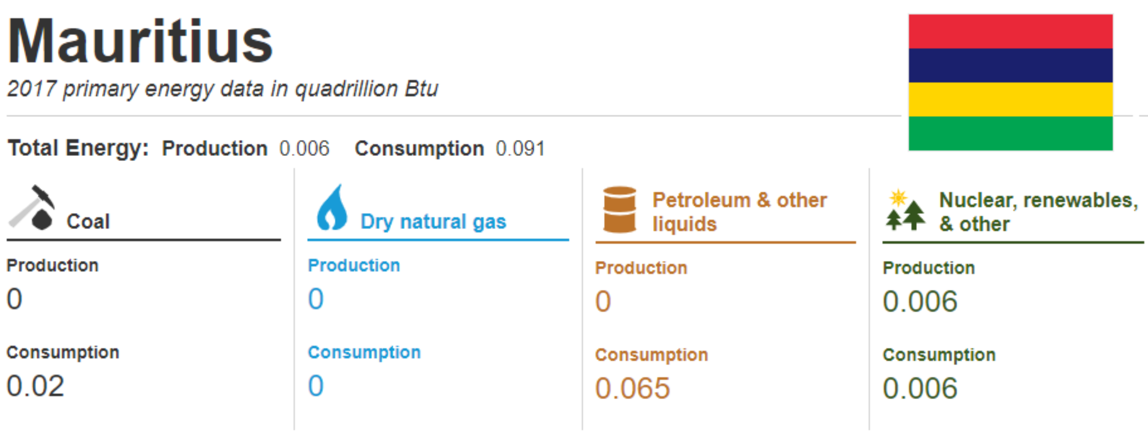
1. United States Energy Information Administration, Department of Energy. https://www.eia.gov/international/overview/country/MDV
2. South Asia Regional Initiative for Energy Integration (SARI/EI): Maldives https://sari-energy.org/oldsite/PageFiles/Countries/Maldives_Energy_detail.html
3. The energy mix of Maldives. GlobalPetrolPrices.com

https://www.globalpetrolprices.com/energy_mix.php?countryId=134

5. Summary of Energy Sector in Mauritius

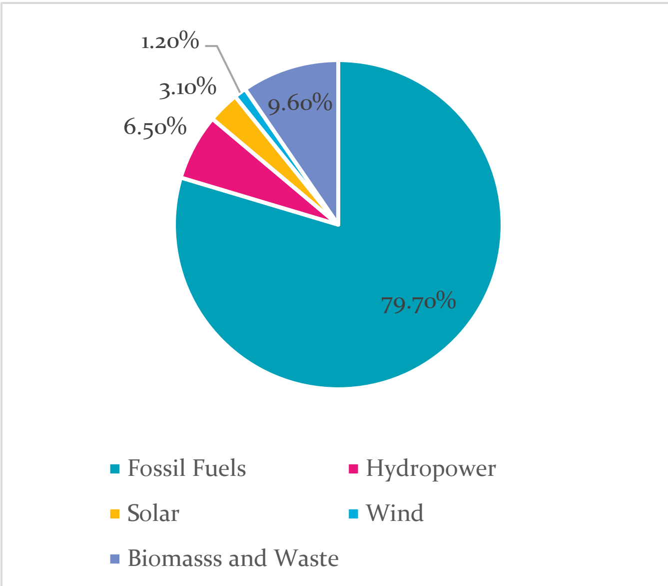
With a population of 1.3 million, Mauritius' total primary energy consumption in 2017 was 0.091 quads (quadrillion BTU) as against the total domestic primary energy production of 0.006 quads. The country's per capita primary energy consumption is 71.65 million BTU, and energy intensity of economic output is 3.3 thousand BTU per US$ at purchasing power parity.

The primary energy mix in Mauritius is dominated (93%) by coal and oil. The remaining, around 7%, of the country's final energy consumption comes from modern renewable sources of energy and this share has gradually decreased over the past two decades. The picture and table below show the relative shares of installed electricity generation capacity in Mauritius by various energy sources. Coal and oil-fired plants account 750 MW out of the 941 MW of total installed capacity. But the relative share of electricity generation is as follows: 94.4% from coal and oil plants, 4.2% from hydropower plants, 0.37% from wind plants, and 1.04% from solar plants. These relative shares of actual generation are based on the last five-year average reported in 2017.



Source: United States Energy Information Administration

Relative Shares of Power Generation Capacity by Source in Mauritius



Mauritius Electricity Market Composition in 2017		
Source	***Installed Capacity (MW)***	***% Share***
Fossil Fuels	750	79.7%
Hydropower	61	6.5%
Solar	29	3.1%
Wind	11	1.2%
Biomass and Waste	90	9.6%
Total	**941**	

References:

The statistical data and information summarized in this section are drawn from the following sources:

1. United States Energy Information Administration, Department of Energy. https://www.eia.gov/international/overview/country/MUS
2. The energy mix of Mauritius. GlobalPetrolPrices.com

https://www.globalpetrolprices.com/energy_mix.php?countryId=84

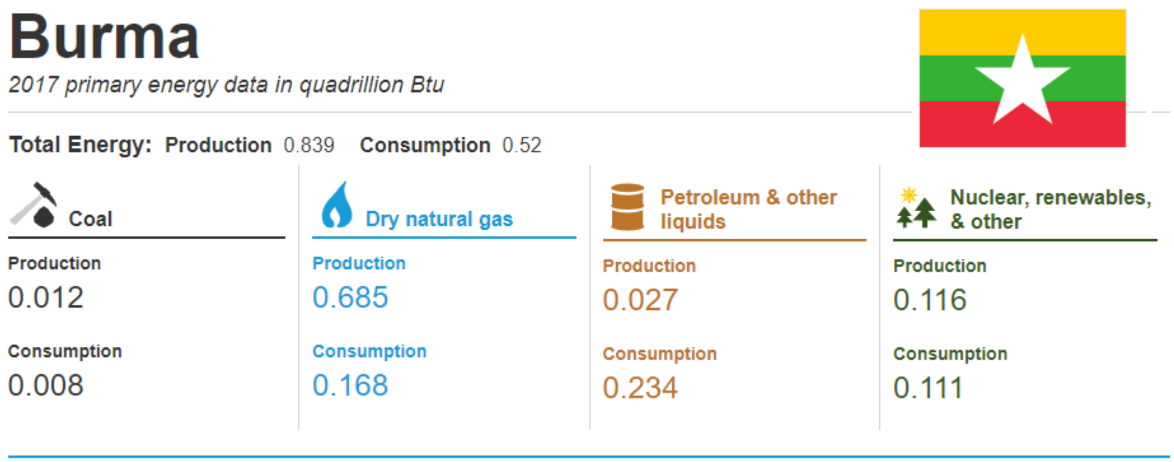
6. Summary of Energy Sector in Myanmar

With a population 54 million, Myanmar's (Burma) total primary energy consumption in 2017 was 0.52 quads (quadrillion BTU) as against the total domestic primary energy production of 0.84 quads. Myanmar is a net energy producer and endowed with natural energy resources, especially hydropower and biomass. Myanmar's per capita primary energy consumption is very low at 10.1 million BTU despite its resource potential, and energy intensity of economic output is 1.83 thousand BTU per US$ at purchasing power parity.

Myanmar has abundant energy resources, particularly hydropower and natural gas. Strategically located between Bangladesh, India, China, Laos, and Thailand, it has the advantage of exporting its energy resources to these countries. The energy sector accounts for a major share of its exports earnings (55%) and foreign investment (86%). Even though Myanmar was one of the earlier countries in Asia to have an oil and gas industry, which was developed by the British, no new oil reservoirs were discovered in the last 25 years. The country's energy sector remains underdeveloped due to a lack of financial and technical capacity, and international isolation it faced until the past 10 years. Traditional biomass (mainly firewood and agricultural wastes) is the most widely used primary energy resource of the rural population.

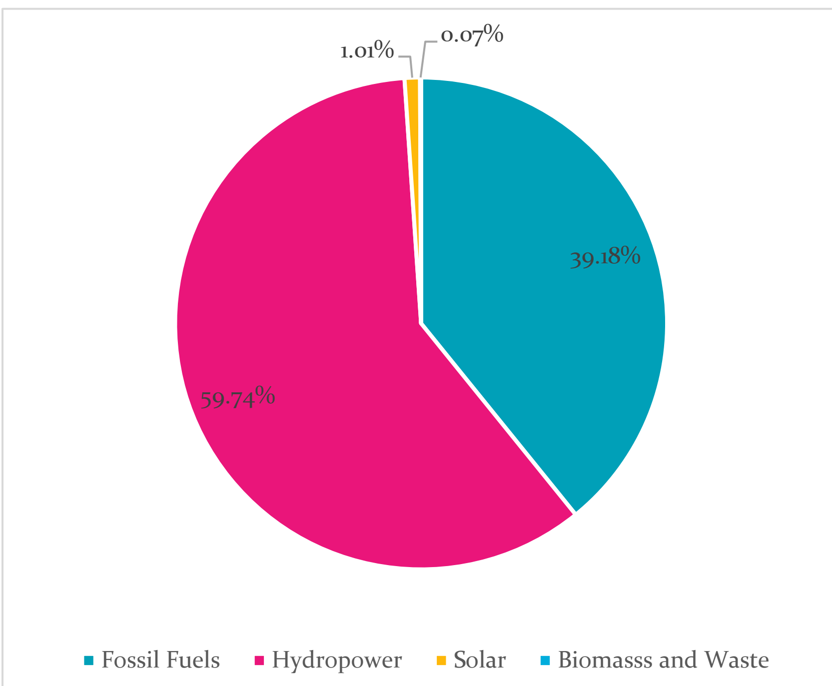
Myanmar exports a large fraction of the total primary energy produced. Most of the natural gas produced is exported and the remaining is left for use in the power sector. Myanmar has very large hydropower potential (estimated greater than 100,000 MW) that drains the four river basins of the Irawady, Chindwin, Thanlwin, and Sittaung. The government has identified potential projects that could exploit at least 50% of this potential but will take enormous financial and technical resources to develop. If developed it could export electricity easily to countries in South Asia and Southeast Asia.

The chart and table below show the country's electricity sector composition. Of the total installed capacity of 5449 MW, hydropower represents the largest share of installed capacity at 59.74%, followed by fossil fuels (natural gas) at 39.18%. Other sources such as solar and biomass waste account for just a little over 1%. The relative shares of electricity generation are almost same as the relative shares of installed capacity.



Source: United States Energy Information Administration

Relative Shares of Power Generation Capacity by Source in Myanmar



Myanmar Electricity Market Composition in 2018		
Source	***Installed Capacity (MW)***	***% Share***
Fossil Fuels	2135	39.18%
Hydropower	3255	59.74%
Solar	55	1.01%
Biomasss and Waste	4	0.07%
Total	**5449**	

References:

The statistical data and information summarized in this section are drawn from the following sources:

1. United States Energy Information Administration, Department of Energy. https://www.eia.gov/international/overview/country/MMR
2. Myanmar: Energy Sector Assessment, Strategy and Roadmap. Asian Development Bank Report. 2016 https://www.adb.org/sites/default/files/institutional-document/218286/mya-energy-sector-assessment.pdf
3. The energy mix of Burma (Myanmar). GlobalPetrolPrices.com https://www.globalpetrolprices.com/energy_mix.php?countryId=113

7. Summary of Energy Sector in Nepal

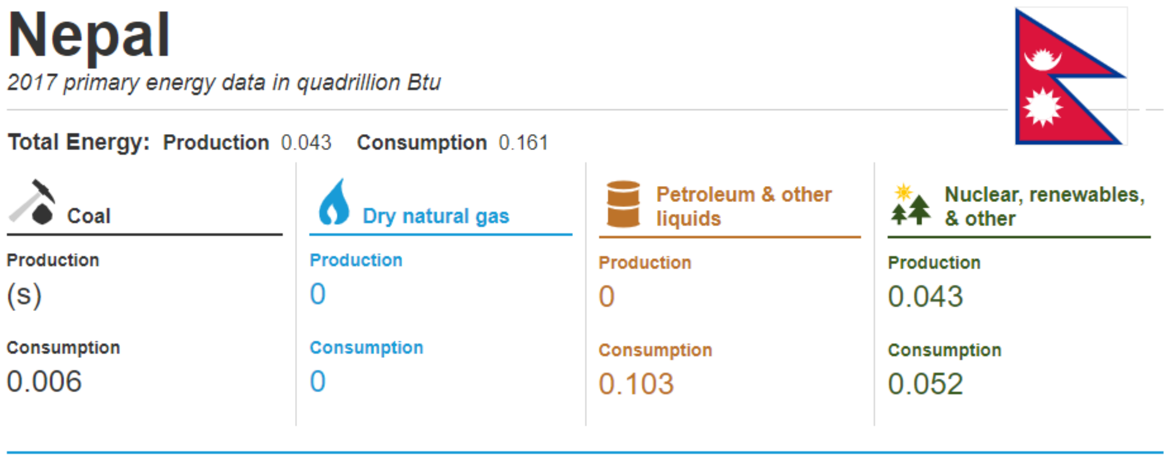
With a population of 28 million, Nepal's total primary energy consumption in 2017 was 0.16 quads (quadrillion BTU) as against the total domestic primary energy production of 0.04 quads. Nepal's per capita primary energy consumption is 5.83 million BTU, and energy intensity of economic output is 2 thousand BTU per US$ at purchasing power parity.

Hydropower plants account for 90% of Nepal's generating capacity, and nearly all of the electricity generated within the country. Currently, 940 MW out of 1046 MW of total installed capacity is hydropower. Still a majority (over 80%) of Nepal's population relies on traditional biomass and waste for cooking. Although Nepal has no fossil fuel deposits, its hydropower resources is estimated to be very large over 80 GW. However, the main constraint to fully tap this potential is due to Nepal's hydrology and geography. Most of the rainfall occurs during four months and so creating reservoirs to generate power during dry seasons is a major challenge. Commercial fuels such as coal and oil are imported from India and international markets which are again routed through India. Coal accounts for just two percent of the total primary energy consumption and used mainly by industries such as brick, lime and cement production.

Nepal's energy predicament is captured by its lowest per capita energy consumption in the South Asian region despite is high hydropower potential. There have been suggestions that Nepal should develop its large hydropower potential and export to India and earn revenue, while environmentalists caution the risks and impact of large hydropower development on Nepal's fragile ecology. A recent white paper by the government proposes to develop at least 15 GW of hydropower capacity for power production, irrigation and flood control.

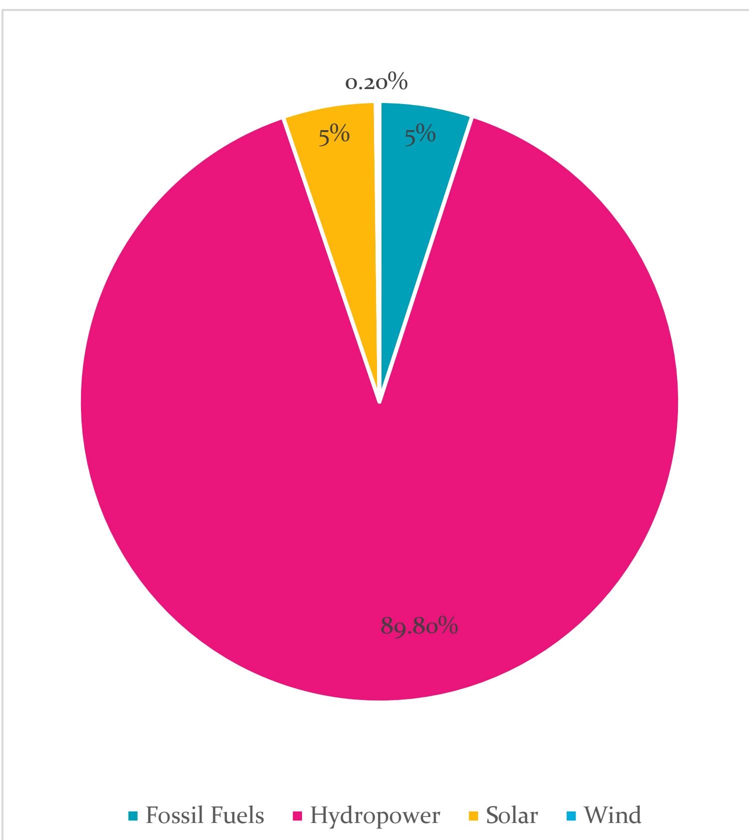
Currently over 90% of households in Nepal have access to electricity through grid, off-grid, and stand-alone solar power systems. Solar plants account for only 5% of total installed generation capacity, offering more scope for further expansion in capacity and generation. Nepal has traditionally suffered severe electricity shortages for extended hours (more than half of the day) during winter season when river flows are low. Following import from India with almost 18 hours of power cuts during the winter season when river flows are low. After importing power from India, this problem has reduced in urban areas and still leaving large parts of rural Nepal in dark and without power during winter.

Hydropower projects under construction could alleviate this problem because about 3 GW of capacity is expected to come online soon and position Nepal as a power surplus country. Political instability has long delayed Nepal's hydropower development and hurt its power sector. Nepal is also unwilling to give India access to tap its hydropower resources for mutual benefit like Bhutan.



Source: United States Energy Information Administration

Share of Electricity Generation Capacity by Source in Nepal



Nepal's Electricity Market Composition in 2017		
Source	***Installed Capacity (MW)***	***% Share***
Fossil Fuels	53	5%
Hydropower	940	89.80%
Solar	53	5%
Wind	0.1	0.20%
Total	1046	

References:

The statistical data and information summarized in this section are drawn from the following sources:

1. United States Energy Information Administration, Department of Energy. https://www.eia.gov/international/overview/country/NPL
2. Dipendra Bhattarai, Who will buy Nepal's hydropower? April 9, 2019 https://www.thethirdpole.net/2019/04/09/nepals-hydropower/

8. Status of Energy Systems in Pakistan

With a population of 217 million, Pakistan is the second most populous country of South Asia and is a major energy consumer in the region. Pakistan's total primary energy consumption in 2017 was 3.37 quads (quadrillion BTU) as against the total domestic primary energy production of 1.86 quads. Pakistan's per capita primary energy consumption is very low at 16.2 million BTU. Its energy intensity of economic output is 3.28 thousand BTU per US$ at purchasing power parity.

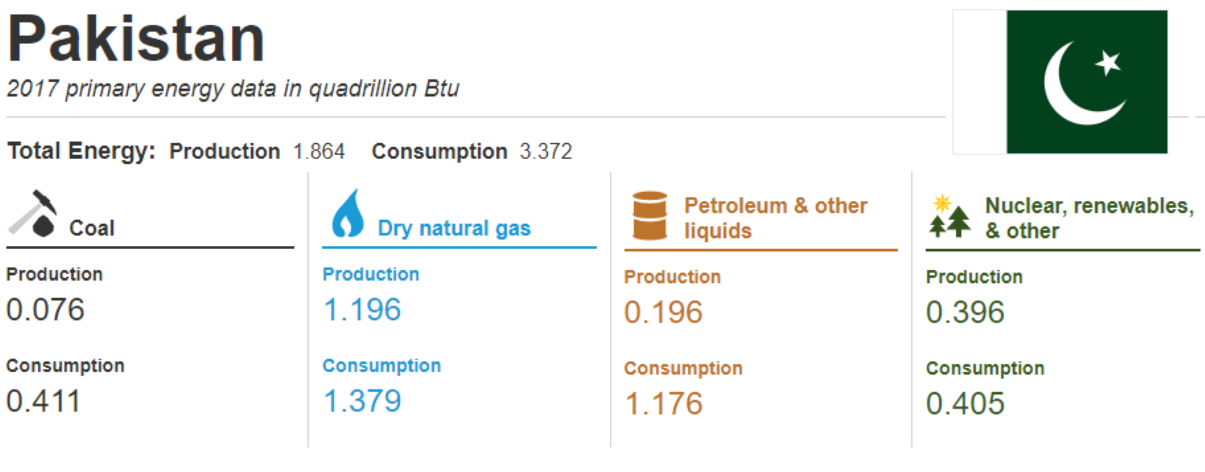
Pakistan's electricity sector has for long been characterized by inadequate generation to meet demand and relies heavily on imported oil and gas and hydropower. The energy crisis has also imposed a huge cost on Pakistan's economy dearly because shortages have forced shutdown of hundreds of small and medium scale industries.

More than 50% Pakistan's population live in rural areas and among them only half have access to electricity. More than 30% of primary energy consumption in Pakistan is from biomass and waste and about 60% of the population uses biomass for cooking. Pakistan is largely dependent on thermal power stations, currently contributing almost two thirds of installed capacity and 70% of electricity generation as shown in the figure and table below.

Older oil and diesel plants are being replaced by LNG and coal plants. Since the fuel is mostly imported power tariffs are subject to fluctuating fossil fuel prices. Pakistan has a small civilian nuclear power program and operates five small nuclear reactor units with a total capacity of 1.3 GW. Two additional reactors are under construction and expected to come line by 2021. In 2015 Pakistan and China signed the China-Pakistan Economic Corridor (CPEC) agreement, which is expected to address electricity deficit by adding 10 GW of generating capacity from coal and renewable energy plants.

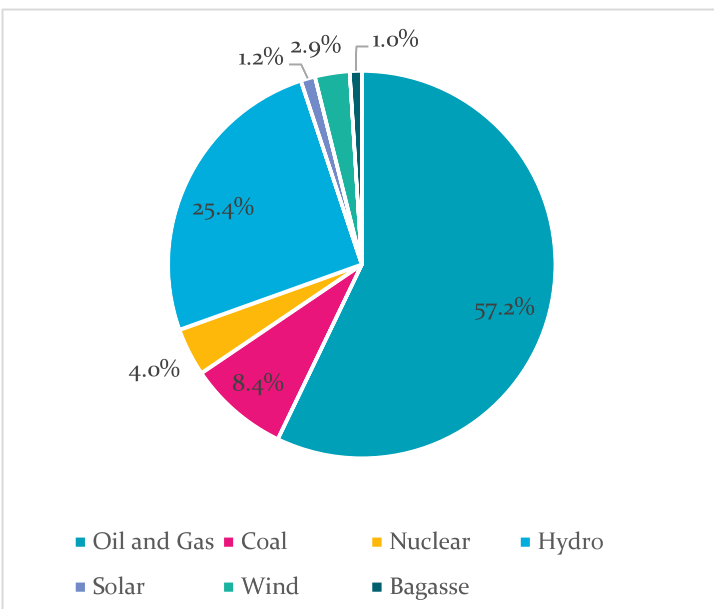
Despite having favorable geography for solar and wind power generation, Pakistan has lagged behind many countries in renewable energy development and has just 1.3 GW of installed solar and wind capacity. Coal generation and hydropower would free Pakistan from import dependence and enhance its energy security and reduce the pressures on its fragile economy. Pakistan has identified abundant coal deposits in all of its provinces with total estimated reserves of 180 billion tons but of very low quality. As a result, most of the coal consumed in Pakistan is imported. Development of coal mines and hydroelectric projects present other complications. Even though coal fields were identified, full scale development has been slow because of cost issues and the low quality of coal. Coal power plants and hydropower plants take a very long time to develop and are known for cost overruns and time delays. Pakistan has over 40 GW of untapped hydropower potential, most of which lies in the northern regions and subject to the future uncertainties of sharing excess river runoffs in the Himalayan region between India and Pakistan. Nuclear power projects in Pakistan have also suffered inordinate delays.

Given Pakistan’s need to expand generation quickly, renewable energy sources such as wind and solar are much suited to meet growing demand compared to power projects having long gestation period and prohibitive costs.



Source: United States Energy Information Administration

Share of Electricity Generation Capacity by Source in Pakistan



Pakistan's Electricity Market Composition in 2017-18

	Installed Capacity		Electricity Generation	
Source	***GW***	***% Share***	***TWh***	***% Share***
Oil and Gas	18.6	57.2	82.4	61
Coal	2.7	8.4	11.9	8.8
Nuclear	1.3	4	8.7	6.5
Hydro	8.2	25.4	28.2	20.9
Solar	0.4	1.2	0.7	0.5
Wind	0.9	2.9	2.1	1.5
Bagasse	0.3	1	1.1	0.8

References:

The statistical data and information summarized in this section are drawn from the following sources: here are drawn from the following resources:

1. United States Energy Information Administration, Department of Energy. https://www.eia.gov/international/analysis/country/PAK
2. Simon Nicholas and Tim Buckley. Pakistan's Power Future Renewable Energy Provides a More Diverse, Secure and Cost-Effective Alternative. December 2018 http://ieefa.org/wp-content/uploads/2018/11/Pakistans-Power-Future_December-2018.pdf

9. Summary of Energy Sector in Sri Lanka

With a population of 21 million, Sri Lanka's total primary energy consumption in 2017 was 0.38 quads (quadrillion BTU) as against the total domestic primary energy production of 0.04 quads. Sri Lanka's per capita primary energy consumption is 17.97 million BTU, and energy intensity of economic output is 1.4 thousand BTU per US$ at purchasing power parity.

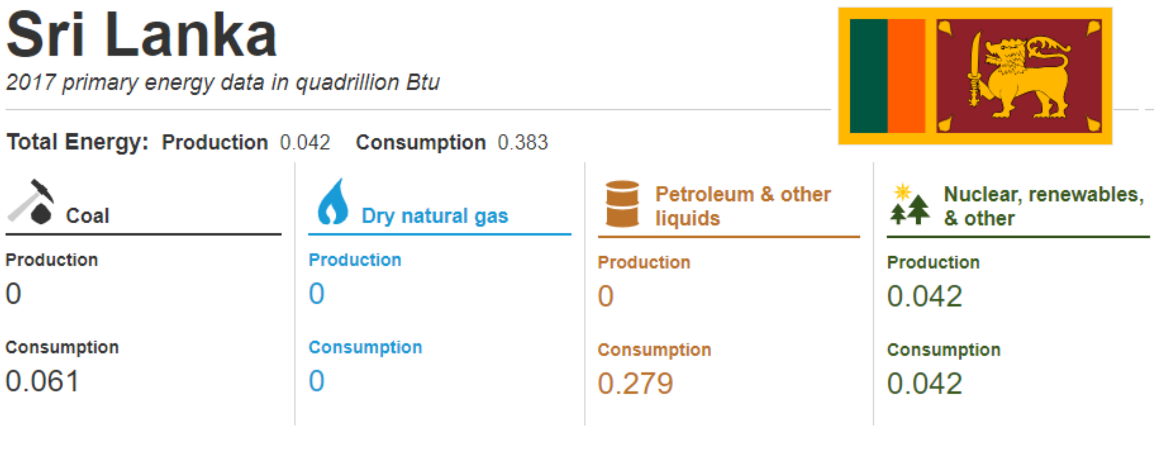
For many years, traditional biomass and petroleum provided the bulk of primary energy supply (over 90%) and the remaining came from hydropower. The use of other renewable energy resources in Sri Lanka is relatively small. Around 6 GW of solar capacity is technically feasible and 5.6 GW of wind generation potential can be tapped. However, only a little over 200 MW of solar and wind capacity has been developed so far. Coal use in electricity generation commenced recently. The 900 MW coal plants run on imported coal. Much of the country's hydropower potential has already been developed and about 250 MW capacity is under various stages of development.

Currently there is 4 GW of total installed electricity generation capacity, of which hydropower accounts for 44%, oil/diesel plants 28%, coal 22% and renewables 5%. The relative shares of total electricity generation are hydro 42%, coal 31%, oil/diesel 24%, and renewables 3% respectively. Despite its low generation capacity and import dependence, Sri Lanka has achieved greater success in addressing energy inequities and delivers almost universal access to modern energy services to its population.

Per capita electricity consumption in Sri Lanka was 626 kWh/person in 2017, significantly lower than many of the developing countries in South and Southeast Asia. However, Sri Lanka tops in human development achievement and has HDI scores comparable to many middle-income countries. The country's electricity sector currently faces some challenges due to shortage in capacity and delays in power projects and skewed power tariff structure that has resulted in financial crisis for power generators and distributors. Electricity demand is dominated by household (37%) and industrial (32%) consumers, and commercial sector demand (currently 29%) has been increasing rapidly.

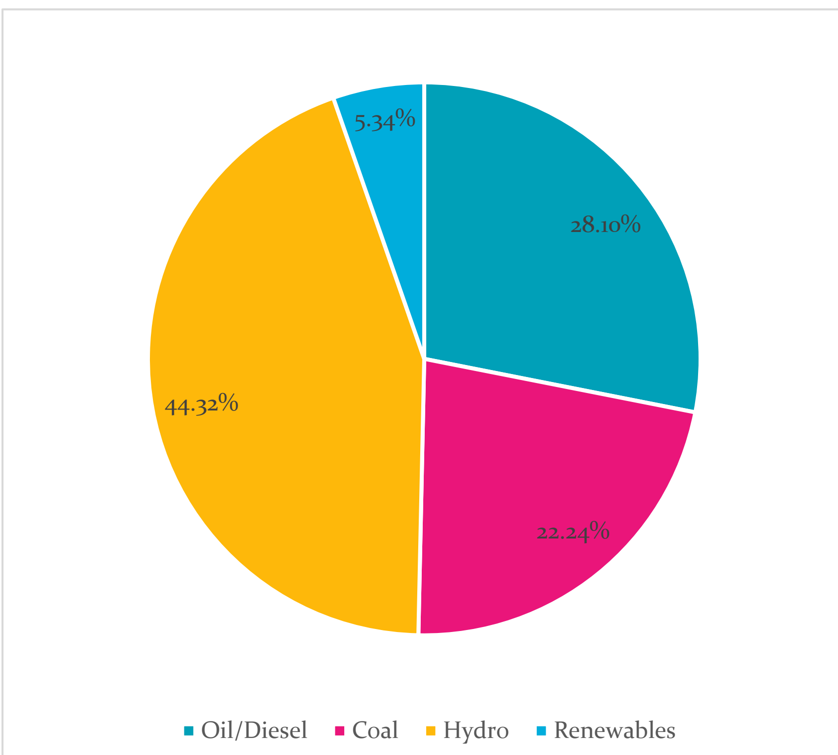
As Sri Lanka transitions to middle-income country, more investments are required for developing the power sector. While renewables dominated by hydropower accounts for 50% of the country's power system, lack of adequate base-load plants affect stability and reliability of the grid. The country's financial stress has delayed several power projects resulting in poor quality of supply for industrial and commercial users.

In 2014 the government conducted a feasibility for setting up LNG terminal for importing gas for manufacturing sector and transport. However, no further progress has been made to solicit bids for developing the infrastructure.



Source: United States Energy Information Administration

Share of Electricity Generation Capacity by Source in Sri Lanka



Sri Lanka's Electricity Market Composition in 2018

	Installed Capacity		Electricity Generation	
Source	***MW***	***% Share***	***GWh***	***% Share***
Oil/Diesel	1137	28.10%	3626	23.72%
Coal	900	22.24%	4764	31.17%
Hydro	1793	44.32%	6381	41.76%
Renewables	216	5.34%	511	3%
Total	**4046**		**15282**	

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The statistical data and information summarized in this section are drawn from the following sources:

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Tackling Water Insecurity in South Asia

A FUTURE EARTH WORKING DOCUMENT

September 2020

C: Tackling Water Insecurity in South Asia

Contents: Tackling Water Insecurity in South Asia

1. Water Security in Bangladesh

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SUMMARY

Almost 80 percent of the landmass of Bangladesh falls under the category of the deltaic floodplain which is built by three major rivers namely the Ganges (Padma), Brahmaputra (Jamuna), and Barak (Meghna). The cumulative average annual flow in the GBM is 981 km^3. Monsoon rains of the country on average provide 284 km^3 of water per year, 85 percent of which is received between May to October. Total usable groundwater is about 54 km^3 per year.

25 to 33 Km^3 of water in Bangladesh is used for agriculture with 80 percent of this is contributed by groundwater. Combined domestic and industrial demand is estimated at around 2.7 km3 per year, which is expected to increase by about 4.1 km3 by 2050.

When total available water resources are compared with the demand, it is seen that Bangladesh has an ample amount of water. According to the World Resources Institute's water stress index, Bangladesh is one of the least water-stressed countries in the world. A 2018 report by the FAO, reported only four percent of water stress for Bangladesh. However, due to the high spatial and temporal variability of the quantity and quality of the water available, it's accessibility has been a major challenge to the country. It is imperative to understand that various water stress indicators, while emphasizing on the quantum of available water and its use, often fail to address the issue of its accessibility. Contrary to this, water security having multiple socio-economic dimensions depicts the extent of sustainable access to adequate quantity and acceptable quality of water. Moreover, it also assesses the capacity of the population to ensure protection against various water-borne diseases and resilience to water-related disasters. Despite the fact that Bangladesh is one of the least water-stressed countries in the world, it is one of the most water insecure countries. According to the Asian Water Development Report, 2016, Bangladesh has been ranked among the countries with the lowest National Water Security Index in the Asia-Pacific region, other South Asian countries being India, Nepal, and Pakistan.

As a low lying deltaic country, with about 10% of the total landmass not more than a meter above the mean sea level, nearly a third of the country is susceptible to tidal inundation. Nearly 70% of the country is subjected to frequent inundation, seasonal floods, and flash floods and periodically is affected by cyclones and droughts. The unfavorable geography with high exposure to water-related disasters has contributed to water insecurity of the country.

Bangladesh is a country with a very high population density in the world. Lack of good disaster risk governance has left the country vulnerable, compromising its resilience towards climate change-induced disasters. According to the World Risk Report 2019, Bangladesh has been ranked 10th most disaster risk affected country in the world. The report assessed the extent of exposure to the disaster and the vulnerability of the country against it. This is in line with the

Germanwatch climate risk index 2020, where it has been ranked 7th most climate change affected country.

It is evident that marginalized communities of the country are highly vulnerable to disasters due to the lack of coping capability and government support. The most vulnerable regions to droughts and floods are in the coastal zone and in the central districts around Dhaka. However, the north-east districts and the Ganges corridor are also moderately vulnerable to water issues.

Over 93% of the catchment area of the rivers flowing in Bangladesh lies outside the country, indicating the importance of transboundary cooperation for the country's water security. As a lowermost riparian country in the GBM basin, transboundary water dispute with neighboring countries significantly hinders the country's development agenda.

Around 96 percent of the population has access to improved water supply, 90 percent of which is from groundwater. Only 10 percent of the population has access to a centralized piped water supply. There are serious concerns regarding water quality. Especially the presence of arsenic in the groundwater which is considered as a dreaded contaminant in the world. Only about 35 percent of the population has access to clean improved water sources with E.Coli count and Arsenic content. Despite various mitigation approaches, more than 40 million people are exposed to arsenic poisoning by water having more than 10 μg/L of arsenic. Other major contaminants of groundwater in Bangladesh are iron, manganese, and salinity, the latter especially in the coastal areas of the country due to seawater intrusion.

There is a rising concern of surface water pollution due to the discharge of untreated sewage and also wastewater from continuously expanding industrial establishments, especially the textile industries. Studies have shown that surface as well as groundwater is contaminated by pesticide chemicals from the agricultural fields.

In spite of the improvement in sanitation coverage, with about 63 percent of the population having access to improved sanitation and near-total elimination of open defecation, the country has still failed to achieve the Millennium Development Goal (MDG) in sanitation. This is mainly due to the fact that a large portion of the population is still using shared toilets that lack proper fecal sludge management facilities. Those who have little or unimproved WASH facilities are the bottom 40 percent on the economic ladder and those who live in remote and hard-to-reach villages, disaster-prone areas, and crowded urban slums. With only zero to two percent of fecal sludge being managed in some cities, fecal sludge management is virtually lacking in the country.

The poor sanitation status of the country has led to various water and vector-borne diseases like diarrhea, dengue, malaria, and chikungunya. Among which diarrhea poses a major threat to public health in the country with causing around 25,500 deaths in the year 2018 alone. Moreover, the number of diarrheal cases is projected to increase in the future with the increase in climate change effects.

It has been observed that it is marginalized people who get severely affected by water pollution. Their poor nutrition related to socio-economic status has made them more prone to Arsenicosis; especially, the poor undernourished women and children. Poor populations are also susceptible to climate change-induced extreme events such as flooding and droughts.

The institutional set-up for governing water in the country is mostly centralized and fragmented with unequal distribution of authority among various agencies. Contrary to this, the water issues in the country vary from region to region and are more local. For instance, coastal regions are prone to salinity, whereas the northeast and urban centers of the country are facing problems with the exploitation of arsenic-rich groundwater. Hence, there is a need for decentralization of power and the water projects should address the issues locally. Currently, Bangladesh has 39 organizations that are responsible for governing the water in the country, leading to enormous confusion and stress within the system. The overlapping of duties should be addressed for the efficient implementation of water projects in the country. Sustainability of groundwater use should be monitored at a regional scale due to varied groundwater properties. Because most of the sanitation systems are on-site, there is an urgent need for improvement of sanitation through proper fecal sludge management in the country.

Since climate change is one of the major drivers of water insecurity in the country, more emphasis should be given to the policies related to climate change mitigation and risk reduction. Having the projection of increasing trends in extreme events and sea-level rise in the future, it is crucial to have resilient water governance policies, especially with respect to water-related disasters. Poverty eradication through various economic development programs, especially in the rural areas of the country is necessary to reduce vulnerability to water-related issues. Keeping in mind the importance of river water sharing in the water-energy-food nexus, a sustainable approach for sharing the transboundary water resources at the river basin level needs emphasis.

1.1 DEMOGRAPHY

Bangladesh is a country with around 163 million people, living in less than 144,415 sq. km, making it one of the most densely populated countries in the world. It has an average annual population growth rate of 1% [1]. The population of the country is expected to reach 214 million by 2050[2]. With a net outflow of about 4.2 million people between the years 2010 and 2020, the country has one of the highest migrating populations in the world [3]. Out of the total population, nearly 55 percent of people are urban, while the other 45 percent is rural which mostly relies on agriculture for its sustenance [4]. According to the United Nations report, Bangladesh is expected to contribute more than 50 million people to the urban increment between 2018 and 2050[5]. The World Bank classifies Bangladesh as a lower-middle-income country with an average GDP growth rate of 8.1 percent for the year 2019. The country has done well in achieving the Millennium Development Goals (MDG) with respect to reducing poverty and closing the poverty gap ratio, increasing access to improved water supply, lowering the infant mortality rate, and reducing the incidence of communicable diseases. The national poverty rate of the country has nearly been halved from 48 percent in the year 2000 to 24 percent in 2016 [6] [7] which in turn reduced to 21.8 percent in 2018[8]. With a rapidly growing economy in recent years, agriculture still dominates employment, with more than 70% of the population involved directly or indirectly in agricultural activities [9]. However, agricultural contribution to the GDP of the country has been low at 15% of the total in the year 2015[10].In this context, the manufacturing sector is the largest single contributor with a 17% contribution to the GDP in the same year. Despite these development achievements, it is still one of the poorest countries in the world. The highest unemployment among the youth, rapid urbanization leading to large informal settlements, one of the highest under-nutrition rates among children is some of the major concerns for the country [11]. Poverty in rural areas is more prominent and extreme as compared to urban areas [12].

1.1.a Topography, and Geology and Climate

Bangladesh is a low lying plain country. Almost 80 percent of its land falls under the category of deltaic floodplain built by three major rivers namely the Ganges (Padma), Brahmaputra (Jamuna), and Barak (Meghna) [13]. The country is bordered by India on the west, north, and northeast, Myanmar on the southeast, and the Bay of Bengal on the south (See Fig.1) [14]. With over 200 rivers that form a complex and ever-changing pattern, Bangladesh has almost seven percent of the total area that consists of rivers and other water bodies [15][16]. Bangladesh has a tropical monsoon climate characterized by high temperatures, heavy rainfall, and high humidity. Climatic conditions are mainly of three seasons; a cool dry season from November through February, the pre-monsoon hot season from March through May, and the rainy monsoon season which lasts from June through October[17]. The geology of the country is dominated by poorly consolidated sediment deposited during the past 10,000 to 15,000 years in the Holocene [18].

1.2 WATER RESOURCE AVAILABILITY

According to the World Resources Institute water stress index, Bangladesh is projected to be one of the least water-stressed countries in the world in 2040 for business as usual scenario, ranking 139 out of a total of 161 countries (See Fig.2) [19]. Similarly, a 2018 report by The Food and Agriculture Organization of the United Nations, indicated that the country has an abundance of water availability with only four percent of water stress (See Fig.3) [20]. However, due to the high spatial and temporal variability of the quantity and quality of available water, its accessibility has been a major challenge for the country. It is imperative to understand that various water stress indices, while emphasizing on the quantum of available water and its use, often fail to address the issue of its accessibility. Contrary to this, water security having multiple socio-economic dimensions depicts the extent of sustainable access to adequate quantity and acceptable quality of water (See Fig.4) [21]. Moreover, it also assesses the capacity of the population to ensure protection against various water-borne diseases and resilience to water-related disasters. Despite the fact that Bangladesh is one of the least water-stressed countries in the world, it is one of the most water insecure. According to Asian Water Development Report, 2016, Bangladesh has been ranked as one of the lowest in the Nation Water Security Index in the Asia-Pacific region along with other low scorers in south Asian countries like India, Nepal, and Pakistan (See Fig.5) [22].

1.2.A Rainfall

The mean annual rainfall of Bangladesh varies between 1270 mm and 1520 mm with almost 85 percent of it occurring in the wet season from June to September[23]. However, a study by Shahid (2010) using the rainfall data from 1958 to 2007 showed the average annual rainfall to be 2488 mm[24]. In terms of volume, annual rainfall availability is 284 km3 between 1985 to 2010 out of which 254 km3 on average was observed from May to October and 30 km3 from November to April[25]. With high spatial variability, the mean annual rainfall can vary from 1400 mm in the western part to almost 4300 mm in the eastern part of the country[26]. However, the mean annual rainfall of the Himalayan region, which is a source of major rivers of the country is about 10,000 mm.

The study on the spatio-temporal variation of rainfall from 1969 to 2003 showed that the amount of rainfall in the central region has decreased with time. However, in the north and in the coastal part of the country, an increasing trend has been observed. In most of the regions of Bangladesh precipitation is about three times the evapotranspiration in the wet season. More than two-thirds of the excess rain becomes runoff and eventually gets discharged to the sea.

1.2.B Surface Water

As the lowest riparian country of three major basins, the Ganges basin, the Brahmaputra basin, and the Meghna basin, out of the total flow of rivers, almost 93 percent originates outside the country. However, the variation in river flow due to anthropogenic diversion upstream or due to natural factors such as rainfall variability leads to water insecurity in the country. Surface water use in Bangladesh is limited due to high fluctuations in terms of both quantity and quality[27]. The total volume of water through transboundary sharing which enters the country is about 1260 Km^3 [28]. The average flow during dry seasons is 148 Km^3, of which 111 km3 is provided by the river Brahmaputra. Apart from a small volume of river water use of perhaps 6 km3 annually (mostly in the dry season), 1373 Km^3 of combined inflows and runoff get discharged to the sea. The total length of water bodies including rivers, streams, and canals is about 24000 Km. The total dam storage capacity was calculated at about 6.5 billion cubic meters in 2013, which is only 0.4 percent of the total annual surface water flow[29]. The surface water resources of the country also include lakes, beels, and haors which together occupy a total area of 12,082 square kilometers[30]. Despite the availability of surface water in abundance, there are several limitations with respect to its accessibility. Among them, non-availability due to seasonal variations is a major concern. Also, financial and technical feasibility is much lower than that of groundwater based systems. Similarly, for coastal regions of the country salinity is a major concern, while industrial pollution in and around the large cities also leads to hindrance in surface water use. Moreover, in rural areas, ponds are mostly polluted by activities such as fish farming and dumping of untreated wastewater[31].

1.2.C Groundwater

Groundwater from Quaternary (Pleistocene and Holocene) sediments is the principal source of water for domestic, industrial, and irrigation use in Bangladesh. The average annual recharge of groundwater through rainfall varies from 28 km3 to 65 km3[32] Since a major part of the country lies in a flood plain, recharge through surface water and rainfall leads to the abundant availability of groundwater. In most of the places, groundwater can be found within a few meters below the ground surface. Groundwater accounts for over 90 percent of the drinking water supply in the country. However, due to the arsenic contamination of groundwater in Bangladesh, its accessibility has become a major concern (See Fig.6). Shallow alluvial aquifers are recharged through rainfall and flooding, and replenished almost everywhere each year, except in areas like Dhaka and Barind, where continuously increasing abstraction is leading to groundwater depletion[33]. The water table falls below a critical threshold of about 8 m particularly at the end of the dry season which leaves regular suction and hand pumps inoperative[34].

1.3 WATER DEMAND

Water use in Bangladesh is dominated by irrigation water demand with estimated annual use varying from 25 to 33 km3[35]. Around 80% of the irrigation water demand is fulfilled by groundwater[36]. Cumulative demand for domestic and industrial use is estimated at about 2.7 km3 per year, which is expected to increase to about 4.1 km3 by 2050. The Food and Agriculture Organization of the United nations estimated that in 2008 the total water withdrawal in Bangladesh was about 36 km^3, of which 31.5 km^3 was for irrigation and 3.6 km^3 for domestic water use, and 0.8 km^3 for industry. Out of which 79 % was sourced from groundwater and 21 % from surface water.

1.3.a Surface Water Use

The surface water use in the urban areas is minimal with around 0.13 km^3 per year of consumption in the largest city of the country, Dhaka. The main consumptive use of surface water is for irrigation with about 6.2 km^3 of surface water used each year for irrigation. Regionally, the surface water use is limited in the north-west region, with the north central, north-east and south-east regions each consuming a little over 1 km^3. The south-west region has the highest consumption of about 2.5 km^3 per year[37]

1.3.b Groundwater Use

The major portion of groundwater in Bangladesh is used for irrigation. In the north-west region of the country, about 95 % of irrigation water comes from groundwater, mainly from shallow tube wells. Groundwater use for dry season irrigation has majorly helped in achieving food security in the country. The most intensive use of groundwater is in the north-west region of the country with over 97% of the area being irrigated by groundwater. The volume of total groundwater use for irrigation has been estimated at about 25 km3. Urban groundwater use is modest, with Dhaka using about 0.62 km3 per year [38].

1.4 TRANSBOUNDARY WATER SHARING

As 93 percent of surface water originates outside the country, transboundary water sharing plays a crucial role in managing the water-food-energy nexus in Bangladesh. River water availability of Bangladesh is often compromised and controlled by upstream countries due to its geographical location. Transboundary co-operation has been crucial for Bangladesh to manage the physical impacts of the river like riverbank erosion, annual flooding, sedimentation, and diminished water flow in the dry season. Bangladesh and India share fifty-four rivers. Agreement has been reached only on the sharing of waters of the river Ganga[39][40]. There have been concerns regarding management, allocation, and equitable sharing of the river flows. The construction of the Farakka Barrage and Teesta Barrage on the Indian side has been a source of conflict between these two neighboring countries. There have been various studies that have indicated inequitable access to the Ganges water[41],[42],[43]. For resolving the water dispute, the

Ganges Water Treaty was signed on 12th December 1996 between the two countries. However, the treaty has not been proved to be satisfactory in resolving the dispute[44].

There is a lack of agreement between India and Bangladesh over the waters sharing of the Teesta river. More than 90% of flow in the Teesta river occurs in the monsoon season while the rest occurs in the remaining eight months. As a lower riparian country, Bangladesh is completely dependent on India, the upper riparian, for keeping minimum flows in the Teesta River. India has been unilaterally constructing a series of dams[45] up north which have reduced the river's flows to as little as 14 m3/s during times of drought, greatly hurting the livelihoods of thousands of farmers, fishermen, and boatmen in Bangladesh[46],[47]. Conversely, during monsoon season, excess water is released by India, which causes heavy floods again disrupting the livelihoods of thousands of Bangladeshis[48].

1.5 ORGANIZATIONAL STRUCTURE FOR WATER GOVERNANCE

There are altogether 30 ministries with 39 departments that are responsible for water governance in the country[49],[50]. Water policy formulation in Bangladesh is by the National Water Resources Council, which coordinates different water agencies and makes recommendations on all water policy issues to the cabinet. Water Resources Planning Organization is the principal agency of the Government of Bangladesh under the Ministry of Water Resources that ensures coordination of all relevant ministries through the NWRC. It also has the mandate to plan various water resource developments including major and minor irrigation, navigation, fisheries, and domestic water supply. Bangladesh Water Development Board (BWDB) is responsible for the planning and execution of various water development projects, ranging from flood control, drainage, and irrigation, coastal protection and erosion control. The small scale projects are implemented mainly by LGED which functions under the Ministry of Local Government and Rural Development, and the large-scale projects are implemented exclusively by BWDB[51]. The Department of Public Health Engineering (DPHE) is responsible for the execution of rural and urban water supply projects. It also handles projects related to arsenic mitigation and planning[52]. Overlapping of duties and responsibilities within various agencies have affected the efficiency of various water supply projects. For instance, Both DPHE and LGED are responsible for implementing water infrastructure developments, especially in rural areas. There is also a lack of decentralization of administrative and financial authority in the sector mainly from the Local Government Departments to various Local Government Institutions [53] [54].

1.5.a Agencies And NGOs Involved In Water Resources Development

Some of the key agencies that are assisting the development of water supply and sanitation(WSS) projects in the country are the Asian Development Bank (ADB), World Bank, United Nations Development Program(UNDP) Global Water Partnership (GWP), International Fund for Agricultural Development (IFAD), Bangladesh Agricultural Research Council (BARC), The Japan Bank for International Cooperation(JBIC), Swiss Agency for Development Cooperation (SDC), the Government of Japan, the Danish International Development Assistance (DANIDA), the Government of Korea, a Chinese firm, Changjiang Survey, Planning, Design and Research (CSPDR), South Asia Urban Knowledge HubDSK and ITNBUET [55] [56].

Various Private initiatives have also been involved in water resources development of the country. Among them are Bangladesh: Water PaCT: Partnership for Cleaner Technology by International Finance Corporation (IFC), (Bangladesh Water PACT), Dutch delegation to Dhaka Chamber of Commerce and Industry (DCCI), DFID and the Forum for the Future, The World Wide Fund for Nature (WWF),

1.6 POLICY FRAMEWORKS AND THEIR LIMITATIONS:

The National Water Policy formulated in 1999, has guidelines for governing water in agriculture, fisheries, industry, navigation, and the environment. It also has a guideline for basin-wide planning, water rights and allocations, public and private investment, water supply, and sanitation projects[57]. However, the most recent and important water policy which has absorbed content and superseded all the other previous policies is the 2013 Water Act[58]. There are also a number of additional policies that overlap and connect to the present Water Act; the Disaster Management Act 2012, Integrated Small-Scale Irrigation Policy 2011, Coastal Development Strategy 2006, the Coastal Zone Policy 2005, National Policy for Safe Water Supply & Sanitation 1998, Environment Conservation Act 1995, National Forest Policy 1994, Groundwater Management Ordinance 1985 and the Forest Act 1927[59] The discovery of high arsenic concentration in groundwater, led to the formation of two arsenic mitigation policies, namely the "National Policy for Arsenic Mitigation, 2004" and Implementation Plan for Arsenic Mitigation in Bangladesh (IPAM) 2004 [60] [61]. Despite the existence of national policies on both water resources and on safe water and sanitation, there is a lack of integrated strategy for groundwater management in the country[62].

1.7 STATUS OF WASH

1.7.a Water Supply

In a recent improvement, about 96 percent of the total population of the country has access to technically improved water sources[63]. About 90 percent of the population currently uses varieties of tube wells for its water needs [64]. However, access to improved water sources does not imply that the country has access to clean water. Only about 52 percent of the population has access to a clean improved water source with respect to E.Coli and Arsenic contamination[65]. The use of poorly regulated tubewells often leads to the consumption of contaminated water with either fecal bacteria, arsenic, salinity, or other contaminants. Natural disasters like cyclones and floods often make water supply inaccessible by disabling tubewells that are the primary source of safe drinking water. During the dry season, groundwater is over exploited and tube wells often become nonfunctional in some areas [66]. A centralized urban water supply, presumed to be the safest among other sources, has been found to be contaminated with E.Coli more than 80 percent of the time[67].

Only 10 percent of the population has access to centralized piped water supply, out of which 7.1 percent has access to it within their home periphery. Piped water supply is mostly in the urban area with coverage of 22 percent of the total area. However, rural areas are majorly deprived of the service with coverage of only about 2 percent[68]. Cities which have their own Water Supply and Sewerage Authorities (WASAs) like Dhaka, Chittagong, Rajshahi, and Khulna usually enjoy the piped water supply. In most small towns, operation and maintenance of the water supply system is handed over to the Pourashavas. The Pourashavas have the option to allow private companies to operate and maintain the water supply system. Out of 329 pourashavas, only 151 have piped water systems that too only in core areas[69]. The average amount of water supplied is about 75 liters per capita per day with supply hours varying from 2 to 12 hours per day. Water supply service is the responsibility of local government institutions that are financed and constructed by DPHE and LGED[70].

1.7.b Water Quality

There is a serious concern of water quality issues in the country, especially the presence of arsenic in groundwater which has been considered as one of the world's largest poisoning contaminants. Despite various mitigation approaches, more than 40 million are known to be exposed to arsenic contamination in the endemic areas.[72]. A survey in 2012 by the Directorate General of Health Services identified about 65, 910 arsenicosis patients in the country [73]. Apart from arsenic, the concentration of iron and manganese in the groundwater of Bangladesh has been found to be in excess from the permissible limits as given by WHO standards. In a quality assessment report by JICA, it was found that 60 percent of the groundwater samples at the depth of 50 meters exceeded the permissible limit of 1 mg/l for Iron. For the same depth around 64 percent of the total samples exceeded the permissible limit for manganese[74]. An assessment by DPHE at five municipalities in Bangladesh revealed high Iron and manganese concentrations at various locations ranging up to 14mg/l and 6.98 mg/l respectively[75],[76].

In recent years, Industrial wastewater discharge has become a rising concern for surface water quality in Bangladesh. Most of the industrial units are not well equipped with wastewater treatment plants. For instance, in a study, it was found that, out of 61% of textile units equipped with ETPs, only 29% were compliant and around 51% of them had been either poorly designed or operated effluent treatment plants[77].Various studies have shown the presence of pesticide contamination in the surface and groundwater which is mainly attributed to agricultural runoff[78].

1.7.c Sanitation and Hygiene

Despite the improvement in sanitation coverage with about 63 percent of the population having access to improved sanitation and almost eliminating open defecation, the country still has failed to achieve the Millennium Development Goal (MDG) in sanitation. This is mainly due to the fact that a large portion of the population is still using shared toilets that most likely lack proper faecal sludge management systems. The population which has access to little or unimproved WASH systems is in the bottom 40 percent of the economic status, including those living in remote and hard-to-reach villages, disaster-prone areas, and crowded urban slums[79]. Only 28 percent of the population has access to a designated place for handwashing with both water and soap. About 48 percent of urban residents have a handwashing station with water and soap, as against 21 percent in villages[80]. About 60 percent of children aged two years or below life in households that practice unsafe child faeces disposal. It is surprising that unscientific child faeces disposal is more in urban areas (60%) than in rural areas (33%) [81].

According to the Multiple Index Cluster Survey (MICS) carried out by WHO and UNICEF, in 2011 about one-quarter of pit latrines were covered only by a slab, without a water seal, flap, or lid. These latrines are not able to block disease transmission routes[82]. Moreover, one-third of the households share latrines. In the urban context, currently, there is only one centralized sewage treatment plant in Dhaka with a treatment capacity of 120,000 m3 /day. The treatment plant has 49,000 domestic sewer connections with a total length of 778 km of sewer lines[83]. Fecal sludge management is most likely lacking in the country, with only two to zero percent of fecal sludge being managed in some cities[84]. Moreover, about 74 percent of rural on site sanitation facilities have never been emptied and have been counted as safely managed[85]. Disposal of faecal sludge in low-lying areas and in the lakes and canals within urban areas is common, which is causing serious environmental degradation and endangering the public health[86].

It has been observed that it is the marginalized people who get severely affected by the water-related diseases in the country. For instance, a population with poor socio-economic conditions are more prone to Arsenicosis[87]. Specifically, it is the poor undernourished women and children who are the most vulnerable[88]. They are also more susceptible to climate change induced extreme events such as flooding and droughts.

1.8 WATER-RELATED DISASTERS: DROUGHTS, FLOODS AND TIDAL CYCLONES

According to the World Risk Report 2019, Bangladesh has been ranked 10th most disaster risk affected country in the world (See Fig.7) [89]. Bangladesh is severely prone to flooding; Coastal flooding as well as the bursting of riverbanks is common and severely affects the landscape of the country. 75% of Bangladesh is less than 10m above sea level and 80% is flood plain, rendering Bangladesh as a nation very much at risk of further widespread damage (See Fig.8). Flooding normally occurs during the monsoon season between June and September during the monsoon. The convectional rainfall of the monsoon is added to by relief rainfall caused by the Himalayas. Melt-water from the Himalayas also constitutes a significant input for the flood every year[90]. Bangladesh experiences floods in some parts or the other every year. In the wet season on average, more than 20 % of the country is flooded annually. Flash floods due to intense rainfall have been observed frequently along the central north and north-east hilly regions of the country. Severe flooding incidents occur when the rivers particularly have high flows and the peak flows of the different rivers coincide. The peak flow of the Brahmaputra has been observed a month earlier than that of Ganges. [91]. Cyclones originating in Bay of Bengal which is one the world's most active areas for cyclone development often leads to coastal flooding causing serious damage to public health and property.

Along with flooding, the country is also prone to droughts, mainly due to increase in evapotranspiration with respect to rainfall. A study by Shahid and Behrawan (2008) argues that economic losses from drought due to losses in agricultural production may be greater than that from the floods. For instance, the drought of 1994-5 resulted in a decline in rice and wheat production of about 3.5 million tonnes (of a total production approaching 20 million tonnes) and importation of a large amount of grain. It is evident that marginalized communities of the country are highly vulnerable to the country's disasters due to the lack of coping mechanisms and government support. The most vulnerable regions to droughts and floods are in the coastal area and the central districts around Dhaka.

1.9 CLIMATE CHANGE EFFECTS ON WATER RESOURCES

According to the Germanwatch Climate Change Risk Index 2020, Bangladesh is the 7th most-affected country from climate change from 1999-2018 (See Fig.9)[92]. Due to its high exposure to disasters and its susceptible population and weak institutional capacity to address the problem, it has been ranked the most vulnerable country to climate change effects[93].

Mean annual temperatures in the country are expected to increase by 1.8°C by the 2060s and 2.7°C by the 2090s as compared to the year 2010. However, some projections suggest increases up to 4.1°C for the 90s as compared to the 1970-2000 mean. The largest increase is projected for the dry winter season, where a temperature increase of 4.1°C may occur by the 2070s. The mean annual rainfall is projected to increase on average by 7% in the 2090s as compared to the 1970-2000. Regionally, the increase is expected to be higher in the north northwest, and the south of the country. The IPCC has projected an increase of 14 cm by 2030, 32 cm by 2050, and 88 cm by 2100 as compared to the year 2000.

Simultaneous submergence of low coastal areas will lead to higher relative sea level rise as compared to many other countries. By 2050, about 27 million people in the country will be at risk due to the effects of sea-level rise. It has been estimated that a 1-meter sea-level rise would inundate 18% of the country's land. Moreover, cyclone-induced storm surges are projected to inundate an additional 15% of the coastal area.

There is an estimation of higher irrigation water requirement due to increase in evapo-transpiration which may increase by 10-20% by 2030. An increase in temperature will also lead to. glacial melt in the Himalayas, which in combination with increased monsoon rainfall in the GBM Basin (up to+20%) will lead to higher quantities of river discharge Median summer discharges of the three rivers is expected to increase by 6-18% by 2050 and up to 50% by the 2070s which will lead to more flooding incidents. Both coastal flooding and inland flooding is expected to increase. [94] The increase of soil salinity due to sea-level rise is expected to vary from 26% up to 55% in most affected areas, by 2050[95].

1.10 RECENT GOVERNMENT DEVELOPMENT IN WATER RESOURCE DEVELOPMENT

According to the Sector Development Plan 2011-2025, the Government of Bangladesh has plans to invest USD 20.9 billion for drinking water, sanitation, and drainage.

The draft of the Bangladesh Delta Plan 2100 was approved by the National Economic Council in the year 2018. The plan has been enacted to ensure long term water and food security, economic growth, and environmental sustainability while effectively reducing vulnerability to natural disasters and building resilience to climate change[97]. A total of 80 major project proposals have been selected for implementation. Among these, 65 projects are related to infrastructure development, while the rest is institutional capacity development and research.

“Groundwater Management in Agricultural Activities Bill, 2018”, passed by the parliament empowers an Upazila Parishad to form and supervise an Upazila Irrigation Committee (UIC). The committee has the responsibility to conduct field research and provide licenses among the interested and qualified farmers in exchange for a fee. According to the law, any unlicensed user of groundwater will be fined up to BDT 10,000 (approx. USD 117) with a provision of seven days of imprisonment[98].

Regarding the issue of faecal sludge management, the Institutional and Regulatory Framework for FSM (IRF-FSM) was published and disseminated by the Local Government Division (LGD) under the Ministry of Local Government, Rural Development and Cooperatives (MoLGRD&C) in 2017.

1.11 SUGGESTIONS

Decentralization of authority within various water institutions is crucial, for efficient water management. Interaction between various stakeholders will be crucial for implementing Integrated Water Resource Management (IWRM) in Bangladesh. The overlapping of duties within government institutions should be addressed for the efficient execution of water-related projects in the country. The sustainability of groundwater use should be monitored at a regional scale because of varied groundwater properties. There is also an urgent need to focus on sanitation improvement through proper fecal sludge management in the country since most of the sanitation systems are on-site. Climate change is one of the major drivers of water insecurity in the country therefore more emphasis on policies related to climate change mitigation and risk reduction should be given. Having the projection of increasing trends in extreme events and sea-level rise in the future, it is crucial to have a resilient water governance policy especially with respect to water-related disasters. Poverty eradication through various economic developments especially in the rural areas of the country is recommended for reducing the water vulnerability[99]. Sustainable approach to transboundary water sharing at basin level should be emphasized keeping in mind the importance of river water sharing in the water-energy-food nexus.

Fig.1. Map of Bangladesh (Source: https://geology.com/world/bangladesh-satellite-image.shtml)

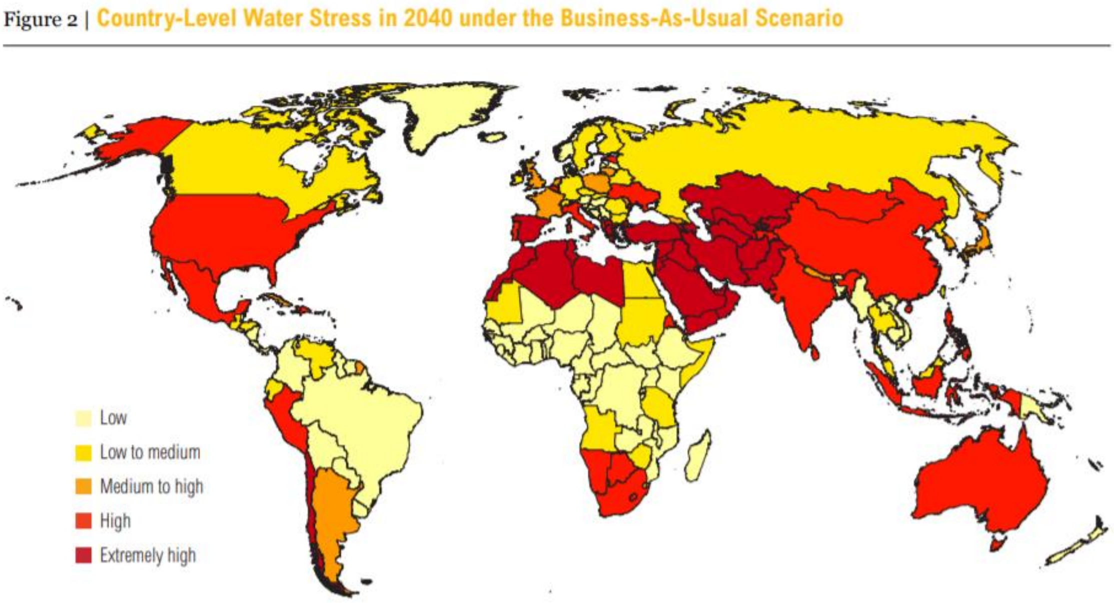

Fig.2. Projected Water Stress Level in 2040 (Source: WRI)

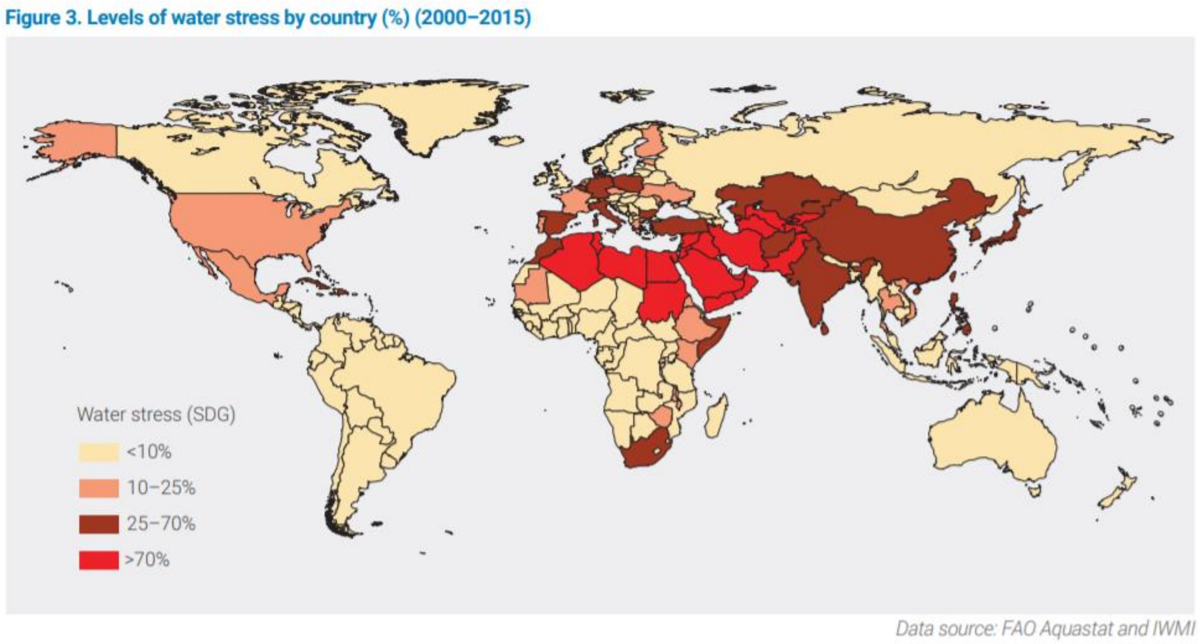

Fig.3. Percentage of Water Stress(2000-20150 (Source: FAO)

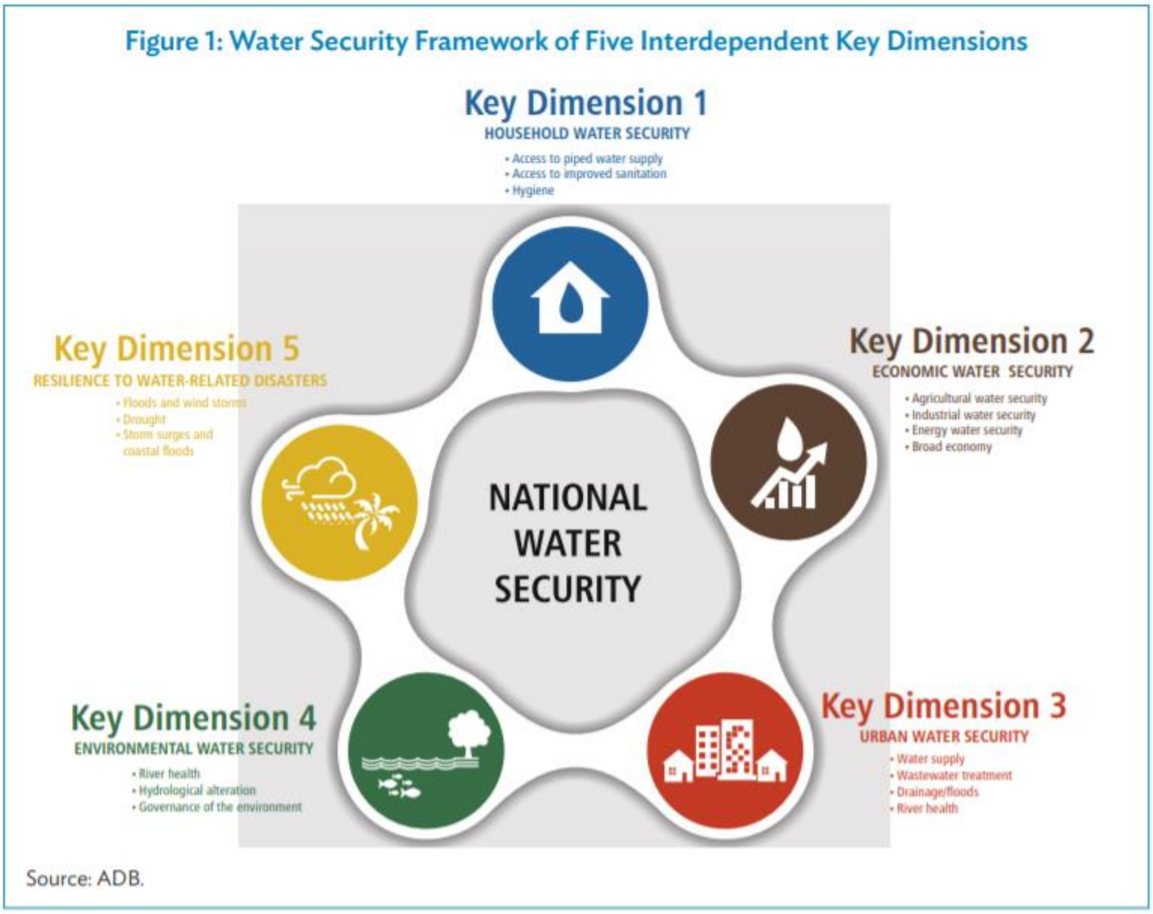

Fig.4. Key Dimensions of Water Security (Source: ADB)

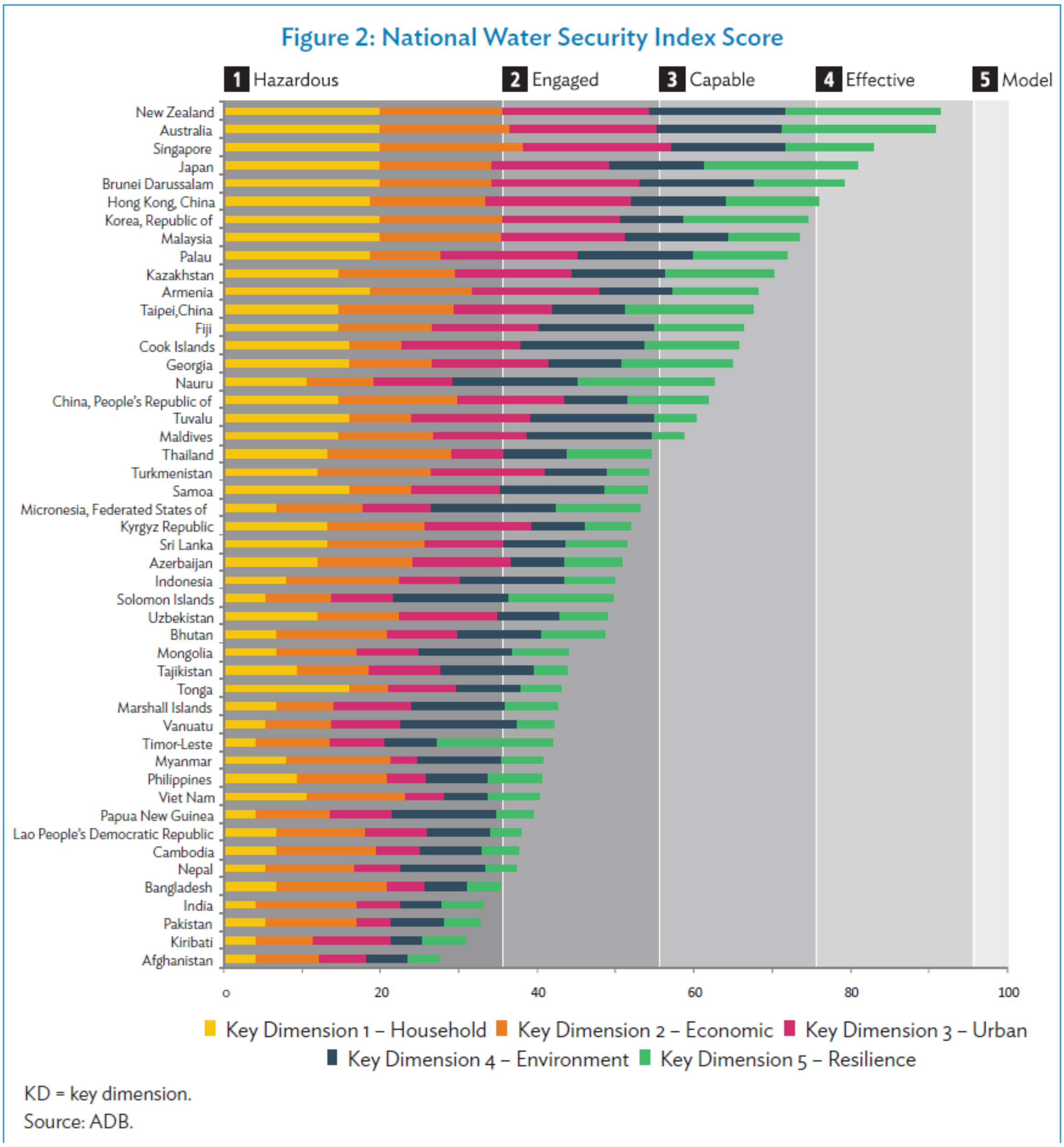

Fig.5. National Water Security Index, 2016 (Source: ADB)

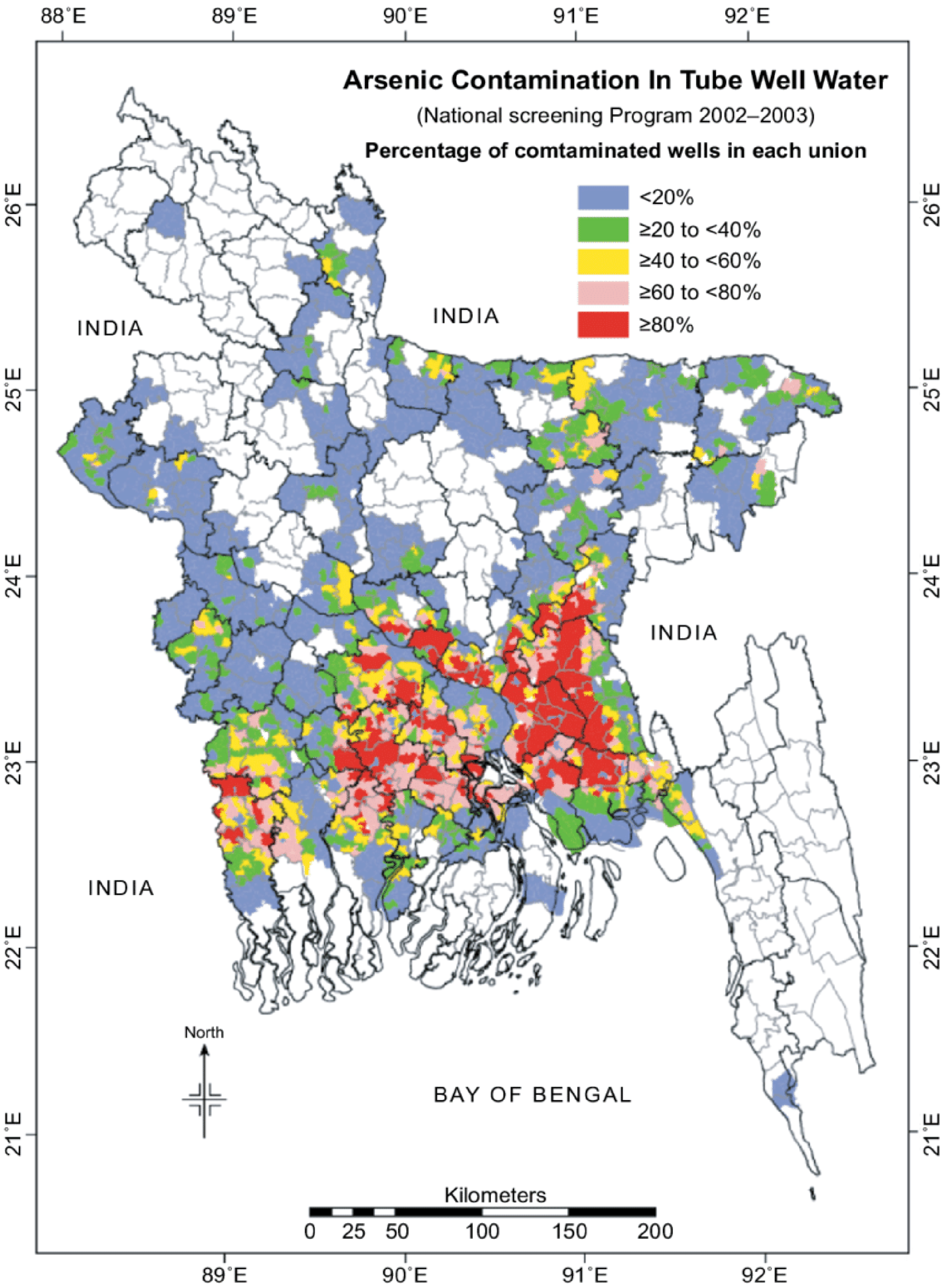

Fig.6. Arsenic Contamination in Tubewells

(Source: https://www.dovepress.com/arsenic-contamination-in-groundwater-in-bangladesh-implications- and-ch-peer-reviewed-fulltext-article-RMHP)

Rank	Country	Risk
1.	Vanuatu	56.71
2.	Antigua and Barbuda	30.80
3.	Tonga	29.39
4.	Solomon Islands	29.36
5.	Guyana	22.87
6.	Papua New Guinea	22.18
7.	Brunei Darussalam	21.68
8.	Guatemala	20.69
9.	Philippines	20.69
10.	Bangladesh	18.78
11.	Cape Verde	18.02
12.	Fiji	17.83
13.	Costa Rica	17.37
14.	Djibouti	16.46
15.	Timor-Leste	16.39
...	...	...

Figure 2:
Extract from the WorldRiskIndex 2019

Fig.7. World Risk Index 2019 (Source:https://reliefweb.int/sites/reliefweb.int/files/resources/WorldRiskReport-2019_Online_english.pdf)

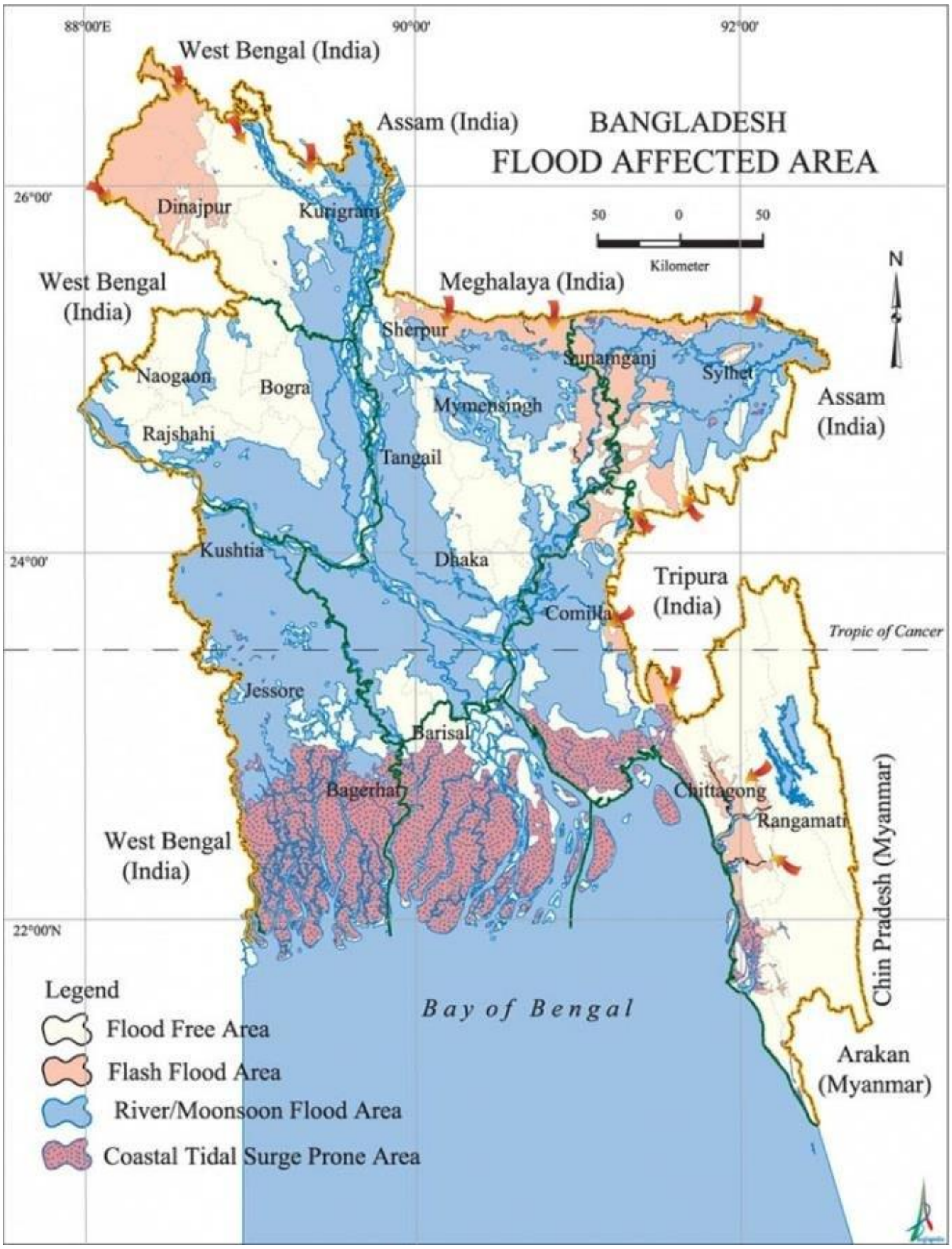

Fig.8. Flood affected areas in Bangladesh (Source: https://www.researchgate.net/figure/Map-of-flood-affected-areas-in-Bangladesh_fig1_326263766)

Table 2: The Long-Term Climate Risk Index (CRI): The 10 countries most affected from 1999 to 2018 (annual averages)

CRI 1999-2018 (1998-2017)	Country	CRI score	Death toll	Deaths per 100 000 inhabitants	Total losses in million US$ PPP	Losses per unit GDP in %	Number of events (total 1999–2018)
1 (1)	Puerto Rico	6.67	149.90	4.09	4 567.06	3.76	25
2 (3)	Myanmar	10.33	7 052.40	14.29	1 630.06	0.83	55
3 (4)	Haiti	13.83	274.15	2.81	388.93	2.38	78
4 (5)	Philippines	17.67	869.80	0.96	3 118.68	0.57	317
5 (8)	Pakistan	28.83	499.45	0.30	3 792.52	0.53	152
6 (9)	Vietnam	29.83	285.80	0.33	2 018.77	0.47	226
7 (7)	Bangladesh	30.00	577.45	0.39	1 686.33	0.41	191
8 (13)	Thailand	31.00	140.00	0.21	7 764.06	0.87	147
9 (11)	Nepal	31.50	228.00	0.87	225.86	0.40	180
10 (10)	Dominica	32.33	3.35	4.72	133.02	20.80	8

Fig.9. The Long-Term Climate Risk Index (Source: Germanwatch Climate Change Risk Index 2020)

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2. Water Security in Bhutan

2. Water Security in Bhutan

SUMMARY

Bhutan is a small land locked country present in the Eastern Himalayan region, with a total territorial area of 38,117 km^2. Current population of the country is recorded at 772,535 with 45.8% urban population. Literacy attainment rate is at 71.4%. Bhutan has a total life expectancy of 72.8 years.

The country has steep rugged mountains and deep valleys in the northern and central region and undulating plains are found in the southern region. 72.5% of the land is covered with forests and rest is flooded with 4 river basins. Southern Bhutan has hot and humid sub tropical climate, central part has more temperate climate with warm summers and dry winters and the northern colder alpine mountains are perpetually covered in snow with cool summers. The northern mountains receive about 40mm of annual precipitation (snow), central regions receive about 1000mm of rainfall and the southern regions receive about 7800mm of rainfall.

Bhutan is endowed with enormous fresh water resources - wetlands, glaciers, supra-snow lakes, supra-glacial lakes, glacial lakes, lakes, rivers, streams, springs, peat lands, marshes, peat-bogs and fens. Bhutan has one of the highest per capita availability of water in the world. With average surface water flow of 2,238 m3 /s. Bhutan generates 70,572 million cubic meters (mcm) per annum, i.e. 94,500 m3 per person per year, the highest in the region. In 2015, the water demand in Bhutan was recorded for Domestic (drinking) use at 36.09 mcm/yr, Agriculture at 666.9 mcm/yr and Industrial use at 74.39 mcm/yr.

Bhutan is broadly divided into four major river basins - Amochu, Wangchu, Puna-Tsangchu, and Manas River Basins. They all originate from the high alpines in the north, and flow to join the Brahmaputra River in the Indian plains. About 1.6% of Bhutan's total land area in the elevation range of 4,050 to 7,230 meters above sea level is covered by glaciers, snow, and ice. There are more than 59 natural non-glacial lakes in Bhutan, covering about 4,250 hectares.

Although water resources are abundant, Bhutan is aware of seasonal and local scarcity of water. Accessing water for drinking and irrigation purposes is not easy due to the country's difficult terrain. Water availability during the lean winter season is marginal. Consistent efforts are being made to protect and conserve drinking water sources and allocation of the best available water sources for drinking purposes. The water supply infrastructure both in rural and urban area need to be upgraded.

97.7% of Bhutan's population has access to improved drinking water sources. Rapid assessment of rural drinking water quality showed that only 17% of streams and 28% of spring water was safe to be used for drinking purposes. Bhutan's water quality is threatened with population growth, burial customs, and rapid urbanisation which are outpacing the installation of sewerage treatment and solid waste collection. Deforestation and land degradation from

over-grazing by livestock contribute to soil erosion and increase the sediment load in the rivers during high water flows. This further deteriorates water quality.

78% of people in Bhutan have access to improved sanitation services. Bhutan faces less than 1% open defecation. Only 74.8% of households have improved toilet facilities. Beyond the household, septic tanks and pit latrines are the dominant form of primary treatment of wastewater in urban areas of Bhutan. Grey water is typically discharged directly to open drains without treatment. The sites for treatment plant and disposal of sludge are often unavailable for small towns and peri-urban areas resulting in illegal disposing of sludge in canals and landfill sites.

The current poor sanitation and hygiene situation in Bhutan is placing a significant and preventable burden on the rural health care system accounting for an estimated 30% of the health cases reported annually. The prevalence is significantly higher among poor rural families. Various diseases such as diarrhoea, dysentery, typhoid and cholera, intestinal worms, skin infections, conjunctivitis, insect vector diseases, rodent-borne diseases and so on are all associated with poor sanitation. Out of 826,375 cases reported in 2009, 30% of the cases were related to poor sanitation. 13% of childhood deaths in Bhutan are attributed to diarrhoea. 88% of diarrhoea cases are caused by unclean water or improper sanitation facilities and 30% of all health problems reported in rural areas of Bhutan stem at least partially from unsafe drinking water or improper sanitation methods. Bhutan government teamed up with UNICEF's WASH (water, sanitation and hygiene) program and formed the Rural Sanitation and Hygiene Program (RSAHP) to promote proper hygiene and sanitation practices and improve sanitation facilities.

Mountain ecosystem of Bhutan is becoming more vulnerable to the increasing threats from climate change. The predicted climate change is likely to induce the following changes in climatic and hydrological variables like precipitation, rainfall and snowmelt. Precipitation will increase and it will take the form of rainfall rather than snowfall. Rainfall will be more erratic and intense. Snowmelt will start earlier than usual. Winter seasons will be shorter. Wet season flood flows and transportation of sediment and debris will also increase. Dry season flows, in contrast, are expected to decrease. With the emerging threats and uncertainties surrounding climate change, combined with increasing demand resulting from population growth and lifestyle changes, has led to increase in the per capita cost of delivering water services.

Bhutan is mindful of the importance of managing water resources for a secure future. It has chosen to adopt the Integrated Water Resources Management (IWRM) approach to achieve this. In translating the principle of IWRM into practice, the concept of Bhutan Water Security Index (BWSI) was adapted, from the Asian Water Development Outlook of Asian Development Bank (ADB), comprising five key dimensions (KD), eleven sub dimensions, and 57 indicators, each further defined by specific data parameters. The basin committees were formed to prepare and implement a basin management plan to promote water security, and to monitor and report progress toward water security in the basin. In essence, the water security dimensions and indicators provide the platform for assessing the contribution of the agencies towards each of the dimensions as well as the overall national and basin-level water security allowing planners and decision makers to visualize sectors contributions to the water security index thereby providing them with the basis for prioritization in the planning.

Bhutan has achieved remarkable success in its environmental stewardship so far, as well as its reduction of poverty and inequality. In order to continue its unique story of growth while judiciously managing its water resources so as to preserve its foundation for future growth, Bhutan can benefit from strategic partnerships that better equip it to maintain the balance. Development partner who work with Bhutan's government like WWF, WHO, ADB, UNICEF, IPCC etc. and its people have a responsibility to ensure their efforts are designed and implemented in the manner that strengthens Bhutan's management of its water resources. Their support is welcome to help leverage Bhutan's biggest economic asset Water, while ensuring that development decisions made do not result in consuming or otherwise damaging the principal.

2.1 COUNTRY PROFILE

Bhutan is a small landlocked country bordered by People's Republic of China to the North and Republic of India to the South, East and West. It shares about 477 kms of its border with China and about 659 kms with India. Closest neighbours, Myanmar, Bangladesh and Nepal are separated only by small areas of India. Thimphu city, located in the river valley is the capital city of Bhutan. (1)

Territorial area of Bhutan is 38,117 km^2. Its current population is 772,535 (as of Tuesday, August 11, 2020) which is about 0.01% of the world's population. The population density here is 20 per Km^2. 45.8 % of the population is urban. 71.4 percent of population is literate. Bhutan has a life expectancy of 72.8 years; 72.3 for males and 73.3 for females. (2)

Topography of the country is rugged with steep mountains and deep valleys in the northern and central part. Many mountain peaks in northern Bhutan reach heights of over 7,000 meters. Bhutan's highest point is Gangkhar Puensum, which reaches a height of 24,840 ft (7,570 m) (1). To the south of this terrain is the region of lesser Himalaya. Numerous small rivers drain the land, including the Dangme, Mangde, Sankosh and Torsa rivers. Close to the southern border, the terrain is more plain and undulating. The lowest point of the country is the Drangme Chhu River at 318 ft (97 m) above sea level. (3)

Bhutan is blessed with diverse biodiversity, rich enough to be considered as one of ten global environmental 'hotspots'. About 72.5 per cent of the area is under forests. Law in Bhutan requires that the country maintains 60 per cent of its forests. Human settlement is confined mostly to the river valleys and a swath of southern plains. Nomads and other tribes live in the north in the mountains raising sheep, cattle and yaks. (4)

Bhutan's economy is largely based on agriculture, forestry, tourism and hydropower generation. Agriculture and forestry are the primary components of the domestic economy, providing employment and livelihood to over 60 per cent of the population. Hydroelectric power export to India, accounts for approximately 28.7 per cent of Gross Domestic Product (GDP) and contributes to about 33% of the GDP. Tourism is the next major foreign exchange earner.

2.1.a Climate and Weather

Southern Bhutan has a hot and humid subtropical climate that is fairly unchanging throughout the year. Temperatures can vary between 15^{o}-30^{o}C. In the Central parts of the country, which consists of temperate and deciduous forests, the climate is more seasonal with warm summers and cool and dry winters. In the far northern reaches of the country, the weather is much colder during winter. Mountain peaks are perpetually covered in snow and lower parts are still cool in summer owing to the high altitude terrain.

Bhutan's spring starts early in March and lasts until mid-April. It is generally dry. Summer weather commences in mid-April with occasional showers which continue through the pre-monsoon rains up to late June. The southwest monsoon lasts from late June through late September. The monsoon weather, blocked from its northward progress by the Himalayas, brings heavy rains, high humidity, flash floods and landslides, and numerous misty, overcast days. Autumn, from late September or early October to late November, follows the rainy season. It is characterised by bright, sunny days and some early snowfalls at higher elevations. From late November until March, winter sets in, with frost throughout much of the country and snowfall common at elevations above 3,000 metres *asl*. The winter northeast monsoon brings gale-force winds down the high mountain passes. The existence of distinct rainy and dry seasons are the main reasons for large seasonal variations in river flows.

2.1.b Precipitation

In the northern mountainous terrain about 40 millimetres (1.6 in) of annual precipitation is recorded primarily as snow. In the temperate central regions, a yearly average rainfall of around 1,000 millimetres (39.4 in) is recorded. About 7,800 millimetres (307.1 in) rainfall per year has been registered at some locations in the humid, subtropical south, supporting the growth of thick tropical forest, and savannah [(9)].

2.2 WATER RESOURCES IN BHUTAN

Bhutan is endowed with enormous water resources. Water bodies and wetlands, glaciers, supra-snow lakes, supra-glacial lakes, glacial lakes, lakes, rivers, streams, springs, peat lands, marshes, peat-bogs, fens and other forms of wetlands are the important fresh water sources. According to a study carried out by Ugyen Wangchuck Institute for Conservation and Environment (UWICE) in 2010, there are 110 supra-snow lakes, 495 supra-glacial lakes and 637 glacial lakes with a total area of 5183.78 Ha. The same study also shows an area of 4,997.33

Ha of lakes. The National Land Cover Assessment of Bhutan carried out by the Ministry of Agriculture and Forests (MoAF, 2011), shows that there are 319.47 Ha of marshes, 22,684.66 Ha of river systems and 38,39,400 Ha of their hydrological basins in the country. [(5)] Bhutan's water resources can be classified under are i) glaciers, ii) glacial and high altitude wetlands, iii) rivers and river basins, and iv) groundwater and reservoirs. [(6)]

Bhutan has one of the highest per capita availability of water in the world. With an average surface water flow of 2,238 m^3/s, Bhutan generates 70,572 million cubic meters (mcm) per annum, i.e. 94,500 m3 per person per year, the highest in the region.

Water demand in Bhutan is from domestic uses, agriculture, tourism, industrial use and hydropower generation. Small scale cottage industries such as breweries, bottling plants, paper factories, hot stone bath houses and chip board industries utilize the available water resources (NEC, 2016). In 2015 report, the water demand in Bhutan was recorded as

- Domestic (drinking) use at 36.09 mcm/yr
- Agriculture at 666.9 mcm/yr
- Industrial use at 74.39 mcm/yr.

2.2.a River System

The major rivers of the country flow north to south, with their sources in the alpine zone of the Himalaya Mountains and flowing right down to the tropical zone on the border and drain into the plains of India. The rivers are mostly fed by rainfall, supplemented by an estimated 2%-12% glacial melt and another 2% from snow melt. The volume of river flow is relatively low during the dry season (from late November to early March) due to the limited rainfall and limited existence of major groundwater reservoirs. Snowmelt from the high altitude alpine areas in the north contributes to the flow at the end of the dry season.

The rivers of Bhutan generally have steep gradients and narrow steep-sided valleys, which occasionally open up to give small areas of flat land for cultivation. They carry large volumes of water and sediment during the monsoon season and significant snowmelt at the end of the dry season. Apart from the major north to south flowing rivers, Bhutan has a dense network of small perennial and rain-fed tributaries that flow down the steep slopes and side valleys, often as waterfalls, to join the major rivers. Due to the steep longitudinal gradients and the high annual runoff, these rivers provide significant potential for hydropower development, with an estimated theoretical potential of 30,000 MW.

Bhutan is broadly divided into four major river basins - Amochu, Wangchu, Puna-Tsangchu, and Manas River Basins. They all originate in the high altitude alpine snow clad area in the north, and flow towards south to join the Brahmaputra River in the Indian plains.

The Amochu is trans-boundary River that takes its birth in China and flows through the western districts of Ha and Samtse and exits Bhutan via Phuntsholling. The Jaldhaka is a small trans-boundary river that that originates from south eastern Sikkim in the eastern Himalaya. The river enters into Bhutan and is joined by Bindu Khola and other small tributaries under Sibsoo Dungkhag, Samtse.

The Wangchu consists of three major tributaries from the three valleys of Thimphu, Paro and Ha. They originate in Bhutan from glaciers and snow-capped mountains in the north and flow south to the Indian plains through Chukha district.

The Punatsangchu (or Sankosh River) consists of two major tributaries, Phochu and Mochu that originate from Gasa Dzongkhag. The two rivers join at Punakha Dzong to become Punatshangchu (Sankosh) that flows through Wangdue Phodrang, Tsirang and Sarpang dzongkhags

The Manas is the biggest river basin, which drains almost all the catchments of Central and Eastern Bhutan. It comprises of four major sub-basins, namely: Mangde Chu and Chamkhar Chu (which both originate close to Gangkhar Puensum), Kuri Chu (which originates from China), and Dangmechu (formed by joining two main tributaries- Kholongchu that originate from the northern-eastern part of Trashi Yangtse and Gongri that originates from China and flows from Arunachal Pradesh in India to Bhutan). Kurichu and Gongri are trans-boundary Rivers that originate from the Autonomous region of Tibet, China.

The three minor rivers that drain through the south eastern corner of the country are Nyera Ama Ri, Nonori Chu and Jomo Chu (Dhansari). [(7)]

2.2.b Lakes, Glaciers and Glacial Lakes

Glaciers and snow fields: About 1.6% of Bhutan's total land area in the elevation range of 4,050 to 7,230 masl is covered by glaciers, snow, and ice. An analysis of recent Landsat satellite images shows that Bhutan had 885 clean Ice (CI) glaciers and 50 debris covered (DC) glaciers in 2010 covering an area of 642 ± 16.1 km^2.

Lakes: There are quite a number of lakes located in remote and high altitude alpine areas of this country. These lakes are formed due to increased melting of glaciers.

Glacial and freshwater lakes are major natural reservoirs in Bhutan. Glaciers cover about 10% of the total surface area of the country and are important renewable sources of fresh water for Bhutan and downstream riparian states of India. When glaciers melt, the water accumulates in depressions, forming glacial lakes over time. There are some 2,674 glacial lakes in Bhutan. Although they contribute substantially to the country's water resources, the fragility of the Himalayan landscape in which they are located makes glacial lake outburst floods (GLOF) a major threat to the downstream communities. Freshwater lakes on the other hand are natural water bodies formed and recharged through runoff from rain, melting snow, and glaciers. [(6)]

There are more than 59 natural non-glacial lakes in Bhutan, covering about 4,250 hectares (16.4 sq mi). Most are located above an altitude of 3,500 metres and most have no permanent human settlements nearby. Many of them are used by grazing yaks and scattered temporary settlements.

Only four lakes are below an altitude of 2,000 metres. Three are in the temperate zone heights; they are Ho Ko Tsho in Punakha District at 1,829 metres (6,001 ft); Luchika in Wangdue Phodrang at 1,830 metres; Buli in Zhemgang at 1,372 metres. One is in the sub-tropical zone in the south; that is Gulandi in Samdrup Jongkhar at 366 metres. (8)

2.2.C Groundwater

Groundwater and reservoirs contribute to the country's overall water resource. Although groundwater resources are believed to be limited in the rugged mountain areas of Bhutan, the wide and flat valleys of Paro, Punakha, Thimphu, Wangdue, and areas bordering the plains of India may have significant groundwater reserves.

In spite of availability of abundant fresh surface water, groundwater is already being tapped at individual house hold level in some of these areas.

2.2.d Reservoirs

Bhutan has no large-scale reservoirs. There are a number of reservoirs that have been constructed on main rivers or their main tributaries; these were built for the purpose of flood attenuation to prevent damage to hydropower infrastructure. Most of the hydropower plants are run-of-the-river type. The live storage of these barrage-type reservoirs is modest, mostly to buffer diurnal flow variation and to trap sediments. There are existing plans to build reservoir-type hydropower stations in Amochhu, Punakha and Sankosh. These reservoirs will be large in order to equalize the seasonal variations of the river discharge. (9)

Latest AQUASTAT data of the FAO shows long term mean precipitation is found to be 2200 mm/year that contributes to 84.46 Km^3 of water. The total renewable water resource (TRWR) in the country is approximately 78 km^3. In Bhutan surface water comprises 100% of the Total Renewable Water Resources (TRWR). Because of the mountainous terrain of the country, groundwater resources are probably limited and are drained by the surface water networks. There is zero overlap between groundwater and surface water resource. For Bhutan the dependency ratio is very low. In 2008, total water withdrawal was about 338 million m^3, all surface water. This represents a mere 0.43 percent of the annual renewable water resources. About 94 percent of this water withdrawn (338 million m^3) is used for agriculture, while domestic and industrial sectors use 5 percent and 1 percent respectively. Falkenmark measure shows that Bhutan is currently a water abundant country with 96582 m^3 of water available per capita.

2.3 WATER ISSUES AND CHALLENGES

72% of Bhutan is covered with forest, about 7.5% by snow and glaciers, about 3% by arable land. The remaining areas are covered by water bodies, shrubs, meadows and other land use types. The bulk of the Bhutan's water resources flow through small streams and rivers located at the bottom of gorges and ravines while human settlements and farmlands are on the upper slopes and hilltops.

Although water resources are abundant (78 million cubic meters per year), Bhutan witnesses seasonal and local scarcity of water. Accessing water for drinking and irrigation purposes is not easy due to the country's difficult terrain. There is a high proportion of runoff into small streams and rivulets. These discharge into tributaries and rivers that are characterised by steep gradients and narrow stream beds that have very little storage. As a result, surface water is quickly lost from the river basins. Whatever water is available during the lean winter season is the result of base flow maintained by subsurface water – and this is marginal. Access to water stored in the lakes up in the mountains is very difficult.

The situation is likely to deteriorate further as the country seeks to modernize and develop. Rapid human population growth is amplifying the pressure on available water resources due to increase in agricultural farming, animal husbandry, industrial and domestic uses. This has led to complaints about the available quality and quantity of drinking water.

Bhutan is mindful of the emerging threats and uncertainties of climate change coupled with increasing anthropogenic threats on water resources and watershed conservation even with the existing policy of sustainable management of natural resources. [(9)]

2.4 WATER SUPPLY AND ALLOCATION

In Bhutan, for drinking purposes, water is abstracted from various sources such as rivers, streams, and springs. The water supply systems are divided into two categories; the urban water supply system and the rural water supply system. The urban water supply systems are built and maintained by the Municipal corporation and Dzongkhag administration. The rural water supply systems are built through Rural Water Supply Schemes and maintained by the beneficiaries. [(10)]

Rural water supply was based on fairly small and simple gravity fed piped system. Each rural water supply scheme serves a population of 150-200 and cost is estimated at US$7000 on an average. Water is mainly tapped from springs or streams sources. Springs are considered the best sources. Rural Water Supply scheme in Bhutan started in 1974 under the Royal Government and UNICEF Cooperation. The implementation of rural water supply scheme was shared between the Public Health Engineering (PHE) Section of Public Works division (PWD) and the District Engineering Units under the District Administration (there are a total of 20 districts)[(21)]

Data from UN/WHO country report 2014 indicated that more than 50% of the urban population has intermittent water supply. In rural areas only about 69% of rural water supply schemes are reportedly functional.

The problem of access to water is caused by the settlements being on the slopes, while the major rivers flow at the valley bottom. In rural areas, communities are dependent on small streams and spring waters along the slopes.

The impacts of climate change are beginning to be seen in decreasing quantities of water and the drying up of water sources. Traditional sources are disappearing, and communities must rely on distant water sources. In urban areas, with exceeding migration from rural areas, municipalities are facing increasing challenges in meeting growing demand for water, both in terms of quantity and quality. Middle class and low income urban residents are faced with limited supply of treated water, resulting in poor sanitation and reliance on alternative, untreated sources. Inadequate and poor water distribution systems are rendering it difficult for municipalities to provide a reliable and uninterrupted supply of water. Urban areas are also beginning to experience flooding, due to expansion of non-permeable surfaces and poorly planned drainage systems, and pollution from inadequacy of sewerage and waste management systems.[(6)]

The water supply infrastructure both in rural and urban area need to be upgraded. Consistent efforts are being made to protect and conserve drinking water sources and allocation of the best available water sources for drinking purposes. In addition, alternative sources like groundwater and rainwater harvesting are being explored in areas with water shortage. [(9)]

An article about rainwater harvesting technique adopted in Bhutan was published in Business Bhutan on April 25th, 2019. According to this, rain water harvesting technology is implemented using silpaulin sheet of 300gsm (gram per sq meter) to store and collect rain from rooftops so that it can be used during dry season for agriculture. Various sizes are being used. However as a standard size, 4.6m length with 2.7m breadth and 1.2m depth is used in Tsirang. For Barshonggewog, 8m*6m is the largest one which has a capacity to hold 25,000 l of water. Currently, 60 households use this technique . It was funded by European Union (EU) managed by International Centre for Integrated Mountain Development (ICIMOD) which is based in Kathmandu, Nepal.

2.5 WATER QUALITY

The National Health Survey of 2012 reports that the proportion of Bhutan's population with access to improved drinking water source is 97.7%. (As per WHO definition: The category 'improved drinking water sources' includes sources that, by nature of their construction or through active intervention, are protected from outside contamination, particularly faecal matter. These include piped water in a dwelling, plot or yard, and other improved sources.)

Until a few years ago, Bhutan did not have its own drinking water quality standards. It used to follow the WHO guidelines. Bhutan Drinking water quality Standard was developed in 2016 to regularly monitor the water used for drinking purposes. Such primary standards protect public health by limiting the levels of contaminants in the drinking water.

Surface water quality is believed to be generally very good in Bhutan, especially in higher elevation areas and away from population pressure. But there is increasing concern that population growth, burial customs, and rapid urbanisation are outpacing the installation of sewerage treatment and solid waste collection, thus threatening the water quality. Deforestation and land degradation from over-grazing by livestock contribute to soil erosion and increase the sediment load in the rivers during high water flows. High sediment loads in water are detrimental to the turbines in hydropower plants and increase demand on management. Many small piped water systems for domestic water supplies are also often blocked by sediment during the monsoon period. [(9)]

A report on rapid assessment of rural drinking water quality, which was carried out by the Royal Centre for Disease Control in 2012, showed that only 17% of stream water sources and 28% spring water sources were safe for use as drinking water. The test was conducted through assessment of microbiological parameters only. This implies that assurance of safe drinking water is still a major challenge in Bhutan.

A detailed study of water quality (physio-chemical, biological parameters and benthic macro-invertebrates) of River Wang Chhu up and down stream in Thimphu the capital city of Bhutan was carried out by Giri and Singh (2013) [22]. This study was undertaken to understand Water quality in relation to land use/land cover changes (LULC) and various ongoing human activities. They observed that the water temperature, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), turbidity, nitrate, phosphate, chloride, total coliform, and Biological Oxygen Demand (BOD) were found to be lower in the river upstream of Thimphu, but higher in the urban area and immediately downstream . Dissolved Oxygen (DO) was found to be higher upstream of Thimphu and lower downstream of the urban area. The pollution sensitive benthic macro-invertebrates population was high in the upstream segment while pollution tolerant benthic macro-invertebrates were more abundant in urban area and downstream of the city . Rapid development in Thimphu city was posing serious threat to water quality. Though the deterioration of water quality was restricted to a few localized areas, the trend was serious and needed proper attention of policy planners and decision makers. Proper treatment of effluents from urban areas was urgently needed to reduce water pollution. This study served as an eye opener on the effect of urbanization on water quality. [(22)]

Pradhan and Mandal (2015)[23], studied water quality of three major rivers of Bhutan-Punatshang Chu, Thimphu Chu and Pa Chu. These rivers are of great economic importance in Bhutan as they have been extensively utilized for generation of hydropower, agriculture and domestic purposes. This study was based on a short term data collection of pH, electrical conductivity (EC), Total Dissolved Solids (TDS), turbidity, Alkalinity, hardness, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), chloride, sulphate, phosphate, sodium, potassium, lithium, calcium, lead, chromium from 15 different sampling sites that were selected along the course of the three rivers. It was concluded from this study that some of the parameters, like pH, COD, phosphates and some of the metal ions like calcium were found to be higher than permissible limits. This was mainly due to anthropogenic activities and the settlements that were developed in the valley along the banks of these rivers.

More recently, Dendup, et al. (2020), in an Impact Assessment of Kuri Chhu Hydropower Plant on physicochemical and biological characteristics of river Water, studied river water characteristics in the pre-monsoon, monsoon and post-monsoon seasons. Water samples were collected from the river stretches upstream and downstream of the dam, and were analysed for pH, TDS, EC, total hardness (TH), DO, acid neutralisation capacity (ANC), nitrate, sulphate, and chlorine. The relative abundance of macro invertebrates was also examined to assess the health of the river. The results showed that the concentrations of physicochemical parameters measured were higher in post-monsoon and pre-monsoon and lower in monsoon except the pH and total hardness. There was minimal variation in concentrations of the physicochemical parameters between the upstream and downstream water samples. Ephemeroptera was dominant in both the post-monsoon and pre-monsoon seasons with its abundance higher upstream of the dam. These results indicated that there is very little impact of the hydropower plant on the river water quality of Kuri Chhu River. (27)

Due to seasonal heavy rainfall in Bhutan which feed the rivers, these above mentioned water quality problem do not appear to get enhanced. But people need to be educated and sensitised about the existence of quality issues and its consequences. There is a need for more such physiochemical and biological studies to understand better the actual status of quality of surface waters over time in Bhutan.

2.6 "WASH" IN BHUTAN

Bhutan is experiencing rapid urbanization. According to the Joint Monitoring Program Report of 2019 (WHO/UNICEF), 78% of people have access to improved sanitation services while 28% in rural and 13% in urban areas lack improved sanitation. According to WHO definition, improved sanitation includes sanitation facilities that hygienically separate human excreta from human contact. Bhutan faces less than 1% open defecation.

According to Population and Housing Census of Bhutan 2017, use of flush toilet by households is predominant in 64.3% houses, while 2% of households do not have toilet facilities. Only 74.8% of households have improved toilet facilities while the remaining 25.2% households use unimproved toilet facilities. Beyond the household, septic tanks and pit latrines are the dominant form of primary treatment of wastewater in urban areas of Bhutan. The Rules for Water and Sanitation 1995 stipulate that both black and grey water outlets should be connected to either a municipal sewer line or septic tank; however the grey water is typically discharged directly to open drains without treatment.

Proper management of septic tanks, safe transport and disposal of sludge is a growing concern for urban and peri-urban areas where connection to a centralized wastewater treatment plant is not available. In addition, the sites for treatment plant and disposal of sludge are often unavailable for small towns and peri-urban areas resulting in illegal disposing of sludge in canals and landfill sites. The current poor sanitation and hygiene situation in Bhutan is placing a significant and preventable burden on the rural health care system accounting for an estimated 30% of the health cases reported annually. This in turn, contributes to one of the high concerns for the government in terms of infant mortality and stunting rates at 21.2% nationally. The prevalence is significantly higher among the poor rural families. Various diseases such as diarrhoea, dysentery, typhoid and cholera, intestinal worms, skin infections, conjunctivitis, insect vector diseases, rodent-borne diseases and so on are all associated with poor sanitation. Out of 826,375 cases reported in 2009, 30% of the cases were related to poor sanitation. [(11)]

13% of childhood deaths in Bhutan are attributed to diarrhoea. The Centre for Disease Control and Prevention (CDC) estimates 88 percent of diarrhoea cases are caused by unclean water or improper sanitation facilities. Likewise, an estimated 30 percent of all health problems reported in rural areas of Bhutan stem at least partially from unsafe drinking water or improper sanitation methods.

Bhutan's Ministry of Health and the Bhutanese Public Health Engineering Division recognize that a lack of access to clean water and sanitation facilities is still a major cause of death and disease. It also recognizes that rural areas are especially in need of better sanitation facilities. In response, improving access to clean water and to high-quality sanitation services has become a priority.

Sanitation facilities that are not properly containing waste can pollute what otherwise would be a clean source of water. However, data from the WHO indicates a lack of access to sanitation facilities in Bhutan which is by far the larger of the two issues. In 2012, when 98 percent of Bhutanese had access to an improved water source, only 47 percent had access to an improved sanitation facility. The problem is especially acute in rural areas, where 80 percent lack access to sanitation facilities.

For improving access to clean water and sanitation facilities in Bhutan, the government teamed up with UNICEF's WASH (water, sanitation and hygiene) program and formed the Rural Sanitation and Hygiene Program (RSAHP). RSAHP works in rural communities across Bhutan to promote proper hygiene and sanitation practices and to help communities develop improved sanitation facilities.

RSAHP was initially brought to three of Bhutan's most backward rural districts. By 2017, all three had improved sanitation coverage by more than 95 percent. Since its inception, the program has now spread to more than 800 rural communities. RSAHP strives to empower these communities by educating people about the importance of proper hygiene and sanitation and helping communities mobilize existing resources and manpower to construct new, effective sanitation facilities.

Access to clean water prevents numerous diseases, including cholera, typhoid, diarrhoea, dysentery and dracunculiasis. It is also associated with improved net attendance of girls in schools and women in the workforce. Without easy access to clean water, many girls and women are forced to spend their time accessing and transporting water and, as such, stop attending school or are unable to work. The progress Bhutan has made toward ensuring access to clean water and modern sanitation facilities will help ensure a better future for all. (12)

2.6.a Drinking Water Treatment Process

Like in all countries, water accessibility, sanitation, and treatment vary widely from location to location in Bhutan. Most urban water supply systems in Bhutan have a basic water treatment facility. However, due to lack of monitoring of water quality, inadequate treatment facilities, and poor maintenance of the system, water that flows from taps is not always safe to drink. Majority of the residents in urban areas either boil or filter the tap water before drinking. (13)

In any basic water treatment plant raw water is fed to the plant through sediment channels. The water moves into sedimentation tanks aided by chemical coagulants. Then the water passes through rapid sand filtration. Next, water is disinfected by chlorination and then treated water is stored on site at the water treatment facility. Distribution is carried out via intermediate storage tanks, which are located in the distribution system. Points of delivery is traced through household piped water supply and customer standpipes and finally water reaches household where it goes through traditional domestic water treatment and then is stored for use.

Key water quality challenges that are faced are: seasonal water quality changes (high turbidity during rainy season). Presence of stock in the catchment upstream of the raw water off-take may compromise quality. Intermittent supply because of limited water treatment plant capacity compromises the quality of water supplied. There are many unaccounted water leakages and illegal connections. Inappropriate household water treatment, storage and handling practices further compromises the standard of drinking water and may lead to health disorders and diseases. (14)

Owing to increasing demand, over the years, with the development in technologies and modernisation, compact water treatment plants with better per day capacity were commissioned to replace the conventional treatment plants that previously supplied drinking water in various towns. Some examples of these compact water treatment plants are: Jungzhina Water Treatment Plant, commissioned in October 2004 at Thimpu, Mao Chu Water Treatment Plant, commissioned in 2010 at Gelephu, Bajo Water Treatment Plant, commissioned in 2013 at Wangduephodrang. (15)

2.6.b Waste Water Treatment Plants and Sewage Treatment Plants

Bhutan is struggling to provide adequate public wastewater management infrastructure facilities (collection and centralised treatment systems) to all the urban areas as it requires huge capital investment. It is estimated that Bhutan is served by 5% of sewer connections and 45%

by septic tanks. It is also reported that 13% of the population lack access to improved sanitation facilities; thus safe management of waste water has become a concern in both rural and urban areas with grey water being discharged directly to drains without proper treatment.

Currently, in Bhutan, only 10 out of 61 towns have proper municipal wastewater infrastructure connectivity. Rest depend on, onsite sanitation systems like septic tanks and soak pits that treats only black water (from toilets) while grey water (from bath rooms and kitchen) is simply discharged into the environment. The Urban areas like Thimphu and Phuentsholing have adopted waste stabilization ponds (WSP) or lagoons, which requires large land area and hence not appropriate for Bhutan with limited flat land. WSPs have become obsolete and they are undersized now due to continuous population growth in the cities. This under sizing of the existing sewage treatment plants now became the source of undesirable odour in places around it. (16)

The conventional onsite sanitation via septic tanks – soak pits practised in all the urban areas is not adequate in Bhutan anymore under the changing urban settings and stricter environmental regulations. Supernatant sewage water from the septic tanks discharged in to the natural environment is undesirable. The onsite sanitation system releases methane, a highly potent greenhouse gas that significantly contributes towards greenhouse gas emission. Most existing onsite sanitation systems are normally poorly constructed. Poor operation and maintenance result in frequent overflow of untreated wastewater to the drains, natural gullies and streams. Overloading of the old septic tanks/ soak pits is observed due to change in the land use and population density. Plot sizes in urban areas are small and inadequate for onsite sanitation system and soil conditions in urban spaces are generally compacted to allow parking and other developments and hence they are not suitable for infiltration using soak pits. (17)

Amidst such challenges, Municipal authorities and concerned agencies have now started to explore and develop locally implemented wastewater management systems to encourage integration of Decentralized Wastewater Treatment System (DEWATS) technologies that consume less energy. DEWATS is a combination of systems used for collection, treatment of waste water collected from individual, clustered communities and industrial facilities and discharge after proper treatment. In this system treated effluent is of a high standard thus making wastewater reusable for gardens and cleaning. It is affordable and is a low-maintenance approach for the treatment of organic waste. It has become an alternative concept for sustainable urban sanitation throughout Asia in recent decades, where treated wastewater is reused by the community for irrigation of landscapes. It is reliable and robust and increases the wastewater reuse. It does not require much external energy. Minimum sludge is produced. Skilled professionals are not required for operation and maintenance work. It also reduces the risks associated with system failure. Studies have found out that DEWATS has the capacity to treat organic waste water from 1-1000 cu.m per day. It can save about 75% of cost incurred in water supply and wastewater transportation. This system has the capability of meeting the demand of the growing problem in a water scarce community that hinders economic development, human livelihood and environmental quality. [16]

2.7 CLIMATE CHANGE

Bhutan is fortunate to be blessed with rich water resources and the highest per capita water availability. Even so, sporadic seasonal scarcity of water in some parts of the country and localized pollution is a national concern. Mountain ecosystem is becoming more vulnerable to the increasing threats from climate change. Glaciers are turning into glacier lakes, glacier lakes are turning into GLOFs, and this is the reality of Climate change. [18]

The retreating glaciers will also adversely affect the hydropower projects that presently drive much of the economic growth of the country and provide most of the government revenue for development activities. There is a consistent finding across climate projection models of a warming pattern, with greater temperature changes during the winter months. Recent studies throughout the country suggest a change in climatic variables with an overall increase in temperatures, resulting in more rainfall, but with large spatial and temporal variations. This increase is projected to occur during the monsoon, whereas during the remainder of the year rainfall will not increase and may even decrease. The increase in rainfall is likely to be more pronounced in the southern part of the country than in the north. The projected increase in rainfall is attributed mainly to a greater intensity of precipitation rather than increase in the number of rainy days.

The predicted climate change is likely to induce the following changes in climatic and hydrological variables like precipitation, rainfall and snowmelt. Precipitation will increase and it will take the form of rainfall rather than snowfall. Rainfall will be more erratic and intense. Snowmelt will start earlier than usual. Winter seasons will be shorter. Wet season flood flows and transportation of sediment and debris will also increase. Dry season flows, in contrast, are expected to decrease.

2.8 WATER RESOURCE MANAGEMENT (IWRM) IN BHUTAN

With the emerging threats and uncertainties surrounding climate change, combined with increasing demand resulting from population growth and lifestyle changes, Bhutan is mindful of the importance of managing water resources for a secure future. It has chosen to adopt the Integrated Water Resources Management (IWRM) approach to achieve this. Bhutan has progressively expanded its focus from single-purpose engineering works in the 1960s (hydropower plants, irrigation schemes) to include environmental concerns in the 1970s and 1980s. Multiple stakeholders became involved in the planning and management of watershed conservation programs. The drive during the 1990s for more sustainable development paved the way to adopt a comprehensive system of water resources management, one that emphasized the coordinated development and management of water, land and ecological resources. With that, IWRM became the new paradigm. Over the past decade, the management scope of water resources has further expanded to include concerns about the impact of climate change. The emergence of IWRM in Bhutan may be traced back to the work of the Bhutan Water Partnership (BhWP) in the early 2000s. At that time, the Partnership began to advocate, alongside the Royal Government, the establishment of the necessary mechanisms to safeguard Bhutan's water resources. This was adequately considered in the Bhutan Water Vision and Policy document of 2008. [(6)]

2.9 WATER SECURITY INDEX - BHUTAN

Water Security is "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human wellbeing, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability." Water security may be viewed in physical or economic terms. Physical water security is a situation wherein water is abundant to meet all demands, whereas economic water security depends on providing adequate investments in water infrastructure and services.

The Water Act of Bhutan 2011 states that water resources are the property of the State, which must be managed sustainably at the level of river basins using Integrated Water Resources Management (IWRM) principles. Subsequently in 2016, the National Environment Commission Secretariat (NECS) published the first National Integrated Water Resource Management Plan (NIWRMP) to foster co-ordinated planning, implementation, monitoring and reporting progress toward the goal of water security. In translating the principle of IWRM into practice, the plan defined five management basins, namely Amochhu, Wangchhu, Punatsangchhu, Mangdechhu and Drangmechhu. It introduced the concept of Bhutan Water Security Index (BWSI) comprising five key dimensions (KD), eleven sub dimensions, and 57 indicators, each further defined by specific data parameters. And finally the management emphasizes coordination among concerned government agencies and stakeholders to act collectively to foster IWRM at the basin level.

Bhutan Water Security Index (BWSI) has been adapted from the Asian Water Development Outlook of Asian Development Bank (ADB). The five key dimensions with a set of indicators against which progress can be monitored are:

- KD1 - Rural drinking water supply and sanitation
- KD2 - Economic Water Security
- KD3 - Urban Water Security
- KD4 - Environmental Water Security
- KD5 - Disaster and Climate Change Resilience

Water resource in each management basin is to be coordinated by a basin committee. Among other responsibilities, committees of each basin are required to prepare and implement a basin management plan to promote water security, and to monitor and report progress toward water security in the basin. The Wangchhu Basin, which is most populated and has diversified economy, was prioritized as the pilot basin to implement operations of NIWRMP. Accordingly, the Wangchhu Basin Committee (WBC) was established under government Executive Order in 2016. The WBC, in fulfilling its Terms of Reference, formulated the first Wangchhu Basin Management Plan (WBMP).

Some 22 different agencies have been designated to submit and annually update the values of the parameters. These agencies are 'bound together' in this concept, although they remain sovereign within their own domain. NECS is the custodian of the water security system, and hence the coordinator for inputs by the respective agencies. In essence, the water security dimensions and indicators provide the platform for assessing the contribution of the agencies towards each of the dimensions as well as the overall national and basin-level water security. Online data entry system allows yearly progress to be gauged by both indicators and dimensions. The computed scores are presented in the form of spider web diagrams and allow planners and decision makers to visualize sectors' contributions to the water security index thereby providing them with the basis for prioritization in the planning. (19)(9)

2.10 CONCLUSION

Bhutan has achieved remarkable success in its environmental stewardship so far, as well as its reduction of poverty and inequality. In order to continue its unique story of growth while judiciously managing its water resources so as to preserve its foundation for future growth, Bhutan can benefit from strategic partnerships that equip it better to maintain the balance. Development partners who work with Bhutan government like WWF, WHO, ADB, UNICEF, IPCC etc. and its people have a responsibility to make sure that their efforts are designed and implemented in the manner that strengthens Bhutan's management of its water resources. Their support is welcome to help leverage Bhutan's biggest economic asset Water, while ensuring that development decisions made, do not result in consuming or otherwise damaging the principal. (20)

Bhutan is very fragile to climate changes. Though a water abundant nation, Bhutan needs to invest more into water resource management and further secure water future. Bhutan has made considerable progress in terms of coverage for both rural and urban water supply and sanitation in the last three decades. However, the functionality of the water supply infrastructure in both rural and urban areas needs improvement. The hydropower sector is also vulnerable to climate change, with the most significant climate risk coming from glacial lake outburst flooding which can cause catastrophic failures of dams and hydropower infrastructure. (24)

Bhutan can also largely benefit from good relations with its neighbouring countries. The bilateral relations between the Himalayan Kingdom of Bhutan and the Republic of India have been traditionally close and both countries share a 'special relationship', making Bhutan a protected state, but not a protectorate of India.

Based on the existing policies, guidelines, acts, regulations and legislations, to further improve in its water future, Bhutan needs to continuously strengthen its current resources and infrastructure. Bhutan needs to focus on the following key objectives which are already a part of their strategic planning [24]

•Strengthen and capacitate IWRM institutions to

•Improve integrated service delivery

•Manage water resources for a changing climate

• Strengthen enforcement of effluent discharge standards

• Improve sewerage treatment facilities

• Monitor drinking water quality

• Intensify urban clean-up campaigns

• Rejuvenate rural water sources

• Promote climate-resilient water harvesting, storage and distribution

• Expand water and sanitation facilities

• Implement integrated approach to flood risk management

• Extend flooding early warning systems

• Prevent landslides from floodwaters

• Manage risks of glacial lakes

• Artificially lower glacial lake levels

• Expand current hydropower capacity

• Protect and manage upstream watersheds

• Promote alternative renewable energy

• Carry out cumulative impact assessments

• Ensure environmental flows in rivers

• Manage water demand

• Adopt water-saving technologies

• Raise community awareness

• Promote total efficiency in water resource use

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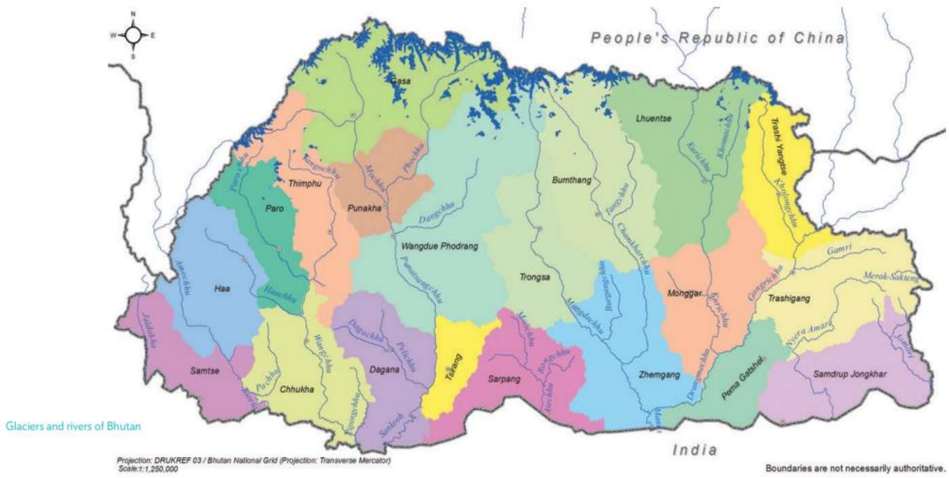
Bhutan Physical Features Map

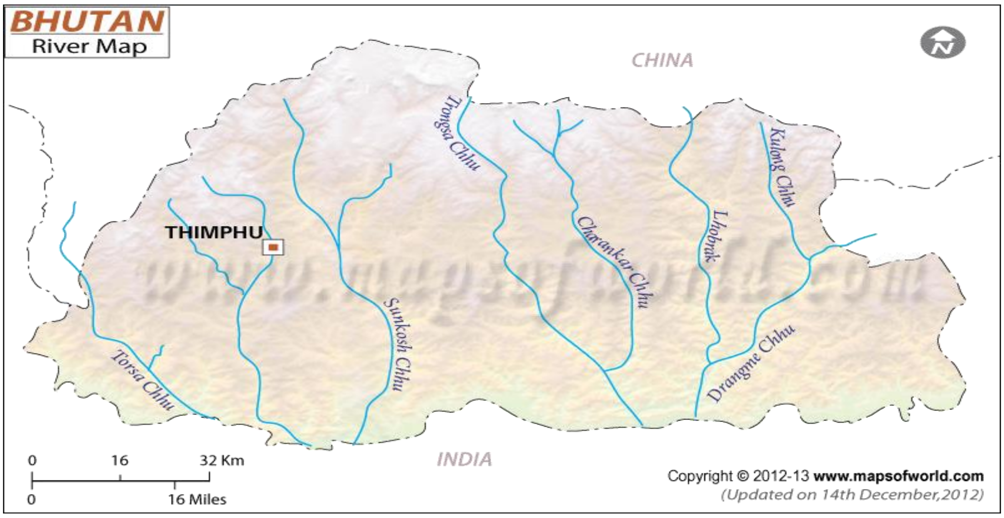
Source: www.freeworldmaps.net

Bhutan Map with Glaciers and Rivers



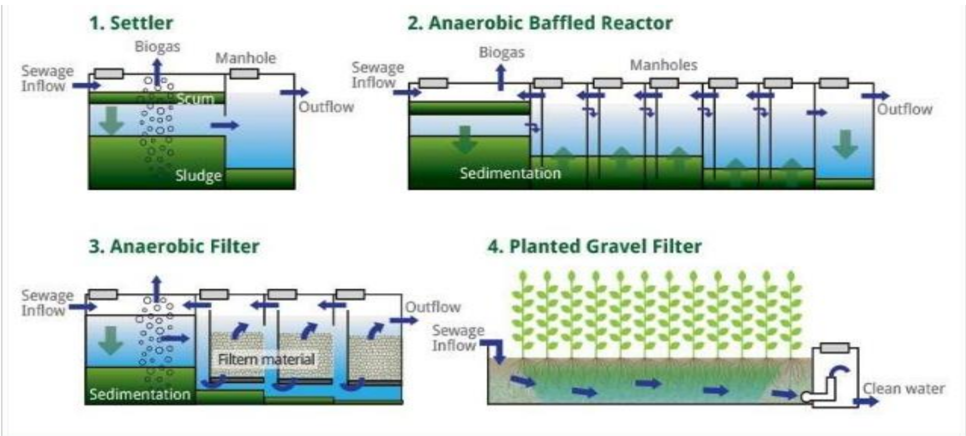
Source: *Water, Securing Bhutan's Future, Yeshey Dorji, Asian Development Bank, National Environment Commission, Royal Government of Bhutan, 2019.*

Bhutan River Map



Source: Maps of the World, Bhutan River Map

Decentralised Waste water Treatment Technology



Source: Slideshare.net, Decentralised Waste water Treatment Technology

3. Water Security in India

3. Water Security in India

3.1 AREA AND DEMOGRAPHY

India, with an area 3.28 million km² occupies just about 2.45% of the total global land area, but supports 17 per cent of the world's population and 15 per cent of world's livestock. Its current population as per Worldometer is 1.339 billion. 34.47% is urban and rest rural. During the last decade, there has been a 4 % increase in urban population. India is a middle riparian country and has contributions of water from the Hindukush Himalaya region of China, Nepal and Bhutan. Its dependency on water generated externally is 30.52 %.

3.2 UTILIZABLE WATER RESOURCE

The annual rainfall in India principally occurs during the southwest and northeast monsoons and also by the westerlies in the Himalaya. Precipitation at elevations above 5000m in the Himalaya is in the form of snow. Precipitation within the country is 4000 BCM, which contributes to 69.48 per cent of its water resources within the country. The rainfall and the transboundary water flows mainly from the melting of snow and glaciers and the monsoon in Nepal and Bhutan contribute to the water resources in the Indo-Gangetic and Brahmaputra plains. After accounting for evapotranspiration and transboundary water losses, a total quantity of utlizable water resource of 1123 BCM is generated annually in India. Out of this 690 BCM is surface water and 433 BCM is groundwater. After allowing 35 BCM/year to account for evapotranspiration losses, support of base flow of rivers and keeping the sea water/freshwater boundary stable, the net annual ground water availability for the India is 398 BCM

The annual per capita availability as of now is 1689[3] which is below the 1700 m^3 which assigns India to the group of Water Stressed countries on the Falkemark scale. Water availability projected for the year 2025 is 1,434 m3/Yr and further negative downward trend is predicted. This negative trend needs to be arrested at the earliest to avoid India slipping into the group of "water scarce" countries in the coming decades.

3.3 UTILIZATION OF WATER RESOURCES

Utilization of water resources of the country is based on land use and land changes. As of now, India's land mass is classified in to agricultural land (46.05%), forest land (24%), pasture land (3%), fallow land (8%), constructed and uncultivable wastelands, and lakes (14%). The land area which can be cultivated, but not utilized for various reasons, constitutes about 5%. Water is principally utilized by agricultural sector, industrial sector and municipal water supply and sanitation sector. Utilization in each of these sectors is depicted in Fig. 1.

3.3.a Agricultural Sector

For irrigation purposes, a storage capacity of 253 BCM of surface water had been created by the end of 11th Five-year plan and an additional 51 BCM is being created by the projects under construction. About 282 BCM of storage capacity of surface water has been achieved so far. Additional capacity of 308 BCM is in the planning stage. As of now 60 per cent of irrigation water is met by groundwater. Out of the total amount of groundwater resource available in the country, 89 per cent gets utilized by agricultural sector.

Lack of scientific knowledge of average Indian farmer on water budgeting, free power supply for pumping out the groundwater for agricultural/irrigation purposes, tax rebates, have all led to excessive pumping of groundwater for agriculture leading to decline of groundwater level in many parts of the country. Surveys by the Central Ground Water Board and GRACE technology have shown deepening of water table in the Indo-Gangetic plains and in the Indian Peninsula to the extent of causing serious damage to the groundwater resources. These areas have been declared as groundwater stressed blocks of India which are further classified into over exploited, critical and semi critical areas (Fig.2). In over exploited areas cent per cent groundwater has been utilized, and in critical areas more than 90 per cent has been utilized. 16 states and 2 union territories come under overexploited category. Punjab, Rajasthan, Delhi and Haryana are the northern states of India where groundwater has been exploited most. In southern India some districts in Karnataka, Telangana, Andhra and Tamil Nadu belong to the overexploited category.

For future security, groundwater allocation for various sectors need to be guided by groundwater balance modeling by studies under the National Project on Aquifer Management. Installation/improving water harvesting facilities wherever possible in the fields is called for and could be incentivized. Excessive use of water for irrigating a unit area of agricultural land, needs to be brought down by replacing flood irrigation by sprinkler and drip irrigation. Recycling of irrigation water as well as treated industrial effluents in the lands close to industrial establishments or close to urban centres, must be promoted. Water taxation must be revisited and suitable changes made for bringing in more responsible use of water resources in agricultural sector. Water extractions from surface or groundwater resources could be metered and compliance to allotted amount of water per unit area enforced for reducing the consumption. This is in line with recommendation of the Controller and Auditor General's 2011-12 report that water used beyond allotted quantity could be charged. Farmers need to be educated about the importance of water budgeting. Government of India passed a Groundwater (Sustainable Management) Bill, 2017 to arrest indiscriminate use of groundwater. The bill empowers local bodies with regulatory control and treats groundwater as a public trust just as the surface water. Passing bills is not enough. Implemention and follow up is required.

3.3.b Industrial Sector

According to FICCI 2011 report and latest AQUASTAT figures, Industrial sector utilizes about 2 per cent of the total water resources available in the country. Iron and steel, smelters, textile and jute, leather products, inorganic chemicals, pharmaceuticals, distilleries, and paper and pulp industries are the major users of water resources in the country. Together they use 41% surface water and 35 % groundwater. Rest 24 % is met by treated municipal waste water in the industries located in or close to urban centres. Although 77% of industries procured water easily, 17% had to pay heavily for the water. 23% of industries did not have easy access for water. 64% of them have had pay heavily for procuring water. While inadequate availability is the major risk facing 37 % of the industries, 14% of the industries are suffering from poor quality water. Sectors like pharmaceuticls, power, food processing and agriculture, feel the brunt of poor quality water. High costs for obtaining water are hindering the business interest of smaller industries which are located in the drier regions of the country. The Industrial sector which was using 56 BCM in 2010 is expected to consume up to 151 BCM by the year 2050. Water treatment capacity near industrial centres and recycling of water needs attention. Public private participation model could be a feasible approach.

3.3.c Municipal Water Supply Sector

Municipal water utilizes 7% of the total water resources in the country. 20 % of the municipal water supplies are met from surface water and 80% by ground water. Domestic water is used for drinking, bathing, washing, gardening and sanitary purposes. Each of these classes of water has to meet certain quality requirements. Most water resources in nature are not pristine. They have organic and inorganic suspended and solution loads which arise from anthropogenic and natural causes. The anthropogenic contaminants could arise from sewage and solid waste disposal from urban and rural settlements, discharge from agricultural fields, industrial discharges including mining etc. The contamination level should be within limits as prescribed by the WHO or the Bureau of Indian Standards for water to be suitable for drinking and domestic uses. The criteria based on organic parameters, is summarized in Annexure -1. The chemical contaminants whose abundance levels should within the limits are listed Annexure 2**.** Chemical contamination can arise from anthropogenic sources (such as industrial discharges or discharges from agricultural fields) or from natural causes (geogenic) like dissolution of minerals present in the soils or rocks.

3.4 POLLUTION STATUS OF RIVERS

Central Water Commission (CWC) of the Government of India has brought out a report in 2019 on the status of trace and toxic elements in the rivers of India. The report presents data on the concentration of common industrial pollutants such as arsenic, cadmium, chromium, copper, iron, lead, nickel and zinc in the samples collected at the CWC’s 424 water quality monitoring stations located on all the major rivers of India. The permissible limits for these elements in drinking water as given by the Bureau of Indian Standards is summarized Annexure 3.

The report lists 351 continuous river stretches on 323 rivers of the country which are polluted. Some of the major rivers contaminated with two or more inorganic elements are listed in Table 1.

Name of the River	Water Quality Station	Contaminating element
Brahmaputra	Dibrugarh, Pancharatna and Pandu Tezpur	Pb, Fe Cu,Cr,Fe
Brahmani	Gomal Paposh	Pb, Fe Ni, Fe
Buridehing	Chemimari Margherita	Cd, Pb, Fe Cu,Pb and Fe
Dikhow	Bihubar Shivsagar	Cr,Cu, Fe Cd,Pb,Fe
Ganga	Ankinghat Azamabad Bhaitura Fatehgar Kanpur Kachala Bridge	Pb,Fe Pb,Fe Cr,Pb,Fe Cr,Pb,Fe Cr,Pb,Fe Cr, Cu, Ni, Pb & Fe
Ghagra	Elgin Bridge Turtipur	Cd,Cr,Pb,Fe Cr,Pb,Fe
Gomti	Lucknow	Pb,Fe

	Neemsar	Pb,Fe
Kopili	Dharamtul Kampur Kheronighat	Cd, Fe Cd,Fe Pb,Fe
Krishna	Huvenhedgi	Ni,Pb,Fe
Purna	Gopalkeda Mahua	Ni,Pb,Fe Cr,Fe
Ramganga	Bareili Dabri Moradabad	Pb,Fe Pb,Fe Cr,Pb,Fe
Rapti	Bairam Bensi Regauli Bird Ghat	Cd,Cr,Pb,Fe Cd,Cr,Pb,Fe Cd,Cr,Pb,Fe Cr,Pb,Fe
Sabarmati	Vautha	Cd, Cu, Ni, Pb , Fe
Sone	Kolewar Kuldha Bridge	Pb,Fe Cd,Fe
Subarna Rekha	Ghatsila Jamshedpur Jamsolghat	Cu,Ni,Pb ,Fe Ni,Fe Cu,FE
Tungabhadra	Bawapuram Mantralayam	Cd, Ni,Pb Cd,Ni,Pb
Vaitarana	Dhruvesh	Cd,Ni,Pb,Fe

Yamuna	Delhi Railway Bridge	Cd, Ni,Pb
	Mohana	Cd,Pb
	Agra	Pb,Fe

Table1. List of Water quality stations on some major rivers and polluting elements at those stations; Source CWC Report

3.5 POLLUTION STATUS OF GROUNDWATER

Over and above the anthropogenic contamination, there are natural contaminants that affect the quality of groundwater. Central Groundwater Board in its report of (2018) on the "Groundwater Quality in Shallow Aquifers of India" has listed some major geogenic contaminants in the ground water of the country and their health effects. These are listed in Annexure 4. The data from water quality wells show that 103 districts in 20 States have arsenic contamination; 191 districts in 23 states have fluoride contamination; 276 districts in 26 States have iron contamination; 337 districts in 20 states have nitrate; 166 districts in 19 states have high content total dissolved solids; 86 districts in 14 states have chloride contamination.

Arsenic contamination is found in the groundwater of West Bengal, Bihar, Chhattisgarh, Assam and Uttar Pradesh. Fluoride is much more widespread than arsenic contamination in the country. It is found in the arid and semi-arid districts of the country in the states of Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. Iron is the most widespread contaminant in the country. It is found in Assam, West Bengal, Orissa, Chhattisgarh, Karnataka, Bihar, UP, Punjab, Rajasthan, Maharashtra, Madhya Pradesh, Jharkhand, Tamil Nadu, Kerala and North Eastern States. Nitrate contamination has been recorded in Andhra Pradesh, Bihar, Delhi, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa. Punjab, Tamil Nadu, Rajasthan, West Bengal and Uttar Pradesh. Salinity has been observed in the groundwater both inland and in the coastal areas. The states in which inland salinity is observed are Rajasthan, Haryana, Punjab and Gujarat. It is also reported from Uttar Pradesh, Delhi, Madhya Pradesh, Maharashtra, Karnataka, Bihar and Tamil Nadu. Salinity has affected the groundwater, in the coastal region of Tamil Nadu, Saurashtra, Orissa, Pondicherry and Sundarban region of West Bengal. Unpublished data with the Bhabha Atomic Research Centre the Divecha Centre for Climate Change and Coyte (2018) record high uranium content in groundwater in Andhra, Gujarat, Karnataka, Rajasthan, Punjab, Tamil Nadu and Telangana,

Origin of the geogenic contaminants is an area of active research in the country. Arsenic contamination is attributed to high arsenic content in Holocene sedimentary aquifers. Fluoride contamination is more widespread in the country, dominantly in the arid and semi-arid belts where aquifers are in the Precambrian crystalline granitic rocks and carbonate rocks. Inland salinity is associated with evaporites in the Rajasthan deserts and in the evolving desertic lands in parts of Telangana, Andhra and Karnataka. Coastal salinity can be attributed to sea water intrusion which is on the rise because of overexploitation of freshwater and also because of sea water surge and flooding during the cyclones. Although uranium contamination in Punjab was initially considered as due to anthropogenic activity (use of fertlizers and chemicals) modeling studies indicated that natural causes may be more important than agricultural activity. Geological context of uranium contamination is currently under study at the Divecha Centre for Climate Change. Preliminary observations are that, in the states of Punjab and Haryana, it can be related to Tertiary aquifers of the Siwalik Group that underlie the Quaternary sands. In Gujarat uranium is enriched in the aquifers of Tertiary age in the Cambay graben. The Tertiary sediments being enriched in uranium sediments is also known from uranium exploration studies by the Atomic Minerals Directorate in the Siwalik belt (Pandit, Pers.Comm). High uranium in groundwater seems to be related to Precambrian cabonatites and alkaline rocks in Rajasthan and in Tamil Nadu. Uranium in Karnataka, Telangana and Andhra Pradesh seems to be related to higher uranium content in the granitoids of this region. Nitrate content is largely attributable to the nitrogenous fertilizers used for irrigation in the country. Iron contamination can be traced to iron formations and laterites widespread in the country.

3.5.a Diseases from Anthropogenic And Geogenic Contaminants

The foregoing review shows that anthropogenic and geogenic contaminants are responsible for many diseases in the country. Researches on diseases in relation biological contaminants have received considerable attention in the country. While arsenicosis arising from arsenic contamination, dental and skeletal fluorosis arising from fluoride rich water have been studied more intensively, other diseases arising from geogenic and anthropogenic metal contaminants are yet to be studied in any detail in India. These are also directly relatable to sanitation status in the country which is described in the section below.

3.6 SANITATION STATUS

3.6.a Sewage

As of May 2018, urban centres in India produced 61,948 mld (million litres per day) of sewage, while there was capacity for treatment for only 23,277 mld, leaving 38,791 mld to contaminate the surface and ground water resources in the country (Fig. 3). In 44.4 per cent villages in the country, there is no arrangement for sewage disposal. 15.8%, 24 % and 6.8% of untreated sewage generated in the villages is disposed into ponds, streams and rivers respectively.

3.6.b Industrial

Water intensive chemical industries, distillery, food, dairy and beverage, pulp and paper, sugar, textile, bleaching and dying, tannery and other industries produced 501 mld of wastewater, while there are treatment facilities only for 193 million litres. Wastewater from pharmaceutical industry and hospital discharges, although has many parameters similar to municipal waste water (sewage), it has certain contaminants at significantly different levels of abundances (see Annexure 5). Hospital waste water and effluents from pharmaceutical industries contain higher levels of antibiotics, which may lead to development of antibiotic resistant bacteria that may contaminate surface and groundwater resources. Wastewater from hospitals where radionuclides are used may release radioisotopes into the environment**.** Hospital waste water could be three types –black water, grey water and storm water. According to WHO black water has fecal matter and urine of patients with or without infectious diseases; grey water contains residues from washing, bathing, laboratory processes, laundry, and other technical processes such as cooling water or the rinsing of X-ray films, potentially loaded with a genotoxic or cytotoxic agents; storm water essentially contains rain water from the roof and court yards. It is the first two varieties that need proper treatment before disposal.

As of May 2018, as per the data presented to National Green Tribunal there were only 193 common effluent plats and 920 sewage treatment plants in the country. Most of the STPs also handle the hospital waste. If we look at the total number of hospitals in the country of all classes and the total number of STPs and ETPs, it is not difficult to infer that most hospitals do not have their own dedicated ETPs and STPs for treating the hospital waste water. A detailed study on this aspect is called for to arrive at hard numbers and plan strategies for meeting the hospital and wastewater treatment. Effective implementation of suggested measures of treatment of sewage and industrial wastes, however, needs evaluation and improvement from time to time.

3.7 PRESENT STATUS OF POLLUTION MANAGEMENT

Central and State Pollution Control Boards are in charge of monitoring of water pollution in rivers, lakes and groundwater. The number of monitoring stations are inadequate and do not monitor pollution on real time basis. There is virtually no monitoring of wastewater from irrigated agricultural fields, which contain pollutants such as agrochemicals, pesticides and insecticides. Government of India passed the "Prevention and Control of Pollution of Water Act" as early as 1974 to prevent, control and abate water pollution. Environmental Protection Act, 1986 prohibits discharging or emitting of water pollutants in excess of the prescribed standards by any industry, operation or process. The law needs to be strongly implemented.

Government has encouraged researches in the country to bring down the fluoride and arsenic contamination in groundwater before using it for drinking purposes. National Environmental Engineering Research Institute, Indian Institute of Science, IITs and some NGOs have developed several techniques which are being tried in the different states of the country. Yet, sustainability of techniques has been a challenge, especially the area of management of wastewater or precipitates produced by water treatment units.

In the light of wider definition of water security, India has made considerable progress in the implementation of WASH Programme. India was declared open-defecation free (ODF) on 2 October 2019 under the Swatch Bharat Mission and is now moving to phase II of the program of management of solid and liquid wastes and on sustainability. The National Annual Rural Sanitation Survey monitors the progress of achieving the objectives of the SBM.

Jal Jeevan Mission is envisioned to provide safe and adequate drinking water through individual household tap connections by 2024 to all the households in rural India. Out of 189 million rural households, 54.9 million have been provided with tap connections as on 23/09/2020.

Government of India wants to address the problem of sustainability of safe water supply through river linking and bringing surface water to areas where there are no such resources. Environmental impact of such massive scale engineering s is however not fully understood. To protect groundwater resources in the coastal areas Government has taken up Salinity Ingress Prevention Scheme which regulates lifting of groundwater in coastal areas and construction of recharge dams. It has also given fillip to research for developing new strains of rice which are arsenic and salt resistant.

3.8 SOME ASPECTS OF FUTURE WATER SECURITY

The foregoing appraisal throws light on the water stress and water security in India and the various initiatives the Government of India is taking to address the problem of adequate supply of water to the agricultural, industrial and municipal sectors in the country. In addition to the existing problems in water resource management which have been covered in the earlier sections climate change, land use changes, socio-economic aspects like population growth, urban development and trans-boundary water sharing issues would influence the future water security significantly.

3.9 CLIMATE CHANGE RELATED ISSUES

Although climate change touches on every aspect of human environment, discussion is restricted to a few issues that are directly related to water resources and water security. They are (i) sea level rise, tropical cyclones-super cyclones and intense precipitation events, (ii) glacial recession and (iii) land use changes- urbanization, land degradation and desertification.

3.9.a Sea Level Rise, Tropical Cyclones and Intense Precipitation Events

Global warming is driving climate change all over the world. Increase in sea surface temperature and sea level rise have increased the frequency of storm surges, cyclones, intense rainfall events. Unnikrishnan et al (2015) have estimated sea level rise along the Indian coast line based on the data from satellite altimeter and tide-gauge measurements. Analysis of altimeter data for the period 1993–2012, reveals a sea-level-rise trend of 3.2 mm yr–1 as in many other oceans. They observed a notable exception along the northern and eastern coasts of the Bay of Bengal, which experience larger trends (5 mm yr–1 and more).

Vellore et al (2020) based on long term records between 1951 and 2018 on the northern Indian Ocean observed that the frequency of tropical cyclones in general is decreasing. However, they observed that during the past two decades there is a significant rise [+0.86 per decade] in the frequency very severe cyclonic storms (VSCS) during the post-monsoon October–December moths.

Vellore et al (2020) also observed a 34 % decline in the frequency of local thunderstorm days between 1981 and 2010 relative to that between 1950 and 1980 over the Indian region. But they noted a rise in short-span, high-intensity rain occurrences (mini-cloudbursts) along the west coast of India (5 per decade) and along the foothills of western Himalayas (1 per decade) during the period between 1969 and 2015. Although short-lived cloudburst and mini-cloudburst occurrences generally are showing decline in frequency in the recent decades, it is observed that there is a significant increase in these events along the Himalayan foothills (1 per decade) and west coast of India (5 per decade).

Short lived cloud bursts, mini cloud bursts as well as cyclonic storms lead to flooding. This flooding also brings about mixing of sewage and waste water with the drinking water sources like rivers, shallow wells and lakes. Very severe cyclonic storms lead to invasion of sea water inland and flooding which pollutes the coastal water resources with salinity. In the wake of flooding, water borne diseases like diarrhea, cholera, typhoid etc. and vector borne diseases like malaria will increase. Water supply and sanitation management resilient with flooding, especially in the coastal areas is a major challenge that needs to be addressed.

3.9.b Glacial Recession

Among other effects, global warming is leading to melting of glaciers in the higher mountain ranges. Mighty rivers of India like Indus, Ganges and Brahmaputra take birth by melting of the glaciers and snow in the Higher Himalaya and grow with the addition of monsoon water as they travel to the lower altitudes in the lesser Himalaya and on the plains. Many glaciers in the Higher Himalaya are found to be retreating, because of melting of glaciers over and above the amount of snow that is added to them annually by precipitation. Formation of new glacial lakes dammed by terminal moraines, have been observed in satellite imageries. 30 per cent of water that flows in Indus, Ganga and Gangetic and Brahmaputra river systems is partially contributed by the glaciers. Future water security in these river basins, therefore, needs to be assessed in the light of loss of one of the sources - the glaciers. Estimation of quantity of water derived from glaciers, the balance of glacier that is still present, rate of retreat, life of the remaining glacier in the light of increasing temperature, all these require dependable data on climate parameters at higher altitudes. Such data is very limited in the Higher Himalaya. Large variation in the climate in the Himalaya from southern Terai plains and Siwalik hills to northern Central Himalayan ranges, and also, from the west to east in the

Himalaya and limited observational data base at higher altitudes have prevented understanding of the impact of glacial melting on the water resources in Himalayan river basins. However, it is generally known that glaciers in the eastern Himalaya are receding quite significantly in contrast to those in the western Himalaya. Fully aware of the limitations of the data base, Immerzeel et al.,(2011) developed high resolution combined cryospheric hydrological model and calibrated that explicitly simulating the glacier evolution and all major hydrological processes. They applied the model to assess the future development of the glaciers and the runoff using an ensemble of downscaled climate model data in the catchment of the Langtang river in Nepal. The study showed that both temperature and precipitation would increase resulting in a steady decline of the glacier area. Rain runoff and base flow will increase at the expense of glacier runoff. The melt water peak coincides with the monsoon peak. The river flow would increase significantly due to the increased precipitation and ice melt and the river would transition towards a rain river. This mode of transition of a glacial melt river to a monsoon rain river is widely considered as the possible scenario for the rivers at least in the Eastern Himalaya. The monsoon rainfall, however, is predicted to increase in the future. While water resources would not decline, there are concerns related to increasing cloud burst and mini-cloud burst events, and occurrence of GLOFs in the Eastern Himalaya.

3.10 LAND USE CHANGES, LAND DEGRADATION AND DESERTIFICATION

Urban development: National Commission on Population (NCP) in its report of 2020 predicts that India's population would increase from 1.35 billion at present to 1.52 billion by 2036. It also predicts that 70% of this increase will be in urban population which will increase to 594 million from 377 million at present. The demand for water, therefore would grow heavily in the municipal and industrial sector. Already many cities in India are water starved. Chennai almost reached day zero status couple of years ago. At present, about 70 per cent of water supplied to cities goes out as sewage and wastewater. Most of this water is not recycled and used effectively. Demand for fresh water can be kept under check, if the STPs and WTPs in urban India are developed to treat the municipal and industrial wastewaters to tertiary level. Also there is a clear need to increase the number of STPs and WTPs. Conjunctive use of piped fresh water for drinking and cooking, harvested rainwater and recycled water for washing, sanitation and industrial uses appears to be sustainable way forward for the Indian cities.

Desertification and Land degradation: Increasing temperature, changes in rain fall pattern, land use changes and associated loss of forest land, overexploitation of surface and ground water resources for irrigation, greedy exploitation of fertile lands, together are causing land degradation and desertification. A "Special Report on Climate change and Land" prepared by the Intergovernmental Panel on Climate Change (IPCC) in 1999 called for countries to halt land-use change, work on forest conservation and step up land restoration to halt land degradation. United Nations Convention to Combat Desertification (UNCCD) and preparation of National Action Plans (NAPs) for combating desertification is an important activity for the well-being of humanity in the future. Ministry of Environment, Forest and Climate Change

(MoEF&CC), Government of India therefore promoted a study to evaluate the status of land degradation and desertification in the country. Central Arid zone Research Institute and Space Application Centre, Ahmedabad, brought out Desertification and Land Degradation Atlas of India in 2016. The analysis of data for this Atlas revealed that, as of 2013, 96.40 mha (million hectares) area of the country was undergoing process of land degradation (29.32% of the total geographic area of the country). Area under desertification (in the arid, semi-arid and dry sub-humid regions of the country) was 82.64 mha. During the decade between 2003-2005 and 2011-2013, it was observed that there was an increase of 1.87 million hectares of degraded land and 1.16 million heactares of desertic land.

Degraded lands and deserts lose the capability to absorb greenhouse gas emissions leading further warming of the atmosphere which in turn affects rainfall. The desertic lands have tendency to develop duricrusts that do not promote recharge of groundwater and would drive the region to degrade further in terms of water availability. The biodiversity of the region would get affected. Groundwater would become more saline and lose its usefulness for agriculture.

As a responsible respondent to the international effort to combat Climate Change, India has committed to restore the degraded land and arrest further deterioration. It has committed to restore 2.5 per cent of its degraded land by 2030. Some of the measures undertaken include water harvesting, creation of windbreaks through afforestation, tree planting and ecosystem restoration which can function as “green walls” and “green dams” that reduce dust and sandstorms and sand dune movement.

3.11 CHALLENGES OF DEVELOPMENT OF WATER RESOURCES IN INDIA AS A MIDDLE RIPARIAN COUNTRY

According to Sisodia (2010) “Rivers, a crucial source of water resources, physically link upstream and downstream users. While their flows offer ample opportunity for water harnessing, equally, they create barriers. The management of rivers does not take place in a vacuum but rather in a complex political and economic framework. ……In the backdrop of water challenges in the region, while it is important to adopt sensible riparian policies and 'healthy rivers' schemes it is equally important not to ignore the political realities. Many of the existing treaties may have to be evaluated afresh and new treaties based on current hydrological knowledge will need to be framed. The geographical contours of India as upper, middle and lower riparian is likely to develop into the epicentre of riparian politics. As an active regional player, riparian issues for India, will be crucial for settling many of the water-induced conflicts in the region. It will thus have to balance its growing water needs and larger security concerns with effective 'hydro-diplomacy”.

China's aggressive unilateral decision to harness water of Yarlung-Tsangpo through large number of dams, would seriously affect flows in the Brahmaputra plains downstream and is a matter of concern for India and Bangladesh. China should be cognizant of the ecological damage its water diversion plans can cause. Frozen and flowing waters of Tibetan part of China are important resource for nearly 2 billion people living in south and southeast Asian countries. This nature's bounty, is not for China alone. The 1997 UN Convention on the Non-Navigational Uses of International Watercourses requires that international water courses be used for development and protection in an equitable and reasonable manner.

With regard to India's water relations with Nepal and Bangladesh, there is a need to overcome political deadlocks through sensible water sharing arrangements and resource developments. Indo-Nepal treaties have largely been dysfunctional, because of Nepal's lack of confidence on India's intentions. India should invest in Nepal's water infrastructure, particularly irrigation and flood control considering the benefits that can come about. Building political confidence is critical in this case. With Bangladesh, the Ganges Treaty is working more or less satisfactorily. But serious concerns have been expressed by Bangladesh with regard to sharing of Teesta waters and construction of multipurpose Tipaimukh Dam across Barak river in Manipur. India should continue its dialogue with Bangladesh on joint river basins and convince that India needs to look after its own interest and that it would not ignore the just claims of Bangladesh.

India- Bhutan water relations have been extremely beneficial. The two countries have benefited by sharing the benefits of river co-operation. The co-operation led to development hydroelectric power in Bhutan which has significantly helped its economy. At the same India has been able to get power for its needs in the NE States.

On the whole India has great responsibility to take the lead to build co-operation between Nepal, Bhutan, Myanmar and Bangladesh to sensitize China that it should not ignore the dependence of nearly 2 billion population in these countries while going ahead with its own projects.

The existing Indus Water Treaty between India and Pakistan has many stringent provisions that restrict India's plans of developing projects on the western rivers. Modification of provisions of the treaty is called for under a new treaty, with regard to sharing of water resources of western rivers. If Pakistan chooses to continue unfriendly relations with India and abets terrorism from its soil, Provisions of International Law Commission 'Responsibility of States for Internationally Wrongful Acts, 2001' empowers India to consider abrogation of even the existing treaty commensurate with the damage Pakistan inflicts on India. This raises fundamental question as to whether the two countries would choose to continue formal arrangements on long lasting peaceful sharing of river waters, although at present the political climate is hostile to the co-operative approach.

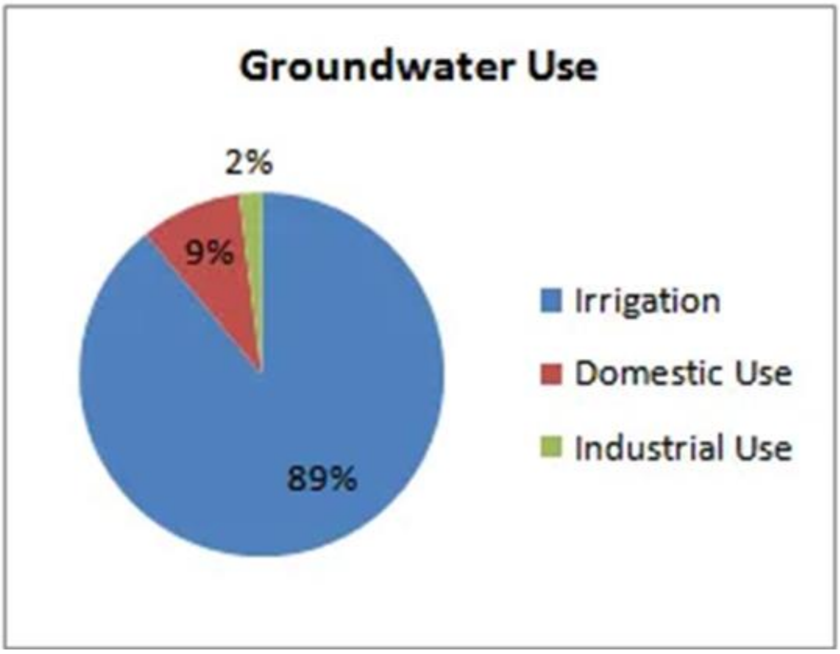


Fig.1 : Utilization of water resources of India

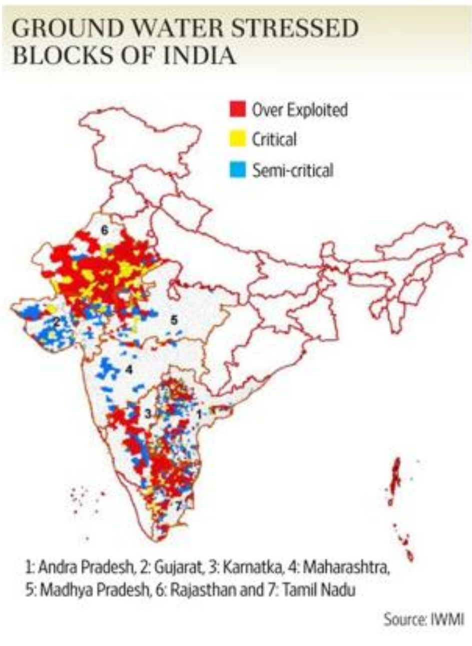


Fig 2 : Classification of Indian States based on quantum of groundwater exploitation

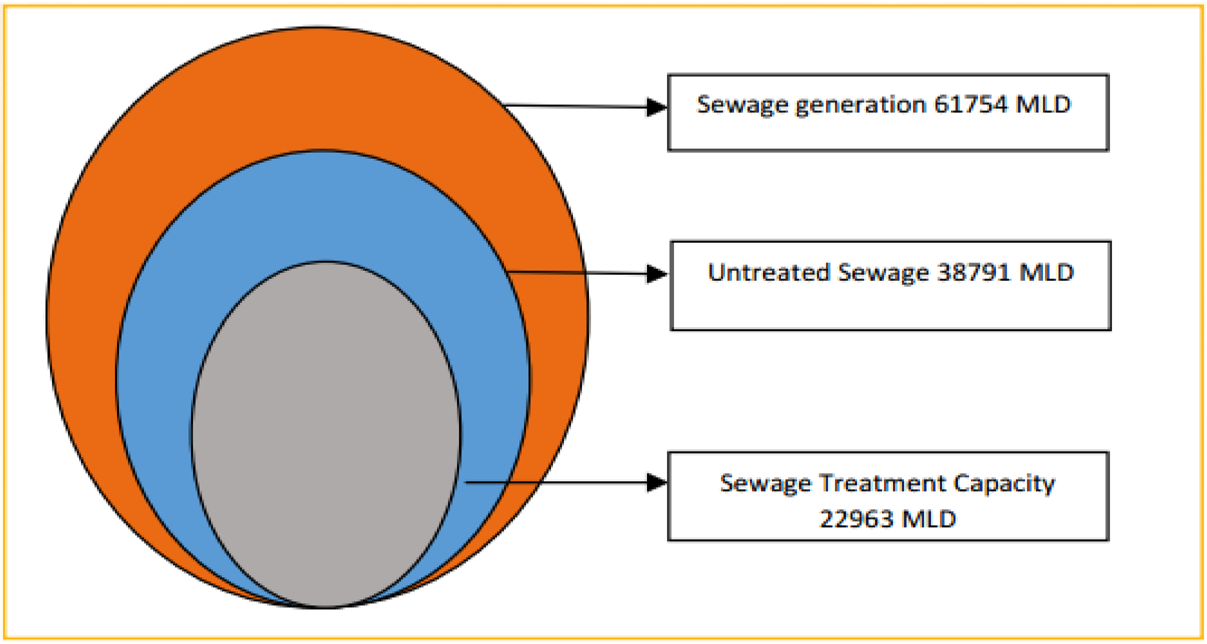


Fig.3. Status of sewage generation and treatment, MOEF, May 2018 submitted to National Green Tribunal

Primary water quality criteria for various uses of fresh water		
Designated best use	Class of water	Criteria
Drinking water without conventional treatment, but after disinfection	A	Total coliform organisms MPN/100 ml 50 or less; pH 6.5-8.5; BOD 5days 20°C 2mg/l or less
Outdoor bathing (organised)	B	Total coliform organisms MPN/100ml 5000; or less; pH 6.5 -8.5; BOD 5days 20°C 3mg/l or less
Drinking water after conventional treatment and disinfection	C	Total coliform organisms MPN/100ml 5000 or less, pH 6-9, 5days 20°C 3mg/l or less
Propagation of wild life and fisheries	D	pH 6.5 -8.5; dissolved oxygen 4mg/l or more; free ammonia (as nitrogen) 1.5mg/l or less

Irrigation, industrial cooling, contro lled waste disposal	E	pH 6-8.5; Electrical conductivity at 25^{o}C Micro mohs Max 2250; Sodium absorption ratio Max. 26; Boron Max 2 mg/l

Category below E does not meet the above criteria; MPN stands for most probable number; BOD for biological oxygen demand

Annexure 1: Classification of water for various domestic uses based on biological parameters

Toxic metal	**Permissible limit**		**Relaxable limit in case there is no alternative source**	
	mg/l	**µg/l**	**mg/l**	**µg/l**
Arsenic (As)	**0.01**	**10**	**0.05**	**50**
Cadmium (Cd)	**0.003**	**3**	**No relaxation**	
Chromium (Cr)	**0.05**	**50**	**No relaxation**	
Copper (Cu)	**0.05**	**50**	**1.5**	**1500**
Iron (Fe)	**0.30**	**300**	**No relaxation**	
Lead	**0.01**	**10**	**No relaxation**	
Mercury	**0.001**	**1**	**No relaxation**	
Nickel	**0.02**	**20**	**No relaxation**	
Zinc	**5**	**5000**	**15**	**15000**

Annexure 2: Permissible limits for toxic metals as prescribed by the Bureau of Indian Standards IS 10500: 2012

Constituent	Drinking water standards recommended by BIS and WHO (in mg/l)			Health effects
	BIS (2012)		WHO	
	Acceptable Limit	Permissible limit*		
Arsenic	0.01	0.05	0.01	Skin lesions and cancer
Chromium	0.05		0.05	Cr ^{Vi} Toxic and causes Ulcers & Dermatitis
Total dissolved solids as indicated by Electrical conductivity	500	2000	1000	Gastrointestinal diseases
Fluoride	1.0	1.5	1.5	At low levels causes dental caries (0.5mg/l); >1.5 causes dental ,skeletal and non-skeletal fluorosis
Manganese	0.1	0.3		Affects taste and appearence ; has adverse effect on domestic uses and water supply facilities Total concentration of Manganese (as Mn) and Iron (as Fe) shall not exceed 0.3 mg/l
Iron	0.3	No relaxation		
Selenium	0.01	No relaxation	0.01	Selenium deficiency is associated with juvenile, multifocal myocarditis called Keshan disease and chondrodystrophy called Kaschin-Beck disease. High urinary selenium levels are associated gastrointestinal disturbances, discoloration of skin and decay of teeth

Uranium	0.06**		0.03	Chemotoxicity and radiotiona damages; Carcinogenic, liver damage or both.
Nitrate	45	No relaxation	50	Methanoglobinamia

- Threshold suggested AERB of India;

Appendix 3 : Geogenic contaminants and their health effects ; Source : Groundwater Quality in Shallow Aquifers of India, CGWB, 2018, Faridabad, 218p.

Parameter	Hospital waste water	Municipal waste water
BOD mg/l	200-300	150-400
COD mg/l	120-500	50-170
Total suspended solids (TSS mg/l)	150-160	50-60
Total N mg/l	5-80	20.70
Total P mg/l	0.2-13	4-10
Chlorides mg/l	65-360	30-90
Total surfactants mg/l	3-7.2	4-8
E Coli MPN/100ml	10^3-10^6	10^6-10^7
Fecal coliform MPN/100ml	10^3-10^7	10^7-10^8
Total coliform MPN/100ml	10^5-10^8	10^7-10^{10}

Appendix.4: Comparison of usually determined constituents in municipal and hospital waste waters (modified after Kumari et al., 2020) .

4. Water Security in Small Island Developing States: Focus On Maldives and Mauritius

4. Water Security in Small Island Developing States: Focus on Maldives and Mauritius

SUMMARY

Small Island Developing States (SIDS) is a group of 38 developing island countries formed in 1992 Rio de Janeiro meeting of UN in Brazil. They share the common features of small size, remoteness, vulnerability to external (both natural and socio-economical) shocks, limited natural resource base and exposure to global environmental challenges. Climate change further impacts the already narrow resource base negatively. Water security in SIDS's is directly affected by any change in the rainfall patterns, as rainfall is the only reliable natural source of freshwater in most of them. SIDS are now burdened with the urgent need to address several interlinked issues to build a water secure future [1]. Water security in two such islands in South Asian region – Maldives and Mauritius – are reviewed here.

Maldives, lowest of any SIDS – is a republic consisting of around 1200 atolls (small islands). Primary source of freshwater in the republic has been rainfall – which is captured directly in the catchments and stored, and groundwater lenses on top of saline water. The groundwater lenses are highly vulnerable to salination and pollution [2]. Thus, densely populated capital region of Male depends on water from desalination pants. Further most of the resort islands have their own desalination plants. Water Security is hampered by a) climate change with rise in extreme events such as flooding, inundation, and extreme winds b) anthropogenic reasons affecting water quality, and c) increasing demand with increasing population and related food security concerns. The use of best clean-technologies available for desalination of sea water and efficient rain water harvesting are seen as the way forward for water security in Maldives

The Republic of Mauritius is an island nation in the Indian Ocean located about 800km east of Madagascar. It consists of 25 major river basins, with most of the rivers being perennial in nature. The country receives ample rainfall of about 4000 mm/year [3]. However, climate change has resulted in longer dry spells and shorter wet spells which has affected the water available for use throughout the year. Also, the leakage in the water distribution network amounts to nearly 50%, which further exacerbates the problem of water availability. Because of these reasons the country has been identified as water-stressed country since 2013 with a possibility on becoming water-scare country soon [4]. The National Water Policy of 2014 [5] identifies an efficient, equitable, socially just and environmentally sustainable ways, with an integrated approach to better apportioning, pricing of available water for drinking, food and energy as a way forward for a better management of the resource.

4.1 INTRODUCTION

Small Island Developing States (SIDS) is group of developing island countries which were separately recognised in 1992 Rio de Janeiro Meeting of UN in Brazil. The UN's SIDS list consists of 38 island states across geographical regions in the Caribbean, the Pacific, the

Atlantic, Mediterranean, Indian Ocean and South China Sea. They can be broadly characterized by the following common features: small size, remoteness, vulnerability to external (both natural and socio-economical) shocks, limited natural resource base and exposure to global environmental challenges. One of the common features that binds them together more than others is their high vulnerability to natural disaster and impacts of climate change. The 2004 Tsunami in the Indian Ocean etched the memories of devastation and loss of lives and livelihoods caused in the South-Asian Indian Ocean SIDS. The IPCC predicts that intensity and frequency of disasters will further increase, thus making the challenge of adapting to various environmental risks and develop resilience, a pressing concern for the developing island states.

Climate change further impacts the already narrow resource base negatively. Several SIDS observed decrease in freshwater supply with the decrease in rainfall – directly impacting the only reliable natural source of freshwater in recent years in some SIDS. -. This is in addition to the local concerns of increase in demand, population, urbanization, pollution, and tourism related developments.

Reviewing the disaster risk and water security challenges and strategies for SIDS in Jana et al [1], note that if no comprehensive and efficient governance policies on Disaster Risk Reduction (DRR) and Integrated Water Resource Management (IWRM) are formulated, disaster and low water security scenarios can adversely affect SIDS' economy loss of natural resources, forced migration and degradation in the environment. They also note that about 70% of SIDS already are showing negative rate of migration of skilled people, contributing to increased poverty and loss of human capital, thereby affecting their capacity to cope with natural, social, economic, and financial stress. Through capacity building of island communities and vulnerable groups can benefit from effective governance and policy measures, possibly leading to situation of less conflicts, more political stability and improving the enabling environment in which water security, DRR and climate change adaptation can take place.

Finally, the paper notes that if SIDS want to achieve the SDG 6 agenda, capacity development on: 1) different levels and various stakeholders is pertinent; 2) preparation to manage environmental and climate changes requires up-to-date comprehensive data analysis and information base; 3) water security planning gaps and needs to formulate efficient and sufficient adaptation policies; 4) improving governance of these with mainstreaming water security and DRR into all policies and developing comprehensive approach towards these challenges with better co-ordination among different agencies. Thus, SIDS are burdened with an urgent need to start addressing the issues that are heavily interlinked to build more resilient states.

Here, we consider the two island countries in the Indian Ocean region – Maldives and Mauritius to assess the water security status through existing literature.

4.2 MALDIVES

4.2.a.i Geography

The Republic of Maldives (Fig. 1) is located about 700 km south-west of Sri Lanka in the Indian ocean. The republic is composed of 1190 low-lying islands spread across the equator over a length of 1000km. The total area is about 90,000 sq.kms. Of these 1190 islands, about 198 are inhabited (2). Only 300 sq.km is the land area of the republic. Most of the islands have land area less than 1 sq.km and they are not more than 1.5m above sea level. The highest elevation in the island nation is slightly less than 2.5m above the sea level. Maldives is also known as the world's lowest country due to its near zero elevation.

4.2.a.ii. Climate

Located close to the equator, the Maldives group of islands witness rains both during the southwest monsoon (from May to September) and northeast monsoon (November to March). Thus, it rains most of the year here except for a short dry period between January and March. The long-term average annual rainfall in the islands is 1972mm. The daily temperature varies little throughout the year. The annual mean temperature is 28^{o}C.

4.2.A.Ii Demography

According to the census of 2014, population of these islands is 339,700. Majority of the population is concentrated in the Male island, while most others are scarcely populated [3].

4.2.a.iii Economy

Tourism and Fisheries are the major industries in the Maldives. Fisheries is the largest employer and tourism the largest foreign exchange generator. GDP growth of the islands hovers around 6% to 8%.

4.2.b Water Resources

Freshwater is the scarcest resource in the country. Rainfall is the primary source which is captured directly in the catchments and stored in tanks or infiltrated into the ground and stored in aquifer. These are the only natural sources of freshwater in the Maldives.

According to the findings of Govt of Maldives and UNICEF in 2000, 75% of the population depended on rainwater for drinking and groundwater for other purposes. According to 2014 census, 87% of the population in Atolls use rainwater for drinking purposes, while in Male – the capital city – only 1.5% of the population used rainwater. This is because 28.9% of the population used Desalinated water and 68% used bottled water for drinking purposes. Concentration of population and developments in the capital cities make the socio-economic characteristics very different from the rest of the Republic. This was observed in the sanitation infrastructure as well: while 100% of the households in Male were connected to sewerage network while it was only 55% for the entire republic. This is due to 38% of households were connected to septic tank and 11.8% discharged to the sea in other Atolls of the republic. It has also found that only 1% of the households did not have sanitation facility within their dwelling unit [3].

Groundwater exists in unconfined aquifers of extremely limited capacity and high level of fragility. Groundwater has been the traditional source of potable water (until recently) [5]. It is noted that all existing storage systems, including the available groundwater lenses are not capable of storing water to last a dry period beyond a couple of months.

Because of this and due to pollution and/or contamination of available groundwater with salt water, the people of densely populated islands (Male in particular) have come to source their own water through desalination plants. Lack of other alternative freshwater sources and constrains with the existing resources, although expensive, desalination has increasingly become the only way to get safe water.

The desalination plant in Male was established in 1988 with a capacity of 200 m^3/day, which has now been increased to 5800 m^3/day. Total generation of desalinated water is estimated to be 1.225 million m^3/year. 132 Resort Islands in the country have their own private desalination units. [5]

4.2.c Water Stress

Climate stress: Geography of Maldives has made it extremely vulnerable to impacts of climate change. The country is exposed to risks of intensifying extreme events such as damage caused by frequent floods, inundation and extreme winds.

Natural constraints: Despite receiving sufficient rain, the total available land area extremely limited to completely hold and utilize the rainwater. Also, the near flat topography does not permit natural storage structures leading the country to face water shortages. The rainwater tanks are inadequate to last the requirements in dry months. *Anthropogenic reasons*: Groundwater in the shallow aquifer lenses floats on the top of the sea water. Heavy abstraction of water from them for municipal water supply has depleted them, causing saltwater intrusion. Further, the groundwater which once was the source of potable water is extremely polluted because of absence of safe sewerage network in most of the places. 51% of the population relies on on-site sanitation systems. This along with increase in the population has led to the contamination of already scare groundwater lenses thus making the seasonal constraints even severe [3,4].

Increasing demand: Even with the best efforts by the government agencies to increase the storage of rainwater with community storage tanks, household roof-top storage tanks and other means, the population is increasing at a pace that is making the gains of these effort negligible.

4.2.d Way Forward

Given the stress experienced by multiple dimension and constraints – such as increased water demand due to population and limited land area to store rainwater - by the country, it is required that the Republic of Maldives should make every effort to make use of the best clean-technologies available for desalination of sea water. Also, international cooperation and negotiation could be leveraged to seek the best technology for much greener, efficient, and sustainable way of desalination technology to ensure safe potable water to its public.

In addition, every effort should be made to enhance collection of as much of rainwater as possible. Government should encourage conjunctive use with the help of advanced state-of-the-art technology for suitable wastewater treatment and reuse of the water.

Lastly, improving international relationship with neighbouring counties could help mitigate the damages of sudden and unforeseen damages of extreme events.

4.3 MAURITIUS

4.3.a.i Geography

The Republic of Mauritius (Fig. 2), is an island nation in the Indian Ocean located about 800km east of Madagascar. The archipelago has a total area of 2040 sq.kms with Mauritius as the main island, Rodrigues Island (to the east), island Agalega (to the north) and uninhabited archipelago of Cargados Carajos Shoals (to the north east).

4.3.a.ii Climate

The island witnesses hot, humid summer from December to April and dry winter from May to November. The long-term average rainfall in the island is 2041mm. The northern and western part constitute drier regions with 1200mm and 900mm respectively and the central plateau, the wettest region with about 4000mm of rainfall [(8)].

4.3.a.iii Demography

The archipelago has a total population of 1,233,000 (as of 2011 census) with majority (97%) living in the central island of Mauritius [(9)]. This makes the country having one of the highest population densities in the world.

4.3.a.iv Economy

The country's economy was predominantly agriculture, employing about 10% of working population contributing to 6% of GDP. Sugarcane is the main crop. In recent years there is diversification of agriculture to food crops and vegetables. Recent decades have also witnessed tourism making a significant contribution to the economy.

4.3.b Water Sources

Mauritius consists of 25 major river basins, most of them being perennial, originating from the central plateau. Total renewable water resources are estimated at 2.75 km^3/year. Total exploitable water resources are 1.08 km3/year.

Total storage capacity of the dams is 93 million m3. There are also minor reservoirs for hydropower generation in some places. The country also treats some of its wastewater. This practice has been there for a long time. As on 2002, a total amount of 20.8 million m3/year of wastewater was treated.

Several small to medium sized desalination plants mostly run by hotels for captive use produce drinking water

4.3.c Water Use

Of the total withdrawal of 725 million m^3/year, agriculture utilizes 67%, public utilities 29% and industries 2%. 148 million m^3/year of water is abstracted from groundwater through 360 borewells [1] A more recent estimate reports that, of the total water produced (920 million m^3/year), 46% is taken up by irrigation, 32% for production of electricity and 22% for domestic and industrial use. [9]

4.3.d Water Stress

Climate stress: It is noted that highly vulnerable to climate change, Mauritius has already been witnessing to longer dry seasons, shorter wet seasons and increasing intensity of droughts. These have resulted in 20% of the population suffering from intermittent water supply under normal conditions and up to 75% during the dry seasons [9]. Sea level rise also is a threat posed by climate change. In the medium to long rage this threat would induce risks related to saltwater intrusion which will destroy the built infrastructure for water supply services in the country.

Operational stress: Distribution of water to the cities, the leakages (Unaccounted for Water, UfW) is close to 50% of the throughput. of this leakage, 65% is physical leakage and the rest is said to commercial loss [10].

4.3.e Measures Adopted

Ministry of Energy and Public utilities drafted and adopted National Water Policy (2014) which envisions to (a) provide 100% access to safe and reliable water supply in the Republic of Mauritius by 2020; (b) extend public sewerage infrastructure to achieve 75% coverage by 2040 [7]. In addition to fair and optimum allocation of water among different sectors in efficient, equitable and sustainable way, the Government also sets out to improve the technical and operational performance of public utilities including the monetary benefits accruing as a result of reduction in non-revenue water to be below 20% by 2040.

4.3.f Way Forward

The National Water Policy (2014) rightly identifies and seeks to address the challenges in the water sector with a new approach to water management based on economic efficiency, equity, social justice, and environmental sustainability. In particular it seeks to focus on integrated approach on the challenges in a) safe water supply to the growing population 2) ensure food security 3) the preservation and protection of eco systems 4) a proper balance in the supply-demand nexus for different sectors of the economy [7]. Experts outside the government also recommend a few measures to prioritize certain measures to improve the water security.

1. Re-allocation of water prioritizing the municipal and industrial demands ahead of diversion of water to marginal hydropower generation (10)
2. Control water losses in distribution network. (11,12,15)
3. Optimal pricing to ensure water conservation (11,12,15)
4. And increase storage to retain the freshwater draining into the sea though rivers. (11)
5. Capacity building and Public awareness (12)

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Appendix: Figures

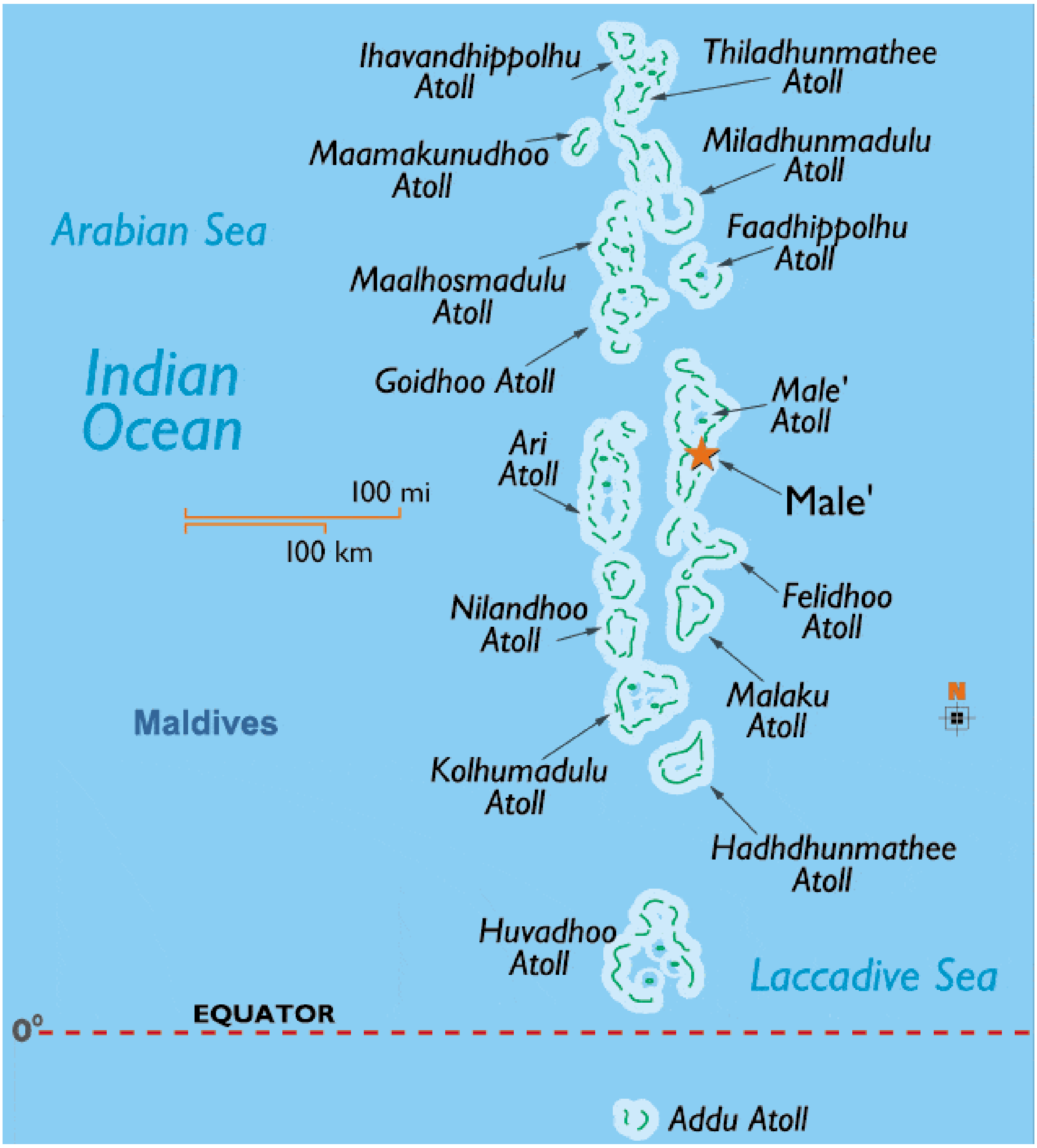


Fig 1: Map of the Republic of Maldives (Source: https://divezone.net/wp-content/uploads/2012/07/maldives-map.gif)

Fig 2: Map of Mauritius (source: https://www.alamy.com/stock-photo-mauritius-political-map-with-capital-port-louis-the-islands-rodrigues-75785862.html)

5. Water Security in Myanmar

5. Water Security in Myanmar

SUMMARY

Myanmar is the country is a water surplus country It has 60 rivers flowing from North to South and reaching the Bay of Bengal. The main rivers are Ayeyarwaddy, Chindwin, Sitting, and Thanlwin. The coastline of Myanmar is about 1470 km long and the deltaic continental shelf has shallow bathymetry[1]. The total land area is 653,290 Km^2.The current population of Myanmar is 54,484,197. It constitutes 0,7 per cent of world population and ranks number 26 in the list of countries by population. Population density in Myanmar is 83 per square kilometre. 31.4 per cent of population is urban. Rest is rural.

Myanmar is characterized by tropical monsoon climate[2]. Most of the rainfall in the country is during the SW monsoon months between Mid-May and October. The country has relatively dry northeast monsoon months between late October and mid-February, Mid-February to mid-May are the dry summer months. The Central Dry Zone is a large inland swath of the country that is prone to extreme heat events and drought. The rainy coasts, such as the Rakhine, Southern Coastal, and Yangon Deltaic areas, are slightly cooler. They are prone to flooding. Long term average annual rainfall in Myanmar is 2091mm. or 1415 billion cubic metres[3]. Significant regional variations associated with the intensity of the southwest monsoon are observed. Annual rainfall ranges from as high as 4000-6000 mm is observed in the coastal region and in the mountains of Rakhin and Tanintharyi while rainfall as low as 500-1000 mm occurs in the central dry zone. Intermediate levels of rainfall are found across the Ayeyarwady delta (2000-3000mm), the Shan plateau (1000-2000mm), and the transitional areas. The predication of the climate change for precipitation, temperature show drastic increase for the time period 2041-2070[3].A large percent change in a dry region can result in a smaller absolute change in a wet region.

Myanmar is endowed with abundant water resources. Precipitation in Myanmar contributes to 1168 billion cubic metres of renewable surface and groundwater per year (2017). The total surface water available is 1082 $km^{3.}$ Groundwater resources have been estimated as 495 km^3 , 80 percent of the surface water discharge is during the monsoon period between May and October and the remaining 20% is during the dry season (November- April). Part of groundwater contributes to the base flow of the rivers[4].Apart from river and groundwater, Myanmar has large natural lakes. Two of them are very big namely the Indawgyi Lake and the Inle Lake. The Indawgyi lake in Kachin district is one of the largest inland lakes in South East Asia. It is 23 km long, 11 km wide and is spread over an area of 260 $km^{2.}$ Lake Inle in Shan state is one of the highest freshwater lakes located at an elevation of 800 m above sea level. It is the second largest lake in Myanmar occupying an area of 116 km^2. Average depth of the lake is 2.1m. Apart from the water generated by the precipitation over the country, Myanmar also receives water from the neighbouring countries. The total annual flow from other countries is about 128.186 km^3. 20 km^3 comes from India, 68.74 km^3 from Nu to Thanlwin, and 31.3 km^3 from west Yunan from China, and 8.156 km^3 from Thailand. The total natural renewable water resources (including flow from incoming or border rivers) are therefore estimated at 1167.8 km^3. The contributions from other countries indicate 14% dependency of Myanmar as far as water resources are concerned.

Utilization of water by different sectors as of 2017 is as follows: 86% for agriculture; 10% for municipal water supply and sanitation; 3% for hydroelectric power generation and 1% for industries. Agriculture is most important sector that utilizes major part of water resources. The major cultivated crops are rice and cash crops such as beans, pulses, sunflower, chilies and vegetables. Earlier jute was one of the important crops. Approximately 91% of the total water utilized comes from surface water and nine per cent comes from groundwater. Groundwater is mostly used for domestic purposes[5].

Although Myanmar is not a water stressed country on the basis of Falkenmark indicator, there are distinct regional differences in terms of water availability[6]. In the central dry zone there is scarcity of water and it is difficult and expensive to access. There is problem of high salinity in Ayeyarwady delta. Flooding in delta regions, flash floods in mountains and dry zones, cyclones and surges, all contribute to water scarcity in different parts of the country at different times of the year. Availability of safe drinking water depends on reservoirs, communal ponds, and private collection of rainwater and groundwater. Many groundwater resources are either saline in the coastal area or contaminated with arsenic.

Anthropogenic pollution of water in Myanmar arises from agricultural, industrial, mining, urban solid and liquid waste disposal. According to the World Bank, Myanmar creates an estimated 0.39 kilograms of waste per person per day. This means that over 20 million kilograms of waste is created daily in Myanmar and this amount is expected to escalate in the coming years[7]. During the rainy season, the major cities of the country are affected by floods. Because of the bad drainage systems, open channels carry the wastes into the major rivers and pollute them. Many factories and industrial zones situated in Yangon and Mandalay discharge huge mass of waste into surface water bodies daily.

Myanmar, similar to several countries in southeast Asia frequently suffers from destructive earthquakes, water-related extreme weathers such as cyclones, periodic flooding, as well as droughts, all affecting the access to clean water, Future socio-economic perspectives such as economic growth and population increase and the associated pressure these have on water, suggest that there is a need to take into account these disasters when one is formulating feasible strategies for management of water resources. Higher demands for agricultural and domestic water, potentially a boom in the demand for industrial water and consequent pollution problems, which is very vivid in the Uru river for example, a sharp increase in the demand for hydropower need are indicated.

Major changes in the climate change, usage of more water for domestic purpose and also improper sewage and sanitation lead to human health problems**.** Diseases that cause diarrhoea, cholera, as well as other serious illnesses including typhoid and dysentery, can be caused by drinking unclean water. Water-borne diseases can spread through contaminated water. Developing countries face more health problems caused by contaminated water than the developed world. As majority of the population resides in the rural part of the country which has lower access to treated water, it is exposed to greater consequences of water pollution. According to research by the Occupational and Environmental Health Division (OEHD) under the Ministry of Health and Sports, released in 2018, over 29 percent of the sources of domestic water in the Ayeyarwaddy region were contaminated with levels of arsenic higher than the WHO standards, and over 8 percent of the arsenic contaminated waters had more than five times the threshold. In the Bago region, over 41 percent of domestic water supply sources had arsenic levels that were above WHO standards. 8 percent, had five times the limit.

20% of newly constructed areas use sewage treatment plant (Aerobic System) while 80% sewage disposal is via Septic Tanks (Anaerobic System) and pit latrine with slab cover[8]. Sewage and waste water are not separated and go together sewage treatment plants.

The impact of climate change will dramatically effect Myanmar due to a number of critical factors including low sea elevations, poor infrastructure, and poverty. Climate change and irregular rainfall patterns in recent years have led to crisis points in the dry zone of the country. Changing aquatic ecosystems in Myanmar inevitably lead to more fertile habitats for water-related intermediate hosts of parasites that are particularly averse to children.

Myanmar is currently undergoing an important water sector reform and the 2030 Agenda with its 17 SDGs provide a framework that can contribute to orient better several sector policies and strategies. With these 16 SDG goals administration of the country is trying achieve proper water supply, establishing more number of STP's also controlling the spread of water borne diseases.

5.1 PHYSICAL GEOGRAPHY

Myanmar formerly called Burma is located between 9° 32' N and 28° 31' N; latitude and 92° 10' E and 101° 11' E longitude. It is bound on the North by China, on the West by India and Bangladesh, on the East by Thailand and Laos PDR and in the South by the Bay of Bengal and the Andaman Sea. Myanmar consists of eight major physiographic regions: The Ayeyarwaddy Delta, Central Dry Zone, Northern Hilly Region, Rakhine Coastal Region, Eastern Hilly Region, Southern Coastal Region, Yangon Deltaic Region, and Southern Interior Region as shown in Figure 1. There are about 60 rivers in Myanmar. Most of the rivers flow to the Bay of Bengal from North to South. The main rivers are Ayeyarwaddy, Chindwin, Sitting, and Thanlwin. The coastline of Myanmar is about 1470 km. The deltaic continental shelf which has shallow bathymetry. The total land area is 653,290 Km^2

5.1.a Demography

The current population of Myanmar is 54,484,197. It constitutes 0,7 per cent of world population and ranks number 26 in the list of countries by population. Population density in Myanmar is 83 per square kilometre. 31.4 per cent of population is urban. Rest is rural.

5.1.b Climate

Myanmar is characterized by tropical monsoon climate[1]. Most of the rainfall in the country is during the SW monsoon months between Mid-May and October. The country has relatively dry northeast monsoon months between late October and mid-February, Mid-February to mid-May are the dry summer months.

The Central Dry Zone is a large inland swath of the country that is prone to extreme heat events and drought. The rainy coasts, such as the Rakhine, Southern Coastal, and Yangon Deltaic areas, are slightly cooler. They are prone to flooding. Climatological data was generated using the NASA NEX-GDDP[2] dataset, which is a combination of observed weather station data and climate model results.

Myanmar is facing climate change in recent decades. In order to study these, 19 weather stations have been set up. 10 weather stations are in the coastal and 9 stations are inland. The data from these two groups of stations were evaluated separately for trends from 1981 to 2010 as shown in the figure. Myanmar recorded an increase in temperature by about 0.25°C per decade during the period 1981-2010, and daily maximum temperatures have risen at a slightly faster rate of 0.4°C per decade over the same period[2]. These rates are similar to global averages for the same time period (IPCC 2014). Inland regions showed an increase of 0.35ºC per decade as compared to 0.14ºC along the coast. Similar to national trends, maximum temperatures rose slightly faster than daily average temperatures in both coastal and inland areas.

Figure 2 shows the daily average (top row) and daily maximum (bottom row) temperatures in the country between 1981and 2010 as recorded in nine inland (blue) and 10 coastal (green) in Weather stations (DMH 2015).

Based on these analyses the future prediction is carried out using data NASA NEX GDDP[2], 2015. 1980-2006 data was considered as Model baseline against which the prediction for the future has been carried out from 2011-2070. The results indicate gradual warming in the range 0.7-1.1°C for the time period 2011- 2040 and 1.2 -2.7°C for the time period 2040-2070 as shown in Table 1.

5.1.c Rainfall

Long term average annual rainfall in Myanmar is 2091mm. or 1415 billion cubic metres. Significant regional variations associated with the intensity of the southwest monsoon are observed. Annual rainfall ranges from as high as 4000-6000 mm is observed in the coastal region and in the mountains of Rakhin and Tanintharyi while rainfall as low as 500-1000 mm occurs in the central dry zone. Intermediate levels of rainfall are found across the Ayeyarwady delta (2000-3000mm), the Shan plateau (1000-2000mm), and the transitional areas.

As mentioned earlier, major changes due to climate change are observed in the rainfall in the coastal and inland regions. Coastal areas have experienced an annual increase in rainfall of the order of 157mm (4.5%) per decade driven by the gains in rainfall during the November-to-May (dry) season much higher than 85mm per decade or 17% during the June-to-October monsoon months (72mm per decade or 2.5% per decade)[2]. Compared to the coastal areas, increases in inland annual precipitation has been more moderate at 37mm (2.5%) per decade as shown in figure 3.

Whether cool (November-February) and hot season (March- May) precipitation will increase or decrease is not known with certainty. Precipitation projections for the period between 2041and 2070 show that precipitation during the hot season may more likely increase than decrease, and in the cold season may decrease or increase. The percentage changes presented offer one way of considering shifts in seasonal precipitation. A large percent change in a dry region can result in a smaller absolute change in a wet region.

5.2 WATER RESOURCES

Myanmar is endowed with abundant water resources. Precipitation in Myanmar contributes to 1168 billion cubic metres of renewable surface and groundwater per year (2017). The total surface water available is 1082 km^3.[3] Groundwater resources have been estimated as 495 km^3 80 percent of the surface water discharge is during the monsoon period between May and October and the remaining 20% is during the dry season (November- April). Part of groundwater contributes to the base flow of the rivers[3].

Apart from river and groundwater, Myanmar has large natural lakes. Two of them are very big namely the Indawgyi Lake and the the Inle Lake. The Indawgyi lake in Kachin district is one of the largest inland lakes in South East Asia. It is 23 km long, 11 km wide and is spread over an area of 260 km^2.[2] Lake Inle in Shan state is one of the highest freshwater lakes located at an elevation of 800 m above sea level. It is the second largest lake in Myanmar occupying an area of 116 km^2. Average depth of the lake is 2.1m.

Apart from the water generated by the precipitation over the country, Myanmar also receives water from the neighbouring countries. The total annual flow from other countries is about 128.186 km^3. 20 km^3 comes from India, 68.74 km^3 from Nu to Thanlwin, and 31.3 km^3 from west Yunan from China, and 8.156 km^3 from Thailand.

The total natural renewable water resources (including flow from incoming or border rivers) are therefore estimated at 1167.8 km^3. The contributions from other countries indicate 14% dependency of Myanmar as far as water resources are concerned.

The population and water resource data indicate that annual per capita water availability is 21,885m^3, which assigns water safe status according to the Falkenmark indicator.

5.3 WATER UTILIZATION

Utilization of water by different sectors as of 2017 is as follows: 86% for agriculture; 10% for municipal water supply and sanitation; 3% for hydroelectric power generation and 1% for industries (Fig.4). Agriculture is most important sector that utilizes major part of water resources. The major cultivated crops are rice and cash crops such as beans, pulses, sunflower, chilies and vegetables. Earlier jute was one of the important crops. The present status of cultivation of crops is shown in the figure 5. Approximately 91% of the total water utilized comes from surface water and nine per cent comes from groundwater. Groundwater is mostly used for domestic purposes.

5.4 WATER SECURITY IN MYANMAR

Although Myanmar is not a water stressed country on the basis of Falkenmark indicator, there are distinct regional differences in terms of water availability. In the central dry zone there is scarcity of water and it is difficult and expensive to access. There is problem of high salinity in Ayeyarwady delta. Flooding in delta regions, flash floods in mountains and dry zones, cyclones and surges, all contribute to water scarcity in different parts of the country at different times of the year.

Availability of safe drinking water depends on reservoirs, communal ponds, and private collection of rainwater and groundwater. Many groundwater resources are either saline in the coastal area or contaminated with arsenic.

Myanmar, similar to several countries in southeast Asia frequently suffers from destructive earthquakes, water-related extreme weathers such as cyclones, periodic flooding, as well as droughts, all affecting the access to clean water, Future socioeconomic perspectives such as economic growth and population increase and the associated pressure these have on water, there is a need to take into account these disasters when one is formulating feasible strategies for water resources management. Higher demands for agricultural and domestic water, potentially a boom in the demand for industrial water and consequent pollution problems, which is very vivid in the Uru river for example, a sharp increase in the demand for hydropower need.

Climate change tends to add to this pressure: increased risks of river floods, changing courses and magnitude of cyclones, longer droughts are key factors to be considered for future integrated water resources planning, implementation and management.

The interrelation between water, food, and energy security provides a useful framework to analyse the trade-offs, because food and energy production will have a large impact on water resources

Regional differences require special attention. The differences of each region require diversification of strategies per region which follow logically from the potential water supply in combination with the envisaged socio-economic development.

From 2013 to 2015, Myanmar showed impressive strides towards integrated and sustainable water resources management, supported by the core of Myanmar's water professionals, public intellectuals, academia and civil society leaders locally and from abroad. Myanmar's water activities are recognized by its neighbours in South East Asia as well as UN-Water.

Myanmar is currently undergoing an important water sector reform and the 2030 Agenda with its 17 SDGs [4]provide a framework that can contribute to orient better several sector policies and strategies. The paragraphs below propose to focus on key SDGs that are directly or indirectly relevant for the water sector in Myanmar.

5.5 WATER QUALITY

Anthropogenic pollution of water in Myanmar arises from agricultural, industrial, mining, urban solid and liquid waste disposal. According to the World Bank, Myanmar creates an estimated 0.39 kilograms of waste per person per day. This means that over 20 million kilograms of waste is created daily in Myanmar and this amount is expected to escalate in the coming years. During the rainy season, the major cities of the country are affected by floods. Because of the bad drainage systems, open channels carry the wastes into the major rivers and pollute them. Many factories and industrial zones situated in Yangon and Mandalay discharge huge mass of waste into surface water bodies daily.

Evaluation of chemical quality of water from tube wells in 17 townships of Eastern Yangon showed that 34% of the wells yielded waters with high iron content (1mg/l). High chloride content- more than 2000mg/l was observed in the Yangon wells which could be attributed to sea water intrusion in the Yangon river and its infiltration.

Apart from sewage and industrial effluent contamination Myanmar's water resources are also affected by geogenic contaminants. A survey of 175 dug wells showed arsenic contamination was present in dug wells and tube wells fitted with hand pumps. 11 percent of dug wells and 3 percent of tube wells had arsenic contamination exceeding the safe limit prescribed by WHO and the Myanmar National Standard. Myanmar Ministry of Health and WHO studied arsenic contamination status in 12 regions of the country in 2010. It found arsenic contamination in groundwater in all the 12 regions beyond permissible limit. Highest levels were found in Rakhine (Arakan) State, Irrawaddy (Ayeyarwady), and Pegu (Bago) Divisions

5.6 WATER SANITATION AND HYGIENE

Drinking clean water is vital for human health. Diseases that cause diarrhoea, such as cholera, as well as other serious illnesses including typhoid and dysentery, can be caused by drinking unclean water. Water-borne diseases can spread through contaminated water. Developing countries face more health problems caused by contaminated water than is the case among inhabitants in the developed world. Rural inhabitants suffer more than people who live in urban locations from the consequences of water pollution, as they have lower access to treated water. According to research by the Occupational and Environmental Health Division (OEHD) under the Ministry Health and Sports, released in 2018, over 29 percent of the sources of domestic water in the Ayeyarwaddy region were contaminated with levels of arsenic higher than the WHO standards, and over 8 percent were contaminated at levels that were more than five times higher. In the Bago region, over 41 percent of domestic water supply sources had arsenic levels that were above WHO standards. 8 percent, had five times the limit. Table below shows the occurrence of water-borne diseases in Myanmar, and their fatalities, in 2017[5].

5.6.a Sanitation Status

According to the estimation by the World Bank in (2012), the solid waste generation in Myanmar was 5,616 tons/day with the per capita waste generation of 0.44 kg/capita/day. This figure was expected to reach about 21,012 tons/day with 0.85 kg/capita/day by 2025[6]. Out of the total waste generation in the country, approximately 55% is generated by three major cities including (Mandalay - 955 tons/day, Yangon- 1,981 tons/day, and Nay Pyi Taw 160 tons/day). Due to the rapid increase in waste generation both City Development Committees prioritized solid waste management as issues of immediate concern, both in terms of the environment and public health.

Liquid waste management in the major cities like Yangon, Mandalay and Nay Pyi Taw sanitation are worse. With the exception of central business districts, there is no central waste water and sewerage collection and treatment system in the three major cities. Domestic waste water is usually released into the storm water drainage and natural waterways. In Yangon, only six areas of the city (7% of total population) was found to manage wastewater and sewage wastes whereby activated sludge was used as fertilizer and treated water was disposed to Yangon River. For other parts of the city, septic tank wastes are transported by vacuum trucks to the treatment pond. In Mandalay, septic tank sewage wastes are collected with a vacuum truck and disposed to oxidation pond in the ground of Ayeyatenyein cemetery, Kyar Ni Kan village, Patheingyi township (old) and Patheingyi township (new). The remaining sludge after evaporation is utilized as fertilizer. Further, all industries generating wastewater have constructed individual temporary treatment systems to connect and dispose liquid waste via a 10-inch drainage pipe line which is subsequently connected to the Dohte Hta Waddy River without any prior treatment. In Nayi Pyi Taw, there is a centralised waste water and sewerage treatment facility which is connected the premises in Wannatheikdeed Quarter comprising 110 units and a population of 10,000. The treatment plant makes use of an anaerobic microorganism system and chlorination processing before discharging treated water to the Bukwe Creek.

The sewage and sanitation facilities consisting septic tanks, pit latrines with slabs, sewage and industrial wastewater treatment plants have been installed in the major cities of the country such as Nay Pya Taw, Yangon city, Mandalay. The tables figure 6(a), (b), (c) given below show the information about percentage of the sanitation facilities in the country. Night soil is the major problem in the Yangon city[6]. The figure 7 below shows the collection of night soil in the year 2017.

20% of newly constructed areas use sewage treatment plant (Aerobic System) while 80% sewage disposal via Septic Tanks (Anaerobic System) and pit latrine with slab cover. Sewage and waste water are not separated and go to sewage treatment plants. Treatment facility distribution is as in the graph[7] (figure 5)

Regional differences require special attention. The differences of each region require diversification of strategies per region which follow logically from the potential water supply in combination with the envisaged socio economic development.

From 2013 to 2015, Myanmar showed impressive strides towards integrated and sustainable water resources management, supported by the core of Myanmar's water professionals, public intellectuals, academia and civil society leaders locally and from abroad. Myanmar's water activities are recognized by its neighbours in South East Asia as well as UN-Water.

Myanmar is currently undergoing an important water sector reform and the 2030 Agenda with its 17 SDGs provide a framework that can contribute to orient better several sector policies and strategies. The paragraphs below propose to focus on key SDGs that are directly or indirectly relevant for the water sector in Myanmar.

5.7 INTERNATIONAL ISSUES

The Mekong River Commission (MRC) came into existence on 5 April 1995. An agreement on the cooperation for the sustainable development of the Mekong River Basin was signed between the governments of Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam. for undertaking joint management of their shared water resources and the development of the economic potential of the river. The MRC was established on the foundation of nearly 50 years of knowledge and experience in the region, starting in 1957 as the United Nations-founded Mekong Committee. In 1996, China and Myanmar became Dialogue Partners of the MRC and the countries now work together within a co-operation framework[8].

The proposed Hatgyi and Tasang dams would generate electricity that would mostly be bought by Thailand, and the Thai and Chinese companies are involved in the construction of the dam. The construction of the dams in Myanmar on the Thanlwin River could displace thousands of ethnic minorities (Karen), who may have to flee into neighbouring Thailand. Damming the Thanlwin river has also raised environmental concerns, both in Myanmar and in the upstream China. It is said that the projects would threaten one-third of the 75 fish species in the river[8]. In 2004, China announced the suspension of all projects on the upstream Nu river pending further scientific study.

5.8 IMPACT OF CLIMATE CHANGE

The impact of climate change will dramatically effect Myanmar due to a number of critical factors including low sea elevations, poor infrastructure, and poverty. Climate change and irregular rainfall patterns in recent years have led to crisis points in the dry zone of the country. Changing aquatic ecosystems in Myanmar "which inevitably lead to more fertile habitats for water-related intermediate hosts of parasites that are particularly averse to children"[8].

These parasites include schistosomiasis, food-borne trematodes and soil-transmitted helminths. Constant monitoring is essential in neighbourhoods of natural and man-made freshwater bodies." The visible effects of climate change include elevated temperatures, shorter monsoon seasons, and greater frequency and intensity rainfall and cyclones". Flooding is a major concern and consequence of climate change in the country. Lowland areas in the Ayeyarwady Delta, where 8 million people live, are extremely vulnerable. The majority of people in the Delta earn their livelihood from agriculture and flood risk is accelerated due to climate change. Moreover, flood risk poses severe economic, social, and health burdens upon the 40 percent of householders who are landless[10]. Thus increased migratory patterns, even the prospect of environmental refugees, are expected for the rural inhabitants in the Ayeyarwady Delta.

The impact of climate change could lead to sea level rise because of thermal expansion, loss of land ice, and global land water storage. The entire coastal area of Myanmar middle range sea level rise estimates for 2020-2029-time period are 5 centimetres to 13 centimetres above the baseline level. By the 2050-2059-time period[2], sea level may rise 20 centimetres to 41 centimetres above the baseline. In the 2080-2089-time period, the middle range of projections estimate sea level to be between 37 centimetres to 83 centimetres above the baseline, with the potential for up to 122 centimetres in the highest range of projections for this time period as shown in the figure 8. Due to the sea level rise projections would mean large increases in permanently flooded areas and in the frequency and magnitude of flooding for those coastal areas not permanently inundated. As was evidenced by the devastating effects of Cyclone Nargis on the densely-populated Delta Region in 2008, Myanmar is already highly vulnerable to coastal flooding. This projected increase in sea levels would carry such flooding further inland in the future, resulting in even greater impacts. For example, it has been estimated that a 0.5-meter rise in sea levels could lead to a retreat of the coastline by approximately 10 kilometres in Myanmar's lowest lying areas (Ministry of Environmental Conservation and Forestry and Department of Meteorology and Hydrology, 2012)

The impact of climate change will dramatically effect Myanmar due to a number of critical factors including low sea elevations, poor infrastructure, and poverty. Climate change and irregular rainfall patterns in recent years have led to crisis points in the dry zone of the country. Changing aquatic ecosystems in Myanmar "which inevitably lead to more fertile habitats for water-related intermediate hosts of parasites that are particularly averse to children. These parasites include schistosomiasis, food-borne trematodes and soil-transmitted helminths. Constant monitoring is essential in neighbourhoods of natural and man-made freshwater bodies." [6]The visible effects of climate change include elevated temperatures, shorter monsoon seasons, and greater frequency and intensity rainfall and cyclones. Flooding is a major concern and consequence of climate change in the country. Lowland areas in the Ayeyarwady Delta, where 8 million people live, are extremely vulnerable. The majority of people in the Delta earn their livelihood from agriculture and flood risk is accelerated due to climate change. Moreover, flood risk poses severe economic, social, and health burdens upon the 40 percent of householders who are landless. Thus increased migratory patterns, even the prospect of environmental refugees, are expected for the rural inhabitants in the Ayeyarwady Delta.

5.9 MYANMAR DEVELOPMENT TRENDS AND NEED FOR INVESTMENTS IN URBAN INFRASTRUCTURE

Although 70% of Myanmar's population resides in rural areas. The urban population has grown at the rate of 2.3% per year, faster than the country's total population (1.8% per year from 14.6 million or 29% of the total population in 2000 to 18.4 million or 31% of the total population in 2010. At present 10% of Myanmar's population lives in two major cities, Yanand Mandalay, contributing to 30% of gross domestic product (GDP), and this share is expected to rise rapidly. It is estimated that by 2030[11], 25% of Myanmar's population will live in urban areas, accounting for roughly 50% of Myanmar's GDP[3].

Once ongoing and planned tax reform in Myanmar results in a functioning tax regime, the majority of tax revenue will also likely come from cities. However, to ensure that urbanization will be a driving force for economic growth and social development, urban planning and management need to be modernized and investments in urban infrastructure need to be increased.

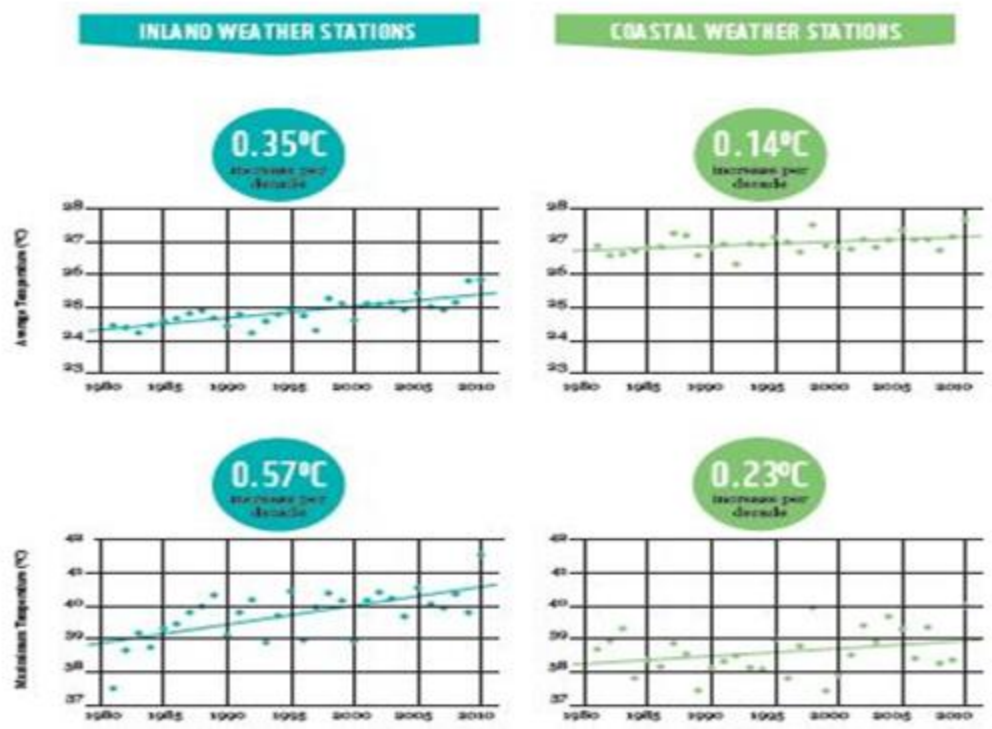
The Myanmar Sustainable Development Plan (MSDP) is the expression of national development vision –a vision that finds resonance in the global sustainable development agenda. Genuine development will only come to Myanmar if, and only if, all these plans move harmoniously and coherently under the aegis of a single national strategy. The MSDP delivers this strategy, providing an overall framework for co-ordination and cooperation across all ministries, and all the States and Regions to forge a common path towards the emergence of a prosperous, peaceful and democratic Myanmar. The MSDP provides a long-term vision; a vision of a peaceful, prosperous and democratic country.

APPENDIX

Figure 1: Physiography of Myanmar

Source: Assessment of Climate Risk in Myanmar Technical Report (2017)

Figure 2:



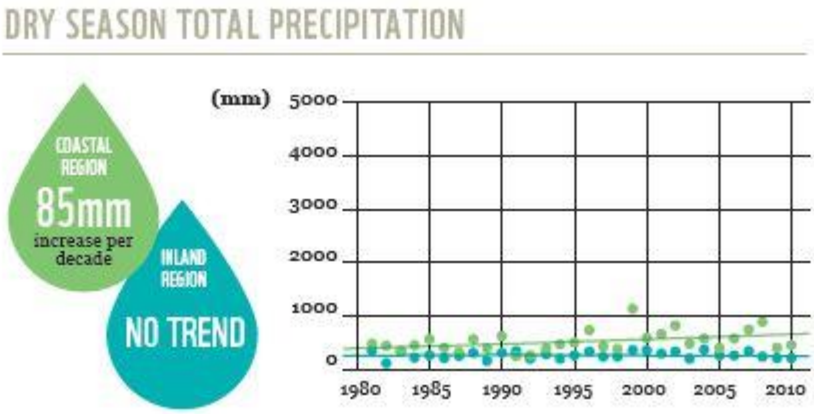
Source: Assessment of Climate Risk in Myanmar Technical Report (2017)

Table 1: Projections for mean annual and seasonal temperature change above the baseline across Myanmar.

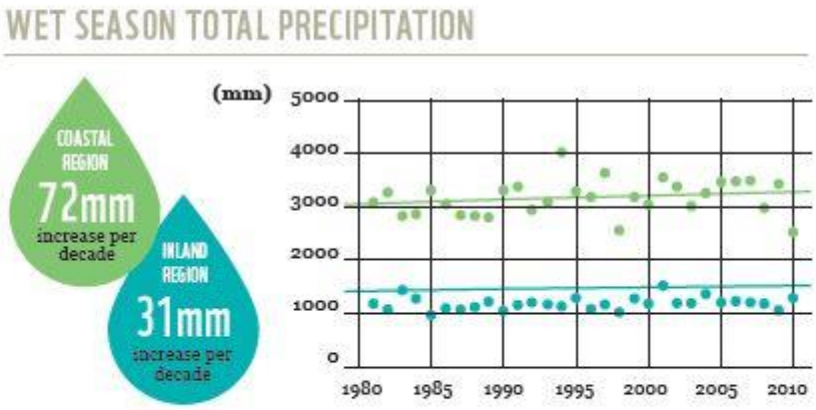
	Model baseline* (1980 to 2006)	Warming by 2011-2040	Warming by 2041-2070
Annual	23.6 °C	0.7-1.1°C	1.3-2.7°C
Hot Season	25.1°C	0.8-1.2°C	1.4-2.9°C
Wet Season	25.1°C	0.6-1.1°C	1.1-2.4°C
Cool Season	20.5°C	0.7-1.2°C	1.3-2.8°C

Source: Assessment of Climate Risk In Myanmar Technical Report (2017)

Figure 3:



Source: Assessment of Climate Risk in Myanmar Technical Report (2017)



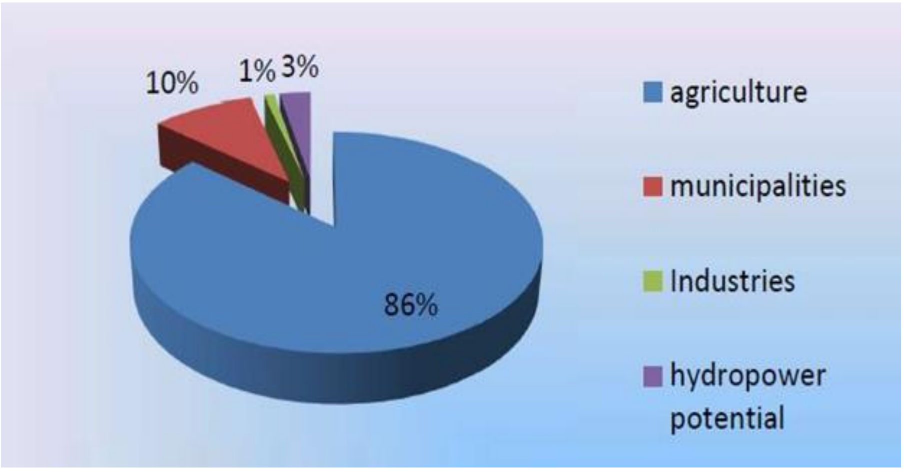
Source: Assessment of Climate Risk in Myanmar Technical Report (2017)

Table 2: Projections for mean annual and seasonal precipitation change from the baseline across Myanmar. (Data Source: NASA NEX GDDP, 2015)

	Model baseline* (1980 to 2006)	Precipitation range 2011-2040	Precipitation range 2041-2070
Annual	2000 mm	+1% to +11%	+6% to +23%
Hot Season	300 mm	-11% to +12%	-7% to +19%
Wet Season	1700 mm	+2% to +12%	+6% to +27%
Cool Season	100 mm	-23% to +11%	-12% to +11%

Source: Assessment of Climate Risk in Myanmar Technical Report (2017)

Figure 4:



Status of current usage of water in Myanmar (2017

Table 4: Water Borne Diseases

No.	Name of Diseases	Cases	Death
1	Diarrhea (mild)	472,275	58
2	Diarrhea (severe)	9,576	1,173
3	Dysentery	123,741	35

4	Typhoid	3,955	7
5	Hepatitis	6,434	7

Figure 5 :

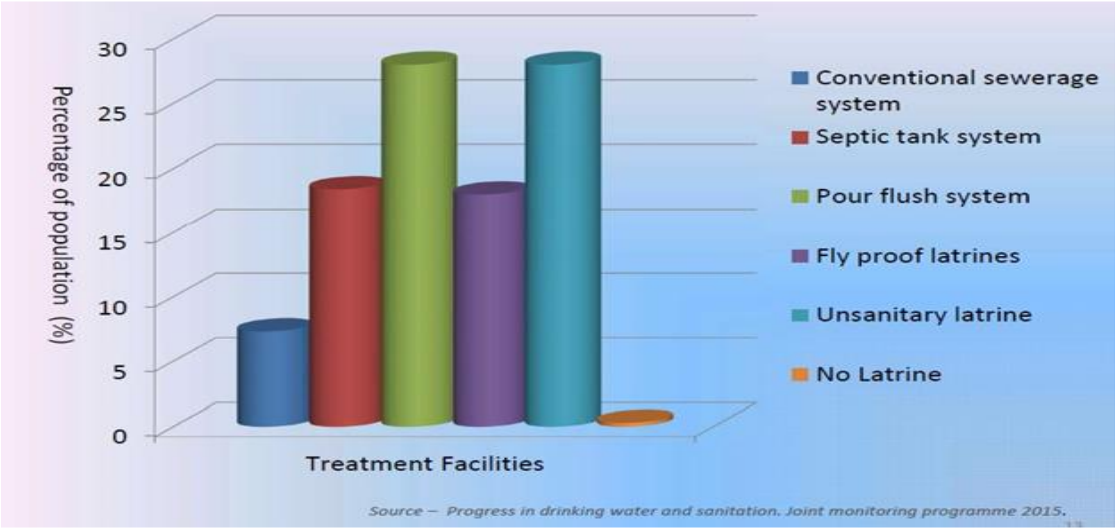


Figure 6 (a) :

Unimproved sanitation facility

State/Region	Flush/ pour flush to some-where else	Pit latrine without slab/ open pit	Bucket	Hanging toilet/ hanging latrine	Other	No facilities/ Bush/field	Total
Kachin	0.6	6.8	0.0	0.1	0.4	0.0	7.90
Kayah	3.0	15.1	0.0	0.0	0.7	0.0	18.80
Kayin	0.0	18.5	0.0	0.1	7.9	0.0	26.50
Chin	0.4	3.0	0.0	0.3	9.2	0.3	13.20
Mon	1.3	1.9	0.3	1.4	3.9	0.0	8.80
Rakhine	0.4	10.6	0.1	0.2	40.7	0.0	52.00
Shan(North)	0.8	27.3	0.0	0.0	3.1	0.5	31.70
Shan(East)	0.9	4.0	0.0	0.1	2.9	0.0	7.90
Shan(South)	6.7	7.5	0.1	0.0	0.2	0.0	14.50
Ayeyarwaddy	2.1	9.3	0.0	0.8	4.7	0.0	16.90
Bago(East)	0.1	8.4	0.0	0.3	5.6	5.7	20.10
Bago(West)	0.0	9.1	0.0	0.0	2.4	0.1	11.60
Magwe	0.0	5.7	0.0	0.0	10.1	0.0	15.80
Mandalay	0.2	1.5	0.0	0.0	6.9	0.2	8.80
Sagaing	0.4	2.5	0.0	0.0	6.2	0.1	9.20
Tanintharyai	5.1	3.0	0.0	3.9	3.6	0.0	15.60
Yangon	2.0	3.0	0.0	5.0	0.5	0.4	10.90
Area							
Urban	1.6	2.6	0.0	0.4	0.8	0.2	5.60
Rural	0.9	8.0	0.0	0.3	9.7	0.7	19.60

Miltiple Indicator Cluster survey (DOH)(2009-2010)

Figure 6(b) :

Improved sanitation facility

State/Region	Flush/pour flush to: Piped sewer system	Flush/pour flush to: Septic tank	Ventilated Improved pit latrine	Pit latrine with slab	Composting toilet	Total
Kachin	0.0	31.6	5.7	53.9	0.9	92.10
Kayah	0.0	4.8	0.4	74.3	1.7	81.20
Kayin	0.0	2.2	1.2	69.4	0.7	73.50
Chin	0.0	0.3	5.6	76.8	4.2	86.90
Mon	0.0	2.9	12.9	75.0	0.4	91.20
Rakhine	0.0	1.0	1.6	41.6	3.9	48.10
Shan(North)	0.0	16.0	3.6	42.8	6.0	68.40
Shan(East)	0.0	71.0	0.4	20.6	0.1	92.10
Shan(South)	0.3	11.7	5.0	68.1	0.6	85.70
Ayeyarwaddy	0.0	3.7	0.9	77.1	1.4	83.10
Bago(East)	0.2	9.6	0.8	69.3	0.0	79.90
Bago(West)	0.0	0.6	1.3	85.8	0.8	88.50
Magwe	0.0	7.0	4.3	71.5	1.3	84.10
Mandalay	0.0	17.5	8.5	65.0	0.0	91.00
Sagaing	0.0	2.1	1.5	86.8	0.5	90.90
Tanintharyai	0.0	20.7	6.4	55.3	1.9	84.30
Yangon	7.3	38.8	0.9	46.7	0.2	93.90
Area						
Urban	3.6	32.3	4.8	53.5	0.3	94.50
Rural	0.0	6.0	3.1	69.8	1.4	80.30

Miltiple Indicator Cluster survey (DOH)(2009-2010)

Figure 6 (c):

Percentage of household population:

State/Region	Using improved sources of drinking water	Using sanitary means of excreta disposal	Using improved sources of drinking water and using sanitary means of excreta disposal
Kachin	89.3	92.1	83.3
Kayah	69.6	81.2	59.7
Kayin	51.1	73.6	42.1
Chin	86.5	86.9	79.9
Mon	86.3	91.2	78.4
Rakhine	57.7	48.0	30.1
Shan(North)	81.4	68.3	59.7
Shan(East)	99.0	92.1	91.0
Shan(South)	89.0	85.6	78.5
Ayeyarwaddy	79.4	83.1	66.2
Bago(East)	83.5	79.8	73.0
Bago(West)	91.2	88.4	81.3
Magwe	79.3	84.2	66.5
Mandalay	81.9	91.1	76.6
Sagaing	86.6	90.9	80.1
Tanintharyai	72.7	84.4	63.5
Yangon	92.5	93.8	88.0
Area			
Urban	93.2	94.4	88.8
Rural	77.6	80.4	65.2

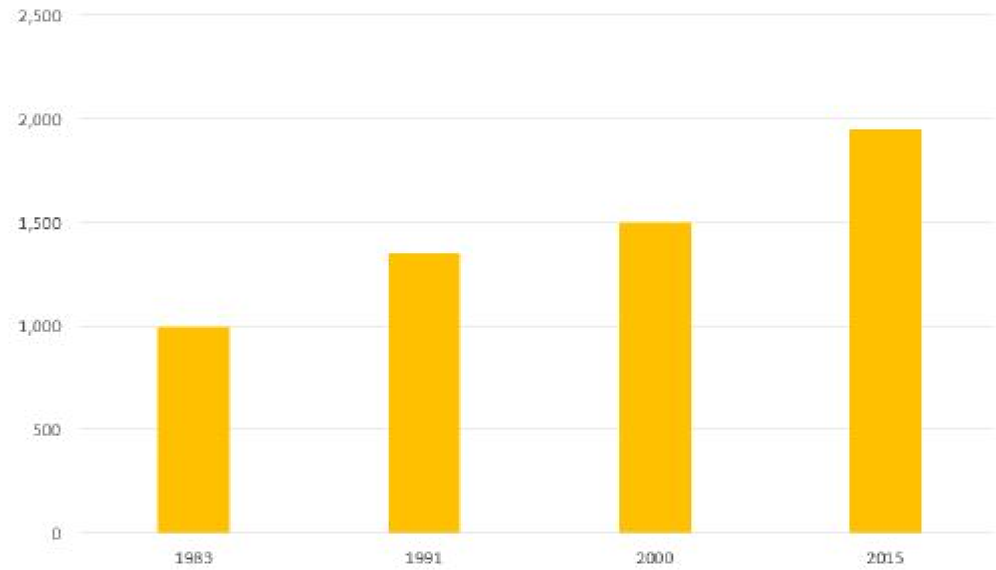
Miltiple Indicator Cluster survey (DOH)(2009-2010)

Figure 7: Night Soil collection in gallons

Night-Soil / No. of Collection at Yangon City for 2017

Months	Eastern District	Western District	Southern District	Northern District	Total
January	521	414	324	898	2157
February	545	408	320	891	2164
March	544	376	318	923	2161
April	633	306	274	759	1972
May	849	364	389	1203	2805
June	646	356	349	1034	2385
July	362	261	259	772	1654
August	435	305	246	735	1721
September	275	284	223	656	1438
October	430	254	256	608	1548
November	464	291	274	711	1740
Total	5704	3619	3232	9190	21745

Increase in Waster Generation in Yangon City in the year 2015



Increase in Waster Generation in Mandalay City in the year 2015

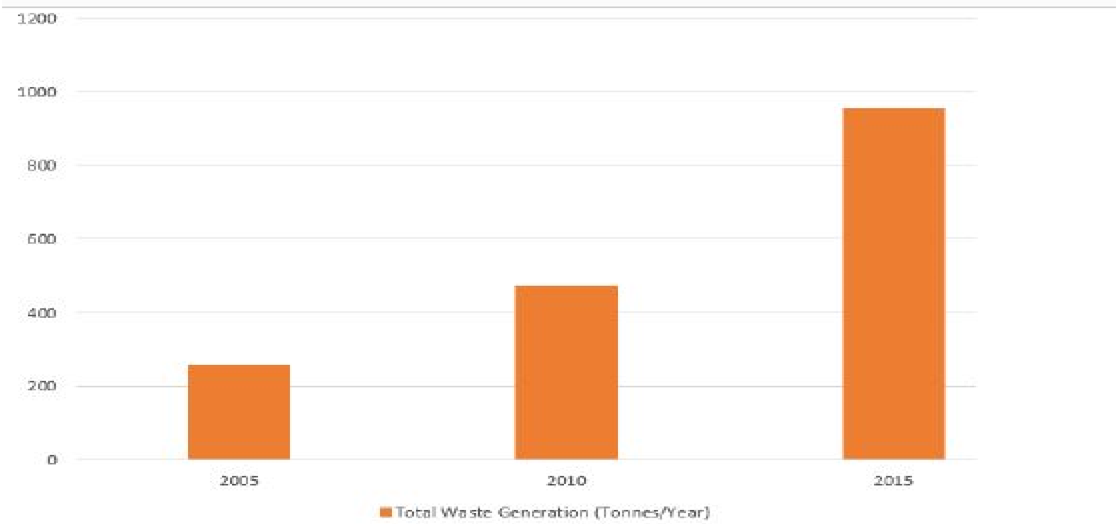
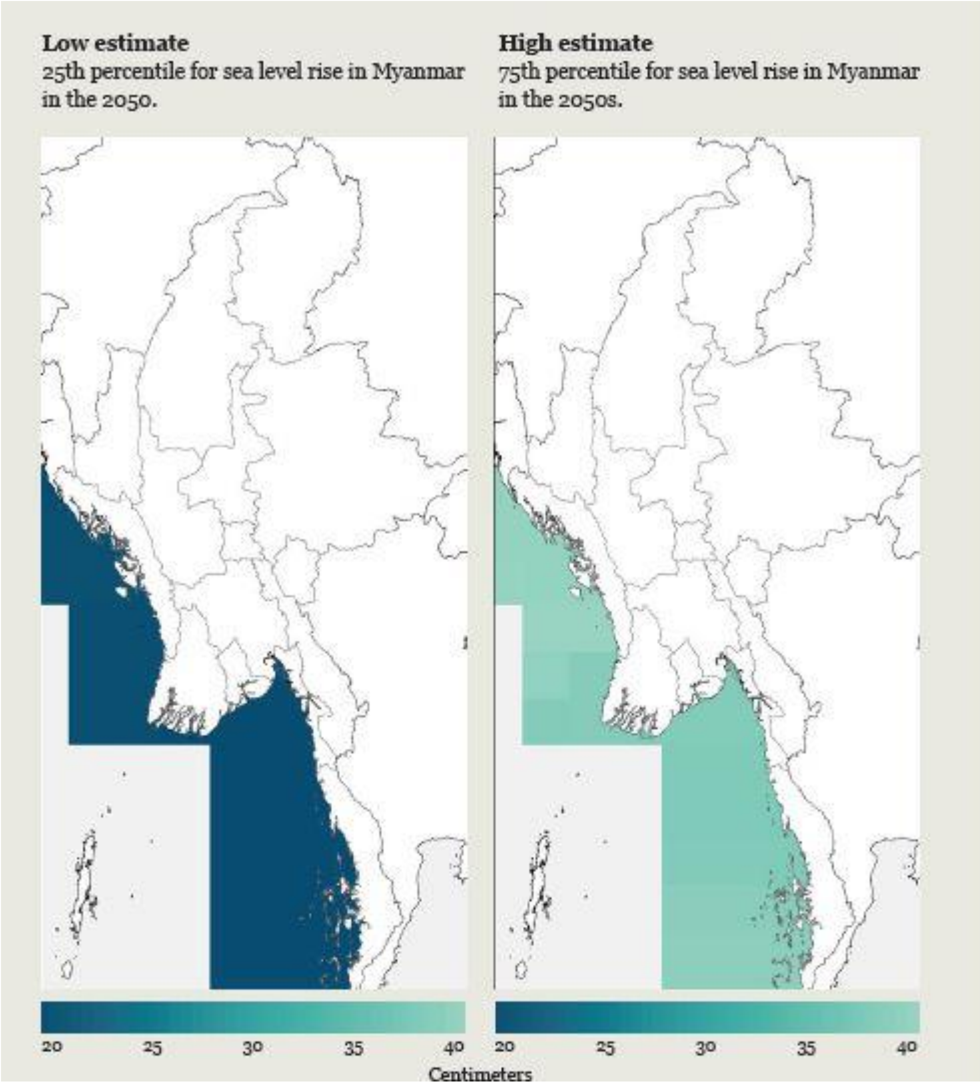


Figure 8: Projections of sea-level rise

Timeslice	Middle range of future sea level rise
2020s	5 cm to 13 cm
2050s	20 cm to 41cm
2080s	37 cm to 83 cm

Source: Report, T. ASSESSING. (2017).



Source: Report, T. ASSESSING. (2017).

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6. Water Security in Nepal

6. Water Security in Nepal

SUMMARY

Nepal is a land locked country in the Himalaya between India in the south and China in the north. Climatic zones vary from tropical monsoon zone in the South to Alpine conditions in the North within a small distance of 200 Km due to topographic variation. Country's physiography plays a major role in controlling the precipitation pattern. Nepal receives substantial amount of rainfall (Av. 1400mm/annum); most of it is received during the southwest monsoon period between June and September. 10% of the precipitation is as snow fall. generally, increases from north to south and from west to east in the country

Nepal's water resources are distributed in 6000 rivers, 5358 lakes, 3252 glaciers and 242 wet lands. In addition, the country has an estimated renewable groundwater potential of about 12 km^3, of which, 5.8–11.5 km3 can be extracted annually without any adverse impacts on water table. Out of an estimated annual renewable water resource of 225 (km3/year), around 74% of the water is generated within the country and rest is contributed by trans boundary rivers mainly from China and India. However, Dependency is small – about 5.7.

The present population of Nepal is roughly 30 million. Out of this population 7.8%, 45.5% and 46.7% live in the northern high Mountains, middle Hilly terrain, and southern Terai plains respectively. 20.15 percent of the total population in Nepal lives in cities (2019). The capital city Kathmandu has a population of 1, 5 million. The next big city is Pokhara with 4, 50,000 people. There are 4 more cities with more than 2, 00,000 people and 9 townships with more than 100,000 people.

Nepal is bestowed with copious water resource. In terms of per capita renewable internal fresh water resources, Nepal ranks second, next only to Bhutan among the South Asian countries. AQUASTAT data of the FAO and World Bank (2014) indicate that per capita 7366 m3/person/year. This per capita availability classifies Nepal as a Water Safe country on the basis of Falkenmark indicator. According to WECS the total annual withdrawal of water in 2001 was 18.5 Km3. Population increase, living style and other similar factors might have changed marginally. This incremental change will not cause any dent if water resources are managed effectively.

Despite of such a positive scenario on availability of water Nepal is facing water security problems. Agricultural sector which is the main sector which consumes over 96% of annual withdrawal has also some issues to be addressed. Domestic sector, consumes only 3%, but in view of its importance this sector has top priority tag. Although people of Nepal have access to water, large section of population is deprived of safe water for their drinking and other domestic needs. UN sponsored WASH program is partially successful as they face some implementation issues, fund availability, public awareness and their participation etc.

Sanitation and disposal of waste water is a serious problem which needs to be attended to on priority. The industrial sector consumes only 0.3% of water and there is an urgent need to improve this sector in order to strengthen the economy of the country. Nearly 25% of the population is found to be below poverty line. These are some of the solvable stumbling blocks of water security in Nepal that can be resolved with good governance and effective administration.

In addition to the above, the Global Climate Change has its impact on water security. Change in the precipitation pattern having high temporal and spatial variation, drying of springs, which are the main drinking water sources for the people and livestock in the mid-hills region, alarming decrease of the ground water levels in the mid-mountain valleys, the threat posed by GLOF are a few examples where global climate change has its imprints. GLOFs are no more hypothetical. They pose risk to human settlements in the river valleys, infrastructure and hydroelectric power plants.

Water resource of Nepal is a gift of nature. It has the ability to change the country's economy. It has a potential to generate 83,000 MWe of hydroelectric power. These have to be managed by deeper understanding of the natural processes by research, good network of observatories, data development, data base creation and interpretation, study from installations for monitoring and warning of glaciers and rivers

To harness the hydro power for mutual benefit of India- Nepal, the two countries have signed treaties for developing Mahakali, Saptakoshi and Karnali multipurpose projects. In view of extricable political relation between Nepal and India there is need to revisit the water treaty agreements particularly in the light of change of government in Nepal. Government of India has to take concrete steps to gain more confidence of people of Nepal on the inevitability of dependence on India for the mutual benefit by any developmental programme.

6.1 PHYSICAL GEOGRAPHY OF NEPAL

Nepal is a land locked country located on the southern slopes of the Himalaya mountain ranges and spreads over an area of 1,47,516 km between Latitudes 26°22' to 30°27'N and Longitude 80°04' to 88°12'E. About 86% of the land area is hilly and mountainous. From South to North, the terrain of Nepal can be divided into four main physiographic regions. They are: (1) the Terai region, a low, flat, fertile land close to the border with India; (2) the forested Churia foothills and the Inner Terai zone rising from the Terai plain up to the rugged Mahābhārat Range (Siwalik region); (3) the mid-mountain region between the Mahābhārat Range and the Great Himalayas (Lesser Himalaya) and, (4) the Great Himalayan Ranges, rising to more than 8,850 metres above the sea level

The climate in Nepal varies from the tropical to the Alpine within a distance of about 200 km from south to north. Regional climate variation is a function of elevation. Climate at any place in Nepal is largely controlled by elevation and location along its west to east stretch. National mean temperatures are around 15 °C, It increases from north to south with the exception of mountain valleys. Much of Nepal falls within the monsoon region. Monsoon precipitation varies from **s**ubtropical monsoon conditions in the Terai to_warm temperate conditions between1,000 to 2200 m in the mid-mountains, and cool temperate conditions in the higher parts of mountains between 2200 to 3900 m. Alpine climate prevails at altitudes between 3900 to 4900 m .Above 4900 m, the land is permanently covered by snow and ice. Though annual rainfall is abundant in the country, its distribution is of great concern. Areas over 3,000 m experience only drizzle, while heavy downpour is common below 2,000 m. Rainfall also increases from west to east. The data sets required to explain precipitation dynamics are limited. Monitoring stations are few (280 for the entire country) and hydro-meteorological data are available for only 60 years. With such limited information, it is rather difficult to adequately capture the temporal and spatial dynamics of precipitation. As a result, modelling exercises have fundamental limitations [1].

Precipitation pattern in Nepal is dominated by the presence of the monsoon circulation and its interaction with the topography. Precipitation occurs in two periods in Nepal: About 80 per cent of precipitation occurs between June and September during the months of the south-west monsoon. Remaining 20% precipitation occurs during the dry season between December and February, Currently, about 10% of total precipitation in Nepal is in the form of snow and the rest is rainfall. The average annual rainfall is about 1400mm, most of which is during the southwest monsoon. Rainfall is heavy in the eastern portion of the Terai and in the lesser Himalaya with 1,800 to 1,900 mm per year as recorded at Bīratnagar; but, the western portion of Nepal receives only 100-150mm rainfall in a year as observed at Mahendranagar.

In the monsoon season between June and September the variability of rainfall is low in the country. But during the dry winter months rain is high in far western region of the country and low in southern and eastern region

The southern slopes of Annapurna range in the middle mountain region receives highest rainfall -nearly 3000 mm. Pokharā Valley is the wettest. The northern slopes of Annapurna range receive least rainfall and is driest part in Nepal, with annual precipitation less than 200 mm. The Siwalik and the Terai belts compared to the middle mountains occasionally receive highest 24-hour rainfall. These regions are therefore prone to landslides, flash floods and inundation.

The catchment area in Nepal alone (excluding China) accounts for 45% of the long-term average annual flow in the Ganges basin. It contributes to more than 70% of the Ganges flow during the dry period.

6.1.a Demography

The present population of Nepal is roughly 30 million. 7.8% of the people live in high mountains, 45.5% in the middle hills and 46.7% on Terai plains. Population density is around 200 per square Km. Male to female ratio is approximately equal. .Adult literacy rate

67.8%.About 20percent of the total population in Nepal is urban (2019). The capital city Kathmandu has a population of 1, 5 million. The next big city is Pokhara with 450,000 people There are 4 more cities with more than 200,000 people and 9 townships with more than 100,000 people. According to current projections, Nepal's population will peak to 35.32 million by 2049 and then fall by the end of the century due to decreasing fertility.

6.1.b Economic Status

Despite the rise recorded in human development index at a World ranking of HDI-147.5, 25% of Nepal's population is below the poverty line with an income less than $3.20/day.

6.2 WATER RESOURCES, USAGE AND PER CAPITA WATER AVAILABILITY

Nepal is rich in water resources. According to WECS report of 2011, it is considered as the second richest country in Asia with respect of water resources [3]. Water resources are available mainly in the form of surface and groundwater resources, besides that stored in huge glacial cover. There is however strong spatial and temporal variability of water resources in the country.

6.2.a Surface Water

6.2.a.i *Rivers*

There are about 6000 rivers in Nepal having drainage area of 1, 91,000 sq. km. Drainage density is about 0.3 km. 74% of drainage area is in Nepal and the rest is in China and India. All the major river systems in Nepal are transboundary, originating in China, flowing through Nepal and joining the Ganges in India. There are 33 rivers having their drainage areas exceeding 1000 sq. km. Major rivers in Nepal are Mechi, Koshi (also spelt as Kosi), Bagmati, Narayani, Gandaki, Karnali (called Ghagra in India) and Mahakali. Among them, the Koshi is the largest, Narayani the deepest and the Karnali the longest. Rivers of Nepal can be broadly classified into three types, viz., (i) rivers fed from glaciers or snow (Koshi, Gandaki, Karnali and Mahakali) ; (ii) rain fed rivers originating from Mahabharat ranges (Babai, West Rapti, Bagmati, Kamala, Kankai and Mechi) and (iii) rain fed streams and rivulets originating mostly from the Churia hills. Total average annual runoff from all the river systems is estimated at 225 billion cubic metres (BCM), of which 172 BCM originate in Nepal (WECS, 2005). Dependency ratio is approximately 5.7. River flow is highly seasonal, about 75% occurring in the monsoon season (June to September). The rain fed rivers cause flash floods during monsoon and remain without much flow during the dry season between October and May. High rainfall and river discharge lead to landslides, floods and flash floods in both mountain and Terai regions.

6.2.a.ii *Lakes and Wetlands*

According to the National Lake Conservation Development Committee (NLCDC) [4], there are 5,358 lakes in Nepal distributed in different physiographic regions. Among them there are

2,323 glacial lakes. 2,700 (51%) are distributed below 500 m, 2,227 (42%) above 3,000 m, and only 419 (<8%) at altitudes between 5000 and 2,999 m [5]. Most of the lakes studied in Nepal are in the Middle Mountain areas of Fewa, Begnas, Rupa, Khaptad, Tilicho, Phoksundo, Dudh Pokhari, Panch, and Pokhari. Some important lakes are Rara, She-Phoksundo, Fewa, Tilicho. Mansarovar. Indra sarovar is an artificial lake created by Kulekhani hydropower project. Dimensions of these lakes are given in Appendix 1. As of now, except for Indra Sarovar, others are not developed as utilizable water resources in Nepal.

There are 163 wetlands in Terai, 79 in the hills and mountains distributed between 90 and 5,000 m. Together they cover an area of about 60,561 ha (NLCDC, 2018).

6.2.a.iii *Groundwater*

Groundwater is more reliable and flexible source of water. It is available in most parts of Nepal at varying depths and amounts. The southern Terai plains constitute water saturated zone in the Gangetic basin. In the intra-mountain valleys like the Kathmandu and Dang, groundwater occurs in isolated basins. The country has an estimated renewable groundwater potential of about 12 km3, of which, 5.8–11.5 km3 can be extracted annually without any adverse impacts on the water table[3]. Groundwater plays a pivotal role in fulfilling domestic water demand all over the country, especially in Terai region and in the Kathmandu valley while it also supports to some extent agriculture. Using measurements of seasonal fluctuations in the water table in shallow tube wells an annual renewable groundwater resource in the Terai region has been estimated at 8.8 BCM [6.] Despite this potential, groundwater use remains relatively low in Nepal. It was almost nil in the 1980. Shrestha et al.[6] estimated groundwater extraction of the order of 1.9 BCM/y in the Terai for irrigation, domestic and industrial use, compared to annual recharge of 8.8 BCM , leaving a groundwater surplus 6.9 BCM/year. This suggests a huge potential in renewable groundwater reserves. The natural recharge of groundwater in the Kathmandu valley is estimated at about 5.5 MCM/year. Here it is overexploited due to which water level in some places has gone down at the rate of 2 m/year. Groundwater from both deep and shallow aquifers is suitable for irrigation, whereas for drinking and industrial uses, treatment is necessary. Very high Arsenic is reported in the groundwater of Terai region.

6.2.a.iv *Glaciers*

About 23% of Nepal's total area lies above the permanent snowline which is at an elevation of 5000 m. Eight of the world's ten tallest mountain peaks, including the Mount Everest are in Nepal. Other prominent peaks are Kanchenjunga, Lhotse, Makalu, Cho Oyu, and Dhaulagiri which are all well known. These mountain peaks are surrounded by number of glaciers around them. There are 3,252 glaciers covering an area of 5,323sq.km with an estimated ice reserve of 481 km3. Known as the water tower of Asia, these glaciers feed the great rivers, including the Ganges, ensuring drinking water for millions of people in the lower riparian countries namely, Nepal, India and Bangladesh. Some better known glaciers are, Ambulapcha, Imja, Khumbu, Langtang, Nangpai Gosum, Ngozumpa. Abrief description of these glaciers in given in Appendix 2.

The status of change in snow/glacier area reported by most researchers is that there is a high rate of shrinkage from previous to recent decades. Due to significant global warming in recent decades, Ngozumpa glacier is showing signs of shrinking and thinning, producing melt water. Some of this water has been pooling on the surface where an enormous lake is growing. This lake, named as Spillway Lake, is about 6 kilometres long, 1 kilometre wide and 100 meters deep. Similar to the Spillway lake, several lakes are developing as a result of glacier retreat, which could lead to catastrophic events like glacial lake outburst floods (GLOF) in future causing destruction of valuable resources like forests and farms and infrastructural facilities.

Nepal is already witnessing the impact of climate change and associated intense short rainfall events causing landslides and floods. Landslides and floods account for about 400 deaths annually in the country.

6.3 LAND USE, AND LAND COVER CHANGES

Analysis of statistical data sets by Paudel et al.[7] indicate that the area of crop land in Nepal increased by 13% over the past 50 years. As opposed to this, forest cover reduced from 43.5% in the 1960s, to 29% in the 1990. However, it regained about 10 per cent by 2010 when the forest cover stood at 39.1% due to the corrective measures taken by the Government of Nepal. Grassland decreased by about 347 km^2. Urban land increased rapidly over the past 32 years from 122 km^2 to 469 km^2. These land use changes would have long term effect on water resources of the country unless proper management plans are not evolved.

6.4 EFFECTS OF CLIMATE CHANGE ON THE WATER RESOURCES IN THE NEAR AND FAR FUTURE

Evaluating the impacts of climate change on water resources is challenging as water availability, quality and stream flow parameters are all sensitive to changes in temperature and precipitation. The results of global climate scenario modelling

suggest that the impacts of climate change are intense at higher elevations and in regions with complex topography. This can be seen in Nepal's mid-hills and higher elevations. Preliminary analyses indicate that climate change in the Ganga and Brahmaputra basins will alter the river flow, which in turn will result in drought, flood, soil erosion and sediment transport. As early as 1999, Shrestha et al.[9] suggested that temperatures are increasing in Nepal and that rainfall is becoming more variable. In 2009, a modelling exercise conducted by team of Nepal, American, British, Pakistani and Bangladeshi experts (NCVST,2009) [10] using the emission scenarios in the IPCC's special report (2007) confirmed that the temperature will indeed increase in the mid-hills. WECS (2011) [3]recorded the following effects:

1. Precipitation trend analysis shows that the annual average precipitation over Nepal is decreasing at the rate of 9.8 mm/decade. However, the Koshi basin shows increasing trend. Trend of annual discharges in three major River basins, Koshi, Gandaki and Karnali indicate that the discharges in these major basins are decreasing annually. The annual discharges in southern basins are however showing an increasing trend.

2. Analyses of monthly flow trend of some of the rivers indicate that the contribution of snow melt in runoff is showing an increasing trend for snow-fed rivers, similarly for non-snow-fed rivers. Dry season flows are decreasing and wet season flows are increasing. It is observed that the numbers of flood events are increasing as well as the effect of single flood is also increasing to more days. The changing precipitation pattern indicated that the drought period is becoming longer, though there is no definite trend in the annual precipitation amount.

3. The impact on snow and glacier is found to be very high. Negative trends are observed in the glacier mass balance. Glacial Lakes are expanding and the threats of Glacial Lake Outburst Floods (GLOF) are increasing. Modelling studies by Immerzeel et al (2012) showed that both temperature and precipitation are increasing resulting in the decrease of the glacier area at Lang tang in Nepal Himalaya. They predicted that river flow would increase significantly due to increase in precipitation and ice melting and the river would transition to a rain fed river. Rainfall runoff and base flow will increase at the expense of glacier run off. They also pointed out that melt water peak would coincide with the monsoon peak, they predicted that no shifts would occur in the hydrograph

6.5 UTILIZATION OF WATER RESOURCES

Nepal's economy is largely based on agriculture which contributes to about 40% of the GDP and provides employment to two-thirds of the population. Nepal has a cultivated area of 2,642,000 ha (18% of its land area), of which two third (1,766,000 ha) is potentially irrigable. Although at present 42% of the cultivated area has irrigation facility, only 17% of cultivated area has year- round irrigation. An estimate shows that less than 8% of the country's water potential is used for irrigation, although 96 per cent of the water exploited is used in the agriculture sector. Industrial activity is also related to agriculture sector confined to processing of agricultural products, including pulses, jute, sugarcane and tobacco. The fraction of water demand for irrigation and domestic purposes can be supplied from groundwater sources also. The annual withdrawal of groundwater for irrigation and domestic purposes is 0.756 km3 and 0.297 km3, respectively [11].

Nepal was self-sufficient in food grain production until 1990. Due to drought in 2005/06 and 06-07 agricultural production fell short by 21553 t and by 179910 t respectively, badly hitting the economy. Massive earthquake of 2015 destroyed the infrastructure of the country and the economic development. Agriculture is the mainstay of Nepal's economy. Climate variability directly affects agricultural production, as agriculture is very sensitive to the risks and impacts of global climate change and water shortages. Any further decreases in water resources, especially during the non-monsoon seasons, would adversely affect agricultural production. It will have a direct impact on the livelihood of the people

There exists a huge scope for exploiting the hydropower. The estimated hydropower potential of Nepal is 83,000 MW of which 114 projects having 45,610 MW have been identified to be economically feasible. However, in the context of climate change, the hydropower development scenario needs to be revisited. At present, Nepal Electricity Authority (NEA) has a total installed capacity of 689 MW, of which the hydropower capacity is 632 MW. Nepal has signed trade and investment agreements with India and China, but political uncertainty and a difficult business climate have hampered foreign investment. The United States and Nepal signed a $500 million Millennium Challenge Corporation Compact in September 2017 which is expected to expand Nepal's electricity infrastructure and help maintain transportation infrastructure.

Water resources and hydropower rank higher in the vulnerability scale than any other sector for obvious reasons. Water resources and hydropower are directly related to rising temperatures that have already been proved. It is also predicted (with high confidence) to increase further in the coming decades. This includes glacier retreat and changes in streamflow, glacial lake outburst floods that pose risk to hydropower facilities, and also to other infrastructure and human settlements. GLOFs are no more hypothetical. Such events have been occurring since 30 years. One of the memorable examples of such event is the total destruction of the Namche Bazaar hydropower facility in 1985. On 4 August 1985 Dig Tsho, a moraine-dammed glacial lake in the Khumbu area of eastern Nepal got burst. The consequences were catastrophic. The destruction of a newly built hydroelectric power plant, 14 bridges, about 30 houses, and many hectares of valuable land was heavily damaged by 5 million cubic metres of water plummeting down the Bhote Kosi and Dudh Kosi valleys

The domestic sector uses about 4 per cent of the water exploited. Women, in particular are often deprived of opportunities to engage in income generating activities because of the need to spend hours in fetching water. A minimum of 30 per cent loss of the total time is estimated. This loss can be saved and more productively women can be used for other economic activities.

6.6 WATER QUALITY

Anthropogenic pollution is virtually unchecked and all water bodies even at the source are getting polluted due to multiple causes, including pilgrimage, Urbanization and industrialization are the main causes of pollution of rivers. Bagmati and the Bishnumati rivers in Kathmandu look like dirty drainages. The resources of water are getting badly affected due to rapid deforestation; water quantity in rivers has been decreasing alarmingly. Lake 'Fewa Tal' in Pokhera is getting polluted at an alarming rate. In the absence of effective law and policy monitoring the pollution control remains unsatisfactory.

There is country wide data on pollutants. Some researchers and NGOs occasionally carry out chemical analysis. Nitrate, ammonia, phosphate, Escherichia coli (E. coli), and total coliform bacteria are examined as possible indicators of sewage contamination. Manganese, iron, sulfate, and heavy metals are examined as indicators of domestic and industrial waste; and nitrate and heavy metals (i.e., arsenic and mercury) as possible indicators of agricultural contamination.

A few samples from the middle Himalayan valleys show higher amounts of fluoride up to 2.75 ppm Arsenic from groundwater from Terai area is much higher than permissible limits given by WHO. Higher values of arsenic is attributed to the derivation of sediments from the Himalaya carried by the rivers and deposited in the Terai region over extended geological time periods

6.7 WASH PROGRAMME IN NEPAL

Sanitation and waste management in the Kathmandu Valley was virtually non-existent. It is estimated that Kathmandu generates 272,000 kg/day of solid waste. Yet only 150,000–190,000 kg/day are collected. There are several landfill sites presently getting filled up. There are many uncontrolled dumping sites located along the rivers[8] Highly permeable sediments of the river bed pose a pollution risk to groundwater. in Kathmandu there was no wastewater treatment facility as of 1999. It is estimated 104 million L /day of wastewater was directly discharged to natural drainage. There appears to be no regulation to control discharge of effluents from industries into public sewer system or on land. Sanitation facility adjacent to city limits was also poor with several instances of drop-toilets located not far from drinking water sources for the household uses. In the agricultural fields manure and chemical fertilizers are spread in excessive quantities.

Every year about 45,000 children below the age of five years used to die in Nepal from sanitation related problems, which are attributed to inadequate supplies of water and/ or its poor quality. Improving the quantity and quality of the water supply and sanitation are well established approaches to reduce the morbidity due to different diseases. The projected reduction in morbidity due to improvement in water supply and sanitation were estimated by WHO (1992)[12] as; Cholera, Typhoid, Dracunculiasis (80-100%); Schistosomiasis (60-70%); and Dysentery, Diarrhoeal diseases (40-50%). The median anticipated reduction in child mortality was estimated at 55% due to improved water supply and sanitation. This indicates that improving water and sanitation is a critical step towards protecting public health in a significant way.

Status of water supply and sanitation is summarized in Appendix 3 and their functionality in Appendix 4. Although It is true that some proportion of the total population still lacks access to improved water supply and sanitation facilities, Nepal has made notable progress in WASH Sector. In 1990, only 46 % of the then existing population had access to drinking water from the improved sources and only 6 percent had access to toilet facilities (Chitra 2019)[13\]. In 2011, these figures changed to 85% and 62% [13]. Data of DWSS (2018)[14] shows that about 97% of the total population has access to basic sanitation facilities and 87% to basic water supply facility. By the end of 2018, 63 districts of Nepal achieved open defecation free status. Almost all people living in the hill and mountain belts have access to basic sanitation facility. Coverage of sanitation facility in Terai is 93 percent which is 3 percent below the national coverage.

Adequate water supply close to the community is another issue. Inadequate water supplies close to the dwellings can also have a significant impact on sanitation. women in Nepal are responsible for fetching fuel and water for their households as well as for various types of microenterprises. The significant amount of time and effort they spend in collecting fuel takes them away from jobs, education, and other activities for "self-improvement.

Community friendly and low-cost technology should be applied in the field of water supply and sanitation so that the local people are confidant to use them and the program will become more sustainable.

In urban areas where there is high demand for water and where people can afford to pay, quality water supply should be encouraged under the concept of cost recovery and public private partnership.

To achieve the goal of quality drinking water at the community level, there exists an immediate need is to assess water quality, health impacts, and sustainability of drinking water systems, both in the Terai and Mountainous regions of Nepal.

The impacts of climate change on Human health. Biodiversity etc. tend to be less direct and appear to have moderate sensitivity. Human health is ranked below water resources and agriculture mainly because of the uncertainty of the impacts. The health related effects of flooding could be one of the problems in the near future. Detailed studies on these aspects are called for.

6.8 TRANSBOUNDARY WATER ISSUES:

Nepal is an upper riparian country for the Indo-Nepal transboundary rivers. Nepal and India share fairly good relationship because of geographical location and common ethnicity [15]. In spite of this, the transboundary river water treaties are yet to transformed into reality because Nepal is still not convinced of the good intentions of India. Public opinion in Nepal has always been very critical of the Kosi (1954) and Gandak (1959) agreements. It is being maintained that as the barrages were constructed quite close to the Indian border, Nepal was unable to benefit from them. Had the projects been located further up in Nepal, it could have received a fair share of waters for irrigation from them [15]. Water agreements were revised in 1964 for Gandak and in1966 for Kosi to accommodate the grievances of people from Nepal's catchment areas. However, a deep distrust was created between the two countries in the area of water harnessing and no major project was undertaken until the signing of the Mahakali treaty in 1996. The reasons are summarised in Appendix 5.

It is estimated that the rivers in Nepal could generate up to 83,000 MW of hydroelectric power. To harness the shared hydro power and for mutual benefit India and Nepal have signed four treaties namely :

1. Mahakali treaty which includes buiding Sharada barriage, Tanakpur Barriage and Pancheshwar mutipurpose dam.

2. Sapta-Kosi High Dam Project and SUN Kosi storage cum diversion scheme.

3. Kamla and Bagmati Multipurpose Projects.

4. Karnali Multipurpose Project.

While these treaties are yet to be implemented, Nepal has invited other countries to develop its hydropower sector. In view of extricable relation between Nepal & India there is a need to revisit the water treaty agreements particularly in the light of change of the government in Nepal. Government of India has to take concrete steps to gain confidence of the people of Nepal on the inevitability of dependence on India for mutual benefit in any developmental programme.

6.9 CHALLENGES TO WATER SECURITY AND NEPAL GOVERNMENT'S INITIATIVES

Water security continues to be a major concern in Nepal despite the abundance of annual rainfall and replenishable water resources. Water demand is likely to increase with population growth, urbanization, industrialisation, more intensive agriculture and increasing standards of living. Nepal's plains contain huge and mostly untapped reserves of renewable groundwater which can be harnessed. The government wants this resource to be used to increase the water supply for agriculture. To tap this resource solar power for pumping is planned. Estimated direct economic gain from providing year round irrigation to the unirrigated agricultural plains in the Terai is of the order of USD 1.1 billion, equivalent to 4.5% of Nepal's annual GDP in 2017.

In addition to these government is also engaged in promoting the private and public institutional involvement in

A) Development of suitable climate model/s,

B) Establishment of a model test laboratory, Redefining water structure design criteria and identification of vulnerable areas and climate friendly technologies, development of adaptive measures and proper implementation,

C) Research on water resources to apply 3R (Reduce, Reuse and Recycle) principle as well as study on addressing the climate change impacts on landslides, debris flows, floods and droughts are also necessary to cope with the climate change

Climate change impacts on water resources may be addressed by continuing the focusing on

1) Research
2) Creation of optimum observation network,
3) Creation of authentic data-base and research based action oriented program/projects.
4) Communication and effective outreach programmes.
5) Other linkages, such as promotion of solar power for pumping, with benefits to stakeholders and industry,

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Appendix 1: Some important Lakes of Nepal

Rara Lake	This lake also called as Mahendra Daha is located at an elevation of 3200m above sea level in Karnali Zone of Jumla and Mugu Districts and is the biggest lake in Nepal, It is 8 km long, 1.5 km wide and 167 m deep . This lake reflects the shadow of Sisne and Kanj[irowa mountains.
She-Phoksundo Lake	This lake is named "Rigmo" locally. This lake located in Dolpa District of Karnali Zone in the Kanjirowa mountain. It is located at an elevation of 3900 m. It is 4.8 km long, 1.5 km wide and has a depth of 145 m.

Fewa Lake	The lake is located in Pokhara, Kaski District of Gandaki Zone. It is the second biggest lake in Nepal; it is 4.8 km long, about a km wide and has a total area of 4 km2. This lake reflects the shadow of Machhapuchhre and Annapurna Mountains.
Tilicho Lake	This is the highest lake in Nepal located at an elevation of 4919 m above mean sea level. It is located in Manang District of Gandaki Zone. Its length is 4 km and breadth is 1.4 km.
Indra Sarowar	This is an artificial lake formed behind the dam of the Kulekhani Hydropower Project. It is located in Makwanpur District snd has a spread of 7 km2.
Man Sarowar	It is located in the southernmost point of Tibet near the Nepal–Tibet border and is one of the pilgrimage sites for the Hindus and Buddhists. It is known as "Pamchu" in Tibet and as "Manslu Ochu" in China.

Source: https://en.wikipedia.org/wiki/List_of_lakes_of_Nepal

Appendix 2: A brief description of important glaciers of Nepal

Ambulapcha glacier	It is located in the Solukhumbhu District, This glacier joins the Imja and Lhotse Shar glaciers and together they form a major glacial region. The glacier also gives rise to Ambulapcha Tsho glacial Lake
Imja Glacier	Located in the Solukhumbhu District of Nepal, Imja glacier originates on the South-eastern slopes of Mount Everest. The glacier feeds the Imja Tsho Lake and further drains through the Dingboche valley to the Imja Khola and Dudh Kosi rivers. Kosi joins Ganges and finally the Indian Ocean. Imja lake is one of the

	fastest-growing glacial lakes and is threat to downstream communities with the potential of a glacial outburst flood. In 2016, the Nepalese Army constructed an outlet and drained more than 4 million cubic meters of water from this lake to reduce the pressure on the glacial morain dam
Khumbu Glacier	The Khumbu Glacier, the largest Glacier of Nepal is located in northeastern Nepal between Mount Everest and the Lhotse-Nuptse ridge. It is considered as the world's highest glacier located at an elevation of 7600m and it terminates at 4,900 meters. The glacier also has a large icefall, the Khumbu Ice fall on way to Mount Everest summit. The high velocity flow near the ice fall has given rise to large crevasses and is an area prone to avalanches
Langtang Glacier	It is because of this glacier that Langtang Valley is known as "the valley of Glaciers". It is the longest glacier in the region and originates from Langtang Lirung peak. The glacier between 4,500 to 7000 meters is partially covered by debris. The debris, has a significant effect on the ablation rate of the glacier, and consequently on the mass of the glacier.
Nangpai Gosum Glacier	Located 25 km west northwest of Mount Everest lies close to the Nepal – China border. The Nangpai Gosum massif consist of three peaks, easily accessible from China side
Ngozumpa Glacier	This glacier is situated below Cho Oyu- the sixth highest mountain peak in the world. It is the longest glacier in the Himalaya. . A large persistent body of ice, the Ngozumpa Glacier flows due to stress ins own wight and it velicity of flow is known to be one of the lowest

Source: Glaciers of Nepal - USGS prof paper No 1386. F-6

Appendix 3: Status of water supply and sanitation by wealth quintile

Water supply	Poorest	Second	Middle	Fourth	Richest

Piped water on Premises	10	14	16	17	35
Other improved water	69	82	84	83	64
Unimproved water	21	4	0	0	1
Sanitation					
Open defecation	69	53	42	28	1
Other improved toilets	11	14	14	8	34
Shared Toilets	4	11	12	22	0
Improved flush toilets	16	22	32	42	65

Source: *WHO/UNICEF, 2015*

Appendix 4: Functionality and Sustainability of WASH Facilities

Situation of functionality of water supply systems

SN	Functionality of systems and tap	Systems (%)
1	Functionality of water supply system	
	Well functioning	25.4
	Need minor repair	36.1
	Need major repair	9.2
	Need reconstruction	8.6

	Need rehabilitation	19.8
	non-functional	0.9
	Providing water to all taps in the whole year	68.2
2	Condition of water tap stands	
	Functioning, no need repair	78.4
	Need minor repair	5.1
	Need major repair	16.5

Source: NMIP 2014, Nationwide coverage and functional status of water supply and sanitation status in Nepal

Sanitary status of toilets and functionality

Sanitary/functional	(%)
Sanitary	93.0
Insanitary	7.3
Unused	0.7
Functionality	
Functional clean and sanitary	78.0
Insanitary and poorly maintained	7.0
No toilet or not used as toilet	15.0

Source: NMIP 2014, Nationwide coverage and functional status of water supply and sanitation status in Nepal

Appendix 5: Concerns of Nepal related to India-Nepal Transboundary Problems

• Water cooperation between Nepal and India have been agreements signed on major rivers like Kosi, Gandaki, Karnali or Mahakali, essentially for large hydroelectric and irrigation projects by building dams or barrages.
• No project except the Kosi barrage has been completed yet. Smaller rivers have been ignored.
• Since 1954, when the Kosi Agreement was signed between India and Nepal, talks between the two governments have stalled and water rights issues have not been addressed.
• There have been various disputes over this agreement fuelled by floods in the Kosi region.
• India and Nepal have also had disputes over the issue of compensation of the Kosi dam.
• Moreover, Nepal had considered India's construction as an encroachment on Nepal's territorial sovereignty.
• The problem with the Kosi River is its high level of sedimentation and embankments have proven to be ineffective to tackle sedimentation.
• The only available option in this case is storage tanks and these cannot be set up without the cooperation of Nepal.
• India and Nepal have traditionally disagreed over the interpretation of the Sugauli Treaty signed in 1816 between the British East India Company and Nepal, which delimited the boundary along the Maha Kali River in Nepal.
• India and Nepal differ on the exact source of Gandaki river.
• The dispute between India and Nepal might seem minor but it gains strategic importance, because the disputed area lies near the Sino-Indian border.

7. Water Security in Pakistan

7. Water Security in Pakistan

SUMMARY

Pakistan has seen its transition from water abundant to water-stressed state with the per capita water availability declining dramatically from 5,238 m^3 in 1962 to roughly 1,253 m^3 in 2017[1]. Per capita water availability is expected to decrease even further in the coming years. Approximately 74.35% of the total renewable water resources (TRWR) is withdrawn annually, thereby raising an immense pressure on renewable water resources. The Agriculture sector draws the highest amount of water (69.85 %) of the TRWR while the municipal and industrial sectors withdraw 0.57 % and 3.91% respectively[1]. As agriculture sector dominates water use; water-saving and efficient utilization of water in this sector is crucial. Over the years, there has been a significant increase in aggregate water demand. The rate of growth in the total water demand between 1975 and 2008 is 20% and between 2000 and 2008 it is 6%. The water demand for the Agriculture and Municipal sector grew by 15% and 530% between 1975 and 2008, and 6% and 50% between 2000 and 2008. The dependency ratio of the country is 77.71%, which means Pakistan's water resources largely originate in the neighbouring countries (Afghanistan, India, and China) and its water security is vulnerable to factors outside its control[1].

Despite impressive changes in the proportion of the population having access to an improved water source and an improved sanitation facility, Pakistan is ranked ninth worldwide on the list of countries with the lowest access to clean water[2]. About 70 million households are estimated to be drinking bacterially contaminated water [3], and 30% of the population does not have access to adequate sanitation facilities[4].

In Pakistan, waterborne diseases are a leading cause of suffering and death, which is the result of old and leaky sewage and water supply lines that permit sewage contamination of drinking water. The World Bank report states that "Inadequate water supply, sanitation, and hygiene contribute to high levels of childhood stunting, undermining human capital. Women and children are the most vulnerable, especially in rural areas where sanitation is particularly inadequate, and most water supplies are contaminated"[5]. According to WHO (2015), cholera has remained a public health problem in the country due to water pollution[6]. An approximate 39,000 children under five years of age die every year from diarrhea caused by unsafe water and poor sanitation[7].. Groundwater in the Indus plains contains five times more arsenic than permitted by WHO standards, placing 50 to 60 million people at risk of contracting arsenicosis[8]. Wastewater treatment system has remained profoundly obsolete both in urban and rural areas. The potential for service is insufficient and the current facility is poorly managed and maintained. Sewerage network capacity is very minimal and the existing partial network is not well managed. The poor social outcomes from water, best characterize water insecurity[5].

Changing climatic conditions can also enhance health-related risks, both because of water pollution and increase in vector-borne diseases. In recent years, a particular uncertainty has been growing about the possible effect of climate change on Pakistan's already strained water supplies. Increasing temperatures, increasing influx of saltwater in coastal areas due to sea-level rise, a growing threat of glacier lake outburst flooding, variation in the pattern of monsoon and winter rains causing frequent and intense floods and droughts, and increasing incidence of high-intensity rainfall are some of the adverse effects of climate change which will impact Pakistan's hydrological resources[9]. The effect of climate change on water flows within the Indus Basin is of particular concern. The Indus River and its tributaries are a significant source of renewable water resources in the country. It is mainly fed by snow and ice melt in the Hindu Kush-Karakoram-Himalaya Mountains[10]. Any change in water flow in the Indus basin will have significant implications for food security in Pakistan as 80% of the water for irrigated agriculture comes from the Indus Basin Irrigation System [11]. The water supply needs of domestic, municipal, the industrial sector as well as the country's energy production (hydropower) are also largely dependent on the Indus basin water flows. Scott et al (2019) from modelling studies however predicts that glaciers feeding the Indus River system may not show much recession unlike the glaciers in the Eastern Himalaya[12].

These risks exacerbate the existing water security challenges since Pakistan is among the world's most water-stressed countries. Pakistan will only see modest changes in water quality and quantity without significant reforms. Per capita water availability both in terms of quality and quantity will possibly decrease, with the increasing rate of deterioration of groundwater and surface water and with the rapid rate of population growth and urbanization coupled with climate change.

Indus valley Treaty for sharing the waters of Indus Valley has been working well ever since it was signed 1960. Although the upper reaches of Indus are in China, it was not a part of the Indo-Pakistan Treaty. Pakistan, being lower riparian country, should work with India and Bangladesh, to bring home that water from Hindu Kush Himalaya - the water tower of Asia- is a global resource, not just meant for China. Indo-Pakistan relations should remain strong to achieve this goal.

7.1 WATER RESOURCES, AVAILABILITY AND DEMAND

Water availability in Pakistan is largely dependent on summer and winter rains in the watersheds and river flows from snow and glacier-melt. Pakistan is an arid country with monsoonal climate which receives bulk of its rainfall during the months between July and September[1]. Long term mean precipitation is found to be 494 mm/year that contributes to 393 Km3 of water[2]. The rainfall distribution varies across the vast geographical extent of the country. The southern region (including the Balochistan Plateau) of the country remains dry compared to the northern region.

The three main hydrological units of Pakistan are Indus Basin, the Makran Coast, and the Kharan Desert. The Indus Basin covers 65% of the area of the country. The Makran Coast and the endorheic Kharan Desert cover 18% and 17% percent of the area respectively[3]. The Indus basin contributes to 95% of the total renewable water resource (TRWR) of the country.

The Indus basin is spread over the provinces of Punjab, Sindh and Khyber Pakhtunkhwa (KP) and the eastern part of Balochistan covering an area of 520000 km^2. The Indus River and its tributaries have been the main source of renewable water resources with 80% of the water for irrigated agriculture[3]. Kabul and Panjnad are the main tributaries of the Indus River. The major flow of Panjnad results from five main rivers, three eastern (Ravi, Beas and Sutlej) and two western rivers (Jhelum and Chenab). The total drainage area of the Indus basin is approximately 1.1 million km^2 47 % of which is in Pakistan, and the remaining 53% is in China, Afghanistan and India. The average annual inflow into the country through the Indus is approximately 265.08 km3, of which 21.5 km^3 is from the Kabul river and other tributaries of the Indus river flowing from Afghanistan, 11.1 km3 from the eastern rivers (Sutlej, Beas and Ravi) of the Indus basin and 232.48 km3 from the western rivers (Jhelum and Chenab)[4] .

According to the India-Pakistan Indus Water Treaty (1960), it is estimated that 170.27 km3 / year is reserved for inflow from India into Pakistan [4].

Gilgit-Baltistan contains 22,000 km^2 of glaciers, the largest area of perennial glaciers outside the polar region[5]. It is estimated that as much as 28% of the region is glaciated and that winter snow cover occupies as much as 30-40% of the area. More than 100 glaciers are over 10 km long, with several glaciers stretching beyond 50 km. Hence, glaciers and seasonal snow constitute a huge reservoir for freshwater in the area and contribute vastly to the flow of the Indus river[6].

The Kharan desert is located to the west of Balochistan and the Mashkel and Marjen rivers are the principal source of water here. The Marjen is a minor tributary to the Mashkel. The water is discharged into the Hamun-i-Mashkel Lake in the southwest, on the border with the Islamic Republic of Iran. The arid Makran Coast basin receives its bulk quantity of water from Hob, Porali, Hingol and Dasht rivers.

The Tarbela and Chashma (on the Indus), and the Mangla (on the Jhelum) are the three major dams in the country that account for most of the built water storage. The initial total live storage capacity of the dams was 19.4 Km3 (Tarbela -12Km3, Mangla-7.3Km3 and Chashma-0.87 Km3). The increased influx of sediments have brought down the storage capacity of the dams by around 1% per year. By 2007 it had come down to 15Km3 [3]. Between 2005 and 2009, the Mangla Dam was extended adding 3.6 billion cubic meters of live storage. The total live storage is estimated to be about 16 billion cubic meters due to continued sedimentation[3].

The total renewable water resource (TRWR) in the country is approximately 246.8 km3, of which about 55 km3 is internal renewable water. In Pakistan surface water and groundwater comprise 81% and 19% of the Total Renewable Water Resources (TRWR). 57 % of TRWR is contributed by the snowmelt water. In general, higher the snowmelt contribution to the TRWR, greater is its vulnerability to warming temperatures[2].

For Pakistan the dependency ratio is 77.71 %—indicating that the water resources in the country are vulnerable to factors outside its control.

In 2008 the total renewable water withdrawal was approximately 183.4 Km3 which means that 74.35% of the available TRWR was withdrawn. The surface and groundwater withdrawal account for 66.4% (121.9Km3) and 33.6% (61.6 Km3) of the total water withdrawal. The water demand in a country is the sum of water withdrawn by the Agricultural, Municipal and Industrial sector. Among the three sectors, the Agriculture sector draws the highest amount of water, 69.85 % of the TRWR while the Municipal and Industrial sector withdraws 0.57 % and 3.91% respectively (Table 1). Hence, water-saving and efficient utilization of water in the agriculture sector is crucial, given that this sector demands the highest amount of water.

Table 1 (Appendix) shows the amount of water withdrawn by the three sectors and the total water withdrawal from 1975-2008. From the table, it is evident that there has been a significant increase in aggregate water demand. The rate of growth in the total water demand between 1975 and 2008 is 20% and between 2000 and 2008 it is 6%. The water demand for the Agriculture and Municipal sector grew by 15% and 530% between 1975 and 2008, and 6% and 50% between 2000 and 2008. In contrast, there was a drop in water demand from the Industrial sector in the last decade (2000-2008). During this period the water demand fell from 3.47 Km3 to 1.4 Km3. The decline in industrial water withdrawals may be due to the considerable economic uncertainty the country experienced around 2005[7]. Several studies have reported that there is a linear relationship between Gross Domestic Product (GDP) and industrial water demand[8–10].

Since Pakistan's independence in 1947, six national censuses have been conducted during the years 1951, 1961, 1971, 1981, 1998 and 2017. They have shown high population growth rates in the country, ranging between 2.4% and 3.77% (Table 2, Appendix). The United Nations Department of Economics[12] (2015) projected that the country's population would reach 245 million people in 2030 and 309 million people in 2050.

Table 4 (Appendix) shows the relationship between water availability, usage and population in Pakistan between 1962 and 2017. According to the AQUASTAT data of FAO, water availability per capita has declined dramatically in the country, having decreased from 5,238 m3 in 1962 to roughly 1,253 m3 in 2017. Based on the Falkenmark measure (Table 3, Appendix), Pakistan is currently a water stressed country with 1253 m3 of water available per capita. The demand for water in Pakistan is most likely due to the increase in urban sector expansion[11]. With increasing population and urbanization Pakistan seems to be heading towards a water scarce situation.

7.2 WATER QUALITY IN PAKISTAN

In 2002, Pakistan Council of Research on Water Resources (PCRWR) launched the National Water Quality Monitoring Program (NWQMP). This project generated the first comprehensive water quality profile of 23 major cities in the country. NWQMP (2002–2006) continued for five years. During this cycle, 357 water samples were collected from 364 identified water bodies, and they were tested for 79 physico-chemical parameters including trace, ultra-trace elements and bacterial indicators. Detailed analyses of the data identified four major water quality parameters of concern in Pakistan's drinking water sources, i.e. bacteriological (68%), arsenic (24%), nitrate (13%) and fluoride (5%). Overall, 51 water bodies (9 %) were considered to be "Clean" out of a total of 357, and the remaining 306 (91 %) were found "Unsafe" for drinking purposes[13].

In Pakistan, microbial pollution has been discovered as one of the most serious problems both in rural and urban environments. This might be due to the very old leaky canal networks and sewage and water supply mains that permit sewage contamination of drinking water. Arsenic and iron levels exceed safety limits in 6 percent and 10 percent of piped urban water supplies. To avoid the spread of waterborne pathogens, the government needs to take urgent steps to provide clean drinking water to the public by modernizing water supply and sanitation systems. Water sources in the country are also found to be contaminated by toxic substances from the industrial effluents, textile dyes, pesticides, nitrogenous fertilizers, arsenic, and other chemicals. Issues related to fluorosis persist in areas of Balochistan, Punjab, and Sindh provinces due to high concentration levels of fluoride in drinking water. Dental fluorosis is common in Sindh, Punjab, and KP[14]. Improving Educating the public water quality issues and impressing them to participate in monitoring and taking care of the water supply infrastructure is an urgent necessity.

7.3 IMPACT OF CLIMATE CHANGE

The Fifth Assessment Report (AR5, 2014) for the Asia region by the Intergovernmental Panel on Climate Change (IPCC) states that sensitivity to threats from climate change in agriculture-dependent economies (such as Pakistan) derives from their distinct geography, demographic trends, socio-economic factors, and lack of adaptive capacity to determine the vulnerability profile by perpetuating a vicious cycle of poverty when taken together. The AR5's climate change forecasts for South Asia as a whole indicate that, warming is likely to be beyond the global mean and climate change would influence the trends of melting of glaciers and precipitation, particularly influencing the timing and intensity of monsoon rainfall. The profitability and output of water-dependent industries, such as agriculture and hydropower, would be significantly impacted[15].

According to the Global Climate Risk Index (2020), Pakistan ranks 5th in terms of vulnerability to climate change[16]. This vulnerability has been demonstrated by several floods and droughts which have taken place in the country. The report "Task Force on Climate Change" published by the Government of Pakistan, Ministry of Planning, Development, and Reforms in 2010 highlights the information regarding climate change-related threats to water security. According to the report, water security will be affected by variation in the monsoon and winter showers which will result in the variation in river flows, rains causing frequent and intense floods and droughts. Loss of natural reservoirs in the form of glaciers will bring a decrease in water availability. The decreasing trend in per capita availability of water coupled with a high rate of evaporation at an increased temperature will increase the demand for irrigation water and bring upon an overall increase in water demand. The rapid loss of reservoir capacity, arising due to rise in sediment flow will result from the frequent high-intensity rainfall. The surface and groundwater quality will deteriorate with increased incidence of floods and droughts. Climate change will intensify high altitude snow avalanches and glacial lake outburst floods (GLOFs). GLOFs occur when the ice wall retaining the lake fails, sending the entire stored volume of water downstream as a flash flood. Driven by these changes in climatic conditions, annual and inter-annual changes in the spatial and temporal distribution of water resources are expected[17]. These changes will be driven by alternate patterns of glacial melting in the ranges of Hindukush-Karakoram-Himalayas. It is estimated that snow and ice melt contributes 50 to 70 per cent of the water flow in the Indus River basin. There is considerable uncertainty about how each of these factors will be affected by climate change, and thus how the associated runoff is likely to change in the future[1].

The coastal areas of the country are vulnerable to sea level rise. The average sea level rise in Karachi is observed to be 1.1 mm/year. The rise in sea level will intensify the land subsidence due to over extraction of groundwater in urban areas[18], will increase the risk of coastal flooding, and intensify seawater intrusion into the delta and coastal groundwater.

Changing climatic conditions can enhance health-related risks, both because of water pollution and increase in vector-borne diseases.

Floods often pollute all surface water resources and affect groundwater as well. With rising temperatures due to climate change, floods, droughts and extreme rainfall events would arise and have considerable effect in the future on water quality. Microbial composition in water can change with changing temperatures, as microbial growth is directly associated with temperature. Certain bacteria may thrive at higher temperatures, whereas others may develop at lower temperatures. Water quality metrics often react automatically to shifts in flow rate which is climate-dependent; microbial growth is enhanced by a low discharge rate along with increasing temperatures. The melting of glaciers can affect water chemistry and runoff, and may increase in the future as global warming continues. Waterborne and water-related illnesses, such as cholera, may increase in flood-affected areas due to enhanced surface water contamination. Vector borne diseases such as malaria are closely associated with the availability of water, as the larval stage of mosquitoes develops in different kinds of water bodies. The ecology of the disease is also dependent on sun-lit or shaded, with or without aquatic vegetation, stagnant or slowly streaming, fresh or brackish as mosquito species vary considerably under such conditions[19].

In Pakistan malaria is of particular concern. According to the country's Coordination Mechanism- among the country's top 10 priority diseases in Pakistan, malaria is the second most prevalent, severe and fatal at times [20]. Malaria is triggered in Pakistan by the propagation of P. vivax (in 80% of cases) and P.falciparum (12% of cases),[21]. Transmission happens every year in the post-monsoon season (September through November). The dominant species of mosquitoes that transmit these parasites are culicifacies Anopheles and A. Stephensi[21]. In Balochistan and the Federally Administered Tribal Areas, the mosquito species A. fulviatilis and A. annularis have been identified[22]. Temporal variability in malaria is closely correlated with environmental factors such as temperature and average rainfall in the area[23]. Surface water, foliage, and temperature of the mid-season provide shelter for breeding and promote development of the mosquitoes that bear the parasites that cause the disease. The population density and regional spread of malaria-carrying mosquito species would also change with changing rainfall patterns and the temperature rises related to climate change.

According to Naseer and Jamali (2014), between 1992 and 2005, there was not a single case of cholera reported to WHO by Pakistan[24]. In 2010 The Ministry of Health reported about 99 cases of V. cholera (O1) to WHO, the incidence was reported from flood-affected provinces such as Punjab, Khyber Pakhtunkhwa and Sindh. According to WHO (2015), in 2014, Pakistan recorded 1,218 cases of cholera, and it remains a public health problem in the country due to water pollution[25].

Knowledge of the effects of climate change on water quality and safety is inadequate. Thus it is strongly advised to investigate water quality in various climatic conditions. Future effects of climate change on water quality should be implemented in applicable national policies. Water supplies need to be secured and water safety enhanced to mitigate severe health impacts arising from waterborne and associated diseases, now and in future.

7.4 FUTURE IMPACT OF GLACIER RETREAT ON THE HYDROLOGY OF INDUS BASIN

A limited number of studies provide future projections for the near term and long-term changes in the hydrology of the Indus Basin.

Immerzeel et al. (2009)[26] studied the potential impact of climate change in the Indus basin hydrological regime, with the help of hydrological models incorporating snowmelt runoff. Immerzeel et al. (2009) also pointed out that there will be a shift in the timing of peak flows (glacier melt runoff) in the Indus Basin. Their model findings indicate that peak flow would occur three to four weeks sooner relative to the baseline of recorded flows between 2001 and 2005, with peak runoff happening in calendar year weeks 26 and 27 (June / July). The model estimation suggests that a 50% reduction in glacier cover, due to the rise in temperature, would lead to a decrease of 22% in the glacial runoff. In such a case the total runoff in the basin will rise by 7% as glacier melt reduction will be compensated by the substantial rise (by 53%) in accumulated rainfall over the period from June to August. At the same time, the model predicted that there would be a significant drop in basin discharge if there is a 100% loss of the glacier in the area. The model results of Immerzeel et al. (2009) are in agreement with an earlier study conducted by Akhtar et al. (2008)[27] for the Upper Indus Basin.

Studies conducted by Laghari et al. (2012), Yu et al. (2013) and Shrestha et al. (2015)[1,28,29] concluded that there would not be a significant change in the volume of water flow in the Indus basin before 2050. Their conclusions are based on model projections which forecast that runoff generated from the increasing monsoonal rainfall would compensate for the decline in glacial melt runoff. However, Yu et al. (2013) model predicted that climate change would bring about a slight shift in the timing of peak flow earlier in the year.

All these models suggest that substantial changes in the total runoff of the Indus River Basin will not happen until after 2100 due to the impact of climate change on the glaciers, but according to Immerzeel et al. (2009) and Yu et al. (2013) a shift in the timing of peak flow is expected.

7.5 WATER, SANITATION AND HYGIENE (WASH)

7.5.a Drinking Water

Pakistan is ranked 9th globally on the list of countries with lowest access to clean water[30]. About 70 million households are estimated to be drinking bacterially contaminated water[31].

As per the UNICEF/WHO Joint Monitoring Programme (2017) data[32], about 92.1% of the population has access to improved drinking water, at the same time the population having access to safely managed drinking water fell from 37.9% in 2000 to 35.3% in 2017. Access to safely managed drinking water services among the rural population saw a marginal rise, 31.6% in 2000 to 32.6% in 2017, in contrast to the urban population which saw a decline from 50.6% in 2000 to 40% in 2017. In terms of access to safely managed drinking water, the gap between urban and rural areas decreased from 19 to 7.4 percentage points.

In 2017 91.5% of people gained access to at least basic services. The population lacking basic services decreased from 14% in 2000 to 8.5% in 2017 and the number of people collecting water directly from surface water sources decreased from 5.2% (2000) to 2.1% (2017).

This composite figure hides a large variance in the level of access to the water supply. In 2017, only 28.4 % of households had access to the improved piped water supply, and 63.7% of households relied on non-piped improved services. There were also persistent rural-urban gaps in water access. Access to piped drinking water is nearly four times greater in urban areas (51.3%) than in rural areas (15.3%). In urban areas, as opposed to 75.4% of rural households, only 43.3% of households rely on non-piped improved sources. UNICEF and WaterAid supports the government with frameworks to plan, prioritize and budget for safe water services with an aim to improve quality of water supply and ensure access to safe drinking water.

7.5.b Sanitation

According to the data from the UNICEF/WHO Joint Monitoring Programme (2017)[32], improved sanitation service in Pakistan has increased significantly over the last decade. Only 35.5% of the population had access to improved sanitation service in 2000, and in 2017 it increased to 70.1%. Disparities exist between rural and urban in terms of proximity to improved sanitation service. In 2017, 82.5% of households in urban areas had access to improved sanitation service, and it was just 62.9% for households in rural areas. Access to improved sanitation service for the rural households increased from 16.3% (2000) to 62.9% (2017). At the same time the gap between urban and rural areas decreased from 58.1 to 19.6% points.

The rate of open defecation has plunged from 40% in 2000 to 10.4% in 2017, yet 20 million people resort to open defecation. Open defecation levels are still considerably high in rural areas, as opposed to urban areas, which has eliminated the practice of open defecation. In 2017 16.4% of rural households resorted to open defecation. Between 2000 and 2017 there is a rise in the number of households having access to improved sanitation facility linked to flush-to-septic tanks (up to 17.6 percentage points) and flush-to-improved latrines and others (up to 11.6 percentage points). The number of households having access to improved sanitation facility linked to sewage systems, by comparison, increased by just 5.3 percentage points. Urban areas relied more heavily on toilets connected to a sewerage system (59.9%) among households with improved sanitation facilities, while rural areas had a higher incidence of toilets connected with septic tanks (41.6%). Disparities exist in terms of access to adequate sanitation facility among the provinces.

The gender issues regarding sanitation is deeply concerning. Women face a number of hidden difficulties in accessing sanitation. They often defecate in private and dispose of the excreta outside the house. This has potential health consequences as well as dignity concerns. Menstruation is a social taboo in Pakistan. Both Water Aid and the Government of Punjab are working together to increase menstrual hygiene management education in schools to create girl friendly environments and the opportunity for girls to stay in school[33].

Access to drainage and safe disposal of faeces are challenges in all the provinces, and could lead to drinking water and soil contamination. Poor water safety, hygiene and poorly sited and constructed pit latrines, as well as poor drainage can lead to drinking water contamination and waterborne diseases even in villages with access to improved water and sanitation[33]. Improving Community awareness and education tools are important to bring about behavioural changes, and also to combat beliefs such as “water is safe to drink, if it is clear and does not smell”.

7.5.c Hygiene

In 2017 59.6% (117.43 million) of the country's population had basic hand washing facilities with soap and water available at home. 79.58 (40.4%) million People still lacked basic hand washing facilities at home, and 62.9 million (32%) had limited facilities lacking soap or water, and 3.3 million (8.4%) had no facility at all. 83.2% of the urban population had basic hand washing facilities with soap and water available at home, at the same time only 46.1% the rural population had access to basic service.

7.6 STATUS OF WASTE WATER TREATMENT PLANTS (WWTP)

Underdeveloped wastewater treatment facilities are a key contributing factor to Pakistan's poor water quality. Across Pakistan, most wastewater is discharged untreated into rivers and coastal waters. This degrades ecosystems and impacts human health. According to the 2012 report, out of 388 cities in Pakistan, a mere eight had wastewater treatment facilities and very little wastewater was treated[34]. Karachi and Islamabad have secondary (biological) treatment, but less than 8 percent of wastewater in these cities is treated to this standard[34]. Lahore, the second largest city, has never received any care for municipal wastewater treatment. Prior to 2005, the two activated WWTP in the city of Islamabad were in poor shape. With financial assistance from the French Government, the French corporation Veolia refurbished them and constructed a fourth plant , under a design and development deal, which was completed in 2007[35]. However, it seems that only one plant continues to function after that date and that even this had ceased to work successfully in 2016[36]. Karachi, Pakistan's largest city, had three WWTPs with a combined capacity of approximately 680,000 m^3/day. Capacity went down to one third by 2005 and no service was received by the plants by 2015[37]. The waste stabilization pond facility in Faisalabad is supposed to handle about 20% of its wastewater, but a recent paper from the Danish Ministry of Foreign Affairs notes that the plant is malfunctioning and can only process 10% of Faisalabad's domestic wastewater (Danish Ministry of Foreign Affairs, 2017). - Failure to de-sludge the plants, a large anaerobic pond is considered as a reason for its malfunctioning[35].

Sambrial has a small functioning plant focused on waste stabilization ponds established under the Punjab Municipal Services Improvement Program, funded by the World Bank. Otherwise there are currently no operating municipal WWTPs in Punjab[35]. A WWTP was planned for Rawalpindi with Asian Development Bank (ADB) funding, but due to late procurement of property and other issues the plant was not built[38].

Throughout other areas of Pakistan, plants have been planned and installed, but seldom used. This might be due to the absence of effective institutions to ensure sound operation of the plants. The WWTP in Jatoi, built with funds from the World Bank in 2008, collects just 29 per cent of the city's faecal waste, because almost half of the wastewater leaks through the sewage pipes. This is a result of residents destroying sewers in an effort to remove blockages. Thus the treatment facility will handle just 40 percent of the wastewater it collects[39]. WWTP in Thatta collects 20 percent and handles 9 percent of the faecal waste in the area[40].

7.7 WATER POLLUTION

Wastewater from Pakistan's cities mostly remains untreated and is eventually discharged into surrounding bodies of water. Wastewater runoff is rapidly affecting surface water sources. In 2013, only 50% of the effluent was collected, and only 10% of the collected waste water was treated[41]. Pollutants from water include heavy metals, phosphorus, sodium, nitrogen, sediments, pathogenic bacteria, fecal coliform bacteria and viruses. Wastewater from Lahore City stays largely unregulated and is collected in the River Ravi, a source of water for the downstream population. The city of Karachi dumps nearly 87% of its waste in the Arabian Sea without any treatment[42].

Untreated wastewater is the major source of groundwater contamination along drainage ducts, rendering it unsafe for human use. This is of major concern to communities and cities that rely on groundwater for drinking.

Open defecation is another type of surface and groundwater pollution that triggers diarrhea and many other infections.

Groundwater in the Indus plains contains five times more arsenic than permitted by WHO standards, placing 50 to 60 million people at risk of contracting arsenicosis[43]

Industries dumping untreated wastewater is a significant cause of surface and groundwater contamination in Pakistan[44]. Industries contaminating water include textile, pharmaceuticals, tanneries, cement, electrical appliances, glass and ceramics, pulp and paperboard, petroleum refining, fertilizers and pesticides. Usually, these industries do not have any wastewater treatment systems and discharge waste water through local sewer networks or directly into the open drains. 1,228 of the 6,634 industries registered in the country are known to be heavily polluting[45].

It is often known that the agriculture sector is one of Pakistan's main causes of water contamination. Agrochemicals, salts, and toxic leachates affect water quality. Agricultural runoff includes fertilizers dependent on nitrogen and phosphorus, and a number of pesticides that reach the soil and through infiltration groundwater.

According to the UN Food and Agriculture Organization (FAO), the chemical nitrate is the most common contaminant of groundwater globally[46]. The presence of agrochemicals, especially pesticides, is a major cause of poisoning. It is estimated that in 2015 alone, around 500,000 Pakistanis suffered from agrochemical poisoning, out of which about 10,000 died[47].

7.8 WATER SECURITY CHALLENGES

The World Bank published a diagnostic report for Pakistan on water conservation[3]. The study lists the key problems that endanger water resource management in the country as:

- inadequate water data, knowledge and analysis,
- ineffective water supply preparation and distribution processes,
- environmentally unsustainable water extraction rates,
- extensive pollution and low water efficiency in agriculture with increased fertilizer usage,
- inadequate irrigation and drainage activities leading to water contamination and soil salinity.

The National Water Policy (NWP) was formally approved by the Council of Common Interests (CCI) on 24th of April 2018, with the consensus of the Provinces. The National Water Policy offers clear guidance for strengthening water resource management, reflecting on other policy documents such as the National Climate Change Policy, the Water Apportionment Accord. Even then, a considerable effort must be made to implement the policy at the provincial level, since the policy framework for irrigation and water resources management are partial, weak, or non-existent, and regulation has been insufficient. The provincial regulatory structures for municipal water systems should be defined and consistent with the legislative requirements, including those of local governments. A significant change has to be brought about, in defining better the different aspects of water resource management, both at national and provincial levels and within organizations at those levels. The administrative responsibility for urban water needs to be made clear, and the gaps need to be addressed. Policy framework would require reasonable understanding and dedication to enhanced sector investments and a comprehensive and open mechanism for tracking and reporting implementation progress to show political commitment and to ensure accountability. NWP proposes the formation of the National Water Council. Establishment of such an institution is essential to address the significant inter-provincial water sharing disputes, which has existed in the country for years. With the existence of a National Water Council, long-term social, environmental and economic strategies for the management of Indus Basin water resources in the national interest which govern cooperative basin planning as well as provincial water management could be implemented[3].

Pakistan will only see modest changes in water quality without significant reforms. Human water availability both in terms of quality and quantity will possibly decrease, with increasing rate of deterioration of groundwater and surface water and with rapid rate of population growth and urbanization coupled with climate change. A lack of resistance, particularly to the increasing intensity of drought, may lead to increased tension between provinces and sectors over water.

Appendix

Table 1. Historical water demand by sector in Pakistan.

Year	Agriculture (km3/ year)	Industry (km3/year)	Municipal water (km3/year)	Total water withdrawal (km3/year)
1975	150.3	1.534	1.534	153.4
1991	150.6	2.5	2.5	155.6
2000	162.7	3.47	6.39	172.6
2008	172.4	1.4	9.65	183.5

Source: AQUASTAT database

Table 2. Historical population distribution in Pakistan

Year	Growth Rate (%)	Total Population(in 1000s)	Population by province (in 1000s)					
			Punjab	Sindh	KP	Balochistan	FATA	Islamabad
1951	-	33740	20541	6048	4557	1167	1332	96
1961	2.43	42880	25464	8367	5731	1353	1847	118
1972	3.77	65309	37607	14156	8389	2429	2491	238

1982	2.9	84254	47292	19029	11061	4332	2199	340
1998	2.7	132352	73621	30440	17744	6566	3176	805
2017	2.4	207774	110012	47886	30523	12344	5001	2006

Source: Amir & Habib (2015)[48], and Pakistan National Census[49].

Table 3. Water scarcity indicator

Index (m3 per capita)	Condition
>1,700	No Stress
1,000-1,700	Stressed
500-1,000	Scarce
<500	Absolute Scarce

Source: Falkenmark (1989)[50]

Table 4. Population growth and water availability per capita.

Year	Total population (in 1000s)	Water availability per capita (m3 per capita)	Water withdrawal per capita (m3 per capita)
1973-1977	70946 (1977)	3479 (1977)	2162 (1975)
1988-1992	113747 (1992)	2170 (1992)	1368 (1991)
1998-2002	144654 (2002)	1706 (2002)	1193 (2000)
2008-2012	177912 (2012)	1387 (2012)	1031 (2008)
2012-2017	197016 (2017)	1253 (2017)	-

Source: AQUASTAT database

Table 5: Water availability

	Long term average annual Precipitation in depth (mm/year)	Long term average annual precipitation in volume (Km^3/ year)	Total internal renewable water resources(Km^3/year)	Total renewable water resources(Km^3/year)	Total renewable surface water(Km^3/year)	Total renewable groundwater (Km^3/year)	Dependency ratio (%)
Pakistan	494	393.3	55.0	246.8	239.2	55	78

Source: AQUASTAT database

Table 6: Proportion of Population having access to drinking water

Pakistan		Basic (%)	Limited (%)	Safely Managed (%)	Surface Water (%)	Unimproved (%)
2000	National	48.1	5.3	37.9	5.2	3.5
	Rural	49.9	6.3	31.6	7.5	4.7
	Urban	44.6	3.3	50.6	0.5	1.0
2017	National	56.2	0.6	35.3	2.1	5.9
	Rural	57.3	0.8	32.6	3.2	6.2
	Urban	54.2	0.3	40.0	0.2	5.3

Source: JMP[34]

Table 7: Proportion of population having access to sanitation

Pakistan		At least Basic (%)	Limited (%)	Unimproved (%)	Open Defecation (%)
2000	Urban	65.7	8.7	19.6	6.0
	National	31.4	4.1	24.4	40.2

	Rural	14.5	1.8	26.7	57.0
2017	Urban	76.6	5.9	17.5	0
	National	59.9	10.2	19.5	10.4
	Rural	50.3	12.7	20.7	16.4

Source: JMP[34]

Table 8: Proportion of population having access to Hand washing

Pakistan		Basic (%)	Limited (%)	No Hand washing facility (%)
2017	National	59.6	32.0	8.4
	Rural	46.1	43.3	10.6
	Urban	83.2	12.1	4.6

Source: JMP[34]

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9. Water Security in Sri Lanka

SUMMARY

Sri Lanka is a tropical island in the Indian Ocean situated about 1420 km to the east of southern tip of India. The topography of Sri Lanka leads to its classification into three zones, namely, the coastal belt, the plains and the central highlands. The central highlands have an elevation more than 2500 m above the mean sea level. Located in the tropical zone it witnesses an average temperature of 26^{o} to 32^{o}C and receives an annual monsoon rainfall that shows regional variation from 900mm mainly in the northern part to 5000mm in the southwestern part. Based on the intensity of rainfall, the island is divided into three zones, dry zone (with annual rainfall less than1900mm), intermediate zone (with annual rainfall between 1900-2500mm) and wet zone (with annual rainfall more than 5000mm). Dry zone covers more than two third of the land mass. Sri Lanka follows the Indian Ocean monsoon system and is marked by four seasons, the first intermediate season, the South West monsoon season, the second intermediate season and the North East monsoon season. Of the total rainfall, only 36 per cent is usable[1]. The rest flows directly to the sea. The rainfall is also affected by El Nino, La Nina and Inter Tropical Convergence Zone (ICTZ).

Total Water Withdrawals for Sri Lanka

The total surface water and groundwater availability of Sri Lanka is calculated as 52,000 MCM (million cubic metres) per year, and 7,800 MCM per year respectively. There is an overlap of 7,000 MCM of ground and surface water resources. Hence the total renewable water available is calculated at 52800 MCM. As per the available data, the total water withdrawal is 24.5 per cent of the total renewable water resources[2,3]. The country estimates total renewable water withdrawals of 12,950 MCM of which 11,314 MCM (87.3 per cent) is used for agriculture and livelihoods, 805 MCM (62 per cent) for municipalities, and 831 MCM (64 per cent) for industrial purposes. The breakup of surface and groundwater extractions are not available separately. The total reservoir capacity behind dams is calculated as 5952MCM in 1996. Further update on this data is not available. Lack of recent information on the availability as well as the withdrawals limits our understanding of the current status of of water utilization in Sri Lanka. Better monitoring systems are needed for instituted for better management of the resources.[2,3]

The per capita water availability is calculated at 2555 cubic meter per year. This as per the Falkenmark index classifies Sri Lanka as a country with adequate supply of water. While this sounds promising, seasonal, spatial, and temporal variations clubbed with the social inequalities show inequitable distribution of water. In some cities (ex: Jaffna, Puttalam and Colombo) the per capita availability is as low as 1000 cubic meter per year[4].

Concerns on Sri Lankan Water Resources

The water stress in Sri Lanka is related to water management issue than water availability. The major concerns identified in Sri Lankan water resources management are water quality,

inadequate sanitation infrastructure especially in rural Sri Lanka, lack of infrastructural capacity and expertise, limitations in data availability, lack of community awareness, extreme weather events leading to acute shortage of water, and lack of financial capability restricting better management of resources.

Recommendations

1. **Institutional**
   i) The lack of data on water consumption, nature and type of water sources, groundwater demand and availability, restrict formulation of effective schemes and programmes for water management in the country. Hence measures for collection and periodic monitoring the quantity, quality of water resources for all sectors should be initiated.
   ii) Public engagements to create awareness on concerns of water quality, the importance of efficient sanitation infrastructure and immediate disaster response should be initiated. Capacity building of decentralised parastatals should be prioritised.
2. **Water Supply and Sanitation**
   i) The rural sanitation systems managed by community-based organisations vary in their efficiency often leading to groundwater contamination by leakage from these systems. To ensure the quality and efficiency of sanitation services provided the technical expertise of these organisations needs to beimproved.
   ii) Greater clarity is required regarding institutional responsibility and accountability for urban sanitation. The planning and guidance in proving water supply as well as sanitation should be addressed preferably by the same agency.
   iii) The functions of NWSDB, DNCWS (Department of National Community Water Supply) and local agencies are overlapping in the case of rural water supply in Sri Lanka. Hence clarity on the functions of each agency as well as coordination between these agencies is indispensable for better services. Coordination among several donors is also essential for successful implementation of services.
   iv) Sri Lanka though has reduced the overall Non-Revenue Water in Sri Lanka from 34 per cent in 2006 to 26 per cent in 2016, the NRW in cities are often high. Currently, the city of Colombo has loss of NRW of 46 per cent[5]. Steps need to be initiated to curb this loss.
   v) Study of eight existing water treatment plants of Sri Lanka in Sabaragamuwa province showed that while the physical and technical aspects of water treatment were satisfactory, the personnel operation and maintenance of these systems were poor[6]. Hence focus has to be given for the capacity building of workers and Operation and Maintenance personnel.
3. **Water Quality and Health**

i) Water treatment measures to ensure the quality of the water should be made mandatory for Collective Based Organization (CBO) systems. The government should provide financial assistance to ensure the same.
ii) The government should promote and implement rainwater harvesting policy to encourage rainwater harvesting for human consumption and domestic use[7]. Providing clean water from rainwater harvesting could prove successful in reducing water quality concerns especially during the floods.
iii) More infrastructural development for septage treatment should be introduced in the country. Measures for regular monitoring of water quality of the treated water by NWSDB (for Urban areas) and CBOs (for rural areas) should be introduced.

4. **Climate Change and Sustainable Development Goals**
   i) Measures to be taken to strengthen coordination and to build capacities of climate change practitioners, government agencies and local stakeholders.
   ii) Existing monitoring mechanisms should be enhanced and new systems should be introduced where they are not available.
   iii) Focus should be given for dependence on alternative water sources, like waste water reuse, rainwater harvesting etc.

8.1 INTRODUCTION

The Democratic Socialist Republic of Sri Lanka also called the pearl in the Indian Ocean is a teardrop-shaped island lying to the east of the Southern tip of the Indian peninsula. Sri Lanka with a total population of 21.4 million[1] is the 58th most populous country in the world. The country with a total area of 65,610 sq. km is divided into 9 provinces which is further divided into 25 districts. The country dominated by the Singhalese ethnic group comprising of 75 per cent of the population followed by Sri Lankan Tamils comprising of 11 per cent of the population[2]. The most important economic sectors are agriculture, industry, and tourism[3].

With flat coastal areas converging to mountainous terrain towards the centre, Sri Lanka, enjoys a tropical climate with temperature varying from 28^{0}C to 32^{0}C [2]. The central hills divide the surrounding plains into two distinct rainfall zones, the dry zone (with rainfall less than 1900mm/annum) and the wet zone (with 2500-5000mm/annum) [4] (Figure 1). An intermediate zone lies between these two regions with mixed characteristics with annual rainfall between 1900-2500mm (Figure 1). The population density is high towards the wet regions given the rainfall and water availability (Figure 2).

Devastated by insurgencies and civil war for around thirty years, the country is witnessing an economic growth and development from 2009 when the conflicts decisively ended. The improvement in Human Development Index of 24.9 per cent between 1998 to 2018 (0.685 to 0.780) [5] as well as the reduction of population under poverty from 23 per cent in 2002 to 9 per cent in 2012 [2] are some of the examples of development. However, the picture painted is not as impressive as projected by the numbers. The repercussions of the internal conflicts exist even today due to the poor post-conflict reconciliation measures by the government. The increasing inequality owing to the liberalisation of the economy also impacts the poor and vulnerable sections of the society.

8.2 TOTAL WATER WITHDRAWALS FOR SRI LANKA

The latest data available on total renewable water withdrawal is for the year 2005. As per the available data, the total water withdrawals reach 24.5 per cent of the total actual renewable water resources[6]. The total surface water availability and groundwater availability of Sri Lanka is calculated as 52,000 MCM (million cubic metres) per year, and 7,800 MCM per year respectively. There is an overlap of 7,000 MCM of ground and surface water resources[7]. Hence the total renewable water available is calculated at 52800 MCM. The country estimates total renewable water withdrawals of 12,950 MCM of which 11,314 MCM (87.3 per cent) is used for agriculture and livelihoods, 805 MCM (62 per cent)) for municipalities, and 831 MCM (64 per cent) for industrial purposes[6,7]. The breakup of surface and groundwater extractions are not available separately. The total dam capacity is calculated as 5952MCM in 1996. Further update on this data is not available. Lack of information on the availability as well as the withdrawals limits our understanding of the current status of Sri Lanka. Better monitoring systems are to be instituted for better management of the resource.

The per capita water availability is calculated at 2555 cubic meter per year. This as per the Falkenmark index classifies Sri Lanka as a country with adequate supply of water. While this sounds promising, seasonal, spatial, and temporal variations clubbed with the social inequalities show inequitable distribution of water. In some cities (ex: Jaffna, Puttalam and Colombo) the per capita availability is as less as 1000 cubic meter per year[8].

8.3 GEOGRAPHY AND CLIMATIC VARIABILITY

Sri Lanka with its varying topography is divided into three morphological zones, the central highlands, the lowland plains, and the coastal belt. The central mountainous mass located somewhat south of the centre, includes numerous mountains, plateaus, and valleys, surrounded by broad plains [9] (Figure 3). The country comes under the Indian Ocean Monsoon system and obtains an annual rainfall of 1,18,000 Thousand Million Cubic ft of which around 43,000 TMC is usable. But the country has only been using 36 per cent of this usable water. The remaining water is discharged to the sea[10]. The evapotranspiration (ET) for the wet zone and dry zone were calculated for 70 drainage basins of Sri Lanka. The values were registered as 900-1500mm/year for the wet zone and 1200-1550mm/year for dry zone[11]. The average annual precipitation (in depth) for the country is calculated as 1712mm per year[7].

Sri Lanka is marked by four seasons, the first intermediate season (Mar-Apr), the South-West monsoon (May-Sept), the second intermediate season (Oct-Nov), and the North-East monsoon (Dec-Feb). The inter-monsoon seasons are characterised by tropical cyclones, depressions, and thunderstorms associated with migration of Inter-Tropical Convergence Zone [4]. The wet zone which lies in the southwestern quadrant of the island experiences a short dry season during

January and February, followed by ample rainfall for the rest of the year. The dry zone which extends in the north, east, and south-eastern part of the island, experiences wet seasons during October and February and Dry seasons for the most of the rest of the year[4].

Precipitation patterns of the country are also influenced by El Niño, El Niña and Inter-Tropical Convergence Zone [4]. Most common impacts of these phenomena include droughts, floods, landslides, cyclones storm surges, and coastal inundations. Majorly, El Niño affects the rainfall by season, with more rainfall in May, and October - December and less rainfall from June to August and January to April[12]. Temporally, the influence of La Niña is strongest during the North East monsoons and spatially it affects the dry zone of the island and is visible during all the three seasons in the dry zone [13].

Sri Lanka with discussion on looming challenges of climate change has been investigated by several researchers to analyse the trends in rainfall with rainfall records of varying time series. The researches using the least square regression method based on historic rainfall data have observed that there exists no significant change in the mean rainfall over the years [14]. The past data also shows that while the change in mean rainfall is not substantial, the variability of rainfall has increased all over the country. The study by Karunathilaka [15] using non-parametric MK trend test and Sen's slope estimator method using data from 32 rain gauge stations for a period from 1966-2015 observed positive as well as negative trends. In his study, 21 stations showed an increase in rainfall trends, while 11 stations showed decreasing rainfall trends. The rainfall indicated increasing trends during first inter-monsoon season, second inter-monsoon season, the northeast monsoon at majority of the stations. On the contrary, the south-west monsoon indicated decreasing trends in most part of the country. The study also observed that over the past half-century, the eastern region of the country showed an increase, while the western, northern, southern regions and the central hills have had decreasing rainfall trends. The study concludes that the major part of the country shows an increasing trend in rainfall (Figure 4).

8.4 WATER SITUATION IN SRI LANKA

Geologically 90 per cent of Sri Lanka is made up of highly crystalline rocks formed more than 570 million years ago from the Precambrian era. The rest 10 per cent comprises of sedimentary formations such as limestone, sands and clay of Jurassic period and tertiary and quaternary periods. The northern zone of Sri Lanka is marked by a layer of limestone formed during the Miocene epoch. The Precambrian rocks are divided into four categories based on their rock types, isotopic characteristics and structures (Figure 4). They are the Highland complex, the Wanni complex (also called Western Vijayan complex), Vijayan complex (also called Eastern Vijayan complex), and Kadugannawa complex. The Highland complex is characterised by *supracrustal rocks together with a variety of igneous intrusions predominantly of granitoid composition that now occurs as banded gneisses*. The vijayan complex have varieties *of gneisses and granitoids ranging in composition from tonalite to leuco- granite and containing* *minor xenoliths of metaquartzites and calcsilicate rocks.* The Wanni Complex consists *predominantly of scattered relics of supracrustal rocks and meta-igneous rocks of granodioritic gneisses*. The Miocene sedimentary rocks form a *major sedimentary sequence that can be found along the north-western and northern coasts of the island. It occupies and area of about 5000km running as a 20-25km wide belt*. [3,17,18]

Sri Lanka identifies six types of aquifers, shallow karstic aquifers, coastal sand aquifers, deep confined aquifers, lateritic aquifers, alluvial aquifers and shallow regolith aquifers (Figure 5). The geological differences of these aquifers contribute to difference in groundwater recharge rates. The most utilised aquifer is the regolith aquifer. The description of the nature of aquifers is provided in Table 1. Aquifers in the dry zones have their water table going down rapidly after the monsoons, leading to water stress in these regions during the dry seasons[19].

The karstic limestone region in the north and north-western Sri Lanka do not have any perennial rivers and hence extensively depend on groundwater extraction. These coastal aquifers are considered highly productive as well as extremely vulnerable to pollution. In the past few years, several development activities have been initiated in the northern region of Sri Lanka leading to overexploitation of groundwater resources from the karstified coastal sedimentary aquifers[3,18].

The total groundwater availability is calculated as 7800 MCM which amounts to 15 per cent of the total surface water resources. The country meets majority of its domestic and industrial requirements from groundwater and irrigation requirements from the surface water. The groundwater meets the domestic needs of the 80 per cent of rural population [6] and 55 [16] per cent of the total Sri Lankan population. The variation in rainfall and geography plays an important role in determining the source of water dependence in dry, wet and intermediate zones. The groundwater resources of Sri Lanka despite its intensive use has not been properly understood and is heavily unregulated. For better management of the resource, groundwater needs to be understood as a critical resource and better regulations need to be put in place.

Apart from the groundwater resources, the country also has inland water bodies that cover around 2905 sq. km of the landmass. This includes rivers, riverine marshes, about 20 major wetlands, as well as irrigational and multipurpose reservoirs. Sri Lanka has 103 rivers most of which flow radially from the central mountains to the coasts. Twenty of these rivers are perennial. The catchment area of the rivers covers nearly ninety per cent of the total land area. The Mahaweli river with a catchment of 10600 sq. km draining 4003mcm/year is the largest in the country, while the Kaluganga river with a catchment area of 2688 sq. km and draining of 4032 mcm/year has the largest discharge. Sixteen rivers in the wet zone nearly drain one-third of country’s land area and carry fifty per cent of total surface water runoff of the country. The major river basins of Srilanka are given in Figure 7. River discharges in Sri Lanka show wide spatial and temporal variations. In the high rainfall areas, river discharges amount to 50-70 per cent of rainfall. Dry zone river flows account for less than 30 per cent of the rainfall even during the rainy seasons. This is because these regions have a high infiltration rate and low to no surface runoff. The wet zone drainage basins account for almost 50 per cent of the total river discharge[11].

8.4.a Agriculture And Surface Water Dependence In Sri Lanka

The surface water resources support 70 per cent of irrigation requirements of the country and hydroelectric power generation [20]. Sri Lanka is one of the oldest civilisations with a history of 2000 years and has seen on water sector development over centuries. The reservoirs and tanks were constructed by intercepting river flows across shallow valleys, or by diverting the water flowing down perennial rivers by weirs[6]. With time new projects were added to the existing irrigation systems to make them more efficient and far-reaching. The tanks and reservoirs provide water to dry and arid regions for cultivation.

Irrigation in Sri Lanka is dominated by surface irrigation mostly using basin and furrow irrigation [6]. The irrigation tanks and reservoirs varying in their capacity and scheme are classified as minor irrigation schemes (irrigating less than 80 ha of land), medium irrigation schemes (irrigating 80 ha - 400 ha of land) and major irrigation schemes (irrigating more than 400 ha of land). The major irrigation schemes are again classified as storage schemes, diversion schemes, lift irrigation schemes and drainage, flood control and saltwater exclusion schemes. Currently, the Irrigation Department maintains a total irrigated land of 7,56,000 acres with 75 per cent coming under major irrigation schemes. Irrigation contributes to 75 per cent of the rice production in Sri Lanka. The Mahaweli Authority of Sri Lanka is a part of the institutional framework of Irrigation Department supplies water for irrigating 1,01,526 ha of land in the dry zone[21]. Paddy has been the largest agricultural produce ensuring food security to the country. The rice production increased from the 1950s with the introduction of new rice varieties. Due to cheaper technologies as well as new subsidy programme of 1989, the dry zone agriculture has shifted to agro-wells and hand pumps which provide more reliable supply from groundwater for irrigation. In the year 2005, the total number of agro wells were 50,000 [22]. Sri Lanka also practices rainfed agriculture in basins of Kalu, Kelani, Gin, Bentota and Nilwala. The major crops under rainfed agriculture are rubber, coconut and tea[17].

In the past, water resources management through tanks and reservoirs were predominantly used for irrigation. But with the advent of technologies towards the late 20th Century, it has further developed the sector for hydropower generation, domestic water supply and other uses as well [23]. Hydropower currently contributes 31 per cent of Sri Lanka's electricity [21].

8.4.b Institutions And Infrastructure

The water resources in Sri Lanka are managed by several governmental and non-governmental agencies. The major governmental agencies include the National Water Supply and Drainage Board (NWSDB), The Irrigation Department, the Water Resources Board and the Mahaweli Authority, the Provincial Councils

National Water Supply and Drainage Board (NWSDB), under the Department of Water Supply and Drainage, is the primary provider of water supply and sanitation facilities across the country except for the wastewater management facilities in Colombo which is taken care of by the Colombo Municipal Council.

The Irrigation department, under the Ministry of Irrigation and Water Resource Management, is responsible for providing infrastructure and guidance in improving the irrigation facilities of Sri Lanka. The Schemes that cater to areas over 400 hectares are administered by the Irrigation Department and Mahaweli Authority.

The Water Resources Board (WRB) was established in the year 1966 with a vision to provide adequate access to clean and safe water for all. The major functions of the Board include providing advice to the government and the people, introducing necessary regulations on assessment, conservation and development of water resources with a focus on demand management.

The Mahaweli development programme was initiated in 1961 to improve the foreign exchange, increase the industrial and agricultural production, and improve nationwide socio-economic conditions [24]. It was also aimed at the generating hydroelectric power, controlling flood, and improving irrigation facilities in the dry zone through the construction of reservoirs and settlement of homeless and unemployed population by improving the physical and social infrastructure using the Mahaweli river. The largest agricultural extension programme in the world, the Mahaweli Development Programme is currently responsible for the irrigation of 365,000 hectares [25]. The Mahaweli Development Programme statutorily comes under the mandate of Mahaweli Authority established in 1979.

The Provincial Councils administer the medium irrigation schemes that cater to land with an area between 80 to 400 hectares and areas under 80 hectares of land are maintained by farmers with the technical guidance of the Provincial Irrigation Department. The village tanks which come under the minor irrigation scheme function with the help of farmer organisations. Department of Agrarian Department and Provincial Irrigation Department play a major role in supporting community-based engagements.

8.5 WATER SUPPLY AND SANITATION IN SRI LANKA

Sri Lanka has seen tremendous improvement in its water and sanitation infrastructure and coverage both in the urban and rural parts in the past decades. World Population prospects estimate Sri Lanka to have an urban population of 3.20 Million and a rural population of 17.90 million [26]. The water supply and sanitation coverage in urban and rural are attained through the sector-specific programs and institutions at place. While the urban water supply is provided through the well-functioning RSCs, the water supply for rural area functions through more decentralized Community Based Organizations (CBO).

Piped water coverage reaches only 48 per cent of the total population and its distribution varies across the country, ranging from 11 per cent in the Northern Province to 65 per cent in the Western Province. The data on distribution shows that the offsite sewerage systems tend to be present in the large urban areas and even here they do not cover the population in each location [27].

8.5.a Urban Water Supply And Sanitation

96 per cent of the urban Sri Lankan population has access to at least basic drinking water [28]. More than 92 per cent of the urban population has access to safe water within their premises [27]. As per the study conducted by the World Bank, the quality of water supplied by NWSDB is perceived safe for drinking without any purification by the household[27].

While the water supply coverage is high in the urban areas, the sanitation coverage lags behind. More than 90 per cent have access to toilet facility with less than 2.7 per cent using public toilets. However, less than 12 per cent of the urban population is covered by the piped sewerage system. Most of the urban population has on-site sanitation facilities through the septic tank and open-pit latrines which are served by the bowers and trucks from municipal and urban councils[27].

8.5.b Rural Water Supply and Sanitation

The main source of rural water supply is protected dug wells although in some villages, depending upon the population density, the government is trying to introduce piped water supply mainly from tube wells. 91 per cent [28] of the rural population has access to safe drinking water mostly through protected dug wells and almost 87[27] per cent of the population has access to water for bathing and washing. In 2012-13, 90 per cent of the rural population attained access to toilet facilities [27]. But most of these toilets are pour-flush, squatting toilets, within the compound in an outhouse. Owing to an understanding of the importance of hygiene, open defecation is uncommon and restricted to coastal areas and estates [27].

The National target for NWSDB had an ambitious plan of achieving 60 per cent national piped water supply coverage by 2020 and to increase it to 70 per cent by 2025[27]. The country has a two per cent connectivity to network sewerage facilities. The target for its improvement is set to be 3.5 per cent.

8.6 INTERNATIONAL AID AND ASSISTANCE

The lack of financial capacity for water supplies in the public sector and good proven performance, Sri Lanka attracts large amount of foreign funds as loans given to developing nations. The NWSDB has been receiving financial aid from various international organisations including Asian Development Bank (ADB), Japan International Cooperation Agency (JICA) and World Bank to develop and improve the water supply and sanitation services. With eight loans amounting to $521 million, ADB is the major development partner. NWSDB is the executing agency for seven loans [29]. In 2007, there were 15 foreign-funded projects with funding mostly from ADB, JICA and GTZ[30].

During 2007-2016, the approved Water Supply and Sanitation (WSS) Sector support provided by WBG (World Bank Group), ADB and JICA is estimated at $2.0 billion. This when compared with average annual investment for WSS in the country for the year 2007-2011 of $200million shows the nature of the dependence of the country on external funding. For 2007-2016, WBG committed $38 million for WSS. ADB, under the first phase of its Water Financing Program (WFP), increased its investments in the water sector from roughly $891 million in 2006 to over $2 billion annually. JICA has committed roughly $12 billion for WSS over the 2006–2015 period.[31]

While these projects have to a large extent helped in building the infrastructure and achieving WSS goals, the overdependence on foreign agencies has raised concern and criticism from various academic circles.

8.7 CHALLENGES IN GOVERNANCE AND INSTITUTIONAL FUNCTIONING

8.7.a Challenges To Community-Based Organisations (Cbos)

The functioning of CBOs, decentralised and effective in many ways, lacks in technical expertise on the ground. This becomes further apparent with the need for improving the on-site sanitation facilities in rural areas. Lack of knowledge in construction and management of these systems is one of the major causes spilling of septic waste that contaminates groundwater [27]. WHO identifies rural school sanitation, sanitation facilities for the disabled, and problem of groundwater contamination through onsite sanitation in congested townships as the major arenas that need attention in terms of water supply and sanitation in Sri Lanka, [28].

8.7.b Water Supply In Conflict-Affected Areas

The northern and north-eastern parts, mostly in the dry zone, are the areas where the population of Sri Lankan Tamils is high. Study in Jaffna, one of the main conflict-affected areas, showed that fewer than 10 per cent there had access to piped- drinking water supplies. It is even lower at 0.7 per cent in Pachchilai and Poonakarai divisions. Less than 15 per cent receive water from NWSBD and other utilities. Jaffna, already existing in the dry zone is vulnerable to the availability of water geographically. The majority of the population in Jaffna depends on groundwater extracted accessed through household wells for daily use. Concerning sanitation, 82 per cent of households have access to latrines, and more than 90 per cent of the households share a latrine with other households. Jaffna Peninsula also has no existing sewerage systems. [29]

8.8 WASTEWATER TREATMENT AND REUSE IN SRI LANKA

As discussed before, while sanitation coverage is promising, the mode of management of sewage in Sri Lanka is depressing. Only 2 per cent of the Sri Lankan households have piped sewerage systems[32]. Most of the domestic sewage is managed via a septic tank system and pit latrines. These mechanisms, if adequately designed and constructed would function well, but in most cases the construction is flawed and the septic tanks are not pumped out at regular intervals [31]. In urban spaces, there is little space for overflow drainage trenches and thus the overflow pollutes the streets and watercourses affecting water quality and public health. In several cities, the wastewater collected is emptied into the sea without undergoing any treatment[33]. One of the major risks of pumping raw sewage into the sea is the contamination of water with the proliferation of harmful bacteria including E.Coli increasing health hazards. It could also lead to heavy eutrophication and infusion of heavy metals affecting the coastal ecosystems.

As per the World Bank report of 2015 major sewerage facilities have only been developed in Colombo, Ekala, Jaela, Moratuwa, and Ratmalana[27]. There exists several housing schemes having individual wastewater systems. New septage treatment plants in a few secondary towns such as Chillaw, Mannar, Puttalam, and Vavuniya, are also being introduced[27]. The poor investment in sewage management has led to the adoption of individual onsite sewage management systems with varying efficiencies [33]. In rural Sri Lanka, the wastewater (without treatment) is mainly used for irrigation. The dry zone where rainfall does not ensure continuous water supply, wastewater becomes a reliable alternate source[34].

The major industries of Sri Lanka include chemical, food and beverages, dairy, textile, tanning, rubber, agrochemicals, pharmaceuticals, Clay, Glass and Ceramics, Health, transport and vehicle services and paper and pulp. Industries in Sri Lanka generate about 30 million cubic meters of wastewater per year [34]. For the treatment of wastewater generated from the industries, many treatment plants are constructed in major industrial parks of the country. This includes Biyakama treatment plant with a capacity of 7.5 mcm/year, Seethawaka treatment plant with 9mcm/year, Horona treatment plant with 11mcm/year and Greater Colombo treatment plant with 2.5 mcm/year. The treated wastewater from these systems is discharged into rivers and streams, and are mostly used for agriculture. The data on wastewater production from other sectors are not available.[34]

Lack of information on wastewater treatment and reuse limits the research to dwell deep into the issue. However, the available information suggests that substantial improvements are required in the wastewater treatment sector to ensure water reuse, public health and preservation of the environment.

8.9 WATER QUALITY CONCERNS IN SRI LANKA

Increasing dependence on pesticides and chemicals in agriculture to increase food production has adversely affected the water resources on the island. Several studies over three decades have proven severe contamination of water resources showing the presence of high levels of nitrates, chlorides, sulphates, heavy metals and hardness in several regions, especially in the dry zone. [35].

Majority of the studies on water quality focus on the dry zone areas. The 1997-1998 study conducted by WHO in the Jaffna peninsula (dry zone), showed nitrate levels in the water exceeded the WHO standards [36]. The causes for the same were identified as intensive agriculture and improper construction of soak pits in the Jaffna Peninsula. Literature also suggests that more than 80 per cent of the wells in the Jaffna peninsula is affected by high nitrate concentrations [37]. The study on the nitrate concentration in the Kalpitiya region of Sri Lanka showed that the groundwater had nitrate concentration in the range of 10-15mg/L whereas, in the non-cultivated regions, it comes down to 0.2mg/L. A study on water quality of all districts of Sri Lanka observed nitrate levels with varying concentrations of 0 to 366mg/L. However, the samples with values higher than 50mg/L (Sri Lankan standards) amounted to 2.2 per cent of the total samples [38]. The direct correlation of agriculture to groundwater contamination becomes more apparent with the study of in wet and dry zones [39]. The study had used 142 samples combined from both climatic zones. 17% of the groundwater samples were over the maximum contaminated level of 10 mg/L as NO_3-N before fertilization and it was increased up to 26% after fertilizer application in the wet zone. In the dry zone, nitrate concentration in all samples was less than the maximum limit before applying fertilizer. But during the cultivation period, 12% of the samples exceeded the WHO prescribed maximum contaminating level.

Apart from anthropogenic water contamination, geogenic contamination also affects the quality of groundwater. Issues related to geogenic contamination of groundwater are mostly observed as '*iron in lateritic formations in wet south-western regions, Fluoride occurrences in central dry regions or intermediate crystalline zones, and hardness in both crystalline hard rocks and sedimentary formations'* [3]. Owing to the high concentration of fluoride several cases of dental fluorosis, skeletal fluorosis. Figure 6 provides the distribution and levels of geogenic fluoride concentrations in Sri Lanka.

One of the major water quality issues in groundwater in recent times was the aftereffect of the Tsunami of 2004. Around half a million wells were rendered unsafe for drinking as they were affected by seawater intrusion and flooding which lead to salinity and E.coli bacteria contamination[40]. Surface inland waters face major contamination from sewage and industrial effluents in the urban areas and agricultural runoffs in the rural area [20].

8.9.a Health Concerns Due To Water Quality

The studies on degrading water quality in Sri Lanka poses severe threats to public health with high incidence of diarrhoea, typhoid, dysentery, infectious hepatitis and worm infestation in vulnerable parts of Sri Lanka [3].

One of the serious health concerns in Sri Lanka is Chronic Kidney Disease with unknown aetiology (CKDu). This disease was first reported among the paddy farmers in 1994. It has been observed in the Northern, Eastern, North Western, Central and Uva Provinces [35]. Even twenty years after the first incidence, it is still the major concern in the North Central Province of Sri Lanka affecting more than 50,000 estimated patients. While the causes of the same are not conclusively determined, several studies point towards the contamination of drinking water by the pesticides and chemicals [35] to be the plausible cause. Recently studies also consider the high levels of fluoride in drinking too to result in CKDu[18].

Typhoid or enteric fever, caused by bacterium Salmonella Enterica is another common public health concern with more cases in the Jaffna district. The distance between toilet pits and drinking water sources in the region is considered as a possible cause [38] for the disease. Dental and Skeletal Fluorosis caused by increasing concentration of fluoride in groundwater is widespread in the dry zone of Sri Lanka. In Anuradhapura district of Sri Lanka, 90 per cent of the children below the age of 15 are reported to suffer from dental fluorosis [38].

8.10 CLIMATE CHANGE

South Asia has emerged as one of the regions most impacted by climate change owing to geography and socio-economic factors. The literature on climate change points to an increase in temperatures across the region and the same is expected to rise for several decades under all possible climate scenarios. The Department of Meteorology estimated an average increase in temperature by 0.016 per year[31]. While a direct correlation between the global emission and variation in temperature has been established in the literature, its effect on precipitation has not been completely gauged [41]. With recurring episodes of extreme weather events and increasing reports on rising sea levels, the effects of climate change have become a tragic reality for the island nation.

Effects of Climate Change are multidimensional, It would have adverse effects on water, agriculture, tourism, society and mental health [42]. The frequency of extreme weather events like floods and droughts have affected the Central Hills of Sri Lanka severely [43]. Sri Lanka, after the floods and destruction of 2017 which claimed more than 200 lives and displaced more than 60,000 people, was listed as the second most impacted country due to climate change[44]. The impact of climate change on agriculture due to erratic weather would affect the production thus affecting the food security of the nation. As for most countries, the impacts of climate change are varied across the country depending on the socio-economic factors and geography. The major impacts on climate change on the island are sea-level rise, seawater intrusion, extreme weather events like floods and droughts, and the impact on the living standards and GDP of the country. For this paper, this section limits itself to the impacts of climate change on water security. The variations in climate, in the recent future, would have severe impacts on water availability, water quality, agriculture as well as health. The increasing incidents of extreme weather events with inherent spatial variation in rainfall affect the freshwater availability of both groundwater and surface water resources. Another concern is the increasing rate of evapotranspiration caused by increasing temperatures in rice paddies which exacerbates water shortage issues.

8.10.a Floods Of Sri Lanka

During the past 16 years, the Eastern and Western provinces of Sri Lanka have been most affected by the flood events. Sri Lanka has seen a steady increase in the frequency of floods in the past two decades. In a period of 13 years from 2000-2013, Sri Lanka faced 25 mega-floods which have affected the lives and livelihoods of more than five million people [45].

The post-disaster analysis of 2017 floods provide clarity on the aftereffects of floods on water resources. The major concerns of floods on water resources are the increasing pollution of sources due to microbial contamination and damages to the sanitation facilities, impacting human health and the freshwater availability. The most vulnerable to these impacts is the rural population. In any events of floods, dug wells both protected and unprotected, are the most affected. Inundation of water after flooding makes the well unusable after flooding. They would in effect carry debris, pollutants including microbial, chemical and physical pollutants. The floods affect the sanitation systems with short term results of water-borne diseases long term issues of excreta disposal. Being more visible, the losses and damages to the superstructure of sanitation facilities get more addressed, neglecting the challenges of excreta disposal systems concealed underground. With receding floods, people unaware of the structural damages continue using the septic tanks further increasing the severity of groundwater pollution from poor sanitation structures. [46]

During floods of 2018, the Southern Province of Sri Lanka was affected by viral flu claiming the lives of 14 people including 11 children[47]. Dengue, Cholera and other diseases including skin infections are common aftereffects of floods. The major challenge in the mitigation of floods is the lack of adequate data which affects the impact analysis and immediate responses.

8.10.b Droughts

The droughts and rainfall variations in Sri Lanka are increasingly becoming more prolonged and unpredictable [48]. The droughts usually affect the dry zone of the country more severely than the wet zones. While the floods of 2017 had huge impacts on lives of more than a 60,000 people, the drought faced by the country a year earlier was the worst in 40 years affecting over 16 districts with over 900,000 people affected by acute water shortage [49]. The northern regions of Sri Lanka depending mostly on irrigation tanks sees a decrease in the water levels of the reservoirs. In 2019, the joint bulletin by World Food Programme and International Water Management Institute reported that major reservoirs of Sri Lanka were at 19 per cent of their capacities compared to the 33 per cent the previous year [50].

Saltwater intrusion to water bodies accompanies droughts as the freshwater resources that put pressure and support the balance of coastal ecosystems keeping seawater from intrusion reduces during droughts. Reducing soil moisture together with increasing temperature might lead to serious disruptions to food systems throughout the country

8.10.c Sea Level Rise

Island of Sri Lanka has a coastline of 1720 km. Sea level rise and associated inundation pose a great threat to the natural coastal ecosystems like estuaries, mangroves, salt marshes and wetlands and also promotes coastal erosion [51]. It also results in the saltwater intrusion of coastal aquifers, reducing the total freshwater availability of the island. With the present landward limit to beaches locked in place, mean long-term sea-level rise will considerably decrease beach widths at uninterrupted coastlines to a national average of 16 m to 25 m. [52]

The low resilience of the communities and lack of information on crisis management poses sea level rise as a significant threat to the economy as well as the coastal communities of Sri Lanka [52]. The most vulnerable areas for the same are the low lying areas of the north and east region of the island, under conflict with a poor economy [42]. The increasing sea level may adversely affect the quality of both drinking water and irrigation water in the coastal areas by disturbing the interface between freshwater and brackish water [53]. It is highly likely that sea-level rise will disturb the Ghyben-Herzberg lens of freshwater found underneath of regosol in coastal regions [53]. These freshwater lenses provide irrigation water for intensive agriculture in those areas.

8.10.d States Response to Climate Change

Sri Lanka is party to many international treaties including the COP 21 Paris Agreement and Sendai Framework for Disaster Management. Sri Lanka Water Development Report of 2010 has identified climate change as a major driver of change in water resources sector [54]. The information in this report points out that currently there exists no policy, plan or programme in the water sector specifically for climate adaptation. However, the National Adaptation Plan for Climate Change 2016-2025[54] in Sri Lanka has identified water resources as one of the key sectors with priority areas on the water for agriculture, water for human consumption, water for industry, and energy and degradation of watersheds. The Plan uses a mainstream approach in the identified key sectors wherein these sectors would respectively be handled by respective ministries and agencies themselves than specialized agencies for climate change.

The overall plan of National Adaptation Plan for Climate Change Impacts in Sri Lanka 2016-2025[54] on water resources focusses on Development and implementation of watershed management plans for critical watershed areas, increasing efficiency and reducing the loss of irrigation water, access the current practices of water management for climate resilience and identify ways to improve them, identification and mapping of areas vulnerable to drought and flood hazards and prepare a disaster management plan, and designing rational intra-basin and trans-basin strategies to harness periodic surplus of water in storage facilities.

While it has been established, there is a need to emphasize that the issues relating to water resources are more of a management concern rather than availability. Hence in time, many initiatives have been put in place to improve water management. These initiatives include the promotion of rainwater harvesting ponds and agro-wells, improving micro-irrigation technology, and augmentation of major and minor irrigation to address the issues concerning water sector[21].

8.11 SRI LANKA AND SUSTAINABILITY DEVELOPMENT GOALS

The Sustainability Development Goals (SDG) was accepted by the United Nation member countries in the year 2015 to come up with benchmarks to achieve a universal goal of poverty eradication, protection of the planet and to ensure peace and prosperity to people by 2030. The Sendai Framework for Disaster Risk Reduction, signed in Japan in March 2015, and the Paris Agreement on COP 21, together with the SDGs *provide a set of common standards and achievable targets to reduce carbon emissions, manage the risks of climate change and natural disasters, and to build back better after a crisis*[55]. Sri Lanka has shown remarkable achievement in meeting the Millennium Development Goals especially in areas of health, education and poverty. However, it still faces challenges in improving the quality and relevance of education, public health for the elderly, and in addressing climate disasters.

While Sri Lanka has achieved Millennium Development goals for water (85%) and sanitation (90%) by 2015, the goals in attaining the stipulated water quality or universal access to piped water supply are still lacking. Understanding the significance of attaining water security, Sri Lanka has been developing policy strategies on improving water productivity and irrigation efficiency by rehabilitating existing systems and investing in new systems and watershed management [10]. The Department of Agriculture has also shifted towards adopting measures for soil conservation and rainwater harvesting to address the issues of land degradation and climate change. However, to achieve Sustainable Development Goals, Sri Lanka has to go a long way. The major challenge for improving the current water scenario for Sri Lanka is the lack of baseline data on water sanitation and finance. Lack of finances also limits the development of the water infrastructure in the country. As of 2018, only 2 % of the national budget was earmarked for water and sanitation sector when at least 4 % was required[56]. Many of the initiatives aiming at ensuring water security have been criticized for their lack of vision and hydrological understanding. Herath[56] observes that the governments initiative to promote the use of groundwater resources in drought-prone areas at high cost is not a long term solution to the people of the dry zone, as it may in time result in lowering of water tables owing to over-extraction of groundwater. The financial requirements for achieving the Sustainable

Development Goals is huge, however, could be considered achievable. The UN ESCAP[57] (United Nations Economic and Social Commission for Asia and the Pacific) in its study estimates the net requirement of investments to have an additional investment of 4.4 per cent of the national GDP.

8.12 RECOMMENDATIONS

1. **Institutional**
   - i) The lack of data on water consumption, nature and type of water sources, groundwater demand and availability restrict formulation of effective schemes and programmes for water management in the country. Hence measures for collection and periodic monitoring the quantity, quality of resources for all sectors should be initiated.
   - ii) Public engagements to create awareness on concerns of water quality, the importance of efficient sanitation infrastructure and immediate disaster response should be initiated. Capacity building of decentralised parastatals should be prioritised.
2. **Water Supply and Sanitation**
   - vi) The rural sanitation systems managed by community-based organisations vary in their efficiency often leading to groundwater contamination by leakage of these systems. To ensure the quality and efficiency of sanitation services provided to rural Sri Lanka, the technical expertise of these organisations needs to be enhanced.
   - vii) Greater quality is required regarding institutional responsibility and accountability for urban sanitation. The planning and guidance in proving water supply as well as sanitation should be addressed preferably by the same agency.
   - viii) The functions of NWSDB, DNCWS (Department of National Community Water Supply) and local agencies are overlapping in case of rural water supply in Sri Lanka. Hence clarity on the functions of each agency as well as coordination between these agencies is indispensable for better services. Coordination among several donors is also essential for successful implementation of services.
   - ix) Sri Lanka though has reduced the overall Non-Revenue Water in Sri Lanka from 34 per cent in 2006 to 26 per cent in 2016, the NRW in cities are often high. Currently, the city of Colombo has NRW of 46 per cent[27]. Steps need to be initiated to curb this loss.
   - x) Study of eight existing water treatment plants of Sri Lanka in Sabaragamuwa province showed that while the physical and technical aspects of water treatment were satisfactory, the personnel operation and maintenance of these systems were poor. Hence focus has to given for the capacity building of workers and O and M personals.
3. **Water Quality and Health**
   - iv) Water treatment measures to ensure the quality of the water should be made mandatory for CBO based systems. The government should provide financial assistance to ensure the same.

v) The government should promote and implement rainwater harvesting policy to encourage rainwater harvesting for human consumption and domestic use [59]. Providing clean water from rainwater harvesting could prove successful in reducing health issues raising from degrading water quality.

vi) More infrastructural development for seepage treatment should be introduced in the country. Measures for regular monitoring of water quality NWSDB (for Urban areas) and CBOs (for rural areas) should be introduced.

4. Climate Change and Sustainable Development Goals

iv) Measures to be taken to strengthen coordination and to build capacities of climate change practitioners, government agencies and local stakeholders.

v) Existing monitoring mechanisms should be enhanced and new systems should be introduced where they are not available.

vi) Focus should be given for dependence on alternative water sources, like waste water reuse, rainwater harvesting etc.

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TABLE

Table 1 Nature and Recharge Characteristic of Different Aquifers in Sri Lanka [37,60]

Type of Aquifer	Nature	Recharge Characteristics
Shallow Karstic Aquifer	Occurs in the channels and cavities (karsts) of the Miocene Limestone	The Shallow Karstic Aquifers get fully recharged by Nov-Dec through the North-East Monsoons. As the rainfall after Feb is scarce, the water level drops rapidly within the next 3months. The aquifer boundary expands and contracts through wet and dry season respectively.
Deep Confined Aquifers	Occur within sedimentary limestone and sandstone formations. They are more than 60 m deep with relatively high discharge rates.	They are the least utilised and not much information on the aquifers could be found in the literature.
Shallow Coastal Sand Aquifer	The shallow coastal sand aquifers occur along a total extent of approximately 125,000 ha of the coastal beaches and spits.	These aquifers are recharged and expand mainly during wet season and contracts during the dry season, and accordingly, brackish and saline boundaries are fluctuating.
Alluvial Aquifers	Occur on Coastal and inland flood plains, and inland river valley sands and old buried river beds.	These aquifers are fully used throughout the year and a reliable volume of groundwater can be extracted from them. Because they are deeper and have a wider alluvial fill they do not get significantly reduced even in extremes conditions.
Shallow Regolith Aquifer	Shallow regolith aquifer does not occur as a continuous body of groundwater with a single water table, but as separate pockets of groundwater.	In the southern province, the amount of recharge is not significant. In the north-central and north-western provinces, aquifer recharge is about 100mm during the Maha season.

South Western Laterite Aquifer	This is a laterite formation or cabook with a considerable water-holding capacity depending on the depth of the cabook formation. They are found in South Western Sri Lanka	This aquifer gets recharged very rapidly with the first rains and is recharged throughout the year with both inter-monsoonal and northeast monsoon. However, in some areas, if the dry period prolongs more than 65 days, the water tables could reduce to depths beyond 15m.

FIGURES

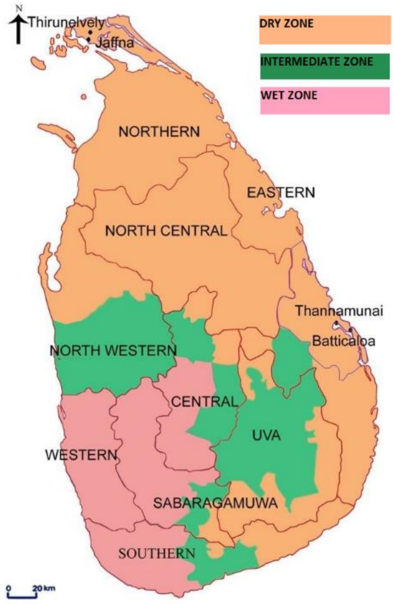


Figure 5 Sri Lanka Provinces and Climatic Zones[61]

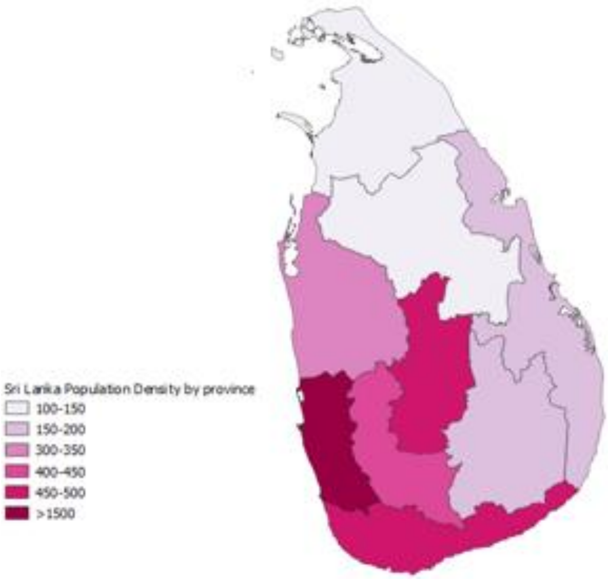


Figure 6 Sri Lanka Population Density by Province[62]

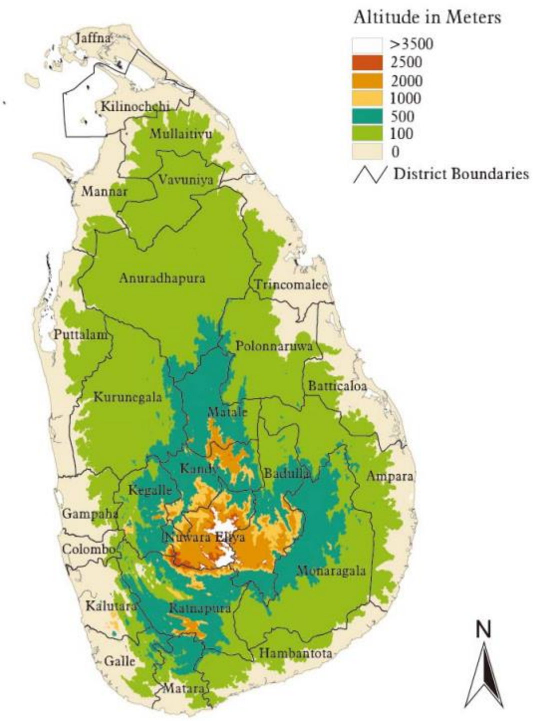


Figure 7 The Topographical Map of Sri Lanka

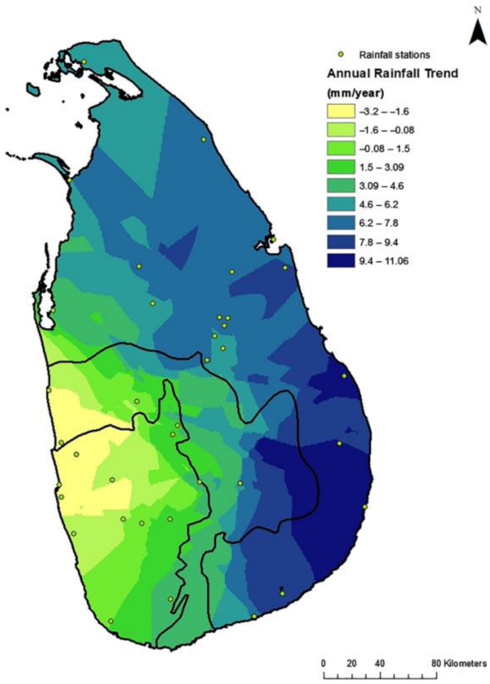


Figure 8 Rainfall Trends of Sri Lanka[14]

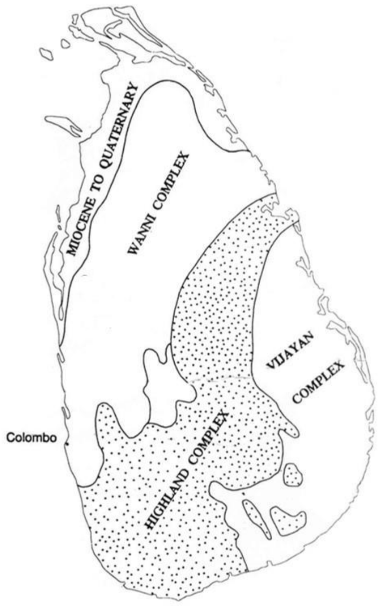


Figure 9 Geological Map of Sri Lanka[17]

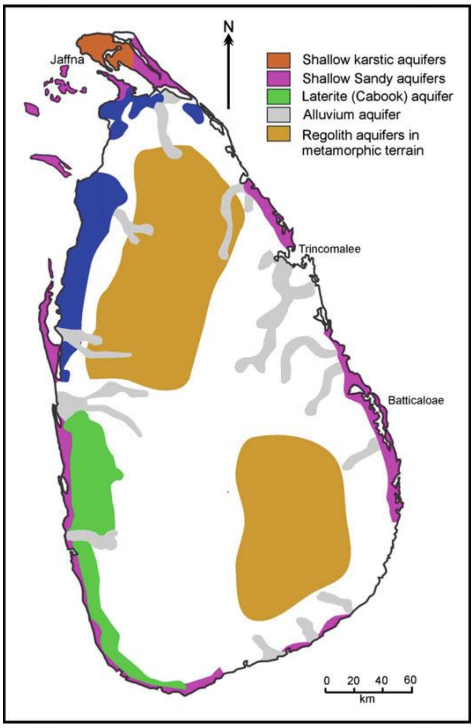


Figure 10 The Groundwater Aquifers in Sri Lanka[18]

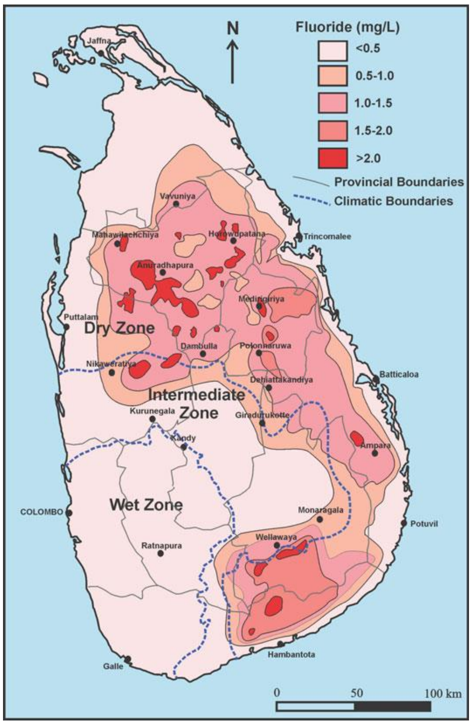


Figure 11 Geogenic Fluoride Concentration in Sri Lanka[18]

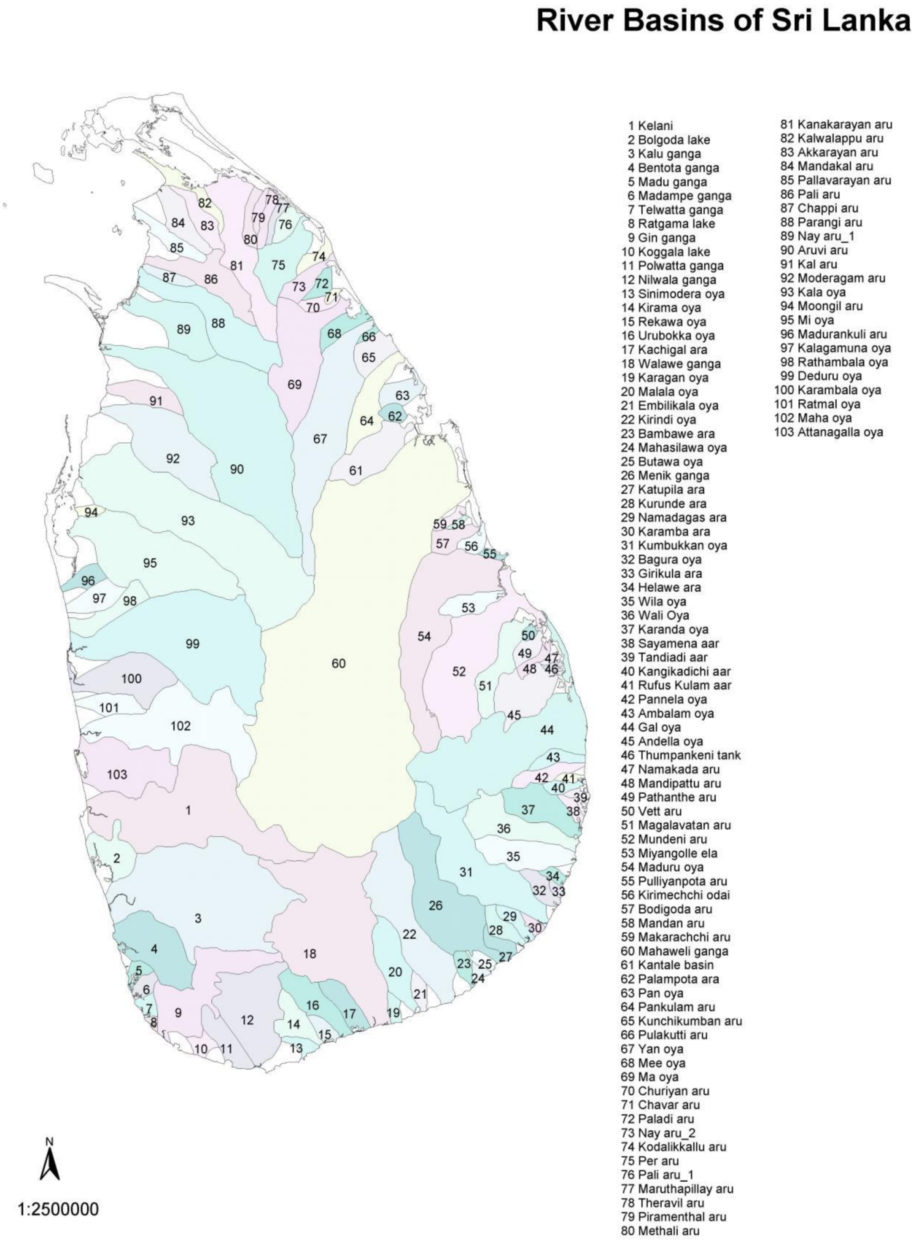


Figure 12 The River Basins of Sri Lanka[63]

D: Health Sensitization in South Asia - Health Risks Associated with Food Insecurity, Air Pollution and Water Insecurity

Contents: Health Sensitization in South Asia - Tackling Health Risks Associated with Food Insecurity, Air Pollution and Water Insecurity

1. Health Sensitization in Bangladesh

1. Health Sensitization in Bangladesh

SUMMARY

Bangladesh, officially known as the People's Republic of Bangladesh, attained its independence in 1971. Bangladesh covers a geographical area of 147,750 square kilometres and has a coastline of more than 580 kilometres. The country ranks as Eighth (8^{th}) most populated country globally with a population of 164,689,383 as of 2020.

Currently, **38.6%** of the population of Bangladesh is **urban**. Infant mortality rate being 25/1000 live births, and life expectancy is 72.7 yrs (at birth) for both the sexes. Adult literacy rate (15 years and above) is around 74%. The maternal mortality ratio, neonatal mortality rate and under 5 mortality rates are 173/1 lakh live births, 17 per 1000 live births and 30 per 1000 live births respectively. Percentage of Low birth weight babies born is also high.

The country has a sex ratio of 950 girls for every 1000 boys. Early marriage, teenage pregnancy with high neonatal and post-neonatal mortality, broken families, unhealthy practices related to Breast feeding, Sex of the child, Religion and caste, Quality of mothering, Brutal habits and customs, Maternal education, Bad environmental sanitation, Illegitimacy, Quality of health care are few of the wide variety of problems the country is facing. As per the estimates of 2015, the economic loss in terms of economic output due to the death and disability of labour has been estimated at $1.4 billion in all urban areas of Bangladesh. The public expenditure on health as a percentage of GDP fpr SEAR countries 0.42% (U.S.$ 6.1) as on 2016.

Bangladesh poses a major challenge from air, water, noise and soil pollution. The two major sources of air pollution concentrated in cities in Bangladesh are Vehicular emissions and industrial emissions. Air pollution kills 195,000 Bangladeshi each year, according to World Health Organisation (WHO) 2016 estimates. Many brick making kilns and Ship breaking industry in the country also adds on to the burden of environmental pollution.

The emerging challenges the country faces include child marriage, early pregnancy, unmet need for family planning, uneven reduction in Total fertility rate, epidemiological transition, threats of climate change/ Migration due to environmental reasons in City Slums, international migration, unemployment and high maternal and child mortality indices.

To achieve the SDGs, Bangladesh faces some considerable challenges. A country like Bangladesh will need a huge investment for basic infrastructure like roads, railways and ports; power stations; water and sanitation and for sectors like agriculture and rural development, climate change mitigation and adaptation, health and education. Efforts to take corrective actions towards universal education, better economic background and Hygienic and better living standards need to be implemented as a priority.

1.1 COUNTRY OVERVIEW WITH DEMOGRAPHY

Bangladesh, officially known as the People's Republic of Bangladesh, is a country in South Asia. It attained its independence in 1971. Bangladesh covers a geographical area of 147,750 square kilometres and has a coastline of more than 580 kilometres. Bangladesh shares land borders with India and Myanmar It is narrowly separated from Ne pal and Bhutan by the Siliguri Corridor, and from China by Sikkim. Bangladesh is one of the emerging and growth-leading economies of the world, and is also one of the Next Eleven countries, with one of the fastest real GDP growth rates.

***Adult Literacy*:** Adult literacy rate was 73.91 % as of 2018.

Population** and **Population Density: The population of Bangladesh as of 2020 is 164,689,383, with a global share of 2.11 % and ranks as the Eighth (8^{th}) most populated country globally. The population density in Bangladesh is 1253 people per Km^2 (3,244 people per square mile), calculated on a total **land** area of 130,170 Km2 (50,259 sq. miles) -2019 figures.

Bangladesh Urban Population

The majority of the population live in rural areas. Lack of education, poor economic background and unhygienic living standards attribute to ill health and poor living standards.

Currently, **38.6 %** of the population of Bangladesh is **urban** (62,865,820 people as of 2019)

The Population of Bangladesh (2020) is 164,689,383. Which accounts for 2.11% of the Global Population and the Country is Ranked Number Eight (8) globally.

1.2 HEALTH SCENARIO IN GENERAL

1.2.a Infant mortality rate: 26.9 deaths per 1,000 live births.

In 2017, infant mortality rate for Bangladesh was 26.9 deaths per 1,000 live births. Infant mortality rate of Bangladesh fell gradually from 149.8 deaths per 1,000 live births in 1968 to 26.9 deaths per 1,000 live births in 2017. The current infant mortality rate for Bangladesh in 2020 is 24.730 deaths per 1000 live births, a 4.1% decline from 2019.

There are some major reasons for Neonatal and post-neonatal mortality in Bangladesh,

Neonatal mortality reasons includes Low birth weight, Haemolytic disease of newborn, Birth injury and difficult labor., Acute respiratory infection (ARI), Measles, Congenital anomalies, Septicaemia, Malnutrition, Conditions of placenta and cord, Diarrheal disease, Tetanus, anemia and lot many more. Post-neonatal causes are Acute respiratory infection (ARI), Diarrheal disease, Malnutrition, Another communicable disease, Accidents and Congenital anomalies.

1.2.a.i Risk Factors of Infant Mortality and Morbidity

Factors associated with infant mortality and morbidity are as follows:

***Biological Factors*:** Birth weight: Babies of low birth weight (under 2.5kg) and high birth weight (over 4kg) are at special risk. Age of mother: When the mother is either very young (below the age of 19 years) or relatively older (over 30years) then the possibility of Infant mortality rates (IMR) is greater. Birth order: After the third birth, the risk of infant mortality escalates.

Cultural and Social Factors includes- Early marriage: The new-born baby of the teenage mother has the maximum risk for neonatal and post-neonatal mortality

Broken families: Infant mortality tends to be high where the mother or father has died or separated.

Few other factors of utmost concern are Breastfeeding, Sex of the child,Religion and caste, Quality of mothering, Brutal habits and customs, Maternal education, Bad environmental sanitation, Illegitimacy, Quality of health care.

1.2.b Deaths under the Age of 5

26.1 (per 1,000 live births)

Infant mortality is low among those who deliver at PHC's, take antenatal check-up and have higher wealth status. Infants with average birth size and female babies have less mortality. To reduce the infant mortality in Bangladesh, institutional delivery, antenatal care, baby birth size, child gender and wealth index are important factors that need to be followed. There is urgent need to focus in these areas to reduce infant mortality in the country.

Fertility in Bangladesh – Live Births per Woman (2020 Figures): Total Fertility Rate (TFR) of **2.1**

1.2.c Maternal Mortality

Maternal mortality ratio is the number of women who die from pregnancy-related causes while pregnant or within 42 days of pregnancy termination per 100,000 live births.

There is a declining trend in the burden of maternal mortality with 214/1 lakh live births in the year 2014 to less than 173/1 lakh live births in the year 2017.[7].

Life Expectancy in Bangladesh: Both Sexes: 73.6 Years. Females-75.6 and Males-71.8 Years.

1.2.d Specific Health Issues – Pollution Related:

There is a good reason to worry about the Air Quality, as Bangladesh ranks 169th (out of 178 countries) at the Environmental Performance Index for Air Quality (2014 score). AQI for 2019 is 165. Furthermore, according to the WHO data, the air quality in Dhaka reaches a yearly average of 90ug/m3 of PM2.5, which corresponds to a 168 which is unhealthy AQI. This is only the yearly average, but actual levels can rise up to hazardous levels as high as 300. Bangladesh is one among the countries with highest rates of pollution in the world. Pollution caused nearly 28% of deaths in 2015- more than 10 times the number of deaths from traffic accidents. The country has lost about Dollars 6.5 Billion or 3.4% of its 2015 GDP due to pollution and environmental degradation in urban areas[3].

1.3 AIR POLLUTION: CAUSES OF AIR POLLUTION IN BANGLADESH

As in the rest of the world, the emission of harmful gases such as carbon monoxide, carbon dioxide, sulphur dioxide and various oxides of nitrogen by natural or artificial means released into the atmosphere causes air pollution. Generally, two main reasons have been identified for air pollution in Bangladesh those are industrial and mining activities and vehicular pollutants

Factories built for various purposes during their operations are spewing out enormous quantities of harmful gases that pollute the air. Mining activities also release harmful gases.

Vehicles throughout the country contribute their share to the air pollution. Although all the motorized vehicles emit harmful gases, the emissions from two-stroke engines are more dangerous. The use of leaded petrol causes a huge amount of lead building up in the streets of the major cities. Dhaka has one of the largest amounts of lead in the air compared to other cities across the world, about 463 nano grams per cubic meter of air. Air pollution kills 195,000 Bangladeshi each year, according to World Health Organisation (WHO) 2016 estimates.

Many children, street children, local streetwalkers, and rickshaw pullers in Dhaka City are at particular risk from air pollution.

There are also many brick-making kilns operated, mainly in dry season all over Bangladesh. Most of these kilns use coal and wood as their primary source of energy, resulting in the emission of particulate matter, oxides of sulphur, and volatile organic compounds.. The tremendous growth of population has made it almost unviable to maintain a clean environment thus greater exposure to pollutants in the capital city of Dhaka[10].

1.3.a Diseases due to Air Pollution

Cancer and respiratory diseases are the top two killers in Bangladesh, with these two diseases being responsible for about 25% of all the deaths in the country. The prevalence of respiratory diseases in the country is an indication of the high air pollution levels in Bangladesh.

1.3.a.i Cancer: is the leading cause of death in Bangladesh where 13% of all deaths being attributed to cancer. Lung cancer and oral cancer are the two most common cancers in Bangladeshi men while cervix cancer and breast cancer are the most common in women. Nonetheless, Bangladesh has established the National Cancer Control Strategy and Action Plan whose primary function is to fight cancer in the country.

1.3.a.ii Lower Respiratory Infections: An estimated 7% of all deaths in Bangladesh are caused by lower respiratory infections, making it the second leading cause of mortality in the country.

1.3.a.iii Chronic Obstructive Pulmonary Disease (COPD): Another leading cause of death in Bangladesh is Chronic Obstructive Pulmonary Disease, a collective term for ailments that affect the lungs. Such diseases include emphysema and bronchitis. Also known by its acronym COPD, the disease is linked to an estimated 7% of all deaths in Bangladesh. More than 1,000 people die from Chronic Obstructive Pulmonary Disease each year in Bangladesh.

1.3.a.iv Ischemic Heart Disease: Also known as coronary artery disease, the disease is a leading cause of mortality in Bangladesh where about 6% of all deaths are attributed to this disease.

1.3.a.v Stroke: Bangladesh has one of the highest rates of stroke in Asia, with an estimated 21.5% of all Bangladeshis having suffered strokes. Strokes are also among the deadliest diseases in the Asian country and attribute to 5% of all deaths in Bangladesh. The risk factors that are linked to stroke include cigarette smoking, unhealthy eating habits, and air pollution, all of which are high in the country.

1.3.a.vi Preterm Birth Complications: Preterm birth complications are another top cause of death in Bangladesh. These complications are linked to 4% of all deaths in the country. The condition is also the leading cause of neonatal deaths in Bangladesh, causing 88% of all neonatal deaths in the country. The preterm birth complications are also linked to most health defects in children including motor problems, blindness, and cerebral palsy.

1.3.a.vii Tuberculosis: The World Health Organization classifies Bangladesh as a "High TB Burden Country" due to the high prevalence of tuberculosis in the country. The disease is responsible for 3% of all deaths in the country. Statistics from the World Health Organization shows that there are about 0.362 million new tuberculosis cases reported in Bangladesh each year.

1.3.a.viii Neonatal Encephalopathy: Another leading cause of death in Bangladesh is neonatal encephalopathy. The disease is linked to an estimated 3% of all deaths in the Asian nation. Neonatal encephalopathy affects new born infants with the symptoms being manifested a few days after birth. The high rate of neonatal encephalopathy among infants in Bangladesh is caused by the lack of proper maternity services in the country due to a shortage of health facilities.

1.3.a.ix Diabetes: Diabetes is linked to an estimated 3% of all deaths in Bangladesh, making the disease one of the top causes of mortality in the Asian country. Interestingly, the rate of diabetes cases in Bangladesh recorded a dramatic increase in the early 21st Century prompting health officials to come up with measures to contain the disease. Diabetes has now become one of the biggest health concerns in Bangladesh.

1.3.a.x Cirrhosis: Cirrhosis is another leading cause of death in Bangladesh, with the disease being responsible for about 3% of all deaths in the country. Studies have shown that the prevalence of cirrhosis among Bangladeshis is not an indicator of the alcoholism levels in the country. As much as 92% of all cirrhosis cases recorded in the country are non-alcoholic. Instead, the most probable cause of cirrhosis rates in the country is aetiological factors such as poor nutrition.

1.3.b Causes for indoor pollution: young children and poorly educated women in poor household face pollution exposures that are four times higher than those of men in higher-income households organized by more highly educated women. In Dasgupta et al. (2004), recommendations were made for feasible changes in cooking locations, construction materials and ventilation practices that could greatly reduce average household pollution levels.

1.3.C OUTDOOR POLLUTION

Acid rain causes many problems in the environment:

Formation of acid rain When acidic gases, such as sulphur dioxide or some oxides of nitrogen, are emitted into the atmosphere, they are absorbed into the moisture in the air to form acid. By the normal process of cloud formation and rainfall, these acids come down to the earth with devastating effects. It increases acidity in lakes, thus making it impossible for many other life forms to survive. The biodiversity changes and only species more tolerant to increased acidity survive. Though this shows the biodiversity decreases in most cases. falling directly on plants causes problems to them, in many cases leading to some form of damage to the leaves Acid rain and can increase the toxic content in the plant produce. Acidification of soil can kill the soil bacteria that play an important part in many nutrient cycles and in nitrogen fixation[10].

1.3.D RECOMMENDED STRATEGIES TO REDUCE AIR POLLUTION

It is estimated that pollution is responsible for 16% of all deaths worldwide. In the most severely affected countries, pollution-related disease is responsible for more than 25% of deaths. It is important to note that pollution disproportionately kills the poor and the vulnerable. Nearly 92% of pollution-related deaths occur in low- and middle-income countries, and pollution-related disease is most prevalent among minority and marginalised communities in countries of every income level. Children are also especially vulnerable to the health effects of pollution.

Air Pollution is associated with various health hazards. Breathing impure air causes many breathing illnesses. Illnesses that are more serious are caused by poisonous components in the air such as lead, which causes brain development disorder in children. Excessive lead in the blood can cause major organs to dysfunction. Pollution control measures that have been implemented or designed include: Introduction of four-stroke engines which pollute less, and unleaded petrol, Proper monitoring of the streets so that vehicles which pollute are identified and proper action taken against them by the concerned authorities. Vehicles should be fitted with catalytic converters, which take away some of the more harmful gases from the vehicle exhaust and minimize acidic gases from being released into the environment.

Factories that emit pollutant gases should be have proper purification units to minimize the effect of harmful gases, which if untreated, would do a great harm to the environment. Based on data gathered from 11 air quality monitoring stations in eight urban areas, concentration of 2.5 microgram particulate matter from 2013 to 2015 was estimated five times the Bangladesh standard and eight times the World Health Organisation standard.

Household air pollution disproportionately affects women and young children, who spend most of the time inside houses. Pregnant women are especially vulnerable to this hazard.

1.4 CAUSES OF WATER POLLUTION IN BANGLADESH

Indiscriminate use of fertilizers, excess of flooding of agricultural land, untreated factory effluents are some of the main causes of water pollution. Unplanned and rapid urbanization compounded with release of sewage water into the water bodies directly adds to the contamination. There are both natural and artificial causes of water pollution. The natural ones occur without any human influence. There are point sources of water pollution, that pollute the water at discrete locations, and there are non-point sources too. The point sources include industrial structures such as factories or sewage treatment plants. Cities, including their roads and railroads, croplands, and forests, are non-point sources of pollution issuing dust, sediment, pesticides, asbestos, fertilizers, heavy metals, oil, grease, and even air pollutants washed down from the sky. Surface water is extensively polluted by industrial and household wastes, as well as chemicals used in agriculture. Of these, the untreated wastes from the industries prove to be the most damaging. When acid rain falls, it pollutes the water bodies.

A number of physical, chemical, and biochemical processes cause the alteration of groundwater properties, either by the addition of new elements or changing the present concentrations. For example: Arsenic contamination in the groundwater is thought to be the main cause of water pollution in the world. Industrial and household wastes disposed off on the ground above seeps into the water underground. Fertilizers used in agriculture and the infiltration of saline water also contaminate groundwater[10].

1.4.a Effects of Water Pollution

Water pollution leads to many health problems. Drinking impure water leads to diseases such as diarrhoea. Other contaminants may lead to more serious water borne illnesses.

1.4.b Possible Solutions to the Problem of Water Pollution

There can probably be no direct solution to the problem. People in general need to be more conscious of their waste disposal mechanisms to reduce water pollution. Proper waste treatment facilities need to be installed in factories so that the waste released into the environment is less harmful. Proper precautionary measures should be taken if material that may be harmful to the environment is to be released . Such materials may include pesticides or fertilizer, and their effects on the environment should be carefully monitored before they are to be used.

Anticipated effects of water pollution include, increased temperatures, especially if combined with standing water eventually leading to an increase in diseases, pests, insect attacks.

Changing seasons (with the length of the crop growing periods decreasing between 2000 and 2030, and erratic rainfall will lead to lower crop productivity or harvest failures;

1.4.c Water Availability

Higher temperatures will lead to higher rates of evaporation, which may increase by 10-20% by 2030-leading to higher irrigation requirements. Glacial melt in the Himalayas, combined with increased monsoon rainfall in the whole of the GBM Basin, river, soil erosion and landslides lead to loss of agricultural land and production. Sea level rise leads to salinity and saltwater intrusion, which negatively affects conditions for crop cultivation and decreases availability of freshwater resources for consumption and production. Unplanned urbanisation is also taking a toll on smaller cities as well as towns like Pabna. Since 1990, Pabna lost half of its wetlands, and its lifeline, the Ich Amati River, is dying.

1.4.d Disappearing Wetlands and Rivers

Dhaka has been ranked as the ninth largest megacity in the world. It has seen its population rise by about three times from 6.8 million to 18.2 million over the past quarter of a century. Continued unplanned urbanisation, filling-up of wetlands and rivers, and shrinking of a canal network across the city has exacerbated urban flooding and contributed to various environmental problems. Flooded roads contribute to traffic congestion and health hazards from the spread of vector-borne diseases. As climate change accelerates, the pressures on rural Bangladeshis' mount. Where previously people might have been able to move away for the worst of seasonal flooding, the regularity of water logging is making it impossible to farm. Crop varieties cannot cope with the saltwater, and career alternatives are limited. This is impacting the agricultural sector and causing reduction in produce and GDP[11].

1.4.e Women Impacted

Women and girls bear a disproportionate burden of limited access to clean and safe water. Water pollution and water scarcity affect women's health, nutrition, workload, and, consequently, their opportunities to overcome poverty. Poor sanitation, lack of safe water supply and arsenic contamination in groundwater lead to diarrhoea and other diseases causing deaths. Urbanisation and industrialisation have increased the amount of waste generation. Without proper collection and disposal, solid waste clogs channels, leading to urban floods. Unsafe recycling of hazardous waste such as used lead-acid batteries poses a growing public health hazard[11].

1.5 SHIP BREAKING INDUSTRY

An estimated 22,000 workers in Bangladesh's ship-breaking industry are exposed to increased levels of asbestos, polychlorinated biphenyls, cadmium, lead, and mercury in the naval and merchant ships they dismantle. Studies reveal that nearly one million people in Bangladesh, mostly poor, are at risk of lead contamination, which can lead to IQ loss and neurological damage, especially for children, and can increase the risk of miscarriage and stillbirth among pregnant women[11].

1.6 ECONOMIC LOSS

As per the estimates of 2015, the economic loss in terms of economic output due to the death and disability of labour has been estimated at $1.4 billion in all urban areas of Bangladesh and at 310 million in Dhaka city alone, equivalent to 0.6 percent and 0.1 percent of the country's GDP.

1.7 NOISE POLLUTION

Transportation systems are the main source of noise pollution in urban areas. Construction of buildings, highways, and roads cause a lot of noise, due to the usage of air compressors, bulldozers, loaders, dump trucks, and pavement breakers. Industrial noise also adds to the already unfavourable state of noise pollution. Loud speaker, plumbing, boilers, generators, air conditioners, fans, and vacuum cleaners add to the existing noise pollution as per environmental protection bureau.

1.7.a Effect of noise pollution

The effect of noise pollution are seldom catastrophic, and are often only transitory, but adverse effects can be cumulative with prolonged or repeated exposure. Sleep disruption, the masking of speech impairs the quality of life. In addition, noise can interfere with the teaching and learning process; disrupt the performance of certain tasks and increase the incidence of anti-social behaviour (Mangalekar et al 2012). According to the MCI, there are direct links between noise and health[11].

1.8 REMEDIAL MEASURES

World Bank's recommendation to put Bangladesh on a greener growth trajectory, is that the government strengthen policies and institutions, and enforce environmental standards with a shift to cleaner technologies to contain the increasing air, water and soil pollution as well as industrial pollution. Bangladesh had its first-ever legal framework "National Environment Policy" on governing environmental conservation in 1992. Since then, more than 25 laws, policies, guidelines, and regulations have been formulated to regulate the environmental footprint.

1.9 SOCIO-ECONOMIC VULNERABILITY

Vulnerability to climate change is related not only to biophysical aspects, but also to social, cultural, and economic aspects as well. Socio-economic aspects that affect climate change vulnerability in Bangladesh include the country's dependence on agriculture (mainly rice cultivation) and other resource dependent sectors, its economic growth and poverty (which form a vicious cycle with climate change effects, health gender, population growth, population density and migration. The current population is projected to grow to over 200 million by 2050 with annual domestic water demand expected to increase 200% compared to current levels, while industrial demand is expected to increase by 440%. Bangladesh's large population already places significant pressure on land and water resources, leading to pollution, the rapid depletion of groundwater resources and determination impacts on food production. These challenges are expected to be exacerbated by the effects of climate change, which is set to impact the population possible solutions to the problem of water pollution[10].

1.10 PUBLIC HEALTH PROBLEMS IN BANGLADESH: ISSUES AND CHALLENGES

The population of Bangladesh as of 2020 is 164,689.383 (or 1.64 million). With a global share of 2.11 % and ranks, the (8th) eighth most populated country globally. Bangladesh is one of the emerging and growth-leading economies of the world, and is also one of the Next Eleven countries, with one of the fastest real GDP growth rates. The national population is projected to grow to between 200 to 225 million over the next four decades.

Bangladesh faces a number of health challenges, which can be grouped as follows: Population problems, communicable diseases problems, Nutritional problems, Environmental sanitation problems and Health problems

1.11 WAY FORWARD

In South-East Asia the main public health issues are infectious diseases and communicable diseases. Public health has improved markedly in Bangladesh over the past three decades. Nevertheless, Bangladesh faces major health challenges.

Bangladesh has one of the worst burdens of childhood malnutrition in the world. Communicable diseases are a major cause of death and disability in Bangladesh. Unsafe food remains a major threat to public health each year; citizens suffer from the acute effects of food contaminated by microbial pathogens, chemical substances and toxins.

Challenges to Zero Hunger will be related to implementation of the Delta Plan 2100 which purports to take account of future uncertainties in climate change, socio-economic development, population growth and regional cooperation, addressing hunger in lagging regions and of disadvantaged groups, building resilience of poor people and problems emerging from urbanization.

Bangladesh still ranks among the top ten countries in the world with the highest TB burden. Pneumonia and other infections are major causes of death among young children.

In Bangladesh, only 1% of the population is reported to be HIV-positive, but rates are much higher among high-risk populations: injecting drug users, sex workers, and men who have sex with men. The toll of non-communicable diseases — chronic diseases, cancer, diabetes, cardiovascular diseases, and chronic respiratory diseases — is increasing in Bangladesh as the population becomes more urbanized.

The converging pressures of global climate change and urbanization have a devastating effect on Bangladesh's most vulnerable populations. The disease burden Bangladesh is further exacerbated by unsanitary living conditions that underscore the poor economic conditions of both urban and rural home dwellers.

1.12 CONCLUSION

There are still several issues that Bangladesh health care system has to tackle. Governance, accessibility, and affordability are key issues that are preventing the implementation of solutions to the public health issues in Bangladesh. ICDDRB, WHO, and several other global organizations are making attempts to aid Bangladesh in resolving the health issues. The converging pressures of global climate change and urbanization have a devastating effect on Bangladesh's most vulnerable populations. At this moment, millions of people in the country are exposed to extremely high food and water-borne disease risks such as bacterial and protozoal diarrhea, Hepatitis A and E, and typhoid fever. The disease burden in Bangladesh is further exacerbated by unsanitary living conditions that under-score the poor economic conditions of both urban and rural home dwellers. These poor health outcomes disproportionately impact children under the age of five years, causing widespread morbidity and mortality; the second leading cause of death in children under five is diarrheal disease.

1.13 RECOMMENDATIONS

The study put forward following recommendations to improve the standard of public health in Bangladesh:

Improving health care-seeking behavior such as education, awareness-raising and skills building in recognizing and treating pneumonia and obstetric emergencies.

Rapid urbanization which creates conditions that make slum dwellers vulnerable to disease as a result of problems of sanitation, hygiene and the supply of clean water. The emergence of arsenic in tube well water, leading to arsenic poisoning, solution measures have to be taken by the Government.

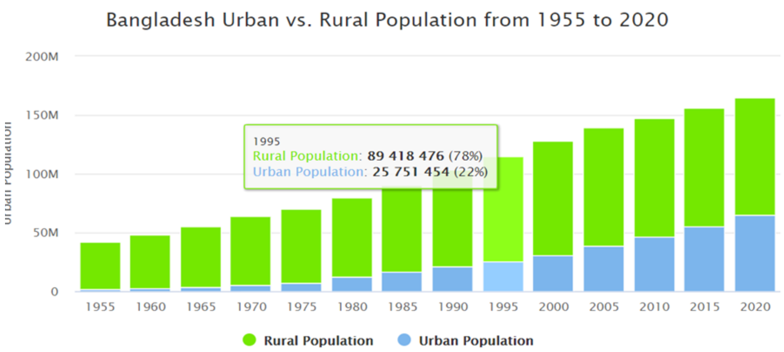
To help reduce the burden of communicable diseases; including vaccine-preventable diseases, tuberculosis, malaria, HIV/AIDS, and neglected tropical diseases by sustaining high immunization coverage and introduce new vaccines; achieve “universal access" to quality diagnosis and treatment for all tuberculosis patients; strengthen diagnosis and treatment of malaria, addressing cross-border transmission; build capacity of the National AIDS/STD (sexually transmitted disease) Programme for effective treatment, care and support to HIV-positive people; strengthen diagnosis and treatment of kala-azar, filariasis, leprosy and dengue.

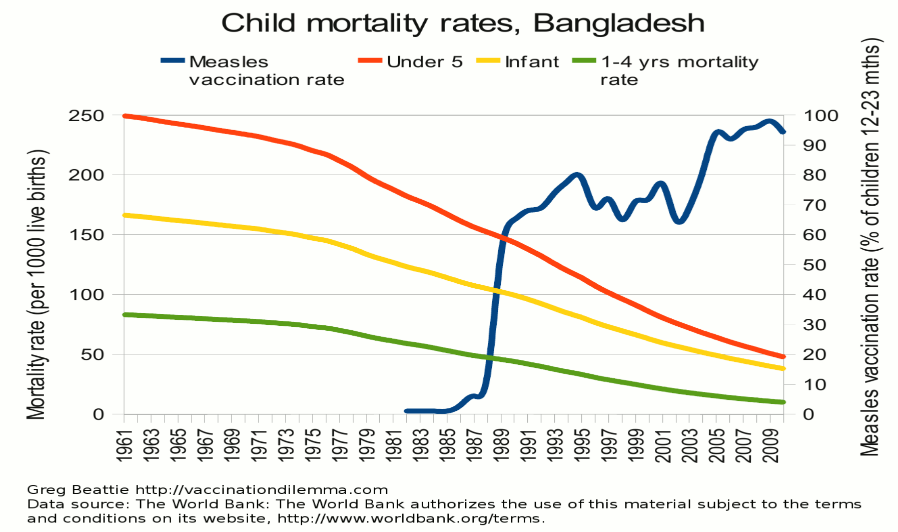
Reduce the burden of non-communicable diseases through health promotion, risk reduction and cost effective management. Reduce health, nutrition, environmental and occupational risk factors throughout the life course by supporting the development, adaptation and use of national policies, guide-lines, standards, and tools to enhance health services for mothers and children from birth to adolescence; build the capacity of health providers to ensure quality services; contribute to the development of a functioning result-based program, monitoring and evaluation system on reproductive, maternal and child health at the national level; support the national strategy to mainstream nutrition through the development of policy, protocols and guidelines involving different sectors; build capacity of the local government on safe water by integrating the Water and Sanitation Program into water supply management and building climate-resilient water, sanitation and hygiene (WASH).

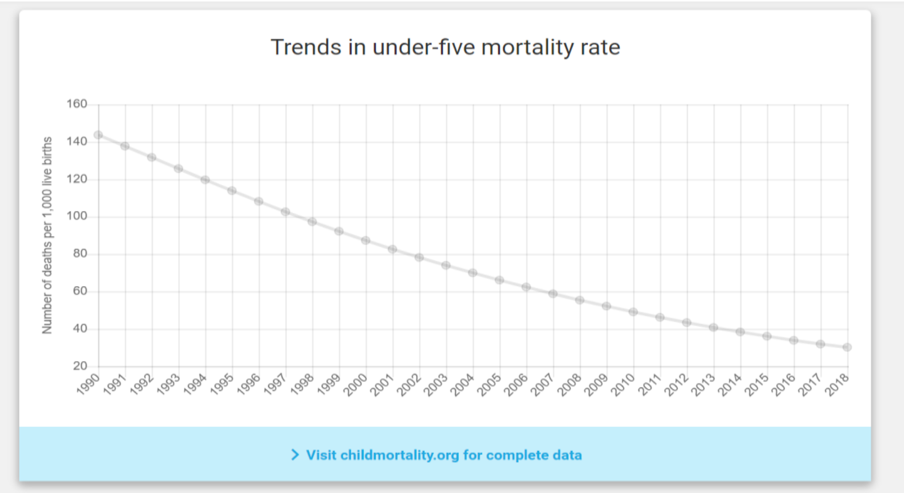
Promote universal health coverage with strengthened health systems based on primary health.

Reduce mortality, morbidity and societal disruption resulting from epidemics, natural disasters, conflicts, environmental, and food-related emergencies, through prevention, preparedness, response, and recovery activities that build resilience and use a multi sectoral approach.

Over the last decades, Bangladesh has achieved strong developmental progress and is now well positioned in the post-2015 era of the Sustainable Development Goals. More than 10,000 children received psychosocial counselling and recreation support through 100 child-friendly spaces (CFSs). More than 10,000 parents and community members, including members of school management committees, enhanced their knowledge on emergency preparedness and response, positive parenting during emergency and hygiene practices. Through child protection interventions, 103,917 children received psychosocial support to cope with trauma. A total of 1,825 unaccompanied and separated children were identified and received services through standardized case management protocols[12].







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2. Health Sensitization in Bhutan

2. Health Sensitization in Bhutan

SUMMARY

Bhutan is a small land locked country present in the Eastern Himalayan region, with a total territorial area of 38,117 km^2. Current population of the country is recorded at 772,535 with 45.8% urban population. Literacy attainment rate is at 59.5%. Bhutan has a total life expectancy of 72.8 years. Infant mortality is recorded to be 15.1 infant deaths per 1000 live births and deaths under the age of 5 years is 34.1 per 1000 live births. Neonatal mortality rate stands at 16 per 100 live births and maternal mortality rate is at 89 per 100,000 live births. Births attended by skilled health personnel are 96%. Institutional delivery coverage in 2019 has seen improvement at 94%, postnatal care coverage stands at over 74% and immunisation coverage has sustained at more than 95% for the last 10 years nationwide.

Cultural and socio-economic factors:

Reproductive, maternal, newborn and child health has made significant progress in the years. Currently Bhutan has recorded the sex ratio to be 1.1 male for every female. The total fertility rate (TFR) is 2 live births per woman. Health has held a prominent place in Bhutan’s economic development where the government spends around 3.5% of total health expenditure as a share of GDP. The Out-of-Pocket (OOP) expenditure for health was at 20% in 2016. The rising health care expenditure is mainly driven by increasing population, changing epidemiology and evolving health needs, and rising demand for better healthcare services. Around 95% of the Bhutanese population live within 3 hours distance to the nearest health facility. In Bhutan traditional and allopathic medicine services are fully integrated and delivered under one roof. The public expenditure on health as percentage of GDP is 2.55% and public expenditure on health is U.S.$ 67.5 as on 2016.

Environmental pollution and health issues:

More than half of the morbidity cases attended by the health facilities in 2019 were due to non communicable diseases, while the proportion of communicable diseases has decreased by 10%. In the last 10 years, the diarrhoeal cases have reduced by 35%, largely attributed to 98% of population with access to safe drinking water. In terms of mortality, alcohol related liver disease remains to be the biggest killer in the country. Bhutan is considered a relatively low Tuberculosis (TB) burden country in South-East Asia Region with an estimated incidence rate of 149 per 100,000 population. Conditions such as hypertension, cardiovascular diseases (CVDs), cancers, and diabetes accounted for 71% of the reported deaths in the country. A significant reduction in the prevalence of diabetes is noted from 6.4% in 2014 to 1.9% in 2018 and hypertension from 37% in 2014 to 28% in 2018.

Environment plays a major role in the health and wellbeing of a nation. Although air quality in Bhutan has long been regarded as pristine, Air Quality Index (AQI) is recorded to be 52.8 which is considered moderate. Available data indicates that Thimphu and Phuentsholing have consistently high levels of air pollution. The country's annual mean concentration of PM 2.5 is 38 $\mu g/m^3$ which exceeds the recommended maximum of 10 $\mu g/m^3$.

Although Bhutan has one of the highest per capita water resource availability in the world with 94,500 m^3/capita/annum, its imbalance in geographical and temporal distributions is leading to experience of shortages in local areas. Although 97.2% population use at least basic drinking water services, 88 percent of diarrhoea cases are caused by unclean water or improper sanitation facilities. Noise pollution is one of the negative impacts of increased urbanization, industrialization and economic development. Construction works, industrial machinery, vehicular transportation are the major cause of noise in any urban setting.

Urbanisation is identified as a direct factor leading to land degradation in Bhutan. From 1998 to 2015, a total of 306.55 Ha of wetland was lost for various purposes and mostly for urban development and other infrastructure development. Direct factors causing degradation include overgrazing, unsustainable agricultural practices and poor irrigation system management, forest fires, excessive forest use, industrial activities, urbanization and infrastructure development (especially road construction), unsustainable mining, and poor management of solid waste, in-situ chemical degradation (which causes depletion of soil organic matter and nutrient mining) and in-situ physical degradation (topsoil capping and subsoil compaction).

2.1 COUNTRY PROFILE

Bhutan is a small landlocked country bordered by People's Republic of China to the North and Republic of India to the South, East and West. It shares about 477 kms of its border with China and about 659 kms with India. Closest neighbours, Myanmar, Bangladesh and Nepal are separated only by small areas of India. Thimphu city, located in the river valley is the capital city of Bhutan. (1)

Topography of the country is rugged with steep mountains and deep valleys in the northern and central part. Many mountain peaks in northern Bhutan reach heights of over 7,000 meters. Bhutan's highest point is Gangkhar Puensum, which reaches a height of 24,840 ft (7,570 m) (1). To the south of this terrain is the region of lesser Himalaya. Numerous small rivers drain the land, including the Dangme, Mangde, Sankosh and Torsa. Close to the southern border of India terrain is more plain and undulating. The lowest point of the country is the Drangme Chhu River at 318 ft (97 m). (3)

Territorial area of Bhutan is 38,117 km^2. Its current population is 772,535 (as of Tuesday, August 11, 2020) which is about 0.01% of the world's population. The population density here is 20 per Km^2. 45.8 % of the population is urban (2). The population is highly scattered and unevenly distributed, with more concentration in the western and southern belts. The uneven population distribution is largely due to migration from rural to urban areas for economic and educational opportunities. In terms of educational attainment, 71.4 % of Bhutan population is literate.

According to ADB, Basic Statistics 2020, in Bhutan 8.2% of the population live below the national poverty line. The proportion of employed population below $1.90 purchasing power parity (PPP) a day is 1.3% and total unemployment rate is at 2.7%.

2.2 HEALTHCARE SYSTEM IN BHUTAN

The Constitution of the Kingdom of Bhutan which was adopted in 2008 mandates the state to provide access to free basic public health services. It is predominantly financed and managed by public health institutions. Government revenue is the major source of health financing. Health policies and system have evolved and grown rapidly in the past decades. (4)

Health has held a prominent place in Bhutan's economic development where the government spends around 3.5% of total health expenditure as a share of GDP. The Out-of-Pocket (OOP) expenditure for health has seen a steady increase from 11% in 2010, to 12% in 2014, and to 20% in 2016. The rising health care expenditure is mainly driven by increasing population, changing epidemiology and evolving health needs, and rising demand for better healthcare services. (5)

2.2.a Access to Healthcare

Around 95% of the Bhutanese population live within 3 hours distance to the nearest health facility. Health services in the country are available through a three-tier structure:

- Basic health units (BHUs), sub-posts and outreach clinics (ORCs) at the primary level.
- District or general hospitals at the secondary level.
- Regional and national referral hospitals at the tertiary level.

Traditional and allopathic medicine services are fully integrated and delivered under one roof. At the grassroots level, village health workers (VHWs) play a key role in health promotion and act as a bridge between health services and the community.

2.2.b Health Infrastructure

To address the emerging challenges associated with evolving health needs and rising demand for better healthcare services, the Ministry of Health continues to invest in infrastructural development including consolidation and up-gradation of the existing health facilities.

Below (Table 1) is the list of types of health facilities present in Bhutan in 2019 (6)

2.2.c Human Resource for Health

While free universal healthcare guarantees that everyone can get the same standard of treatment, the downsides are overworked doctors, lack of specialists and medicines, and long queues.

Below (Table 2) is the list that summarises medical personnel available in Bhutan. (6)

The doctor to population ratio stood at 0.5 in 2019, which is 50% below the WHO recommended ratio of 1 doctor per 1000 population. Similarly, the nurse to population ratio is 18.4 per 10,000 population which is still lower than most countries in South East Asia. The ratio of beds per nurse has reduced from 1.7 in 2012 to 1.1 in 2019. The Ministry of Health has been according high priority on human resource development to overcome the shortage both in terms of quantity and specialties. Currently, about 85 medical doctors are undergoing long-term training in diverse fields of speciality both within and outside the country.

2.3 HEALTH OF BHUTAN

The health indicators in Bhutan are among the best when compared to other low – middle income countries. Bhutan has a life expectancy of 72.8 years at birth (72.3 years for males and 73.3 years for females.) The median age in Bhutan is 28.1 years. Over 6% of the population are currently above 65 years of age and the share of the elderly population is expected to rise.

State of Nation's Health is laid out around four broad thematic areas for measuring the progress against Universal Health Coverage:

1. Reproductive, maternal, new born and child health
2. Infectious or communicable diseases
3. Non communicable diseases
4. Service capacity and access

2.3.a Reproductive, Maternal, Newborn and Child Health (RMNCH)

Reproductive, maternal, newborn and child health has made significant progress in the years. Currently Bhutan has recorded the sex ratio to be 1.1 male for every female. The total fertility rate (TFR) is 2 live births per woman. (A value below 2.1 will cause the native population to decline.) Infant mortality is recorded to be 15.1 infant deaths per 1000 live births and deaths under the age of 5 years is 34.1 per 1000 live births. According to Annual Health Bulletin, 2020, for Bhutan, neonatal mortality rate stands at 16 per 100 live births and maternal mortality rate is at 89 per 100,000 live births. As per the same data, births attended by skilled health personnel are 96%.

Institutional delivery coverage in 2019 has seen improvement at 94% and immunisation coverage has sustained at more than 95% for the last 10 years nationwide. In January 2019, influenza vaccine was introduced in the routine immunization program for high risk groups. Postnatal care coverage stands at over 74%. The high coverage in the RMNCH services has translated into drastic reduction of maternal and child morbidities with concomitant reduction in mortality due to preventable causes. The majority of the newborn deaths are due to preterm births, neonatal sepsis, and birth asphyxia which are largely preventable in nature.

Malnutrition remains persistently a major public health issue in Bhutan impacting the one-fifth of the under-five children suffering stunted growth and two in five children suffering anaemia. In order to improve the nutrition and care for newborns, the three-month maternity leave has been extended to six months.

2.3.b Morbidity and Mortality Rates in Bhutan

More than half of the morbidity cases attended by the health facilities in 2019 were due to non communicable diseases as compared to 43% in 2010. On the other hand, the proportion of communicable diseases has decreased by 10% during the same period.

Common cold and skin related diseases continue to lead the top-ten morbidity list in the country. In 2019, common cold accounted for 19% of the diseases, followed by disorders of skin and subcutaneous-tissues and diseases of the digestive system which accounted to 7% each.

In the last 10 years, the diarrhoeal cases have reduced by 35%, from 65,495 cases in 2009 to 42,366 in 2019. Such an achievement can be largely attributed to increased access to improved drinking water and sanitation facilities. As evident, the proportion of the population with access to safe drinking water has increased from 45% in the 1990s to over 98% in 2017.

In terms of mortality, alcohol related liver disease remains to be the biggest killer in the country as per the facility-based death reports. Of the 1264 reported deaths in 2019, alcohol liver disease claimed the highest number of deaths accounting for 11%, followed by other circulatory diseases at 8%. While communicable diseases such as tuberculosis and other infections are no longer the top-ten causes of mortality in 2019, pneumonia has dropped its ranking from the second position in 2010 to seventh in 2019. On the contrary, non-communicable diseases are increasingly dominating the leading causes of death which calls for the need to scale up our prevention and control efforts.

2.3.c Major Communicable Diseases

2.3.c.i HIV/AIDS

In 2019, 60 new HIV cases were detected (36 males and 24 females), taking the cumulative figure of the total cases diagnosed in the country to 687 since the detection of the first case in 1993. The prevalence of HIV among adults (15-19) stands around 0.8 which is still a modest burden in the region. Social factors hinder people with the disease from disclosing their status to family, friends and sexual partners for timely diagnosis and treatment, contributing to the overall detection gap 46%. In order to prevent and reduce the incidence of HIV, various methods have been adopted such as the revision of the HIV treatment guideline in 2016; hepatitis surveillance in 2017; provision of fixed-dose combination therapy; targeting zero mother-to-child transmission by introducing voluntary counselling and testing for HIV/hepatitis B/syphilis to all Antenatal Care (ANC) attendees, and monitoring of CD4 count and viral load. Also, extensive awareness and advocacy campaigns on the use of contraceptives have resulted in increased contraceptive prevalence rate from 30.7 per cent in 2000 to 65.6 per cent in 2012.

2.3.c.ii Tuberculosis

Bhutan is considered a relatively low Tuberculosis (TB) burden country in South-East Asia Region with an estimated incidence rate of 149 per 100,000 population. The treatment success rate for all forms of TB was 95% in 2018 and 98% for Multi-Drug Resistance TB (MDR-TB) for the 2017 cohort, comparatively higher than many countries in the region. The prevalence of MDR-TB was reported at 13% in new cases and 20% amongst the retreatment cases in 2018 which are higher than WHO estimates.

2.3.c.iii Malaria

Bhutan has seen an impressive decline in the overall incidence of malaria morbidity and mortality over a few decades. In 2019, there were 42 reported malaria cases with two indigenous, 30 imported, and 10 introduced cases compared to 54 malaria cases reported in the 2018 including six indigenous cases. As malaria endemic areas are mostly situated along the international border, curbing the cross-border malaria transmission is a major obstacle to achieve malaria elimination in Bhutan. The Bhutan One Health Strategic Plan 2017-21 and the WASH program are key priority programs that are being implemented to prevent and minimize/control of zoonotic and infectious diseases.

2.3.c.iv Dengue

Dengue is a disease of major public health concern in Bhutan. Since its first outbreak in 2004, seasonal outbreaks have occurred between 2010 and 2017 with the reported cases ranging from 500 to 1000. However, there was a major outbreak in 2019 with total cases of 5480, reported from 18 of the 20 districts. The majority of the cases were reported from Phuentsholing Hospital under Chukha District with 3517 cases, making up 64% of the total. The analysis of

2019 cases revealed that that dengue is more common in adults (20-40 years of age) with a mean age of 29.5 years. As quarter of the reported cases were below 20 years of age in the outbreak areas, WHO reported that Phuentsholing could be gradually advancing to a hyper-endemic state where multiple serotypes co-circulate exposing the community to dengue virus at an early age.

2.3.d Non Communicable Diseases

In 2019, conditions such as hypertension, cardiovascular diseases (CVDs), cancers, and diabetes accounted for 71% of the reported deaths in the country. The rapidly growing magnitude of the diseases is largely due to changes in lifestyle, dietary habits, access to unhealthy diet and aging population. In 2019, a Nationwide WHO STEPS Survey on risk factors for non communicable diseases revealed that the Bhutanese are exposed to varied risk factors:

- 33.5% were overweight.
- 28 % had raised blood pressure.
- 1.9% had raised blood sugar.
- 86.4% of them were not consuming the recommended five servings of fruits and vegetables.

A significant reduction in the prevalence of diabetes is noted from 6.4% in 2014 to 1.9% in 2018 and hypertension from 37% in 2014 to 28% in 2018. Below (Table 3) is the trend in Non communicable Diseases over the years (as per the HMIS data)

2.3.d.i Mortality related to Non Communicable Diseases.

Currently as per Annual Health Bulletin 2020, total mortality rate due to Rheumatic heart disease and Ischaemic heart disease is recorded at 19. Total mortality due to Cancer is recorded at 149, mortality due to diabetes is recorded at 11 and mortality due to respiratory disease is at a very high 204.

2.4 STATE OF ENVIRONMENT BHUTAN

2.4.a Air

Air quality in Bhutan has long been regarded as pristine. However, the statistics of the National Environment Commission (NEC) reveals that the air pollution is emerging to be a major concern. Recent rapid development is placing pressure on air quality in the major urban centres and at several industrial areas with relatively heavy industries. Today, Air Quality Index (AQI) in Bhutan is recorded to be 52.8 which is considered moderate. (10)

Air pollution, though moderate, is becoming one of the emerging issues that have a serious risk to human and environment health. Its quality is deteriorating, particularly in urban centres, industrial area and along the southern border of the country. Available data indicates that Thimphu and Phuentsholing have consistently high levels of air pollution. (11)

Two particulate matters called PM10 and PM 2.5, also known as particle pollution, is the common type of air pollution in Bhutan. It is a complex mixture of extremely small particles and liquid droplets that get into the air. Once inhaled, these particles can affect the heart and lung, and cause serious health problems. Air quality is found to be poor between 6-9AM and from 4-10PM in a day. (12)

In accordance with the World Health Organization's guidelines, the air quality in Bhutan is considered unsafe. The most recent data indicates the country's annual mean concentration of PM 2.5 is 38 μg/m^3 which exceeds the recommended maximum of 10 μg/m^3. [(11)]

The primary sources of air pollution emission in Bhutan are:

- Exhaust emissions from diesel and petrol vehicles, and particulate matter from brake and tire wear and resuspended road dust.
- Industry emissions (in industrial estates in the foothills along the border with India), especially cement plants, inorganic chemical & mineral processing (carbide, ferrosilicon), metallurgy, mining and processing.
- Smoke from wood stove (bhukaris) cooking and space heating.
- Wind-blown dust from building construction sites, bare agricultural soil and road construction areas during the winter dry season, and especially in the windy pre-monsoon season March-April.
- Smoke from forest fires during the dry season and agricultural burning primarily during the dry winter season and in the pre-planting season.
- Smoke from open fires at construction sites and outdoor recreation during the winter season, and from open burning of waste.
- Smoke from roadside wood-fired heating of bitumen in open pans, for road paving, including on city streets.

2.4.a.i Climate Change and Air Pollution

Climatic factors also influence air pollution in Bhutan. Emission of greenhouse gases, which contributes to global climate change, is also on the rise.

Seasonal climate:

Seasonal dryness, wind and cold are important seasonal factors influencing air quality in Bhutan. There are less than five days of rain per month during the dry winter season, November to March, allowing bare soil and road shoulders to remain dry and dusty most of the time. There is rain on more than half the days during monsoon season June-September, which keeps road shoulders and exposed soil well moistened.

Heating seasons:

The heating season, when wood is used for space heating, is also November to March in Thimphu. There is little need for space heating in the lowlands along the border with India. For example, the daily minimum temperature never falls below 10 C in Phuentsholing, so there are no heating-degree days. However, wood is still used for cooking throughout the year in some areas. In spite of extensive use of electrical heaters in Thimphu, use of wood stoves for heating remains a tradition in some homes.

Wind speed:

Average wind speed is low during the rainy summer monsoon season June-September, and increasing during the winter to the maximum at the end of the dry season in March-April. Wind direction is primarily from the south.

2.4.a.ii Key implications of Air pollution on Health:

Air pollution can have direct and sometimes severe consequences for health. Fine particles which penetrate deep into the respiratory tract subsequently increase mortality from respiratory infections. Short term symptoms resulting from exposure to air pollution include itchy eyes, nose and throat, wheezing, coughing, shortness of breath, chest pain, headaches, nausea, and upper respiratory infections (bronchitis and pneumonia). It also exacerbates asthma and emphysema. Long term effects include lung cancer, cardiovascular disease, chronic respiratory illness, and developing allergies. Air pollution is also associated with heart attacks and strokes. (11)

Air pollution in and around the home is largely a result of the burning of solid fuels (biomass or coal) for cooking. Women and children are at a greater risk for disease from household air pollution. Consequently, household air pollution is responsible for a larger proportion of the total number of deaths from ischaemic heart disease, stroke, lung cancer and COPD in women compared to men. In Bhutan, 39% percent of an estimated 110 child deaths due to acute lower respiratory infections is attributable to household air pollution. (14)

According to the latest SDG report available for Bhutan, Age-standardized death rate attributable to household air pollution and ambient air pollution is 124 per 100,000 population. The data was last recorded in 2016, till date it still remains a major challenge to Bhutan and no updated data is available. Annual mean concentration of particulate matter of less than 2.5 microns in diameter (PM2.5) is recorded to be 37.9 μg/m^3 in 2017, though on an improving trend it is important to still have it on the air quality radar. (15)

2.4.a.iii Air Pollution Mitigation and Management:

The air pollution from domestic sources can be controlled by enhancing appropriate existing air quality related standard to more stringent level and strengthening its enforcement. Policies and incentives on the import of vehicles need to be harmonized. Trans-boundary air pollution and its impact can be controlled by strengthening regional cooperation.

To monitor ambient air quality, automated monitoring stations have been established at Thimphu and Pasakha. An additional station is being constructed in Darla gewog, Chukha dzongkhag. All these stations will have capabilities to monitor other parameters in addition to particulate matter. In future, a station to monitor air quality in remote site will be established Chelela, between Haa and Paro. The NECS and competent authorities conduct periodic compliance monitoring of development activities in accordance with relevant provisions of Environment Assessment Act 2000 and NEPA 46 2007. (16)

2.4.b Water and Sanitation

Although Bhutan has one of the highest per capita water resource availability in the world with 94,500 m^3/capita/annum, its imbalance in geographical and temporal distributions is leading to experience of shortages in local areas. Adverse impact of climate change is further aggravating water problem. Rapid human population growth is amplifying the pressure on available water resources due to increase in agricultural farming, animal husbandry, industrial and domestic uses. This has led to complaints about the available quality and quantity of drinking water. Water quality is noticeably deteriorating in and around the urban areas. Middle class and low income urban residents are faced with limited supply of treated water, resulting in poor sanitation and reliance on alternative, untreated sources. There are localized pollution problems that need attention to avoid health problems and deteriorating recipient conditions. Chief among these are the unsanitary conditions found along the banks of streams and rivers both in urban areas and in rural locations. This problem is exacerbated at urban locations where surface drainage, oil and grease spills from workshops, grey water seepage from domestic households and uncontrolled seepage/overflow from septic tanks and piping flow directly into the rivers. [17]

Bhutan is mindful of the emerging threats and uncertainties of climate change coupled with increasing anthropogenic threats on water resources and watershed conservation even with the existing policy of sustainable management of natural resources.

2.4.b.i Climate Change and Water Pollution:

The predicted climate change is likely to induce the following changes in climatic and hydrological variables like precipitation, rainfall and snowmelt. Precipitation will increase and it will take the form of rainfall rather than snowfall. Rainfall will be more erratic and intense. Snowmelt will start earlier than usual. Winter seasons will be shorter. Wet season flood flows and transportation of sediment and debris will also increase. Dry season flows, in contrast, are expected to decrease. [19]

2.4.b.ii Key water quality challenges that are faced are:

Seasonal water quality changes at the source (high turbidity during rainy season). Presence of stock in the catchment upstream of the raw water off-take may compromise quality. Intermittent supply because of limited water treatment plant capacity compromises the quality of water supplied. There are many unaccounted water leakages and illegal connections. Inappropriate household water treatment, storage and handling practices further compromises the standard of drinking water and may lead to health disorders and diseases. [18]

2.4.b.iii Key implications of Water Pollution on Health:

Bhutan's Ministry of Health and the Bhutanese Public Health Engineering Division recognize that a lack of access to clean water and sanitation facilities is still a major cause of death and disease. Improving access to clean water and to high-quality sanitation services has become a priority.

As per the latest SDG country report for Bhutan, population using at least basic drinking water services is recorded to be 97.2% (2017) though on track for SDG achievements, the challenge is to maintain the current status on a long term. As per the SDG Health profile 2019 report for Bhutan mortality rate attributed to exposure to unsafe WASH services in 2016 is recorded to be 3.9 per 100, 000 population.

13% of childhood deaths in Bhutan are attributed to diarrhoea. The Centre for Disease Control and Prevention (CDC) estimates 88 percent of diarrhoea cases are caused by unclean water or improper sanitation facilities. Likewise, an estimated 30 percent of all health problems reported in rural areas of Bhutan stem at least partially from unsafe drinking water or improper sanitation methods. The prevalence is significantly higher among poor rural families. Various diseases such as diarrhoea, dysentery, typhoid and cholera, intestinal worms, skin infections, conjunctivitis, insect vector diseases, rodent-borne diseases and so on are all associated with poor sanitation.

The current poor sanitation and hygiene situation in Bhutan is placing a significant and preventable burden on the rural health care system accounting for an estimated 30% of the health cases reported annually. This in turn, contributes to one of the high concerns for the government in terms of infant mortality and stunting rates at 21.2% nationally. [20]

Rising temperatures in Bhutan and the subsequent melting of glaciers is also leading to a significant threat of flash flooding due to glacial lake outburst. In addition to deaths from drowning, flooding causes extensive indirect health effects, including impacts on food production, water provision, ecosystem disruption, infectious disease outbreak and vector distribution. Longer term effects of flooding may include post-traumatic stress and population displacement.

Some of the world's most virulent infections are also highly sensitive to climate: temperature, precipitation and humidity have a strong influence on the life-cycles of the vectors and the infectious agents they carry and influence the transmission of water and food-borne diseases. Socioeconomic development and health interventions are driving down burdens of several infectious diseases, and these projections assume that this will continue. However, climate conditions are projected to become significantly more favourable for transmission, slowing progress in reducing burdens, and increasing the population at risk if control measures are not maintained or strengthened. [14]

2.4.b.iv Water Management

With the emerging threats and uncertainties surrounding climate change, combined with increasing demand resulting from population growth and lifestyle changes, Bhutan is mindful of the importance of managing water resources for a secure future. The National Integrated Water Resource Management Plan, 2016, was prepared to ensure that the water resources are protected, conserved and/or managed in an economically efficient, socially equitable and environmentally sustainable manner. The Bhutan Water Security Index (BWSI) was also developed in 2015 with five key dimensions, each with set of indicators. The five key dimensions are

1. Rural drinking water supply, sanitation and hygiene.
2. Economic water supply for agriculture, industries and hydropower.
3. Urban water supply, sanitation and drainage.
4. Environmental water security.
5. Disaster and climate change resilience.

BWSI should be adopted as a Key Result Area of successive Five Year Plan. This will help in mainstreaming water into sectoral plans, programs and project. River Basin Committees (RBCs) should be established in all major river basins with the view to prepare River Basin Management Plan (RBMP). RBMP should ensure coordinated development and management of water resources in the country to improve water security.

2.4.c Noise Pollution

There are a number of environmental issues in Bhutan. Bhutan faces challenges in its urban environments due to increased urbanization, industrialization, and economic development. One of the negative side effects is noise pollution. With the advent of loudspeakers, headphones, and rumbling engines, noise pollution has been identified in Bhutanese media as an environmental concern, citing negative potentials ranging from distraction to deafness.

Construction works, industrial machinery, vehicular transportation are the major cause of noise in any urban setting. Due to rampant development, major urban cities like Thimphu, experience noise pollution. Construction sites stretch their work hours to meet the ever increasing demand. Late night construction work cause hindrances and distractions to the dwelling population in the vicinity thus compromising their sleep and lifestyle.

Though there are national standards and policies like Environment Act and Development Control Regulation (2016) in place for checking and prohibiting noise pollution in Bhutan, there is little information on the subject and its implication on human health.

2.4.d Soil /Land degradation in Bhutan

With almost the entire country characterized as mountainous, steep sloping land is the dominant terrain and the population is concentrated in the smaller pockets of valleys and gentler mountain sides. Because of its rugged topography and altitude, Bhutan has limited resources of productive land. Accessible, arable land with fertile soils is a precious resource for national food security, and rural communities' economic prosperity and well-being. Bhutan has 2.93% of agriculture land (Non-Irrigated Agricultural Land- 61.9%, Wetland/Irrigated Land- 27.86% and Horticulture Land - 10.24% - consists mainly of apple, citrus, areca nut and cardamom.)

In recent decades, various types of land degradation have increased. Urbanisation is identified as a direct factor leading to land degradation in Bhutan primarily due to direct utilization of agricultural land and increased requirements for construction materials such as sand and stones and timber along with requirements for waste dumpsites and impacts from pollution. From 1998 to 2015, a total of 306.55 Ha of wetland was lost for various purposes and mostly for urban development and other infrastructure development.

Direct factors causing degradation include overgrazing, unsustainable agricultural practices and poor irrigation system management, forest fires, excessive forest use, industrial activities, urbanization and infrastructure development (especially road construction), unsustainable mining, and poor management of solid waste, in-situ chemical degradation (which causes depletion of soil organic matter and nutrient mining) and in-situ physical degradation (topsoil capping and subsoil compaction)

Indirect factors are population growth and structure, poverty, climate change, and policy and institutional issues. Water-induced degradation - gullies, landslides, ravine formation and local flooding are most prominent and devastating in Bhutan. This worsens with changing rainfall patterns and drying up of water sources. It also causes loss of soil fertility and seepage of nutrients from waterlogged fields. This further affects soil productivity, crop growth and yield.

Improved agricultural productivity and food self-sufficiency have been achieved in Bhutan through modernizing agriculture, intensifying production and expanding commercial production. This was achieved due to Government support with irrigation systems, high-yielding crop varieties, livestock breeding and application of both traditional knowledge and modern techniques. Unsustainable farming practices are also continued in certain pockets of the country, like:

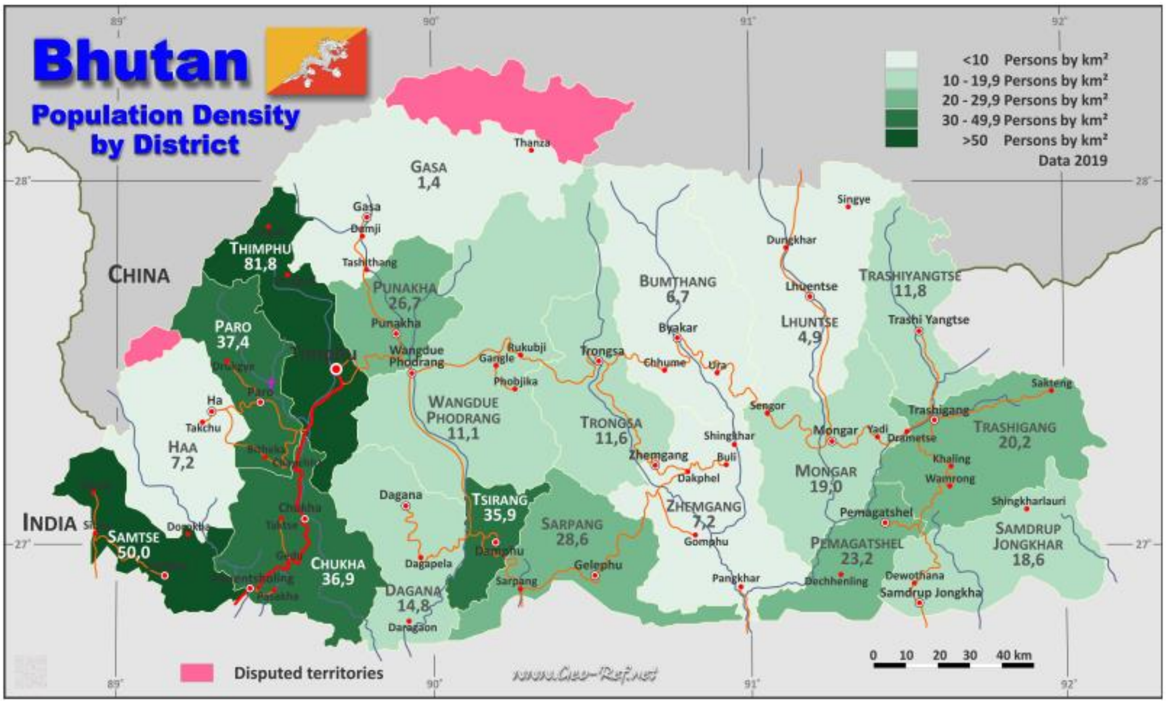
- Imbalanced and prolonged use of inorganic fertilizers.
- Over-application of chemical fertilizers and pesticides.
- Paddy farming on steep terrain without adequate soil and water conservation.

- Burning of crop residues.
- Failure to use cover crops.
- Shifting cultivation without a long enough fallow cycle for soil replenishment.

Other challenges include the absence of a comprehensive national soil map with information on crop suitability and potential, resulting in non-optimal utilization of land.

Responsible Authorities: National Environment Commission, Ministry of Agriculture and Forest (National Action Plan for Combating Land Degradation, National Biodiversity Strategies and Action Plans Land Use and Planning Project- LUPP, Bhutan Land Cover Assessment-BLCA), National Soil Services Centre. (16)

Population Density Map of Bhutan



Source: http://www.geo-ref.net/en/btn.htm

TABLES

Table 1: List of types of health facilities present in Bhutan in 2019 (6)

Sl. No	Category of health facilities	Numbers
1.	Hospitals	49
2.	Primary Health Centre	186
3.	Sub post	53
4.	Outreach Clinic (ORC)	542
5.	Thromde Health Centre	3

6.	Health Information and Service Centre (HISC)	6

Table 2: List of medical personnel available in Bhutan. [6]

Sl. No	Category of health workforce	Numbers
1	Medical Doctor	376
2	Medical Technologist and Technician	1187
3	Health Assistant	620
4	Nurse	1364
5	Drungtsho	54
6	Menpa/Therapy Aide	116
7	Administration & Support	2184
	Total	5901

Table 3: Trend in Non communicable Diseases over the years (as per the HMIS data)

Indicators (per 10,000 population)	2005	2017	2018	2019
Alcohol Liver Diseases Incidence	19.2	35.0	37.5	38.0
Cancer Incidence	8.7	17.0	23.0	26.8
Diabetes Incidence	14.9	82.0	78.0	75.0
Depression Incidence	NA	6.0	9.6	10.4
Hypertension Incidence	261	278	343	307

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3. Health Sensitization in India

3. Health Sensitization in India

SUMMARY

India is the second-largest population in the world and biggest democratic country in the world. India is home to over 1.3 billion people. The 2019 population density in India is 460 people per km2, calculated on a total land area of 2,973,190 km2 .India population is equivalent to 17.7% of total World population. There are 28 states and 8 Union Territories.

At an average of two children born per woman in 2018, the country's birth rate stood at 18.6 for every thousand inhabitants. The average life expectancy has seen a consistent increase since the 1920s and was around 66.9 years for males and 70.3 years for female in 2017. However, this was still lower than the global average of around 72 years. Infant mortality has also been on a steady decline over the years due to increased attention to providing special new-born care units, routine immunization and access to basic mother and child care facilities. Under five mortality rate was 50/1000 live births in 2019, neonatal mortality was 29.5/1000 live births (2015-16), Maternal mortality was 122/ 100000 live births in 2019.

Moreover, female literacy rate was 68.8 and male literacy rate was 84.4 in 2015-16 and Sex ratio being 943 females per 1000 males. The public expenditure on health as a percentage of GDP for SEAR countries is 0.93% and per capita public expenditure is U.S.$ 15.9 as on 2016.

Environmental pollution is one of the most serious global challenges, be it air pollution, water pollution, soil pollution or sound pollution. From past few decades, air pollution is one of the most dangerous problem which everyone are facing. Increased global warming, depletion of glaciers and ozone are few crises which have direct connection with air pollution. 12.5% of all the deaths in India are due to air pollution. It has impact on psychosocial life and has critical economic and social implications.

Water, that is easily accessible, adequate in quantity, free from contamination, safe and readily available throughout the year is required for all living beings for safe and wholesome life. Water is not only a vital environmental factor to all forms of life, but it has also a great role in socio-economic development of human population. Polluted water is the main cause of several diseases. Polluted water not only affects the life of present generation, but it also affects the life of upcoming generations because its effect remains for long. In recent years, water pollution has become a serious problem across the country mostly due to the presence of untreated effluents, chemicals, and pesticides in it. Some of the water borne diseases are typhoid, cholera, paratyphoid, fever, dysentery, jaundice, amoebiasis and malaria. Chemicals in the water also have negative effects on our health. Pesticides can damage the nervous system and cause cancer because of the carbonates and organophosphates that they contain.

Soil pollution is caused by industrial activity, agricultural chemicals or improper disposal of waste, solid waste is a major contributor and also high rate of outdoor defecation in India has caused major problem. Covid-19 pandemic has made it even more difficult, as single usage and disposable of items are dumped and further contaminated. Long term exposure can cause serious trouble to the environment and humans, causing congenital illness and chronic health problems, that cannot be cured easily.

Noise is unwanted sound that affects the health and wellbeing of human or any other organism, be it land or in water. Community noise and industrial noise, both are underestimated threat as it is an invisible danger. As all the construction work and factory work, traffic came to a standstill, the noise levels had dropped significantly during the covid-19 pandemic lockdown. Mitigation measures have to be taken by all stake holders to control and manage the environmental pollution to save environment and people to lead a healthy and quality life. To protect the planet from degradation, sustainable consumption and production, sustainably managing its natural resources and taking urgent action on climate change should be done, so that it can support the needs of the present and future generations.

3.1 INTRODUCTION

India is one of the oldest civilization with over 1.3 billion people and most populous Sovereign, Secular, Democratic republic with parliamentary system of government.

It covers an area of 32,87,263 Sq Km, extending from the snow covered Himalayan heights in the north to tropical rain forests of the South with Bay of Bengal on the East and Arabian Sea on the West. It shares the boundaries with Afghanistan and Pakistan to the North-West, China, Nepal, Bhutan to the North, Myanmar to the East and Bangladesh to the East of West Bengal. Sri Lanka is separated from India by Palk Strait and the Gulf of Myanmar a narrow channel of sea.

The Indian climate is very much influenced by the Himalayas and the Thar Desert, both drive the economically and culturally pivotal summer and monsoon rains. Four major climate groups predominate in India: Tropical Wet, Tropical Dry, Subtropical Humid and Mountain Climate [1].

3.2 HEALTH ISSUES

Since 2005 Central Bureau of Health Intelligence (CBI) bring together all health related information in a single platform by publishing annual National Health Profile covering

1) Demography **2)** Socio-economic health system **3)** Health finance **4)** Human resources in health sector and **5)** Health infrastructure. These information's are very essential for health system policy development, health education, training, service delivery, governance, health research and financing.

India has made a notable achievements since Independence in 1947. Life expectancy at birth has increased, diseases like small pox, guinea warm, polio have been eradicated, leprosy is at the verge of elimination, infant mortality, crude death rate have been markedly reduced. Overall literacy rate is increased.

As per Indian Council of Medical Research (ICMR) the burdens of communicable diseases dropped 61% to 33% and non communicable disease increased from 30% to 55% between 1990 to 2016 [2].

3.3 HEALTH DEMOGRAPHIC INDICATORS [1]

India's population as per census 2011 is 12108.5 lakhs, 28.5% of them are under 14 years of age, 8% are above 60 years of age, the estimated birth rate is declined from 25.8 to 20.4 between

2000 to 2016, 8.5 to 6.4 per 1000 population during the same period. The natural growth declined 17.3 to 14 between 2000 to 2016 per 1000.

The literacy rate increased to 8.2% during 2001/2011. The overall literacy rate is 73%; males 80.9%; females 64.6%; rural literacy rate 67.8%; while uban 84.1%.

The maternal mortality is reduced by 77% from 556/100000 to 130/100000 live births between 1990-2016, 89% of urban birth and 75% of rural births are supervised

India has achieved a significant progress in immunisation in preventing 6 vaccine diseases. We are committed and declared along with other South East Asian countries to control and elimination of Measles, Rabella by 2020.

Our health care is dependent on public and private health sectors. The public health sector predominantly does the primary health care more so in rural areas and less secondary and tertiary care. The private sectors provides majority of secondary and tertiary and quaternary care institutions predominantly on metro cities. It is the small nursing home owned by individual doctor is the back bone of our health care in shouldering the responsibility with the government health care system.

There is an inequity in access to health care as the cost of treatment is rising. We spend only 1.28% of GDP (2017-2018) for health care. The per capita public expenditure on health was ₹621 in 2009-10 now it is 1657 in 2017-18. The centre and the state share the total public expenditure on health in the ratio of 37:63 in 2017-2018.

The health insurance is a growing segment, yet it has to take on fully. The National Health Protection Mission of 2018-19 a largest health scheme which aims to provide a cover of ₹ 5 lakh per family per year for secondary and tertiary care procedures.

Universal health care delivery system both physical and mental is a well articulated goal both global institution and national governments to achieve sustainable development goal by 2030 for all the citizens by tackling environmental pollution of Air, Water, Soil (Food) and Sound Pollution.

3.4 ENVIRONMENT, CLIMATE CHANGE AND HEALTH

The environmental risks to health is the physical, chemical, biological and work-related factors external to a person, and all related behaviour but excluding those natural environments that cannot reasonably modified.

Environmental pollution causes 9 million deaths prematurely in 1915 amounting 16% of all deaths globally-15 times more than from all wars and other forms of violence. Nearly 92% of deaths occur in low and middle income countries, 70% of all diseases are non communicable diseases. The welfare losses due to pollution are estimated to be U.S $ 4.6 trillion /year; 6.2% of global economic output.[1,3]

Pollution endangers planetary health, destroys ecosystem and is intimately linked to global climate change. Coal is the world's most polluting fossil fuel causing pollution and climate change 85% of airborne particulates pollution and for almost all pollution by oxides of sulphur and nitrogen.

3.4.a Air Pollution

Historically in the 13th and 17th century the environment crisis were due to air pollution from growth of urban population, increase in density of population and change in the use of fuel from wood to coal. In the year 1773 Dr. John Arbuthnot presented a paper where he pointed out the poor city's air quality affects the lungs; higher death rate in urban infants and pointed out to Sulphurous streams from fuel[4]

Air pollution has no borders they disperse across countries, continents and oceans and is a major environmental risk to health, it is a silent killer, 3.7 million people die from outdoor air pollution and 4.3 million by indoor air pollution and has an impact from "Womb to Tomb". Air pollution, global warming and climate change are all inter-related caused by anthropogenic activity. Currently our concern is, suspended particulate matter SPM 2.5µ, tobacco smoke and ozone at troposphere. The SPM 2.5µ is the best studied air pollutant causing -51% deaths from COPD; 43% from lung cancer; 26% from ischemic heart disease; 23% from stroke and linked to a wide range of diseases' of almost all vital organs.[5]

The Air quality Index (AQI) is determined by 7 pollutants **1)** SPM 10 and 2.5µ **2)** Sulphur dioxide (SO_2) **3)** Nitrogen dioxide (NO_2) **4)** Carbon monoxide (CO) **5)** Ozone (O_3) **6)** Ammonia (NH_3) **7)** Lead (Pb). It is used for the general public to know the air quality in a simplified way; a politician to invoke quick response, a decision maker to chalk out corrective pollution control strategies, the government official to study the impact of regulatory actions and the scientists who engages in scientific study can use the air quality data[6]

It is the SPM 2.5µ is the fine particle and has the 3% of the size of the hair and is a mixture of solid and liquid. The PM 10 can travel 10 yards to 30 miles. PM 2.5 can travel many hundred miles. It has components of Sulphates, Nitrates, Ammonia, Sodium Chloride, Black Carbon, Mineral dust and Water. PM2.5 can traverse all over the body producing inflammation by oxidative stress on various organs but the major impact is on lungs

The source of outdoor pollution is from automobile exhaust, power plant emission, open burning of solid waste, construction related dust, mining activities, pollens and fungi. The source of indoor pollution is from aerobiological like from dust mites, cockroaches, pollens, fungi, viruses and from irritants like tobacco smoke, smoke from mosquito coils, non commercial cooking fuel, formaldehyde and non volatile organic compounds [7,8]

There are enough epidemiological evidence to prove outdoor and indoor air pollution: Children of heavy traffic school suffer more asthma; urban children suffer more than rural children's, traffic police personnel suffer more from air pollution bursting of fire crackers during Diwali festival produces more wheeze these data are shown in figures 1 to 4 at the end. The indoor air pollution observation data from cooking fuel, tobacco smoke, single room dwelling figures as shown in figures 5 to 7.

3.4.a.i The Impact of Air Pollution On Various Systems:

Respiratory System:

- Decrease lung growth in fetus, Fixed airway obstruction; Still births, Prematurity, Small for date babies, Infections, Allergic Rhinitis and its co morbidities like middle ear infections, sinusitis, conjunctivitis, snoring and sleep apnoea syndrome. Asthma, Chronic cough, COPD, Lung Cancer, Interstitial fibrosis

Cardiac:

- Hypertension, Ischemic heart attack, Heart failure

Vascular:

- Stroke

Endocrine:

- Diabetes (Insulin dependent) Metabolic Syndrome, Obesity

Brain:

- Cognition, Depression, Alzheimer's, Anosmia, Memory loss, Autism

Behaviour Problem:

- Increase crime rate, Impaired Judgement, Worst test score on polluted days, Reduced productivity

Blood:

- Increase Coagulation (Coagulopathy)

Spinal Health:

- Air pollution produces obstructive airway diseases like Asthma and COPD. The air trapping changes the spinal curve, shoulder, neck pain, leaving forward , balancing problems, these people have higher morbidity and mortality during late adult hood.

3.4.b The Impact Water Pollution

Olaniran in 1995 defined water pollution to be presence of excessive amounts of pollutants in water which is not suitable for drinking, bathing, cooking and other uses [9]. There is only one percent of the water is non saline surface water, in that 61% is in lakes, 39% in atmospheric soil moisture and only 4/10% is in rivers as shown in figure 8. Availability of water per capita varies from different countries.

The water related health issues are from water borne diseases, water washed disease, water based diseases and water related vector borne diseases. These are from biological and chemical. According to W.H.O guidelines the potable water should have less than 10 coliform organisms per 100 ml [5].

1.3 m deaths are due to poor unsafe water and 0.8m from unsafe sanitation [4]

Biological:

- Parasites, Fungi, Bacterial, Viruses

Chemicals:

- Arsenic, Fluoride, Lead, Copper, Cadmium, Nitrate, Chromium, Zinc, Mercury, Radium

3.4.b.i Water-Related Infections Primary Public Concern

Waterborne diseases

Cholera. Poliomyelitis. Diarrheal diseases. Roundworm. Enteric fevers: typhoid. Whipworm. Hepatitis A. Cryptosporidium. Giardia

Water-washed diseases

Scabies. Typhus. Trachoma. Louse infestation

Water-based diseases

Schistosomiasis. Dracunculiasis (guinea-worm). Leptospirosis

Diseases transmitted by water-related insect vectors

Malaria. Onchocerciasis. Yellow fever. Dengue. Filariasis. African trypanosomiasis. Leishmaniasis. Chikungunya

3.4.b.ii Chemical Contaminants in Ground Water :

Source

Chemical Contaminants in Ground Water		
Chemicals	**Source**	**Health Effects**
Inorganic Arsenic	Ores, smelting, pesticides	Lung, Kidney, Skin, Cancer, CVS, Neuro development
Lead	Pipes, Solder, Soil	G.I, Neurological, CVS
Mercury	Waste incineration, use of mercury, volcanoes, burning coal	Renal damage Neurologic
Chromium	Ores, steel and pulp mills	Cancer (chromium VI)
Nitrates	Fertilizer, septic tank, sewage, erosion of natural deposits	Blue baby syndrome (meth hemoglobineuie from nitrites
Fluoride	Water with high fluoride, content black rock salt, fluorinated mouth rinse and fluoride tooth paste	Dental, skeletal, Non skeletal fluoridise
Radionuclides Radon	Natural uranium, Thorium	Lung, stomach cancer, Leukemia

CVS = Cardiovascular System, GI = Gastrointestinal

3.4.c The Impact of Soil and Food

The soil contamination or soil pollution is a part of land degradation and the main anthropogenic sources of soil pollution are the chemicals used in or produced as by-products of industrial activities, domestic, live stocks and municipal waste, agrochemicals. The radionuclide deposition can also from atmospheric weapons testing and nuclear accidents. Pollutants also harm soil microorganism and larger soil dwelling organisms changing soil biodiversity. The ill health is from the chemical containments as mentioned in water pollutants and they can also reach humans through the food chain. Soil pollution can reduce food security by reducing the crop yield and decrease protein content and causing crops produced are not useful for consumption by humans and animals.

Food pollution represents a serious issue globally from use of pesticides and agrochemicals. Studies shown children are particularly at risk from food borne pollution from chemicals, additionally the presence of antimicrobial resistance amongst food borne pathogens. Even though it is a significant challenge we need to work more on to identify the magnitude and implication on human morbidity and mortality.

Man-made organic pollutants are most dangerous and hazardous compounds such as pesticides, industrial chemicals and having long half-life persist in the environment for decades, bio accumulate and penetrate food chain. The persistent organic pollutants (POP) are lipophilic deposit in the fatty tissue and are not well metabolised or excreted. The main source of POPs in the environment are Industry, Waste, Traffic, Agriculture transmit in the air, water, land deposition [3].

The polychlorinated Biphenyl (PCBs) mainly enter our body by food chain like Marine mammals; Whales, Seals; Fish; Salmon, Eel, Shellfish, Fish liver, Fish oil. Animal fat: Meat, Poultry; Cow's milk: Butter, dairy products and other source like: Fruits, Vegetables, Cereals.

The comprehensive assessment of soil, heavy metals, chemicals are not available except lead and fluoride. The current estimates are limited to DALYs and does not include mortality . 82% deaths from lead poisoning occurs in countries with lower socio economic status.

3.4.c.i Health impact of POPs.

Effects with long level exposure : Skin rashes. Swelling of eyelids

Hyper pigmentation – CHLORACNE

Headache. Vomiting

Effects from long term exposure : Toxic effects on Liver. Skin. Reproduction. Immunity

Fetal exposure PCBs : Neutral and Developmental changes

Memory loss. Learning effects

Decrease intelligence. Lower psychomotor score

The occupational exposure to toxic pollutants has become highly prevalent in the past 5 decades especially in low income countries. The exposure tends to occur in locally owned small scaled establishments. The global burden of disease from occupational pollutants in the year 2015 is estimated 0.88 m deaths and 18.6% DALYs[3]

3.4.d The Impact of Noise Pollution [10]

Anthropogenic sound pollution causes serious health issues in humans, animals, birds. Noise has cumulative effect and over 800m people are deaf from noise pollution globally which is the most common preventable disease.

The normal recommended level of sound in silent zone is 50 decibels; residential area 55 decibels; commercial area 65 decibels during day time and at night time it is 10 decibels lesser.

Most of our cities experience noise pollution. One has to be aware of the ill effects of noise pollution and convince the leaders both political and religious.

3.4.d.i The ill effects of noise pollution are:

- Premature births . High frequency deafness in the new borne. intrauterine growth failure. sleep disturbance. Annoyance. Headache. Decrease work efficiency . Poor school performance. Increase blood pressure. Birds and animals move away from noise polluted area.

3.5 COVID-19 PANDEMIC AND ENVIRONMENTAL HEALTH

Covid-19 pandemic has brought unparallel global health issue with morbidity and mortality along with tremendous psycho-socio-economic burden. It has brought the powerful nations on their knees, many industries, education institutions, construction work has stopped. Lots of labour migration, social disturbances and stress on agriculture.

With all these negative impact some positive impact on environmental health is observed like:-

- Improved air quality index, decreased green house gases and increased visibility where one can sees blue skies
- Decreased water pollution and waste generation, Decreased noise pollution where birds, animals visiting the cities; Enhanced human kindness and traditional values; Change in the health economic policies; focussing on prevention.

Mother Earth enjoyed cleaning the existing pollution and started smiling. This “Natures randomised multinational observational study with millions are involved in study group” can never be forgotten. We all the stake holders should move forward to clean our mess for sustainable attainment of good health in 21st century **[11]**

3.6 KNOWLEDGE INTO ACTION [12]

The health professionals, the doctors are the service oriented health care teachers, supervisors and investigators. They are the strongest link to mitigate air, water, soil, sound pollution with the important stake holders like scientists, researchers, technocrats, policy makers, society and people of service and social clubs.

With scientific data we could able to achieve:

- Bringing legislation in banning leaded petrol in - 1999
- Bringing face masks to traffic police personnel in - 1999 and it was changed to better ones in - 2015
- Bhuralal committee declaration to clean up megacities in India and look for school environment in - 2004
- Banning tobacco smoke in public places in Karnataka state - 2001 and in India - 2003
- Restricting the use if fire crackers - 2017-2018
- Reducing the burden heavy school bag - 2018.

3.7 THE W.H.O RECOMMENDED STRATEGY FOR SUSTAINABLE HEALTH IN 2030 [13]

1. Make the peoples voice heard by the policy makers for better health and well being
2. Focus of primary prevention in environmental, occupational health services as an integral part of universal health coverage
3. Focus on air quality targets by involving relevant sectors, polluting fuels and inefficient technologies
4. Focus on climate change by meeting the Paris agreement with cleaner energy system, efficient public transport system. More sustainable diets and more resilient food system
5. Water and sanitation safety planning and combat antimicrobial resistance in place
6. Focus on chemical safety and their impact on health and prepare for any emergencies.
7. Radiation safety-by avoiding unnecessary measures for nuclear incidents
8. Focus on health care settings with waste management with clean air, water, sanitation and energy and protect the health safety and security of the health forces
9. Focus on occupational health and safety promotion of work places
10. Effectively deal with global and regional drivers of health with international agreements and policies which are in place
11. All countries should have the capacity to manage health services effectively throughout the emergencies
12. Ensure the national and local government fulfil their obligation to provide the safe environment for their citizens by cross sectoral cooperation and by integrating health in all relevant policies.

We end by quoting “The Earth, The Air, The Land and The Water are not an inheritance from our forefathers but borrowed from our children. So we have to hand over to them at least as it was handed over to us........... **Mahatma Gandhi**

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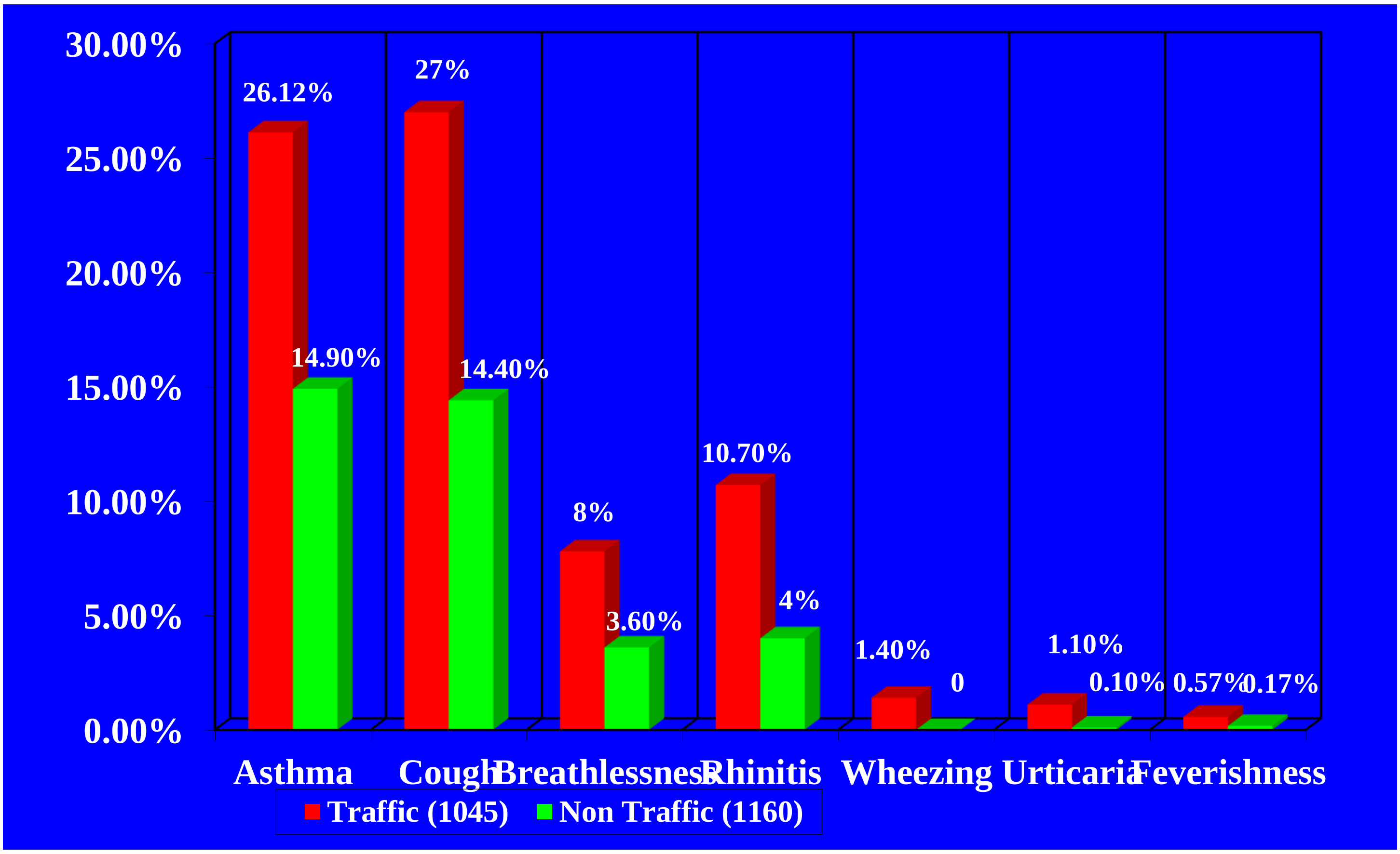
GRAPHS AND TABLES

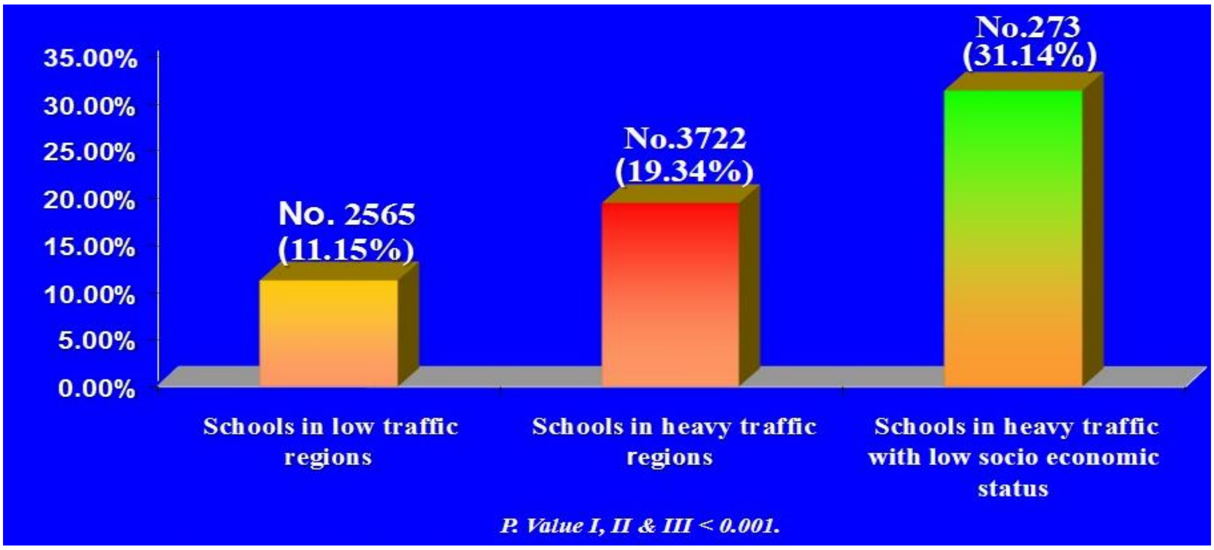
Out Door Air Pollution

Graph – 1



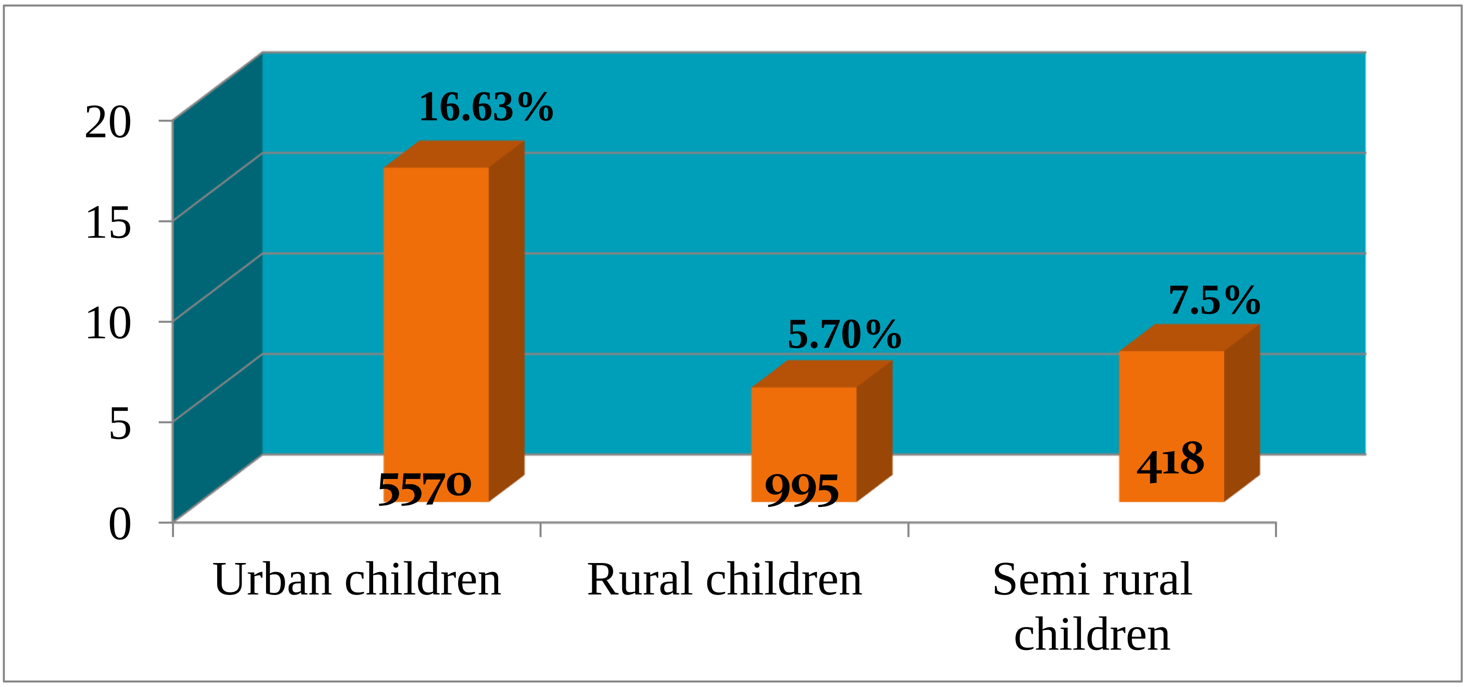
Traffic police suffer more than non-traffic police

Graph - 2



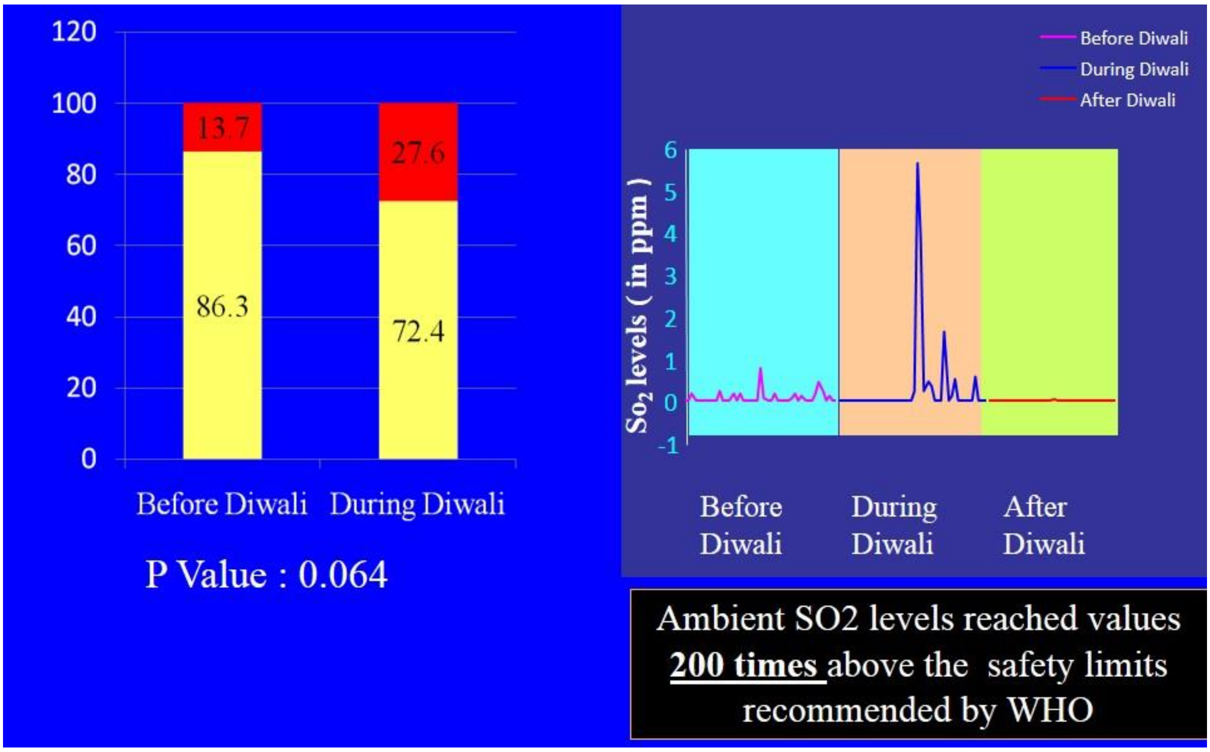
Children of heavy traffic school areas suffer more from asthma it further increases in low socioeconomic children

Graph - 3



Urban children suffer more from asthma than rural children

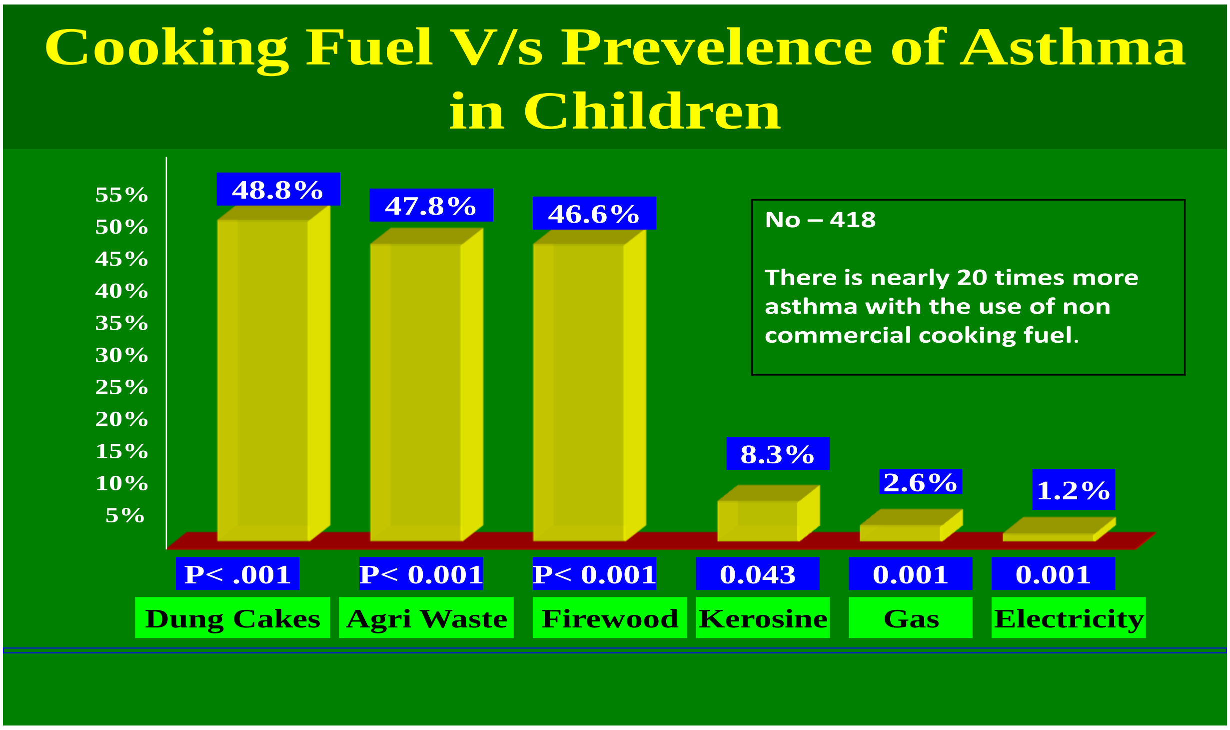
Graph – 4



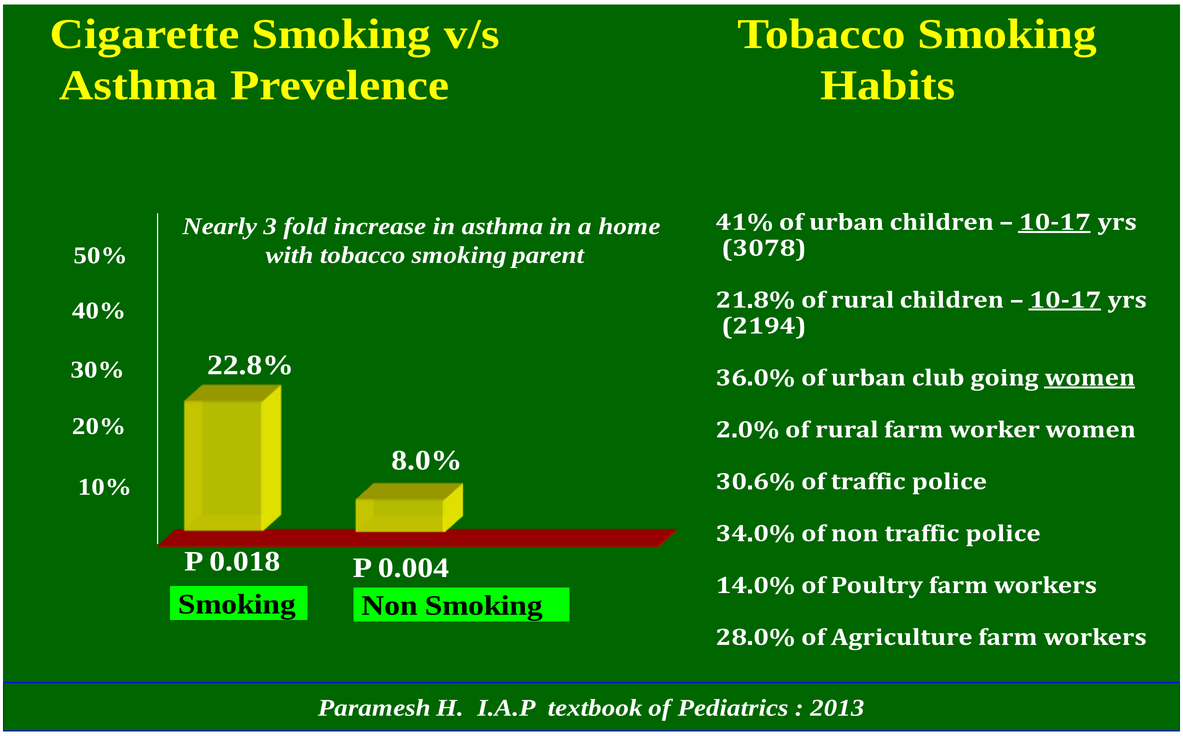
Asthma visits to ER increased by 100% during Diwali festival with bursting of the fire crackers

Indoor Air Pollution

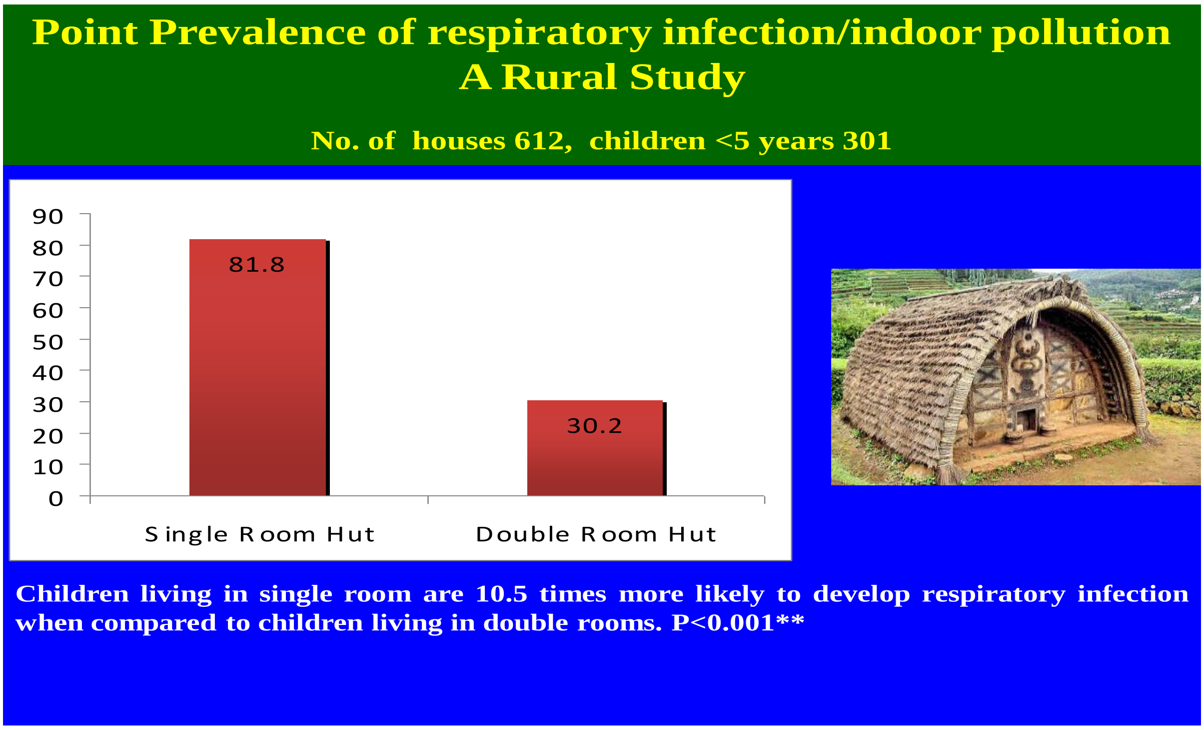
Graph – 5



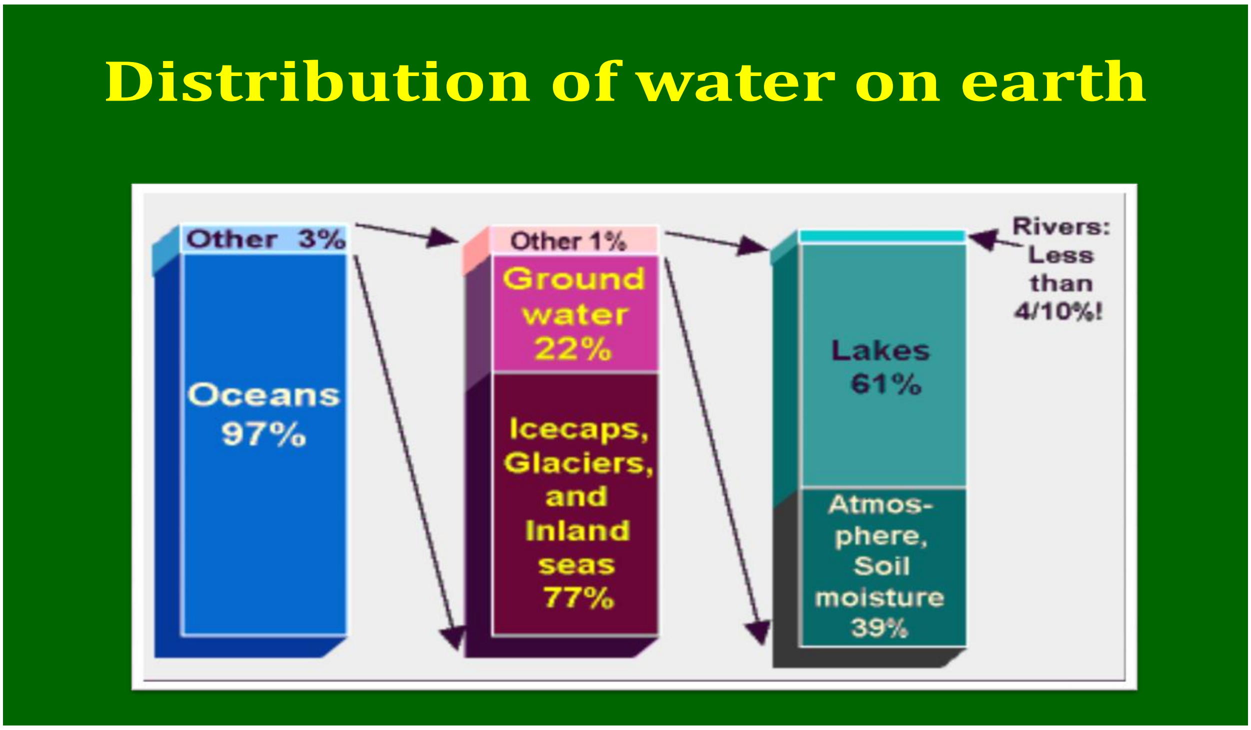
Graph – 6



Graph - 7



Graph – 8



Graphs From National Health Profile 2019

Central Bureau Of Health Intelligence

4. Health Sensitization in Maldives

4. Health Sensitization in Maldives

SUMMARY

The Maldives consists of 1,192 coral islands. There are only 185 inhabitable islands in Maldives. Comprising a territory spanning roughly 298 square kms, the Maldives is one of the world's most geographically dispersed sovereign states as well as the smallest Asian country by land area and population. Male is the capital and the most populated city. 34.5% of the population is urban (186,634 people in 2020). Maldives has a total literacy rate of 97.73%. In Maldives the proportion of employed population below $1.90 purchasing power parity (PPP) a day is 1.7% and total unemployment rate is at 6.1%.

The health status of the people of Maldives has significantly improved in the past few decades. Life expectancy at birth is 79.9 years. Maldives has seen the elimination of many of the communicable disease such as Polio, Malaria, Filaria and Measles while on the other hand, chronic non-communicable diseases are on the rise. Infant mortality is at 6.5 per 1000 live births. Death under 5 years of age is at 7.6 per 1000 live births. Neonatal mortality is at 4.9 per 1000 live births. Maternal mortality (2017) is at 104 per 100,000 live births. The antenatal care coverage has sustained at 99% since 2009. The public sector conforms to the largest share of the health system in Maldives.

Current sex ratio in Maldives is 1.05 males per female. Total Fertility Rate (TFR) is recorded to be 1.9 live births per woman. The total health expenditure in 2019 was 10.6% of GDP. The out of pocket expenditure, as a part of health expenditure was 19.1% (2016). Spending on health is high in Maldives when compared to other countries in similar developmental situations. The public expenditure on health as a percentage of GDP is 7.70% and per capita public expenditure is U.S $ 760.3 as on 2016 highest in South East Asian countries.

Dengue, diarrheal diseases, and Acute Respiratory Infections (ARI) continue to cause significant morbidity among children and adults. Cardiovascular diseases, chronic respiratory diseases, accidents and injuries and cancers are the leading causes of death in the country

Rapid urbanization and increased economic growth in the recent years have raised environmental pollution as a growing concern, particularly in the Male region. The air quality in the Maldives is considered safe - the most recent data indicates the country's annual mean concentration of PM2.5 is 8 $\mu g/m^3$, which falls below the recommended maximum of 10 $\mu g/m^3$. Available data indicates that Male, experiences high levels of air pollution.

The conventional freshwater resources available in Maldives mainly are in the form of rain fed shallow groundwater lens, small fresh or brackish water ponds in few islands and rainwater. Death rate due to unsafe water sources in 2017 was 0.99 per 100,000 population.

Despite the poor and infertile soils, Maldives support extremely rich coastal vegetation. Vegetation and other ecological features vary between islands from north to south in the country. Agro-chemicals have the potential to pollute the environment. Excessive use of fertilizers increases the nutrient levels of nitrogen and phosphorous in the water, causing eutrophication and affecting marine life, cause degradation of soil and pollute groundwater. Waste is poorly managed in Maldives.

Due to rapid development, urbanisation, Male, the most populated city is experiencing huge traffic issues. Noise as an environmental issue that needs addressing is totally neglected. As Male grows in population and high rises stud the landscape of Male, better zoning and timings for allowing noisy work can help to curb some of the rising concerns of the urban population.

4.1 COUNTRY PROFILE

The Republic of Maldives is a small island nation in South Asia, situated in the Arabian Sea of the Indian Ocean. It lies southwest of Sri Lanka and India, about 700 kms from the Asian continent's mainland. The Maldives consists of 1,192 coral islands grouped in a double chain of 26 atolls, stretching from Ihavandhippolhu Atoll in the north to Addu Atoll in the south to the equator. There are only 185 inhabitable islands in Maldives. Comprising a territory spanning roughly 298 square kms, the Maldives is one of the world's most geographically dispersed sovereign states as well as the smallest Asian country by land area and population. Male is the capital and the most populated city.

The Maldives archipelago is located on the Chagos-Laccadive Ridge, a vast submarine mountain range in the Indian Ocean; this also forms a terrestrial ecoregion, together with the Chagos Archipelago and Lakshadweep. With an average ground-level elevation of 1.5 metres above sea level, it is the world's lowest-lying country, with even its highest natural point being one of the lowest in the world, at 5.1 metres. As a result, the Maldives are at high risk of being submerged due to rising sea levels. The UN's environmental panel has warned that, at current rates, sea-level rise would be high enough to make the Maldives uninhabitable by 2100. [(1)]

The current population of Maldives is 542,360 as of September 2020, which is equivalent to 0.01% of the total world population. The population density in Maldives is 1802 per Km^2. 34.5% of the population is urban (186,634 people in 2020). [(2)] According to the latest UNESCO data, Maldives has a total literacy rate of 97.73%. According to ADB, Basic Statistics 2020, in Maldives the proportion of employed population below $1.90 purchasing power parity (PPP) a day is 1.7% and total unemployment rate is at 6.1%.

4.2 HEALTHCARE SYSTEM IN MALDIVES

The Maldives has a universal health insurance scheme. The country’s health system is custom designed based on the size of the population and geographical location, offering targeted levels of service. The public sector conforms to the largest share of the health system in Maldives. The public sector is supported by private health care providers, mainly providing curative and diagnostic services, and medicines and medical products located within the country. Another key sector that forms part of the health system is the voluntary non-governmental parties working on specific health issues. While the public system extends to all inhabited islands, private and voluntary services are concentrated in Male. The health system is also supported by external foreign development partners.

Every inhabited island has a primary health facility, while comprehensive secondary level health services are made available within every atoll and tertiary level health services available at the capital of the country. This structure, coupled with public health programmes, has further facilitated the progress that Maldives has made in the health sector. Maldives has two hospitals on the main island of Male and six regional hospitals. There are 13 atoll hospitals, 87 health centres, 51 family health sections and 37 health posts. The Ministry of Health and Gender is the primary government ministry in charge of the sector, and responsible for meeting the challenge of providing equitable services to a population scattered over many islands.

Geographical limitations, lack of economies of scale, heavy reliance on an expatriate health workforce and dependence on imports of all medical consumables, pharmaceuticals and other medical products has a profound effect on health expenditure, accessibility and availability of quality health services within the country. The unique nature of Maldives also makes it extremely susceptible to unprecedented climate change events that will unduly affect the already vulnerable and marginalised (often women and children) and thereby intensify existing inequalities. (3)(4)

Spending on health is high in Maldives when compared to other countries in similar developmental situations. The total health expenditure in 2019(Health SDG profile) was 10.6% of GDP. The out of pocket expenditure, as a part of health expenditure was 19.1% (2016). Universal Health Coverage was at 68%. (5)

4.2.a Healthcare Accessibility

Despite geographical dispersion being a challenge, basic health services are available in all inhabited islands. The delivery of services at primary health centres are challenged due to high turnover of staff, limited specialties, supplies, equipment, and management. High operational cost makes regular monitoring, evaluation and repeated training of health staff difficult. Means of transport by sea are affected by changing weather patterns, putting patients at risk when in need of transfers to regional or tertiary care facilities. Lack of a robust public transportation system contributes to the issue. According to statistics published by MOH in 2018, number of land ambulances increased from 148 in 2014 to 216 in 2018; while 31 islands were without land ambulances in 2013, this number reduced to four in 2018. Furthermore, a sea ambulance service was introduced in 2015, with 26 sea ambulances in operation in 2018. However, owing to the fact that tertiary care is only available within the Greater Male' region, health service accessibility is costly, especially for those living in the outer lying islands. (6)

4.2.b Human Resources in Health

Recruitment and retention of adequately trained health professionals remains a key issue hindering service delivery in all its forms, especially when it comes to the quality of care afforded to patients. Statistics published by MOH in 2018 indicates that there are 26 doctors per 10,000 people in the Maldives, and that by March 2018; there were 935 doctors and 2,859 nurses working in the country. As per the WHO reports, 82% of physicians and 55% of nurses in the Maldives are expatriates, which translates to a heavy dependency on expatriates to fill the gap in service delivery, especially in outlying islands, and resulting in a high turnover which negatively affects consistency and quality of care. (6)

4.3 Health in Maldives

The health status of the people of Maldives has significantly improved in the past few decades. Life expectancy at birth is 79.9 years (78.5 years for males and 81.6 years for females). The median age in Maldives is 29.9 years. (2) As per the 2019 ICPD report 5% of the population are currently above 65 years of age. (7)

Maldives has seen the elimination of many of the communicable disease such as Polio, Malaria, Filaria and Measles (Ministry of Health, 2018) while on the other hand, chronic non-communicable diseases are on the rise.

4.3.a Reproductive, Maternal, New Born and Child Health

Current sex ratio in Maldives is 1.05 males per female. Total Fertility Rate (TFR) is recorded to be 1.9 live births per woman. Infant mortality is at 6.5 per 1000 live births. Death under 5 years of age is at 7.6 per 1000 live births. Neonatal mortality is at 4.9 per 1000 live births. (8) Maternal mortality (2017) is at 104 per 100,000 live births. (7)

The coverage of antenatal care (ANC) reached 99% in 2009 (MDHS, 2009) with the majority of women having their first ANC visit in the first trimester of pregnancy. And this remained the same in 2016/17. Pregnant women are advised to attend at least 9 times ANC. MDHS 2016/17 also showed that 80% of the women and 82% of the newborn received a postnatal check within the first 2 days of birth.(7) As per the 2019, SDG Health profile, Child immunization coverage is at 99%.

4.3.b Morbidity and Mortality

With the fast changing lifestyle and development, chronic non-communicable diseases are emerging as the main cause of morbidity and mortality in the country.

Dengue, diarrheal diseases, and Acute Respiratory Infections (ARI) continue to cause significant morbidity among children and adults. In 2012, ARI, viral fever, and diarrheal diseases had the highest incidence, amounting to 4,748; 2,130 and 694 per 100,000 populations respectively (Ministry of Health and Family, 2012). Diseases such as scrub typhus and toxoplasmosis also continue to be endemic. Although significant improvements in drinking water and toilet facilities have been achieved, further improvements are still required regarding access to safe drinking water, improving sanitation, and waste management. (7) Below in Table 1 is the reported cases of morbidity in Maldives between 2014 and 2017.

Cardiovascular diseases, chronic respiratory diseases, accidents and injuries and cancers are the leading causes of death in the country. In terms of the number of lives lost due to ill-health, disability, and early death (DALYs), NCDs (inclusive of injuries) account for 78% of the total disease burden (World Health Organization, 2014; 2015). As highlighted in the NCD policy brief, only 22% of the DALYs come from communicable diseases, maternal and child health, and nutrition issues all combined (World Bank, 2011). (4)

Comparative survival probabilities of men and women in Maldives exemplify that they are not favourable to men. They suggest that men are increasingly exposed to high risk mortality factors. Additional effort has to be taken to improve health status of men to be par with women in order to advance their health standing and thus diminution of their vulnerability position to the causes of death. According to a 2016 statistics 13.4% (9) of mortality is due to non-communicable diseases (cardiovascular disease, cancer, diabetes, or chronic respiratory disease). Below in Table 2 is the list of leading causes of death in Maldives in 2015 and 2016.

4.4 STATUS OF ENVIRONMENT MALDIVES

4.4.a Air

Air quality in the Maldives is generally considered good as sea breeze flushes air masses over the small islands easily. However, rapid urbanization and increased economic growth in the recent years have raised air pollution as a growing concern, particularly in the Male region. [10]

In accordance with the World Health Organization's guidelines, the air quality in the Maldives is considered safe - the most recent data indicates the country's annual mean concentration of PM2.5 is 8 $\mu g/m^3$, which falls below the recommended maximum of 10 $\mu g/m^3$. Available data indicates that Male, experiences high levels of air pollution**.** Outdoor air quality in the Maldives, predominantly in Male city, is affected by land and sea vehicle emissions, diesel power generation, transboundary air pollution from other countries, and waste burning (Thilafushi dumpsite). [11] Waste burning at dumpsites and backyards of islands contribute significantly to air pollution.

4.4.a.i Key implications of air pollution on health

Short term symptoms resulting from exposure to air pollution include itchy eyes, nose and throat, wheezing, coughing, shortness of breath, chest pain, headaches, nausea, and upper respiratory infections (bronchitis and pneumonia). It also exacerbates asthma and emphysema. Long term effects include lung cancer, cardiovascular disease, chronic respiratory illness, and developing allergies. Air pollution is also associated with heart attacks and strokes.

As mentioned above Acute Respiratory infections are a major cause of morbidity reported in Maldives, but there are no studies that have been conducted in Maldives to determine the link between health impacts and air quality.

4.4.a.ii Air Pollution mitigation and Management

Maldives is signatory to a number of international conventions relating to air pollution control, however at the national level legal frameworks are weak. Maldives do not have a national air quality policy and national ambient air quality standard has not been established. The main policy initiative for emission reduction includes implementing an investment plan to achieve low carbon development, particularly in the energy and transport sector. [10]

4.4.b Water and Sanitation

Maldives has no rivers or streams. The conventional freshwater resources available in Maldives mainly are in the form of rain fed shallow groundwater lens, small fresh or brackish water ponds in few islands and rainwater. Non-conventional freshwater resources available include desalinated water and bottled drinking water. Groundwater aquifers on islands lie at an average depth of 1-1.5m below the ground surface. 87% of the atoll population use rainwater for drinking purposes. In the Maldives, 98% of households have access to an improved source of drinking water. [18] According to National Water and Sewerage policy 2017, 41% of total population have access to safe water supply with household connections. [13]

The quality of aquifer differs from island to island and is highly vulnerable to contamination from inadequate sanitation facilities, and other human activities, solid waste run off, over exploitation, and saline intrusion through soil erosion and flooding.

In addition, development projects including paved roads decreases the ground surface availability for groundwater recharge. The lack of space in highly consolidated islands such as Male, does not allow for water storage expansion. The continuous annual requests for emergency water shipments shows that the amount of rain water harvested is not sufficient to last the dry season.

Overall, 98% of households in the Maldives use improved toilet facilities (99% in Male region and 98% in other atolls). (18) In Maldives, as per the National Water and Sewerage Policy 2017, 48% of total population have access to sewerage network with house connections. (13) The various type of sewerage systems in place, among others include bore sewerage, conventional deep sewer gravity and vacuum sewerage systems. (10) The use of septic tanks and primitive sewage systems are some of the causes for deteriorating groundwater quality with stinking of effluent causing groundwater contamination. (10)

4.4.b.i Key implications of water pollution on health

It is difficult to get an accurate and full picture of the health issues in Maldives that are related to poor environmental conditions. This is because of lack of data and research that specifically links environmental improvements to health gains. However, available data show that there has been a decline in communicable diseases, which conventional wisdom in public health attributes to better management of the environment with respect to water and sanitation, food availability, better life-styles, the absence of vectors such as malaria carrying mosquitoes, etc.

The environment/development linkage of these health issues is unassailable, and equally so is the fact that the health sector cannot handle these complex issues unilaterally. Thus, for meaningful action, this need to be communicated very effectively to related sectors without whose support productive outcomes would not be possible. (12)

Death rate in Maldives due to unsafe sanitation in 2017 was 0.32 per 100,000 population. Death rate due to unsafe water sources in 2017 was 0.99 per 100,000 population. (14)

4.4.b.ii Water Pollution Mitigation and Management

With the construction of rainwater catchment tanks both in Male and the atolls and the introduction of a comprehensive sewerage scheme in Male and intensive health education on the use of oral rehydration, the situation had improved tremendously.

Desalination has been adopted as a means to provide safe water supply. Reverse osmosis plants with storage tanks are also being installed in targeted islands.

Only few islands have access to locally established water quality testing facilities and equipment. A mechanism that provides accessibility to testing on a regular basis is needed to ensure that the quality of water is checked and proper measures taken to ensure the safety of the water resources used by the communities. (17)

4.4.c Soil/Land Degradation

The soils of Maldives are alkaline deficient in nitrogen, potassium and several micro nutrients and are generally of low water holding capacity. Such soil characteristics are major constraints for the development of successful conventional agricultural production systems. (16) Despite the poor and infertile soils, Maldives support extremely rich coastal vegetation. Vegetation and other ecological features vary between islands from north to south in the country. Furthermore, variations exist between exterior and interior islands in atolls. The characteristics of the foreshore area also influence the ecology and vegetation in these islands.

The lucrative market for agricultural produce, opened up by the growing tourism industry, has started to attract substantial investments to this sector. There has also been an increasing trend in farming in resorts islands for producing a significant part of tropical vegetables and fruits, for which they need to use fertilisers, pesticides and insecticides. (16) Agro-chemicals have the potential to pollute the environment. Amount of fertilizers used on agricultural islands are not monitored at present. In addition, information on chemical pollution emissions from the agricultural sector in Maldives is also unavailable. However, farmers are known to use fertilizers without knowing the manufacturer's recommendations, which results in exceeding the required concentrations. Excessive use of fertilizers increases the nutrient levels of nitrogen and phosphorous in the water, causing eutrophication and affecting marine life. Misapplication of fertilizers can also cause degradation of soil and pollute groundwater. Agricultural soils can also release greenhouse gas (GHG) emissions into the environment. (10)

Waste is poorly managed in Maldives. It is dumped in open sites and uninhabited islands and artificial islands (Thilafushi Waste Disposal site). The waste dumps including the Thilafushi waste disposal site receives mixed waste from the islands, which are usually disposed without segregation. Waste is disposed by open-air incineration and burying. While burning releases harmful pollutants into the air including GHGs and particulates, toxic chemicals leach through the soil into the waters, polluting the shallow aquifers. Furthermore, oil which is used for burning the rubbish also leak into the surrounding area (MEE, 2015c). Leachate could also enter the sea, leading to marine and coastal pollution. This causes soil pollution and land degradation. (10)

Climate change and its adverse effects are the most talked about issue when it comes to environmental challenges in the Maldives. And while this is a serious issue, we do have several other immediately pressing challenges. One such issue is erosion. The reasons for this are both natural and man-made; changing monsoons, wave action, formation of islands, natural disasters, coral mining, land reclamation and building harbours to name a few. (15) Rising temperature, prolonged drought, intense rainfall and flooding, soil erosion, salt water intrusions and wind gusts have destroyed farming activities in the country.

4.4.c.i Key implications of soil pollution on health

Agrochemicals can be acutely toxic if present in the food at high levels and may cause health risks with long-term exposure. Many studies have examined the effects of pesticide exposure and links have been found with cancer, problems with fertility and reproduction, respiratory diseases, disruption of hormones, immune systems and nervous systems. In Maldives import of pesticides under WHO toxicity classes are banned, except few rhodenticides. (10)

4.4.c.ii Soil Pollution Mitigation and Management

The Government of Maldives recognizes the importance of sound management of chemicals and its impacts on the environment and human health. Maldives is signatory to a number of international agreements in relation to chemicals. At national level there is no legislative means addressing chemicals. The Act no: 4/75 is the main Act concerning chemicals in Maldives.

4.4.d Noise Pollution

Due to rapid development, urbanisation, Male, the most populated city is experiencing huge traffic issues. This contributed to significant compaction of the road surface. The main health issues emanating from this sector is the vehicular emissions, noise, and some road accidents. Industrialisation, mainly textile industry and oil corporations, have increased the need to address emerging issues of noise pollution. Noise as an environmental issue that needs addressing is totally neglected. Much needs to be done to locate schools away from high decibel locations and ways to curb the noise from motor vehicles and electric generators and motors. As Male grows in population and high rises stud the landscape of Male, better zoning and timings for allowing noisy work can help to curb some of the rising concerns of the urban population.

MAP OF REPUBLIC OF MALDIVES

Source: https://maldives.org.my/about-maldives/geography

TABLES

Table 1: REPORTED CASES OF MORBIDITY IN MALDIVES 2014 – 2017 [7]

#	Disease	2014	2015	2016	2017
1	Acute Respiratory Infection	173,437	208,910	212,648	244,591
2	Viral Fever	74,931	94,124	90,988	86,621
3	Acute Gastro Enteritis /Diarrhea	19,954	30,442	34,318	35,858
4	Conjunctivitis	19,370	10,174	8,640	9,047
5	Chickenpox	1,753	2,228	2,804	2,547
6	Dengue Fever	775	1,889	1,961	998
7	Hand Foot and Mouth Disease	2,598	1,312	3,102	886
8	Typhoid Fever	145	134	121	101
9	Scrub Typhus	54	43	76	68
10	Mumps	57	43	15	27

Table 2: LEADING CAUSES OF DEATH IN MALDIVES 2015 – 2016 [7]

Rank	ICD Code	Cause of Death	2015	ICD Code	Cause of Death	2016
1	(I30–I52)	Other forms of heart disease	165	(I30–I52)	Other forms of heart disease	168
2	(I10–I15)	Hypertensive diseases	100	(I20–I25)	Ischaemic heart diseases	122
3	(I60–I69)	Cerebrovascular diseases	93	(I60–I69)	Cerebrovascular diseases	99
4	(I20–I25)	Ischaemic heart diseases	92	(R00–R09)	Symptoms and signs involving the circulatory and respiratory systems	95
5	(J40–J47)	Chronic lower respiratory diseases	59	(J40–J47)	Chronic lower respiratory diseases	81
6	(R00–R09)	Symptoms and signs involving the circulatory and respiratory systems	46	(I10–I15)	Hypertensive diseases	66
7	(A30–A49)	Other bacterial diseases	43	(A30–A49)	Other bacterial diseases	52
8	(E10–E14)	Diabetes mellitus	36	(J60–J70)	Lung diseases due to external agents	39
9	(J60–J70)	Lung diseases due to external agents	36	(E10–E14)	Diabetes mellitus	34
10	(E70–E90)	Metabolic disorders	25	(N17–N19)	Renal failure	31

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5. Health Sensitization in Mauritius

5. Health Sensitization in Mauritius

SUMMARY

Mauritius is a small island country in the Indian Ocean, located off the eastern coast of Africa. It is 65 km long and 45 km wide. Its land area is 1,864.8 km^2. The current population of Mauritius is 1,272,163, which is equivalent to 0.02% of the total world population. The population density in Mauritius is 626 per Km^2. 40.8 % of the population is urban (519,330).

Mauritius provides state health services throughout the country, which is free at the point of use to its entire population. The public sector caters, free of any user cost, to the bulk of the healthcare needs of the population (73%). The remaining healthcare needs of the people (27%) are managed by the private sector. Life expectancy is recorded to be 75.5 years at birth. As per the 2019 statistics 11.5% of the population are currently above 65 years of age. The total fertility rate (TFR) is 1.4 live births per woman. Infant mortality is recorded to be 14.0 infant deaths per 1000 live births and deaths under the age of 5 years is 16.5 per 1000 live births. Neonatal mortality rate stands at 10.4 per 1000 live births and maternal mortality rate is at 62 per 100,000 live births. Births attended by skilled health personnel are 99.8%

Mauritius has an adult literacy rate of 91.33%. Currently Mauritius has recorded the sex ratio to be 0.96 male for every female. People have to spend very less on health if care is sought from a public health centre.

Non-Communicable Diseases account for 80% of the disease burden and 85% of mortality in Mauritius. Mauritius is moving towards the elimination of Mother to Child Transmission of HIV (MTCT) through the Prevention of Mother to Child Transmission Program (PMTCT). Environmental pollution can have direct and sometimes severe consequences for health. The air quality in Mauritius is considered moderately unsafe - the most recent data indicates the country's annual mean concentration of PM2.5 is 14 $\mu g/m^3$, exceeding the recommended maximum of 10 $\mu g/m^3$. Share of deaths which are attributed to total air pollution, both outdoor and indoor is 7.31% (0.51% indoor air pollution and 6.82% outdoor air pollution).

The main sources of water pollution in Mauritius are due to industrial effluents, dumping of liquid and solid waste in rivers and streams, run off from agricultural fields and untreated sewage. In 2016, age-standardized death rate attributed to unsafe water, sanitation or lack of hygiene (WASH) (measured per 100,000 individuals) was 1.76. Due to the low fertility of the sandy soil in Mauritius, vegetable growers depend heavily on inorganic fertilisers to sustain crop production. Unsustainable agricultural practices and inappropriate constructions result in soil and beach erosion. All of these collectively cause land degradation and increased sedimentation downstream. Noise is one of the major environmental problems in Mauritius giving rise to a lot of public complaints, mainly due to juxtaposition of residential, religious, industrial and commercial activities. The most common health problem it causes is Noise Induced Hearing Loss (NIHL). Exposure to loud noise can also cause high blood pressure, heart disease, sleep disturbances, and stress. These health problems can affect all age groups, especially children causing impairments in memory, attention level, and reading skill.

5.1 COUNTRY PROFILE

Mauritius is a small island country in the Indian Ocean, located off the eastern coast of Africa. It is geologically located within the Somali plate. It is part of the Mascarene Islands, the capital is Port Louis. Mauritius lies about 800 km east of Madagascar in the Indian Ocean.

Outlying territories and distance from the main island:

- **Rodrigues Island, 550 km to the east,**
- **The Cargados Carajos Shoals, 400 km to the northeast ,**
- **The Agalega Islands, 930 km to the north from the main island.**

Mauritius also claims sovereignty over the Chagos Archipelago (including Diego Garcia), some 2,000 km to the northeast, although this claim is disputed by Britain. These islands are separated by sea pits of 4,000 metres deep. They have emerged from the abysses as a result of gigantic underwater volcanic eruptions that happened thousands of kilometres to the east of the continental block made up by Africa and Madagascar. (1)

The country's landscape consists of a small coastal plain rising to discontinuous mountains encircling a central plateau. Mauritius is almost completely surrounded by reefs that may pose maritime hazards. The main island is of volcanic origin. Piton de la Petite Rivière Noire (Little Black River Peak) is the highest mountain on the island of Mauritius, in the Indian Ocean. Located in the Rivière Noire District and rising to a height of 828 m (2717 ft) above sea level, it forms part of the Black River mountain range. There are two other main mountain ranges in Mauritius: Moka-Port Louis and Grand Port-Savanne. The Moka-Port Louis range includes Pieter Both (820 m) and Le Pouce (811 m) mountains, the second and third highest summits respectively. (2)

Republic of Mauritius has a total territorial area (includes Agalega Islands, Cargados Carajos Shoais (Saint Brandon), and Rodrigues.) of 2040 km^2. It is 65 km long and 45 km wide. Its land area is 1,864.8 km^2. The island is surrounded by more than 150 km of white sandy beaches, and the lagoons are protected from the open sea by the world's third-largest coral reef, which surrounds the island. Just off the Mauritian coast lie some 49 uninhabited islands and islets, several of which have been declared natural reserves for endangered species.

The current population of Mauritius is 1,272,163 (as of Monday, September 7, 2020), which is equivalent to 0.02% of the total world population. The population density in Mauritius is 626 per Km^2. 40.8 % of the population is urban (519,330). According to UNESCO, Mauritius has an adult literacy rate of 91.33% (male literacy rate is 93.36%, for females is 89.37%). (3)(4

5.2 HEALTHCARE SYSTEM IN MAURITIUS

Mauritius has a strong, resilient and equitable health system which is founded on the WHO Health System Framework. Mauritius provides state health services throughout the country free at the point of use to its entire population. Healthcare is financed through general taxation. The Ministry of Health and Wellness is responsible for public healthcare. A dual-tiered system of healthcare services, comprising a government-led and funded public sector, and a thriving well established private sector. The public sector caters, free of any user cost, to the bulk of the healthcare needs of the population (73%). The remaining healthcare needs of the people (27%) are managed by the private sector, on a user fee basis, either through out-of-pocket payments or payments effected by private health insurers. [5]

The NHA Report 2017 indicates that Total Government Expenditure on Health (TGEH) was around 44.01% of Total Health Expenditure (THE) in 2016. For FY 2019/2020, Government's allocation to health as a percentage of General Government Expenditure (GGE) was 7.3%, representing around 2.6% of GDP. The trend of government spending on health has significantly increased since the past ten years. According to 2015 Study on Household Out-of-Pocket (OOP) Expenditure on Health, household expenditure on health declined from 9.0 % in 2003 to 3.6% in 2015. [5]

5.2.a Health Infrastructure

Below in Table 1 is the list of types of health facilities available in Mauritius.

All regional, district hospitals and specialised hospitals (Psychiatric, Eye, E.N.T and Cardiac), have an out-patient department. Out-patient services are also delivered in community hospitals, mediclinics, Area Health Centres (AHC) and Community Health Centres (CHCs). The basic services delivered at CHCs include the treatment of common diseases and injuries, maternal and child care, and family planning. In addition to these services, AHCs also provide dental care. Six Ayurvedic Clinics were providing outpatient care. Out-patient care was also provided in the private sector, including clinics and dispensaries on sugar estates. There are also chest clinics and eight day care centres for the Immuno-Suppressed in operation as at the end of 2018. Each of these peripheral healthcare delivery points is located within a radius of only (1.5 km to 3 km) of the residence of people. [5][6]

5.2.b Human Resource for Health

Below in Table 2 is the list of types of health professionals available in Mauritius.

In addition, nonmedical staff provides administrative support for the day-to-day running of the health services. An estimated 16,000 officers in 375 different grades are employed by the MOHW, of whom 85% are technical staffs who are responsible for delivery of services and 15% are support staff. [5] The doctor to population ratio stood at 26 per 10,000 population in 2019, while there were 3.3 dentists per 10,000 population. The figures are well within the WHO recommendations.

5.3 HEALTH OF MAURITIUS

The general state of health of the population of Mauritius is good and has been improving steadily over the past decades. Life expectancy is recorded to be 75.5 years at birth (72.2 years for males and 78.9 years for females.) The median age in Mauritius is 37.5 years. As per the 2019 statistics 11.5% of the population are currently above 65 years of age and the share of the elderly population has been on an upward trend since 2011.

5.3.a Reproductive, Maternal, New Born and Child Health

Currently Mauritius has recorded the sex ratio to be 0.96 male for every female. The total fertility rate (TFR) is 1.4 live births per woman. (A value below 2.1 will cause the native population to decline.) Infant mortality is recorded to be 14.0 infant deaths per 1000 live births and deaths under the age of 5 years is 16.5 per 1000 live births. Neonatal mortality rate stands at 10.4 per 1000 live births and maternal mortality rate is at 62 per 100,000 live births. WHO, country data 2019, records births attended by skilled health personnel are 99.8%. Institutional delivery coverage since 2017 has sustained at 100% (WHO, 2019) and immunisation coverage is recorded at more than 95% (WHO, Immunisation coverage country punchcards). [5][6]

5.3.b School Health

During the year 2018, the nursing staff responsible for school health visited 525 pre-primary schools and screened 14,797 children. 4% of these children were reported to have nits and lice. The nursing staff also visited 301 primary schools and screened 39,089 pupils. 23,517 pupils of Standards III, V and VI were submitted to vision tests and 1,034 of them were found to have vision problem. 10,833 of the new entrants to primary schools were immunized against diphtheria, tetanus (D.T.) and poliomyelitis. 10,937 of them were also immunized against MMR and 13,234 primary school leavers were immunized against tetanus. [6]

5.3.c Non-Communicable Diseases

Non-Communicable Diseases (NCDs) which include cardiovascular diseases (including hypertension and stroke), diabetes, cancer, chronic respiratory diseases, and kidney diseases are silent killers with insidious onset and debilitating complication. NCDs account for 80% of the disease burden and 85% of mortality in Mauritius. The main risk factors of NCDs include tobacco use, harmful use of alcohol, physical inactivity, and unhealthy diet. Prevention and the adoption of a healthy lifestyle are critical to address the situation. The WHO recommends policy, regulatory, and health promotion interventions to reduce NCD risk factors. [5] (Graphical representation is added below in the Annex)

5.3.d Communicable Diseases

Communicable Diseases include Vector-Borne, HIV and AIDS, Hepatitis C and now Corona virus, CoVID-19.

Most of the communicable diseases have been successfully controlled. Although a good communicable disease surveillance and control programme is in place, challenges of the resurgence of communicable and other vector-borne diseases and emergence of new infectious diseases such as the novel corona virus (CoVID-19) are continuous threats to the country. Below in Table 3 is the summary of Incidence of Communicable Diseases (Reported Cases) 2006-2019.

5.3.d.i MALARIA

No indigenous case of malaria has been detected since 1997. However, there have been 48 imported cases of malaria during the period January 2019 to the 9th June 2020. There have been no local cases of chikungunya since 2012. As far as dengue is concerned, Mauritius has detected 130 local cases and 20 imported cases in 2019. From January to 9th June 2020, 211 local cases of dengue were recorded. [5]

5.3.d.ii HEPATITIS C

It is estimated that there are around 15,000 people infected with Hepatitis C Virus (HCV) in Mauritius. Population at increased risk of HCV infection includes people who inject drugs, children born to mothers infected with HCV, people with homosexual partners who are HCV-infected, people with HIV infection, prisoners or previously incarcerated persons and people who have received blood transfusion and endoscopy before 1997. Hepatitis C is a major cause of liver cancer. Antiviral medicines can cure patients with hepatitis C infection, thereby reducing the risk of death from cirrhosis and liver cancer. Mauritius is presently implementing a HCV Elimination Programme. (5)

5.3.d.iii HIV

The HIV prevalence is 1.2% in the population aged 15–49. From the first case of AIDS registered in Mauritius in 1987, up to December 2019, there were 7,795 HIV (2,072 females and 5,723 males). In 2019, 374 new HIV cases were detected. The number of people living with the virus in Mauritius is estimated to be around 11,000. The trend in the mode of transmission for HIV new cases has changed from injecting drug use to heterosexual. People Who Inject Drugs (PWIDs) represent about 61% of the HIV population in Mauritius. (5)

Mauritius is moving towards the elimination of Mother to Child Transmission (MTCT) through the Prevention of Mother to Child Transmission Program (PMTCT) which has a coverage of >95% for the past four years. Implementation of new strategies to reach pregnant women has resulted in an increase to almost 98% in the compliance rate of PMTCT programme. (5)

5.4 STATE OF ENVIRONMENT MAURITIUS

5.4.a Air

Outdoor air pollution is a mix of chemicals, particulate matter, and biological materials that react with each other to form tiny hazardous particles. It contributes to breathing problems, chronic diseases, increased hospitalization, and premature mortality. The concentration of particulate matter (PM) is a key air quality indicator since it is the most common air pollutant that affects short term and long term health. Two sizes of particulate matter are used to analyse air quality; fine particles with a diameter of less than 2.5 µm or PM2.5 and coarse particles with a diameter of less than 10 µm or PM10. PM2.5 particles are more concerning because their small size allows them to travel deeper into the cardiopulmonary system.

The World Health Organization’s air quality guidelines recommend that the annual mean concentrations of PM2.5 should not exceed 10 µg/m^3 and 20 µg/m^3 for PM10.

In accordance with the World Health Organization's guidelines, the air quality in Mauritius is considered moderately unsafe - the most recent data indicates the country's annual mean concentration of PM2.5 is 14 µg/m^3, exceeding the recommended maximum of 10 µg/m^3. Available data indicates that Beau Bassin-Rose Hill is a city that can experience high levels of air pollution. (7)

The main sources of air pollution in Mauritius are from the burning of fossil fuel for heat generation in industries, electricity generation and transportation. The sources of air pollution can be grouped into three categories:

- stationary sources - power stations and industries (e.g. stone crushing plants)

- mobile sources - motor vehicles
- others - open burning of waste materials and burning of sugar-cane fields

The main air pollutants are sulphur dioxide, oxides of nitrogen, carbon monoxide, ozone, lead, dust particulates. [8]

5.4.a.i Key implications of Air pollution on Health:

Air pollution can have direct and sometimes severe consequences for health. Fine particles which penetrate deep into the respiratory tract subsequently increase mortality from respiratory infections. Short term symptoms resulting from exposure to air pollution include itchy eyes, nose and throat, wheezing, coughing, shortness of breath, chest pain, headaches, nausea, and upper respiratory infections (bronchitis and pneumonia). It also exacerbates asthma and emphysema. Long term effects include lung cancer, cardiovascular disease, chronic respiratory illness, and developing allergies. Air pollution is also associated with heart attacks and strokes. [7] Respiratory tract diseases are a good proxy indicator for air quality. As mentioned earlier, Respiratory tract diseases contribute to 13% of mortality due to non communicable diseases.

Summarised 2017 Mauritius data for effects of air pollution on human health, [9]

The age standardised share of the population with prevalence of Asthma is 5.86%.

Annual number of premature deaths attributed to illness as a result of indoor air pollution from the use of solid fuels for cooking and heating is 53.

The sum of deaths from household and outdoor particulate and ozone air pollution is 755.

Share of deaths which are attributed to total air pollution, both outdoor and indoor is 7.31% (0.51% indoor air pollution and 6.82% outdoor air pollution)

5.4.a.ii Air Pollution Mitigation and Management

In Mauritius, air pollution control is regulated under the Environment Protection (Standards for Air) Regulations 1998. The Ministry of Environment (MoE) has adopted measures to control air pollution: minimising emissions at source, minimising the impact of residual pollution on surrounding developments (industries), monitoring of ambient air at suspected sites.

The National Environmental Laboratory of the Department of Environment is responsible for the ambient air monitoring. The Ministry of Environment has got two ambient air quality monitoring stations. One fixed is at Medco Cassis where regular monitoring is being undertaken. The mobile station is regularly displaced to sites where high pollution levels are suspected. The automatic analysers and equipment at the stations measure the concentrations of major pollutants such as sulphur dioxide, oxides of nitrogen, carbon monoxide, ozone, particulate lead and respirable suspended particles (PM10). [8]

5.4.b Water and Sanitation

The major sources of water in Mauritius are rainfall, surface water and groundwater. Mauritius has a network of 25 major river basins and 21 minor river basins. There are 5 main aquifers, 11 reservoirs and 350 boreholes. [10] In 2019, Island of Mauritius received 3,972 million cubic metres (Mm^3) of precipitation (rainfall), down by 24.4% compared to 5,252 (Mm^3) recorded in 2018. Some 10.0% (397 Mm^3) of the precipitation went as ground water recharge, while evapotranspiration and surface runoff accounted for 30.0% (1,192 Mm^3) and 60.0% (2,383Mm^3) respectively. [11]

In Mauritius, water is mainly abstracted from rivers, reservoirs and surface run-offs for domestic purposes, industrial use, and agriculture and hydropower generation. It has a largely comprehensive system of access to safe drinking water and basic sanitation. 100% of its population has access to improved drinking water source and improved sanitation facilities. [12] The principal challenges in the water sector arise due to increasing demand from economic development, agriculture, industry, tourism and a growing urban population. These in turn result in heavy water extraction and also pollution of water resources.

Climate change has also impacted water resources in Mauritius. The observed decrease in rainfall, increase in rainfall variability, and increase in occurrences of high intensity rainfall and shift in the onset of summer rains have impacted negatively on the country's water resources. [13] The whole population of Mauritius has access to piped potable water. Mauritius has the highest percentage (100%) of total improved drinking water sources (both in rural and urban areas) [14]

The main sources of water pollution in Mauritius are due to industrial effluents, dumping of liquid and solid waste in rivers and streams, run off from agricultural fields and untreated sewage. The extensive use of agrochemicals (fertilisers), pesticides and insecticides can impact on water resources if not properly managed.

5.4.b.i Key implications of Water pollution on Health:

Bacterial, viral and parasitic diseases like typhoid, cholera, encephalitis, poliomyelitis, hepatitis, skin infection and gastrointestinal are spreading through polluted water.

Summarised 2017 Mauritius data for effects of water pollution and unsafe sanitation facilities on human health, [9]

Age-standardized death rate attributed to exposure to unsafe water (measured per 100,000 individuals) is 0.41

Age-standardized death rate from unsafe sanitation (measured per 100,000 individuals) is 0.21

Age-standardized death rate attributed to unsafe water, sanitation or lack of hygiene (WASH) (measured per 100,000 individuals) is1.76 in 2016

5.4.b.ii Water Pollution Mitigation and Management:

Significant investments have been made to increase support and improve water quality. An Integrated water resource management plan is developed to improve water management.

The following measures are adopted in Mauritius for controlling water pollution

Providing sewerage infrastructure and solid waste management system to prevent pollution at source.

Requiring industries to pre-treat their effluent to prescribed standards before discharge into the sewerage system.

Prohibiting industries which use or store large quantities of chemicals to be sited within water catchments.

The National Environmental Laboratory of the Department of Environment in collaboration with other laboratories (Ministry of Fisheries, Waste Water Management Authority, Central Water Authority) perform regular monitoring of inland and coastal water quality around the island. (8)

5.4.c Soil/Land Degradation

About 40 per cent of the island's surface is being used for cultivation, of which roughly 90 per cent is sugar cane, remaining is used for tea, tobacco and food crops. Historically, sugar cane cultivation was the main agricultural activity in Mauritius. (15) Different types of sugars are also being produced today for the export market.

Mauritius is diversifying its agricultural sector into a wider range of crops and livestock. As part of the diversification programme, some 5,000 ha of land unsuitable for sugar cane cultivation will be released for other activities. Part of this acreage would be available for crops and livestock farming, for forestry, while others will be converted for non-agricultural uses such as: expansion of the road network, construction of hotels, Integrated Resort Schemes (IRS), industrial and Information and Communication Technology (ICT) parks and residential estates including those of the Voluntary Retirement Scheme.

The total food requirement of the country is estimated at 686,000 tonnes annually, with a local production meeting only 23% of national consumption. Consequently, additional land will be required for food production, in order to increase national food security, thus putting additional pressures on land.

There is a need to shore up the country's ability to produce its own food. Competing demands on the limited land resources, coupled with the problems of a changing climate, decreasing soil fertility, irrigation water scarcity, increasing pest and disease problems, as well as insufficient interest of the young generation in primary agricultural activities, makes this a particularly ch allenging issue.(13)

Due to the low fertility of the sandy soil in these areas, vegetable growers depend heavily on inorganic fertilisers to sustain crop production. Unsustainable agricultural practices and inappropriate constructions result in soil and beach erosion. In addition, the low water retention capacity and high infiltration of the soil favour leaching of nutrients. All of these collectively cause land degradation and increased sedimentation downstream. The beaches at Belle Mare/ Palmar have been suffering from bulk accumulation of algae (reaching 1m in thickness), for some time, and this is attributed to the heavy use of inorganic fertilisers in onion plantations and to the livestock farming at Palmar Livestock Station (National Status Report on the Coastal and Marine Environment, 2007). [(13)]

5.4.c.i IMPACT OF CLIMATE CHANGE ON AGRICULTURE:

Climatic variation like altered rainfall patterns, prolonged droughts, flash floods, extreme weather events such as cyclones, decreased water availability and the increased incidence of agricultural pests and crop diseases negatively impact agriculture. Other likely impacts of climate change include change in soil moisture, cropping pattern and crop cycle as well as decrease in crop and livestock productivity. Agricultural land located in low lying areas such as: Palmar, Belle Mare, Bel Ombre, is prone to inundation as a result of sea level rise. [(13)]

5.4.c.ii Key Challenges

Reforestation and better agricultural practices are being undertaken to curb soil erosion. There is insufficient local data, knowledge and information to enable the necessary technolog y development in the country to move towards a green economy. There are no island level models scaled down from the global climate models. There is no data on biodiversity (tress and other flora and fauna) of privately owned forests. [(13)]

5.4.d Noise Pollution

Noise is one of the major environmental problems in Mauritius giving rise to a lot of public complaints, mainly due to juxtaposition of residential, religious, industrial and commercial activities. With urbanisation, industrialisation and economic development, Mauritius also faces noise pollution as a negative impact. Hence, Mauritius has included noise pollution in it Environmental Protection (Control of Noise) Regulation since 2008. The above regulation represents the single legislation to control noise.

Under the above regulation:

- No person is allowed to make or cause to be made any noise which constitutes a nuisance.
- Noisy activities in a residential area related to construction works such as demolition of a building, excavation or filling of land and use of heavy machines require prior authorisation from the local authority if such activities are carried out before 7 am or after 7 pm on any day.
- Keeping on any premises any animal which makes noise and whose noise unreasonably interfere with peace, comfort and convenience of another person is also an offence.

Prior authorisation from the Commissioner of Police is required by any person or organisation, with the exception of any public sector agency making public announcement, for the use of a loud-speaker, amplifier, musical instrument or electrical or mechanical device for producing sound in a public place in relation to a social, cultural, religious or an electoral activity. According to Mauritian law, from 7.00 to 18:00 the music volume should not exceed 60 decibels, 18 to 21 hours, 55 decibels and from 21:00 to 6 h00, 50 decibels. [(16)]

Furthermore, the use of the above sound producing instruments within a radius of 100 metres and which may unreasonably interfere with the proper running up of certain institutions such as educational, health, Court of Justice or Government House is prohibited.

Under the EPA, 2002, the Ministry of Health and Quality of Life is the main enforcing agency in relation to noise. Other authorities also empowered under the EPA to enforce noise regulation are the Police Force (including the Police de l'Environnement), all local authorities and the Department of Environment.

Any person contravening these regulations, shall commit an offence and shall –on a first conviction, be liable to a fine not exceeding 50,000 rupees; and on a second or subsequent conviction, be liable to a fine not exceeding 100,000 rupees and to imprisonment for a term not exceeding 12 months.

In 2018, Environmental Health Engineering unit attended to 333 justified noise monitoring complaints, out of which only 3 notices were served.

Noise pollution impacts millions of people globally on a daily basis. The most common health problem it causes is Noise Induced Hearing Loss (NIHL). Exposure to loud noise can also cause high blood pressure, heart disease, sleep disturbances, and stress. These health problems can affect all age groups, especially children causing impairments in memory, attention level, and reading skill. (17)

5.4.d.i Other Related Legislations on Noise

- The Environment Protection (Amendment) Act, 2008 prescribes an environmental standard for noise emitted from a place of worship, which is set at 55 decibels [dB(A) Leq] recorded at the boundary of the site.
- The Environment Protection (Environmental Standards for Noise) Regulations of 1997 and amended in 2003, prescribes maximum exposure limits in decibels for industrial and neighbourhood noise for major activities such as power plants, industries, multi-purpose halls.
- The Occupational Safety, Health and Welfare Act, 2005, provides for occupational noise in a workplace.
- The Road Traffic Act regulates traffic noise.(18)

<u>TABLES</u>

Table 1: List of types of health facilities available in Mauritius.

Health facilities	2011	2018	2019
Hospitals	15	15	15
Hospital beds	3,594	4,588	4,610
Area health centres	26	23	23

Mediclinics	2	5	5
Community health centres	127	130	130
Private clinics	17	19	19

2: List of health professionals available in Mauritius.

Health Personnel	**2011**	**2018**	**2019**
Medical practitioners	1,561	3,210	3,290
Dentists	268	411	412
Nurses & midwives	3,670	4,400	4,494
Pharmacists	408	536	536

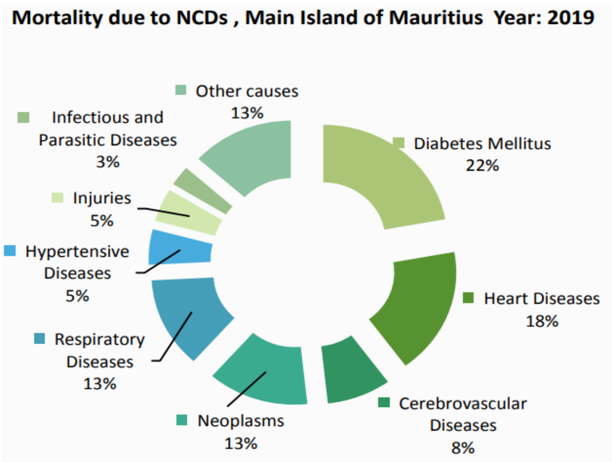
Source: Mauritius in figures 2019, July 2020.

Table 3: Incidence of Communicable Diseases (Reported Cases) 2006-2019.

Disease	Year	2006	2009	2012	2015	2016	2017	2018	2019
HIV/AIDS	Number	542	548	320	262	319	368	382	366
	Incidence Rate*	43.9	43.9	25.5	20.8	25.2	29.1	30.2	28.9
Malaria	Number	38	23	33	32	25	28	37	41
	Incidence Rate*	3.1	1.8	2.6	2.5	2.0	2.2	2.9	3.3
Pulmonary Tuberculosis	Number	111	113	128	128	122	121	123	114
	Incidence Rate*	9.0	9.1	10.2	10.1	9.7	9.6	9.7	9.0

*Source: Health Statistic Reports 2018, *per 100,000 mid-year population*

GRAPHICAL REPRESENTATION



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6. Health Sensitization in Myanmar

6. Health Sensitization in Myanmar

SUMMARY

Myanmar or Burma is a Sovereign State in Southeast Asia with an area of 676,578 square kilometres, a 1,930-kilometer coastline and a population of 54,476,945. Myanmar is one of the world's most disaster-prone countries exposed to multiple hazards, including floods, cyclones, earthquakes, landslides, and droughts, ranking 2nd out of 187 countries in the 2016 Global Climate Risk Index. The country has 66.8 years of life expectancy at birth for both the sexes. Maternal mortality ratio, neonatal mortality rate and under 5 mortality rate of the country are 250 per lakh live births, 23 per 1000 live births and 46 per 1000 live births, respectively.

The According to WHO, NCDs caused about 59% of total deaths in the country in 2014, of which 25% were due to cardiovascular diseases, 11% were due to cancers, 9% and 3% were due to chronic respiratory disease and diabetes respectively.

The country has a total literacy rate nearing 76% (Adult aged 15 years and above) and a sex ratio per capita 970 females per 1000 males. The public expenditure on health as a percentage GDP is 1.02% and public expenditure on health is U.S $ 12.5 as on 2016.

Along with its rapid development since 2011, Myanmar has been experiencing a rise in air pollution in urban areas. In 2017, air pollution is estimated to attribute to more than 45,000 deaths in Myanmar. As a risk factor for death, air pollution is higher in Myanmar than in other countries in the region, almost twice the average for Southeast Asia. Yet actual data with high reliability on air quality in Myanmar is lacking, and arrangements for monitoring of air quality and pollution control are still in their infancy. The three major sources of water pollution are categorized as 1. Agriculture (chemical fertilizer and pesticides); 2. Industry and mining; .3 Urban waste discharge.

Myanmar has always been affected by various climate-related disasters including cyclones and storm surges, river and flash floods, landslides, droughts, heat waves and wildfires. The cost of floods and landslides accounted for 1.7 per cent of GDP in 2015-2016 alone. According to research by the Occupational and Environmental Health Division (OEHD) under the Ministry Health and Sports, released in 2018, over 29 percent of the sources of domestic water in the Ayeyarwaddy region were contaminated with levels of arsenic higher than the WHO standards, and over 8 percent were conta minated at levels that were more than five times higher.

Myanmar has achieved significant growth in recent years, and projections indicate that growth will accelerate due to lower levels of political uncertainty and strong investment. Myanmar's economy is undergoing structural transformation. The sectoral composition of GDP is changing: primary sectors such as agriculture and forestry are contributing less to employment, productivity and manufacturing and the service sector is contributing more. Investment in a climate-resilient, low-carbon development pathway and adopting environmentally sound technologies at an early stage can provide sustainable and resource-efficient opportunities for socioeconomic development, including green jobs and long-lasting business models.

The agriculture, fisheries and livestock sectors play an import role in Myanmar's socioeconomic development. They make significant contributions to GDP, employment, food security, nutrition and poverty alleviation. Climate-resilient responses that include promoting resource-efficient and low-carbon practices will help maintain food and livelihood security, economic growth and social development. By 2030 Myanmar needs to have climate-smart agriculture, fisheries and livestock systems that will maintain productivity and growth and support the livelihoods of dependent communities and households.

Myanmar needs to go a long way in achieving universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all and to reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination. Myanmar has made significant progress in achieving MDG targets, especially in health and education. For example, under-five child mortality fell from 10 to 5.2 per cent between 1990 and 2010. Myanmar is still classified as a 'least developed country' (LDC) and this has an influence on the types of resources the country is able to access to promote the SDGs. The country aims to graduate from 'least developed country' status by 2025.

6.1 COUNTRY OVERVIEW WITH DEMOGRAPHY:

Myanmar or Burma is a Sovereign State in Southeast Asia. The Geographic area of Myanmar is 676,578 square kilometers, which includes a 1,930-kilometer coastline. The Republic of the Union of Myanmar (Myanmar) is situated on the western end of Southeast Asia. Myanmar is currently one of the fastest growing economies in East Asia. The population of the Country (2020) is 54,476,945. The Country constitutes 0.70% of World Population. Myanmar is one of the world's most disaster-prone countries exposed to multiple hazards, including floods, cyclones, earthquakes, landslides, and droughts, ranking 2nd out of 187 countries in the 2016 Global Climate Risk Index and 9th out of 191 countries in the INFORM Index for Risk Management.Currently Myanmar's population is growing at a rate of about 0.67% per year. The 2019 population density in Myanmar is 83 people per km square (214 people per mile2).

6.2 HEALTH SCENARIO IN GENERAL

BIRTH RATE**:** Myanmar's birth rate is on the decline resulting in the decline in population grown. In 1983, the fertility rate was Five (5) Births per woman, now it is 2.13 births per woman. The fertility rate is shown to be significantly lower in urban areas. The main reasons for the decline in growth rate, is due to the high number of, unmarried and single women in the reproductive age (25.9% of women aged 30–34 and 33.1% of men and women aged 25–34), (uncommon in developing countries generally seen in developed countries) and delayed marriages (the average age of marriage in Burma is 27.5 for men, 26.4 for women)due to low economic status. The prevalence of illegal abortions, contraception and social acceptance of celibacy following the Buddhist values (Burmese are predominantly Buddhist) are added causes for the falling birth rate.

Maternal mortality ratio of Myanmar fell gradually from 335 deaths per 100,000 live births in 1998 to 250 deaths per 100,000 live births in 2017[4]. In 2018, neonatal mortality rate for Myanmar was 23.1 deaths per 1,000 live births. Infant mortality rate of Myanmar fell gradually from 120.4 deaths per 1,000 live births in 1969 to 36.8 deaths per 1,000 live births in 2018. **I**n 2018In 2018, child mortality rate for Myanmar was 46.2 deaths per 1,000 live births. Child mortality rate of Myanmar fell gradually from 177.7 deaths per 1,000 live births in 1969 to 46.2 deaths per 1,000 live births in 201

Myanmar - Life expectancy

Among ASEAN countries, Myanmar has the lowest life expectancy and the second-highest rate of infant and child mortality. In 2018, life expectancy for Myanmar was 66.9 years.

The sex ratio at birth is 1.06 males/female

6.3 HEALTHCARE ACCESS

Access to basic infrastructure and services remain a challenge in both rural and urban areas. Access to comprehensive healthcare and other basic services is limited in rural areas, where 87 percent of the poor reside. The poor live far away from public or private hospitals. Although health centres have filled in some of the gaps in healthcare provision, the services available at these facilities are largely restricted to primary care. Access to improved sources of drinking water, sanitation facilities, and clean sources of energy are relatively limited among the poor. Poor households also face greater barriers in connecting to the public grid due to issues of both affordability and accessibility.The lack of an educated workforce skilled in modern technology contributes to the growing problems of the economy.

6.4 HEALTH – ISSUES

In Myanmar, cerebrovascular disease, ischemic heart disease, and chronic obstructive pulmonary disease (COPD) were the top three killers in 2016. According to WHO, NCDs caused about 59% of total deaths in the country in 2014, in which 25% were due to cardiovascular diseases, 11% were due to cancers, 9% and 3% were due to chronic respiratory disease and diabetes respectively.

Unhealthy lifestyles including physical inactivity, excessive sugar intake, alcohol and drug abuse, as well as environmental pollution, are all major contributors to the rising trends of NCDs. It is crucial that governments and health organizations focus on tackling this pressing problem before the aging populations are worn out

6.5 CLIMATE PARAMETERS AND HEALTH:

Climate change can affect human health directly (e.g., impacts of thermal stress, death/injury in floods and storms) and indirectly through changes in the ranges of disease vectors (e.g., mosquitoes), water-borne pathogens, water quality, air quality, and food availability and quality. The actual health impacts will be strongly influenced by local environmental conditions and socio-economic circumstances, and by the range of social, institutional, technological, and behavioral adaptations taken.

6.6 POLLUTION - SPECIFIC HEALTH ISSUES

In accordance with the World Health Organization's guidelines, the air quality in Myanmar is considered unsafe - the most recent data indicates the country's annual mean concentration of PM2.5 is 36 µg/m3, exceeding the recommended maximum of 10 µg/m3.

6.6.a Air Pollution:

Along with its rapid development since 2011, Myanmar has been experiencing a rise in air pollution in urban areas. In 2017, air pollution is estimated to attribute to more than 45,000 deaths in Myanmar. As a risk factor for death, air pollution is higher in Myanmar than in other countries in the region, almost twice the average for Southeast Asia. Yet actual data with high reliability on air quality in Myanmar is lacking, and arrangements for monitoring of air quality and pollution control are still in their infancy

6.6.a.i Outdoor Pollution: The World Health Organization's air quality guidelines recommend that the annual mean concentrations of PM2.5 should not exceed 10 µg/m3 and 20 µg/m3 for PM10.

The Ambient air pollution attributable death rate (per 100 000 population) in Myanmar is 48.

6.6.a.ii Indoor Pollution:

The causes for indoor air pollution is inefficient combustion of household fuels for cooking, lighting and heating (in the rural population upto 95% and the urban areas 81%).

The WHO finding show an alarming 92% of the world's population inhale air which has pollutants above permissible limits.

The poor and less educated are most likely to use tobacco and have reduced access to tobacco prevention and treatment services, and endure lower levels of access to education and other health messaging opportunities.

6.6.a.iii Prevention of Air pollution

The high air pollution during the previous weeks, despite the closure of factories and lack of traffic due to COVID-19, showed that traffic and industry were not the major contributors. This was also backed by the low measurements of ozone (which is associated with traffic pollution). It was noted that PM2.5 can travel long distances, and agricultural burning even 200 miles away can have an impact.

It was noted that even where municipalities collected waste it was often burnt, or caught fire, or else dumped in the rivers. Greater separation of organic waste and installation of biodigesters etc. was needed. A solution would also require actions such as composting leaves as an alternative to burning. Tackling stubble burning in favor of 'stubble retention;' in the soil could only be achieved if support for alternatives was provided to farmers, in addition to law enforcement, as mixed experience in India and other countries has shown.

6.6.b Soil Pollution:

The main anthropogenic sources of soil pollution are the chemicals used in or produced as byproducts of industrial activities, domestic, livestock and municipal wastes (including wastewater), agrochemicals, and petroleum-derived products. These chemicals are released to the environment accidentally, for example from oil spills or leaching from landfills, or intentionally, as is the case with the use of fertilizers and pesticides, irrigation with untreated wastewater, or land application of sewage sludge.

Awareness on the importance of soil pollution is increasing around the world, leading to an increase in research conducted on the assessment and remediation of soil pollution The *Revised World Soil Charter* (FAO, 2015b) recommends that national governments implement regulations on soil pollution and limit the accumulation of contaminants beyond established levels in order to guarantee human health and well-being.

Over the last 10 years, two devastating cyclones, including Nargis (2008) and Giri (2010) claimed thousands of lives and affected more than 2.5 million people living along the coastline. The cost of floods and landslides accounted for 1.7 per cent of GDP in 2015-2016 alone. The severe dry spell in the summer of 2010 killed 260 people and brought food and water insecurity.

6.6.c Noise Pollution

The government's "No Car Horn Zone" launched ten years ago in Yangon City has failed, according to traffic police. Yangon is Myanmar's commercial hub has growing reputation for noise pollution where drivers over-rely on their car horns to push their way through heavy traffic. Six main townships in the city were firstly designated as no horn

6.6.d Water pollution

Causes of Water Pollution: The sources of water pollution are categorized in three sections that are the major contributors of water pollution: (2.1) Agriculture (chemical fertilizer and pesticides); (2.2) Industry and mining; (2.3) Urban waste discharge.

6.6.d.i Health Problems

Drinking clean water is vital for human health. Diseases that cause diarrhea, such as cholera, as well as other serious illnesses including typhoid and dysentery, can be caused by drinking unclean water. Water-borne diseases can spread through contaminated water. Developing countries face more health problems caused by contaminated water than is the case among inhabitants in the developed world. Rural inhabitants suffer more than people who live in urban locations from the consequences of water pollution, as they have lower access to treated water.

6.6.e Ozone Pollution

Ozone is a highly reactive, oxidative gas associated with adverse health outcome, including mortality and morbidity. Well-established evidence has been produced for short-term effects, especially on respiratory and cardiovascular systems, associated to ozone exposure. Less conclusive is the evidence for long-term effects, reporting suggestive associations with respiratory mortality, new-onset asthma in children and increased respiratory symptom effects in asthmatics.

6.6.f Patterns of infection

Climatic conditions strongly affect water-borne diseases and diseases transmitted through insects, snails or other cold-blooded animals. Changes in climate are likely to lengthen the transmission seasons of important vector-borne diseases and to alter their geographic range.

Underlying factors of vulnerability relate to high socio-economic dependence (employment, income, food security) on climate sensitive sectors like agriculture; large portion of the population lives in high-risk zones such as the Ayeyawady Delta, and the Central Dry Zone. These regions have the highest socio-economic vulnerability and exposure to climate change.

Unsustainable natural resources utilization (e.g. deforestation, illegal fishing, unsustainable agricultural practices); High poverty, unemployment and migration rates; Human settlements/towns/cities are not prepared for the changing climate (e.g. Inadequate urban planning and construction techniques, poor infrastructure); Low adaptive capacity characterized by limited access to knowledge, technology and financing.

6.7 MONITORING AND EVALUATION OF THE 2030 SUSTAINABLE DEVELOPMENT AGENDA

In 2016, a National SDG Steering Committee was established. The Central Statistical Organization (CSO) and the National Statistics Office serve as a focal point on this committee, which has the job of monitoring the SDGs. Their role is to work with all government departments to access to good quality data, which is disaggregated to understand how different groups such women and men, rich and poor, and urban and rural citizens are benefiting from sustainable development

6.8 OPEN DEVELOPMENT MYANMAR

To increase the adaptive capacity of — and maximize opportunities from — low-carbon and climate resilient development, the strategy will guide investment in the six key social and economic development sectors that contribute to current and planned economic and social development in Myanmar. These six sectors are: agriculture, fisheries and livestock sector; natural resource management; energy, transport and industrial systems; towns and cities; disasters, risks and health impacts; and education, awareness and technological systems.

Measuring the health effects from climate change can only be very approximate. Nevertheless, a WHO assessment, taking into account only a subset of the possible health impacts, and assuming continued economic growth and health progress, concluded that climate change is expected to cause approximately 250 000 additional deaths per year between 2030 and 2050; 38 000 due to heat exposure in elderly people, 48 000 due to diarrhoea, 60 000 due to malaria, and 95 000 due to childhood undernutrition.

Who is at risk?

All populations will be affected by climate change, but some are more vulnerable than others. People living in small island developing states and other coastal regions, megacities, and mountainous and polar regions are particularly vulnerable.

Children – in particular, children living in poor countries – are among the most vulnerable to the resulting health risks and will be exposed longer to the health consequences. The health effects are also expected to be more severe for elderly people and people with infirmities or pre-existing medical conditions.

Areas with weak health infrastructure – mostly in developing countries – will be the least able to cope without assistance to prepare and respond.

WHO response

Many policies and individual choices have the potential to reduce greenhouse gas emissions and produce major health co-benefits. For example, cleaner energy systems, and promoting the safe use of public transportation and active movement – such as cycling or walking as alternatives to using private vehicles – could reduce carbon emissions, and cut the burden of household air pollution, which causes some 4.3 million deaths per year, and ambient air pollution, which causes about 3 million deaths every year.:

6.9 ENERGY, TRANSPORT AND INDUSTRY

The energy, transport and industry sectors have largely been the defining factor of economic growth and will continue in this role for decades to come, supporting the process of economic transformation. About 75 per cent of Myanmar's electricity is generated through hydroelectricity; 20 per cent with natural gas, 3 per cent with coal and 2 per cent with other sources (MOEPE 2013). The transport sector is also expanding, with demand increasing alongside economic growth. It is predicted to grow further for the next 15 years.

Although these sectors are vital for Myanmar's socioeconomic development, they are also potentially so demanding on environmental capital in the context of climate change, that keeping the balance between enhancing these sectors and protecting the environment will be a key area for action over the next 15 years. By 2030, the country would like to achieve resilient and low-carbon energy, transport and industrial systems to sustainably support its socioeconomic development goals. This would mean increasing the resilience of the nascent energy, transport and industrial systems, making them sustainable through efficient, low-carbon and green.

6.10 CLIMATE HAZARDS AND HEALTH

Myanmar has made significant progress in achieving MDG targets, especially in health and education. For example, under-five child mortality fell from 10 to 5.2 per cent between 1990 and 2010 (ADB 2015). Climate change projections for Myanmar suggest that the population's social and economic development is at risk if the country does not strengthen and support public health and social protection measures.

By 2030, Myanmar's communities and economics should be able to respond to — and recover from:

Climate-induced disasters, risks, and build a healthy society. This is aligned with the national development vision of 2030; national and sectoral policies; SDG3: “good health and wellbeing for all at all ages” and SDG13 “take urgent action to combat climate action and its impact”.

6.11 EDUCATION, SCIENCE AND TECHNOLOGY

The education, science and technology sectors play a key role in developing a knowledge-based society that will drive Myanmar's inclusive and resilient economic and social development. The education, science and technology sectors can play a significant role in formal education, professional development and awareness-raising to build a climate-smart society.

The six integrated programmes for the pursuit of environmental education and public awareness activities, which are: Formation of national advisory and coordination body for environmental education and training. Improvement of environmental education in school.

Improvement of environmental education and research at tertiary and professional level. Building the capacities of business, industry, academic and private sectors for proper code of conduct in environmental conservation. Launching a public education and awareness campaign and developing partnerships with other national and international stakeholders.

By 2030, Myanmar should develop a climate-responsive society with the human capital to design and implement climate-resilient and low-carbon development solutions for inclusive and sustainable development.

6.12 UN DEPARTMENT OF ECONOMICS AND SOCIAL AFFAIRS

GDP per Capita in Myanmar (formerly Burma) (with a population of 53,382,523 people in 2017) was $1,489, an increase of $85 from $1,404 in 2016; this represents a change of 6.1% in GDP per capita.

The UN and its partners in Myanmar are working towards achieving the Sustainable Development Goals: 17 interconnected and ambitious Goals which address the major development challenges faced by people in Myanmar and around the world. Myanmar is still classified as a 'least developed country' (LDC) and this has an influence on the types of resources the country is able to access to promote the SDGs. The country aims to graduate from 'least developed country' status by 2025.

Myanmar has achieved significant growth in recent years, and projections indicate that growth will accelerate due to lower levels of political uncertainty and strong investment. Myanmar's economy is undergoing structural transformation. The sectoral composition of GDP is changing: primary sectors such as agriculture and forestry are contributing less to employment, productivity and manufacturing and the service sector is contributing more. Investment in a climate-resilient, low-carbon development pathway and adopting environmentally sound technologies at an early stage can provide sustainable and resource-efficient opportunities for socioeconomic development, including green jobs and long-lasting business models.

6.13 MYANMAR: POLITICAL ECONOMY ANALYSIS

Myanmar has a multi-layered civil society with a great many types of CSOs, ranging from grassroots movements to more organized and professionalized NGOs. These engage in various roles in the context of limited state presence and capacity and armed conflict (mutual self-help, humanitarian relief, public service delivery and political advocacy), and with complex relations between CSOs and the state.

Religious actors. Religious institutions have long traditions of providing important services in Myanmar society, especially in education, health services and welfare support, including humanitarian assistance to displaced persons. The strong and complex links between Buddhism and politics in Myanmar have underpinned the recent re-emergence of Buddhist nationalism. The period since 2011 has seen a wave of anti-Muslim rhetoric and violence, especially in northern Rakhine state.

Myanmar has one of the fastest-growing economies in Southeast Asia, with average economic growth of 7.5% during the period 2012–2016, and this is expected to continue for several years. One explanation of the rapid economic growth is the country's young population, which helps ensure high growth in consumption and incomes during the period 2015–2025. Members of the urban middle class in areas dominated by the majority Bamar ethnic group have been the major beneficiaries of the new reforms, whereas the economic benefits for rural constituencies have been less noticeable, especially in conflict-affected ethnic states where land-grabbing has been widespread

6.14 COVID-19 STATUS

(Updated September 10, 2020)

Cases: 2150

Deaths: 14.

Recovered: 625

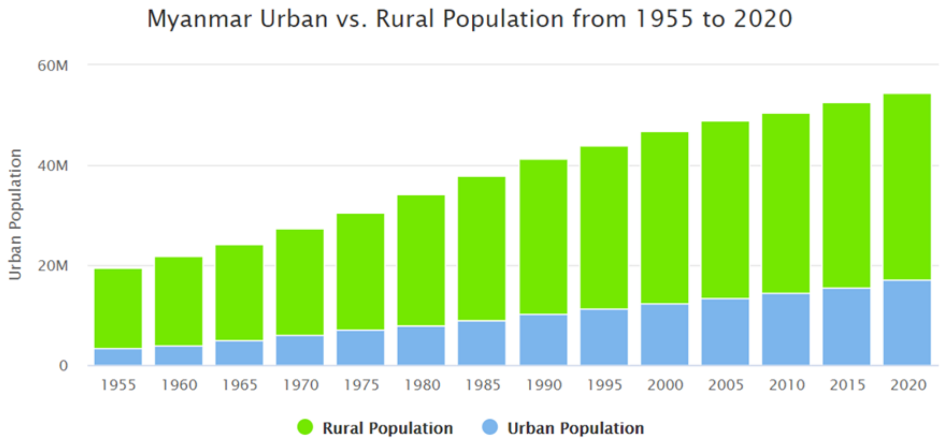
Myanmar – Geographical Map

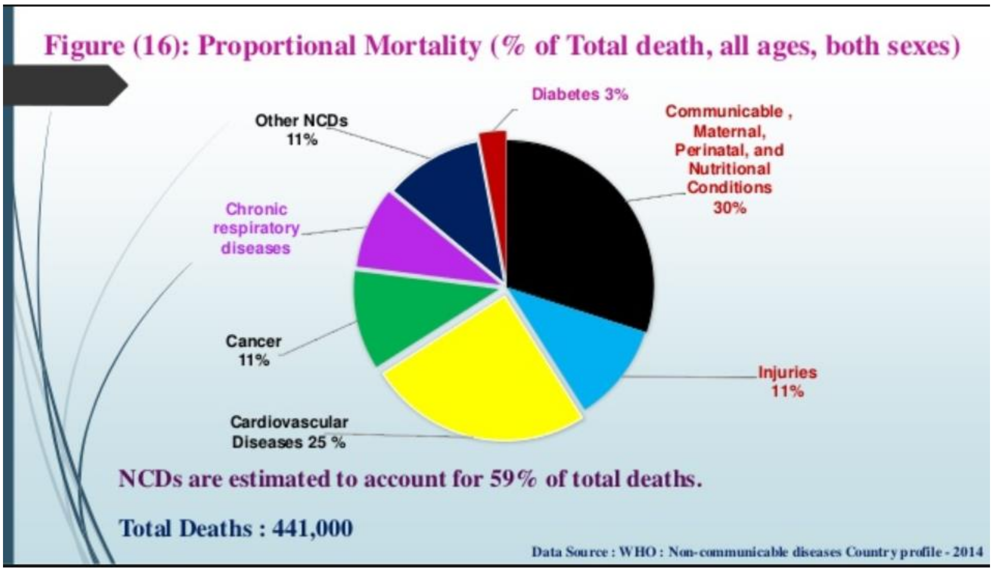
2020 world percentage	**0.70%**
2020 population rank	**26**
Growth rate	**0.67%**
Density	**80.42/Km2**
Area	**676,578Km2**

Capital city	**Naypyidaw**
Region	**Asia**
Sub region	**South Eastern region**
Government	**Myanmar**
GDP (IMF)	**Dollar 71.403**
GDP (UN)	**Dollar 65.70 Billion**

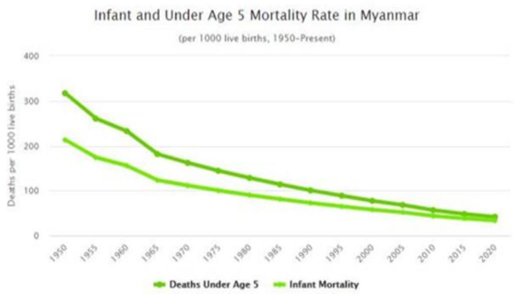
Myanmar Urban Population

Currently, **31.0 %** of the population of Myanmar is **urban** (16,763,626 people in 2019)

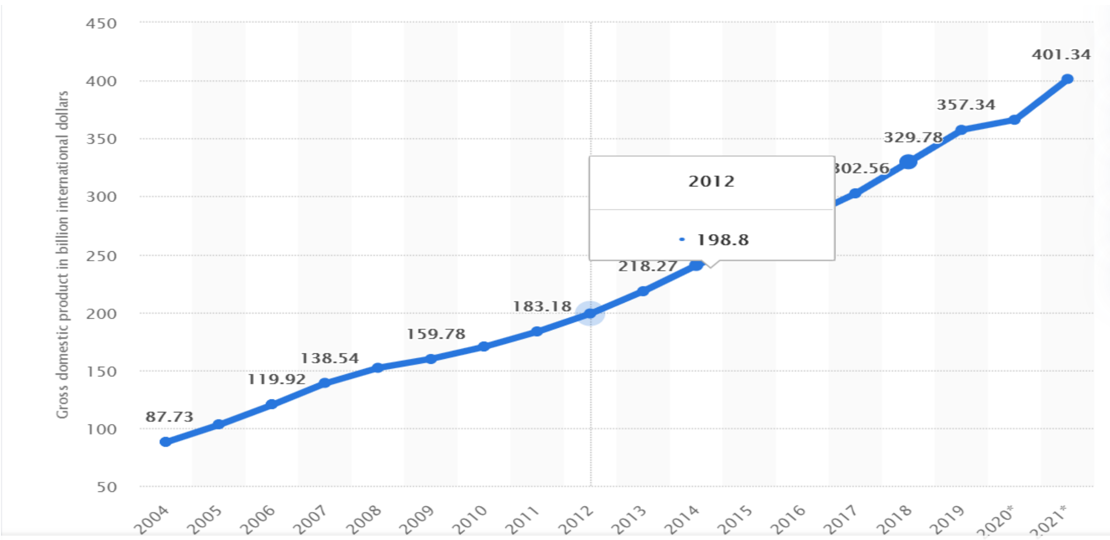




Proportional Mortality



Sustainable Development Goals



Myanmar GDP 2004-2021

Table: Climate change impacts on health sector

Health concerns	**Climate change impacts**
Temperature-related morbidity	Heat and cold-related illness Cardiovascular system illness
Vector-borne diseases	Malaria, filarial, dengue and other pathogens carried by mosquitoes, ticks and vectors
Health impacts of extreme weather	Diarrhoea, cholera and poisoning caused by biological and chemical contaminants in water Damaged public health infrastructure due to cyclones Injuries and illness Social and mental stress from disaster and displacement
Health impacts of food insecurity	Malnutrition and hunger, especially in children

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7. Health Sensitization in Nepal

7. Health Sensitization in Nepal

SUMMARY

Nepal is a landlocked country located in South Asia, lying in the southern slopes of the Himalayan mountain ranges between the Tibet Autonomous region of China to the north and India in the south, east and west. The country occupies 147,516 sq. km of land. The entire distance from east to west is about 800 km while from north to south is only 150 to 250 km. The current population of Nepal (2020) is 29,136,808. The urban population (2020) of the country is 21.4 % of the population

The average life expectancy at birth for both sexes combined is 71.7 years, for females it is 73.2 years and for males it is 70.1 years. According to the 2017 estimate, the maternal mortality rate is 186 deaths/100,000 live births. Nepal ranks 44 globally in maternal mortality. In 2018, neonatal mortality rate for Nepal was 19.9 deaths per 1,000 live births. The infant mortality rate for Nepal is 25.1 deaths/1,000 live births and the under age of five mortality rate in Nepal is 27.2 deaths/1,000 live births.

According to the estimated value, 12,765,697 persons or 64.9% of adult population (aged 15 years and above) are literates. The nominal (current) Gross Domestic Product (GDP) of Nepal is $24,880,266,905 (USD) as of 2017. The sex ratio in Nepal is 96.1 male(s)/female. Current fertility rate for Nepal in 2020 is 1.880 births per woman, a 1.42% decline from 2019. The sex ratio in Nepal is 940 females/1000 males. The public expenditure on health as of percentage GDP for sears countries is 1.17% per capita public expenditure is U.S.$ 8.4 as on 2016.

The three major disease conditions and their mortality rates are Ischemic Heart Disease – 100.5 deaths/10,000 population, COPD – 60.2 deaths/10,000 population and Diarrheal Disease – 36.1 deaths/10,000 population. Of NCD's cardiovascular diseases have caused a maximum death of 22% followed by chronic respiratory diseases 13%, cancer 8%, and other NCDs 14%.

In accordance with the World Health Organization's guidelines, the air quality in Nepal is considered unsafe - the most recent data indicates the country's annual mean concentration of PM2.5 is 100 µg/m3, exceeding the recommended maximum of 10 µg/m3, data indicates that Kathmandu has consistently unsafe levels of air pollution. More than 50% of the PM2.5 concentrations in Nepal was estimated to result from emissions outside the country.

Airborne occupational hazards are equally present in brick kiln workers and grocery workers in Kathmandu, whose health has been seriously hampered and needs quick action for protection. Ambient air pollution attributable death rate (per 100 000 population) is 76 in Nepal.

The surface water in Nepal is polluted by industry and domestic waste along with discharge of untreated sewage from tightly packed residential neighbourhoods. Mortality rate attributed to exposure to unsafe WASH services (per 100 000 population) is 19.8.

Nepal faces a high number of water-borne diseases such as diarrhoea, dysentery, typhoid, gastroenteritis and cholera. Children under the age of five are the most affected with an estimated 44,000 children dying every year in Nepal from waterborne diseases. Few of the heavy metals concentration in water also worsens the problem.

Due to distinct attitudinal, topographical, climatic and vegetational characteristics, the soils of Nepal are highly variable. Soil fertility loss is the main problem in the country, particularly on the hill tracts due to improper soil management.

A significant proportion of antibiotics, used widely in agriculture and human healthcare, are released into the environment causing much of the burden of antibiotic resistance indirectly.

Noise pollution in urban cities is a serious problem and has been steadily increasing over the years. This has direct and indirect effect on the people and can lead to a major health hazard. Some of the major sources of noise pollution are: Vehicular traffic, Air traffic, Stone cutting industry, Construction sites etc.

7.1 COUNTRY OVERVIEW WITH DEMOGRAPHY

Nepal is a landlocked country located in South Asia, lying in the southern slopes of the Himalayan mountain ranges between the Tibet Autonomous region of China to the north and India in the south, east and west. The country occupies 147,516 sq. km of land. The entire distance from east to west is about 800 km while from north to south is only 150 to 250 km. The capital of Nepal is Kathmandu.

Nepal contains some of the most rugged and difficult mountain terrain in the world. Roughly 75 percent of the country is covered by mountains [1]

Nepal has vast water systems which drain south into India. Nepal holds the so called "water towers of South Asia" with its 6,000 rivers which are either snow-fed or dependent on rain. The perennial rivers include Mahakali, Karnali, Narayani and Koshi rivers originating in the Himalayas.[2]

7.1.A DEMOGRAPHICS

Population: The current population of Nepal (2020) is 29,136,808 and the 2020 Global population rank of Nepal is 49 and the country constitutes about 0.37% of the World population. The urban population (2020) of the country is 6,226,233, which is 21.4 % of the population. The 2019 population density in Nepal is 200 people per Km^2 (517 people per mi^2), calculated on a total land area of 143,350 Km2 (55,348 sq. miles). Currently**,** 21.1 % of the population of Nepal is urban (6,034,147 people in 2019).[3]

7.1.b Literacy Rate

According to the estimated value, 12,765,697 persons or 64.9% of adult population (aged 15 years and above) in Nepal are able to read and write. Accordingly, about 6,902,857 adults are illiterate.

7.1.c Economy:

Nominal (current) Gross Domestic Product (GDP) of Nepal is $24,880,266,905 (USD) as of 2017.GDP Growth Rate in 2017 was 7.91%, representing a change of 1,572,562,357 US$ over 2016, when Real GDP was $19,891,395,830.GDP per Capita in Nepal (with a population of 27,632,681 people) was $777 in 2017, an increase of $47 from $730 in 2016; this represents a change of 6.5% in GDP per capita.[4]

7.2 HEALTH SCENARIO IN NEPAL

Life Expectancy: The average life expectancy at birth for both sexes combined is 71.7 years. Life expectancy for females at birth is 73.2 years and for males is 70.1 years.

Sex Ratio: at birth: 1.06 male(s)/female[5]

Fertility Rate: The current fertility rate for Nepal in 2020 is 1.880 births per woman, a 1.42% decline from 2019.

Maternal Mortality: According to the 2017 estimate, the maternal mortality rate is 186 deaths/100,000 live births. Nepal ranks 44 globally in maternal mortality.[6]

Neonatal Mortality: In 2018, neonatal mortality rate for Nepal was 19.9 deaths per 1,000 live births. Between 1999 and 2018, neonatal mortality rate of Nepal has seen a drastic and a steady declining rate from 41.9 deaths per 1,000 live births in 1999 to 19.9 deaths per 1,000 live births in 2018.

Infant Mortality: The infant mortality rate for Nepal is 25.1 deaths/1,000 live births. For males, it was 26.3 deaths/1,000 live births and females it was 23.8 deaths/1,000 live births. The mortality rate gradually fell from 224.16 in 1950 to 25.1 in 2020.

Under the age of five Mortality: The under the age of five mortality rate in Nepal is 27.2 deaths/1,000 live births. The rate gradually fell from 333.51 in 1950 to 27.72 in 2020.

Disease prevalence and mortality rate:

The previous two decades have marked an epidemiological transition from communicable diseases to NCDs. The death rate due to communicable, maternal, neonatal, and nutritional diseases declined rapidly by 78% between 1990 and 2017; while the decline is sluggish at 18% and 20% for death rates due to NCDs and injuries, respectively.[7] The major disease conditions that cause deaths are:Ischemic Heart Disease – 100.5 deaths/10,000 population,COPD – 60.2 deaths/10,000 population, Diarrheal Disease – 36.1 deaths/10,000 population, Lower Respiratory Infection – 31.1 deaths/10,000 population[8] [According to the 2017 data]

7.3 SPECIFIC HEALTH ISSUES

7.3.a Magnitude of Air Pollution and its sources

In accordance with the World Health Organization's guidelines, the air quality in Nepal is considered unsafe - the most recent data indicates the country's annual mean concentration of PM2.5 is 100 µg/m3, exceeding the recommended maximum of 10 µg/m3.[9]

Air pollution levels can also vary at different altitudes, with high levels occurring in the morning and evening in plain and valley locations, and during the afternoon in high altitude locations. Available data indicates that Kathmandu has consistently unsafe levels of air pollution due.[10] EPA establishes an AQI for five major air pollutants regulated by the Clean Air Act. Air pollution is not limited to a local area but has regional as well as global impacts. emissions from the HKH region and beyond have a major influence on pollution levels and their impacts in Nepal, owing to the transboundary transport of pollutants. More than 50% of the $PM_{2.5}$ concentration in Nepal was estimated to result from emissions outside the country.[11]

7.3.a.i Health Issues due to Air Pollution: Short term symptoms resulting from exposure to air pollution include itchy eyes, nose and throat, wheezing, coughing, shortness of breath, chest pain, headaches, nausea, and upper respiratory infections (bronchitis and pneumonia). It also exacerbates asthma and emphysema. Long term effects include lung cancer, cardiovascular disease, chronic respiratory illness, and developing allergies. Air pollution is also associated with heart attacks and strokes. Noncommunicable Diseases (NCDs) have been the major cause of human death accounting for 60% of deaths. Of NCD's cardiovascular diseases have caused a maximum death of 22% followed by chronic respiratory diseases 13%, cancer 8%, and other NCDs 14%. Premature (between ages of 30 and 70 years) mortality due to NCDs is 22%.[12]

7.3.a.ii Psycho social and economic burden:

As Nepals economy is dependent on tourism due to its natural beauty and rich cultural and archeological significance, the high level of particulate pollution will directly impact the tourism. Impact of air pollution on agriculture, forestry and biodiversity is very well established. Air pollution can be produced both outdoors and indoors. For the poorest families, indoor smog from coal- or dung-fired cooking stoves is typically the more serious problem.

According to reports, the estimates are that the outdoor air pollution will cause 6-9 million premature deaths annually by 2060, compared to three million in 2010. That is equivalent to a person dying every 4-5 seconds. Cumulatively, more than 200 million people will die prematurely in the next 45 years as a result of air pollution.The most visible and significant impact of air pollution is on human health. Reducing $PM_{2.5}$ and O_3 can help reduce large-scale health risks. Emissions from all sources in 2010 and 2015 resulted in an estimated annual air pollution health burden of 23,000 and 30,000 premature deaths, respectively; this accounts for around 1 per 1000 people.[13]

7.3.a.iii Measures to mitigate Air pollution:

The four major sources of air pollution is the burning of solid waste, transport, industry/brick kilns, and household energy sectors. The viable solutions to mitigate air pollution is:

- Clean cooking technology, modern energy access, efficiency improvement in industrial processes, efficiency improvement in lighting, efficient mass transportation, renewable energy electricity generation, control on open biomass burning, intermittent aeration of rice field, animal waste management, waste management, and recovery of methane.[14]

- From the perspective of sources, residential and commercial sectors are the prime sources of air pollutants. Thus, any strategy must place a strong emphasis on this sector. Meanwhile, in other sectors such as transport and industries, stringent pollution control regulations can help reduce pollution. The remaining sources either require low-emissive technological transformation or awareness to reduce emissive activities, such as reducing the open burning of wastes and biomass and waste reuse and recycle.[15]

- In an attempt to improve air quality in the Kathmandu Valley and across the whole of Nepal the government has created a National Plan for Electric Mobility (NPEM). As part of the NPEM, the government has set out a number of ambitious targets which should have a positive impact on air quality. These include:

- By the end of 2020 to have increased the share of electric vehicles up to 20% from 2010 levels.
- By 2050 to have cut the use of fossil fuels in the transport sector by 50%
- By 2040 to develop its electric (hydro-powered) rail network
- To decrease the rate of air pollution through proper monitoring of sources of pollutants across waste, old and unmaintained vehicles and industries.

- Immediate prohibition of open burning of waste.
- Shift from traditional brick-making technologies to cleaner ones. Provision of effective methods, equipment, and capacities (such as emissions measurement and environmental monitoring) to authorities.
- The need for regional cooperation among countries in the HKH region to act jointly in effective mitigation of SLCPs and reducing their impacts in the region. It is also essential that voices are raised in international organizations like UNEP and CCAC, requesting the necessary assistance in mitigating SLCPs, as the transboundary effects are at a much larger scale than the national-level effects.[16]

7.3.b Water Pollution

Magnitude of water quality and its sources: Globally, Nepal ranks 135 in water and sanitation; 136 in drinking water; and 134 in sanitation. The WQI for Betani, Dipeni, Haatkhola, Dhukure and Ratuwa were 95.4, 443.1, 54.4, 42.7, and 162.6 respectively according to the 2019 reports.[17] The result shows that none of them is excellent for drinking purpose however, Dhukure is quite reasonable for drinking. The quality of Ratuwa and Dipeni is severely damaged and unfit for any purpose like domestic, drinking, irrigation and industrial due to its higher value of iron and manganese.[18]

7.3.b.i Health issues due to water pollution:

- According to the Department of Water Supply and Sewerage in Nepal, even though an estimated 80% of the total population has access to drinking water, it is not safe. Nepal faces a high number of water-borne diseases such as diarrhea, dysentery, typhoid, gastroenteritis and cholera. Starting with the dry season in the month of March to the end of the rainy season in September, one is extremely vulnerable to waterborne illnesses. Coupled with unhygienic environmental situation, the risk of food and water contamination is increased. Children under the age of five are the most affected with an estimated 44,000 children dying every year in Nepal from waterborne diseases.[19]

7.3.b.ii COVID-19 and its impact on water pollution:

Safely managed water, sanitation, and hygiene (WASH) services are an essential part of preventing and protecting human health during infectious disease outbreaks, including the current COVID-19 pandemic. According to a WHO/UNICEF technical brief on WASH and waste management for COVID-19:

- Frequent and proper hand hygiene is one of the most important measures that can be used to prevent infection with the COVID-19 virus. WASH services should enable more frequent and regular hand hygiene by improving facilities and using proven behaviour change techniques.

- WHO guidance on the safe management of drinking water and sanitation services applies to the COVID-19 outbreak. Measures that go above and beyond these recommendations are not needed.

- Many co-benefits will be realized by safely managing WASH services and applying good hygiene practices. Such efforts will prevent other infectious diseases, which cause millions of deaths each year.

- Safe water supply, sanitation and hygiene services and medical waste management in health care facilities are essential to deliver quality health services, protect patients, health workers and staff, and to prevent further transmission.[20]

7.3.b.iii Measures to mitigate water pollution:

- Water pollution is the most serious environmental quality issues in Nepal. Research findings on the relative public health importance of providing safe drinking water supplies, sanitation and hygiene education may seem counter intuitive.

- Improved hygiene and sanitation have more impact than drinking water quality on health outcomes.

- Combining the results of the many studies and reviews conducted, it becomes evident that improvements in excreta management, hygiene and water supply may reduce diarrhoeal morbidity, diarrhoea mortality and child mortality by significant amounts

- Improving access to safe water sources and better hygiene practices can reduce trachoma morbidity by 27%, ascariasis by 29% and hookworm by 4%.

- Better management of water resources reduces transmission of malaria and other vector borne diseases.[21]

- There are numerous technical options for excreta management, many of which, if properly designed, constructed, operated and maintained will provide adequate and safe service as well as health benefits.

- Research conducted in South Asia demonstrates that involving women in sanitation programmes has resulted in higher coverage, better maintenance of the facilities, increased hygiene awareness, and lower incidence of faecal-oral disease in the community

- In order to protect the aquatic environment and aquatic resources, an immediate step by the municipality is essential.[22]

7.3.c Soil Pollution

Magnitude of soil pollution and its sources:

Nepal is a mountainous country having eight distinct physiographic provinces ranging from south to north. Due to distinct attitudinal, topographical, climatic and vegetational characteristics, the soils of Nepal are highly variable. Major soil orders found in Nepal are Entisols, Inceptisols, Mollisols and Alfisols. The soil fertility loss is the main problem in the country, particularly on the hill tracts due to improper soil management. The deficiency of nutrients such as phosphate (P), potassium (K), sulphur (S), manganese (Mn), zinc (Zn), cadmium (Cd), lead (Pb), sulphur (S), calcium (CA), magnesium (Mg), boron (B) and molybdenum (Mo) is widespread in different regions of the country.[23] In addition, population growth, industrialization and unsustainable urbanization are leading to the accumulation of heavy metals in soils. The high concentration of heavy metals in soils produces negative impacts on both the environment and human health.

Soil pollution affects food security by reducing crop yields and quality. Safe, nutritious and good quality food can only be produced if our soils are healthy. Without healthy soils, we won't be able to produce enough food to achieve #ZeroHunger. Unsustainable agricultural practices reduce soil organic matter, compromising soils' capacity to degrade organic pollutants. This increases the risk of the pollutants being released into the environment.

The significant amount of antibiotics use din agriculture can seep into our soils and spread throughout the environment. This creates antimicrobial resistant bacteria, which decreases the effectiveness of antibiotics. Each year around 700 000 deaths are attributable to antimicrobial resistant bacteria. By 2050, if not tackled, it will kill more people than cancer, and cost, globally, more than the size of the current global economy.

7.3.c.i Health issues due to soil pollution: Until two decades ago, intestinal parasitic infection in some communities was very high (over 70%) and multi-parasitic infection was common. Among the soil-transmitted helminth infection, *Ascaris lumbricoides* infection alone was over 75% in some communities with a mean annual prevalence of 35% among patients visiting a hospital in the capital city, Kathmandu. Over one-third of soil samples tested revealed helminth parasites eggs.[24], [25]

7.3.c.ii COVID-19 pandemic and its impact on soil pollution:

The COVID-19 crisis has unleashed a plastic pandemic, reversing the achievement of a decade of activism against single-use plastic worldwide, including Nepal. Personal protective gear (PPE) like disposable gowns are made from polyester or polyethylene. Surgical masks and N95 respirators are made from non-woven polypropylene fibre. Face shields and visors use polycarbonate or polyvinyl chloride. Coveralls are made with high-density polyethylene (HDPE). Most of these are single-use plastic. In Nepal, there has been a big increase in plastic waste from provision stores, relief distribution to the destitute during the lockdown, and quarantine centres.[26]

7.3.c.iii Economic Burden of soil pollution:

It is estimated that the environmental income contributes to 50% of national GDP with agriculture, forestry, and fisheries. Agriculture, which is largest contributor to Gross Domestic Product (GDP) of Nepal, is highly climate sensitive since only 53% of arable lands have year around irrigation facility. WHO reports find, low- and middle-income countries in South-East Asia annually show have 3.8 million deaths. Through WHO's water safety plans, which work to identify and address threats to drinking-water safety, Amarapuri in Nepal identified open defecation as a water quality hazard contributing to diseases in the area. As a result, the village built toilets for each household and was later declared an Open Defecation Free Zone by the local government.

Agricultural development has been sluggish, and has failed to keep pace with population growth. Of the 28% of Nepal land that is degraded, 10% is poorly managed sloping agriculture terraces. (Andreatta, 1998).

7.3.c.iv Measures to mitigate soil pollution:

- Removal of contaminants of pollutants from the soil is necessary for maintaining quality and fertility.
- Bioremediation of arsenic-contaminated soils and groundwater shows a great potential for future developments.
- Plant growth promoting rhizobacteria are fruitful for combating heavy metal stress through the process of exclusion, extrusion, accommodation, bio-transformation, methylation and demethylation.
- Implementing suitable erosion management measures is needed to prevent land from being irreversibly damaged by soil erosion.[27]
- There is no single legislative act and/or policy formulated to combat land degradation in Nepal. However, there are numerous sectoral policies and periodical plans of the Nepalese government that have listed soil and land degradation management as a high priority.[28]

7.3.d Noise Pollution

Noise pollution in urban cities is a serious problem and has been steadily increasing over the years. This has direct and indirect affect on the people and can lead to a major health hazard. Some of the major sources of noise pollution are: Vehicular traffic, Air traffic, Stone cutting industry, Construction sites and many more.[29]

7.3.d.i Health issues due to noise pollution: Some of the health related issues due to noise pollution was Tinnitus (Ringing or Buzzing in the ears), Nausea, Dizziness, Aural Pain, Headache, Hypertension, Speech Interference, Irritation, Difficult to concentrate, Loss of sleep (Insomnia), Nervousness, Psychiatric problems, Argumentativeness, Blood pressure rise, Loss of sexual potency, Sleep disturbance.[30]Among the people who are exposed to this on a daily basis, about 80% had high respiration rate (>20/min); 31.4% had high pulse rate (>80/min) and high blood pressure (31.4%) and only 2.9% were suffering from heart disease.[31]

7.3.d.ii COVID 19 pandemic and its impact on noise pollution: The noise level was reduced up to 30 to 40% during the lockdown period and in most of the places where there were stone quarrying and crushing areas the entire study units fall under the noise level < 65dBA. With no traffic, and flights all grounded, there was no noise pollution in the street or the sky.[32], [33]

7.3.d.iii Measures to mitigate noise pollution: Doctors recommend that in any industry the level of noise should not exceed 90 db, while over 100db of noise level is harmful for human beings. The government has not given serious priority to control such activities even under the Environment Protection Act, 1997. The government should introduce a certain standard of noise level for road traffic noise, aircraft traffic noise, rail traffic noise, industrial noise, neighbourhood noise, saw mill noise with restriction on location of establishment. Damaged road, airport ground and railway tracks, need to be repaired timely to reduce vehicular noise pollution. The major cause behind noise pollution is lack of awareness. People's ignorance could lead to hearing loss, and the heart and other body parts could also be affected.[34]

ANNEXE: FIGURES, TABLES, GRAPHS

TABLE: Nepal Demographics

2020 world percentage	**0.37%**
2020 population rank	**49**
Growth rate	**1.85%**
Density	**203/Km2**
Area	**143,350Km2**
Capital city	**Kathmandu**
Region	**South Asia**
Government	**Federal Parliamentary Republic of Nepal**

Fig 1: Life expectancy in Nepal (1955 – 2020)

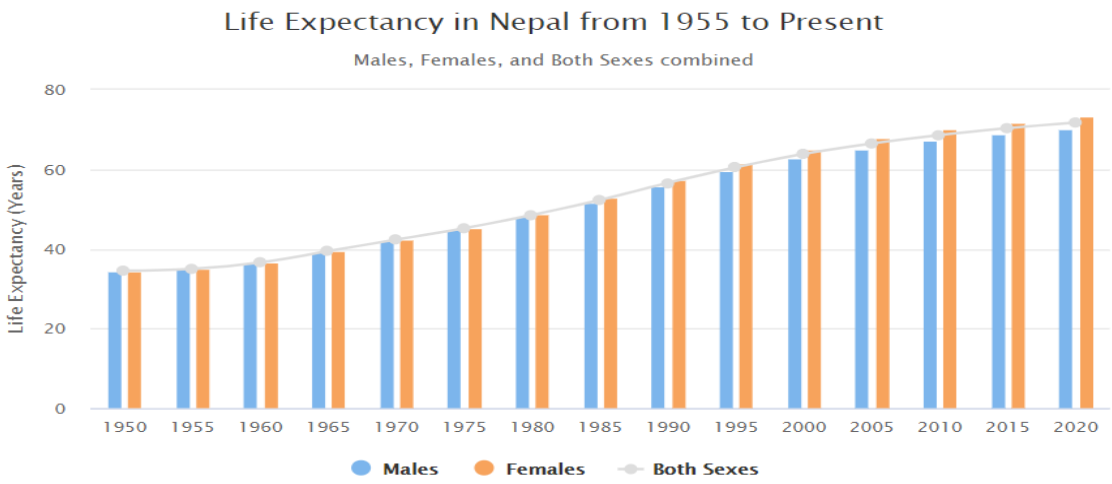

Fig 2: Infant and Under age five mortality

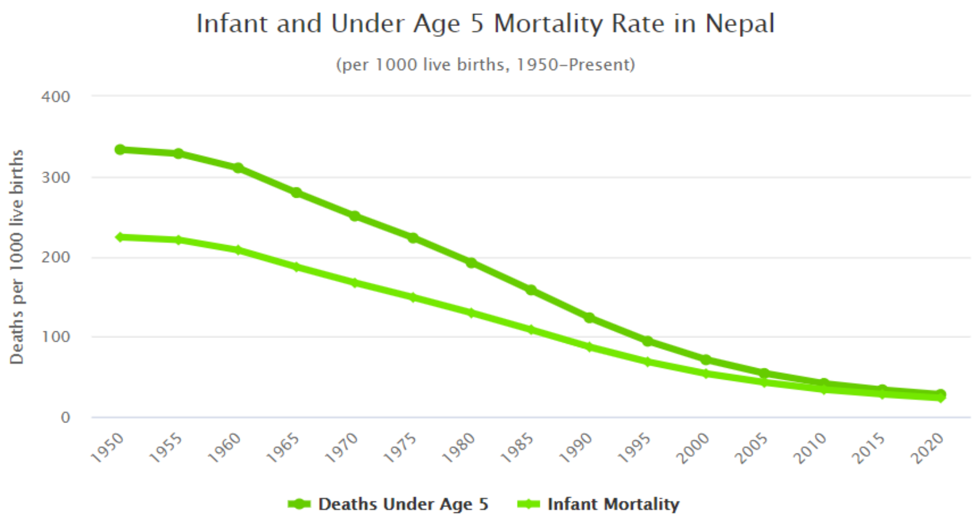

TABLE 2: Air Quality Index of Nepal

	PM 2.5 (24 h)	**PM 10 (24 h)**	**SO_2 (24 h)**	**O_3 (8 h)**	**NO_2 (1 year)**	**CO (8 h)**
Units	**µg/m³**					**mg/m³**
Nepal	100	120	70	-	40	10
WHO	10	50	20	100	40	-

Fig 3: Air Quality in Kathmandu during Covid-19 pandemic lockdown(April 2020) and before the pandemic (April 2019)

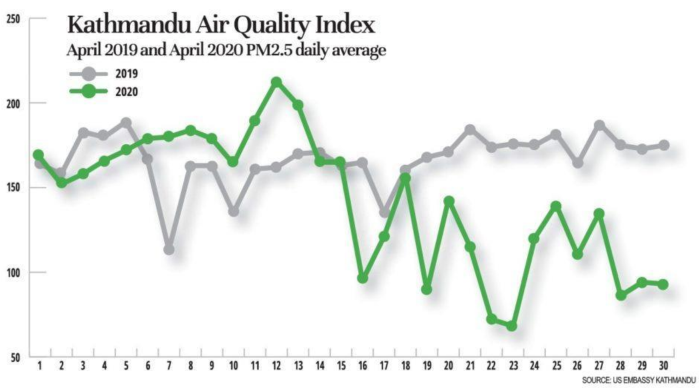

Table 3: Economic burden of Air pollution

Table 2.5: Mean Annual PM2.5, Total Deaths from Pollution, Total Welfare Losses, and Total Forgone Labor output, in Nepal and Its Neighbors

Country	Mean Annual Ambient PM2.5		Total Death from Air Pollution		Total welfare losses (mill US$) (% GDP)		Total labor Foregone output(mill US$) (% GDP)	
	1990	2013	1990	2013	1990	2013	1990	2013
Nepal	29.68	46.09	16436	22038	1033 (4.60)	2833 (4.68)	195 (0.87)	287 (0.47)
Bangladesh	29.92	48.36	92880	154898	6379 (4.66)	27452 (6.14)	1195 (0.87)	2579 (0.58)
China	39.30	54.36	1518942	1625164	126592 (7.35)	1589767 (9.92)	12558 (0.73)	44567 (0.28)
India	30.25	46.68	1043182	1403136	104906 (6.80)	505103 (7.69)	28742 (1.86)	56390 (0.84)

Fig 4: Water quality of some major rivers in Nepal

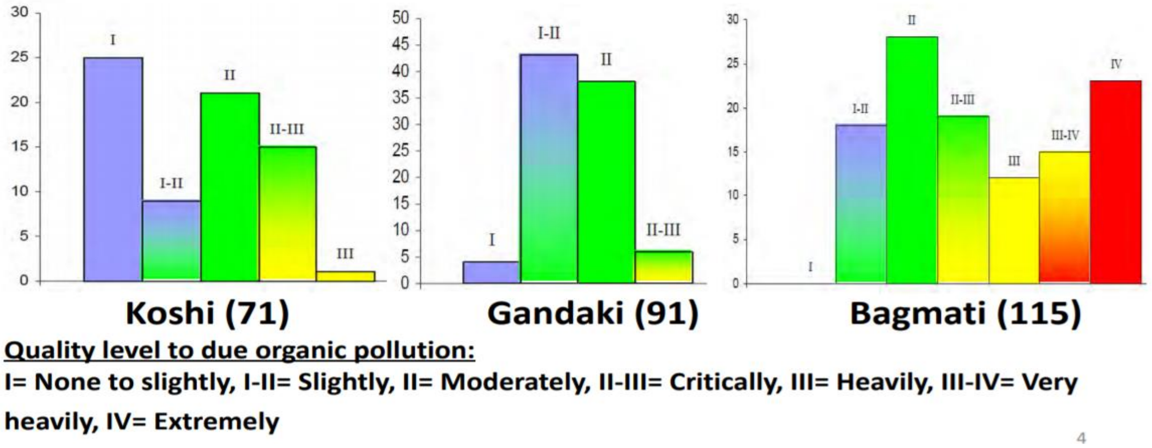

Table 4: Chemical status of groundwater in Kathmandu

Ground Water Source	Hardness (mg/l)	Chloride (mg/l)	Alkalinity (mg/l)	Iron (mg/l)	Arsenic (mg/l)	Fluoride (mg/l)
Shallow Well	230.7	81.8	366.0	1.47	0.004	0.43
Tube Well	218.8	61.1	258.0	1.90	0.003	0.27
Deep Tube Well	251.2	59.0	302.7	1.80	0.009	0.74
WHO Guidelines	500	250	NA	0.3	0.01	1.5

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8. Health Sensitization in Pakistan

8. Health Sensitization in Pakistan

SUMMARY

Pakistan is bounded to the west by Iran, to the northwest by Afghanistan, to the northeast by China and to the east and southeast by India. The Arabian Sea coast forms its southern boundary. Pakistan encompasses a rich diversity of landscapes. The current population of Pakistan is estimated to be 221,659,738; it is equivalent to 2.83% of the total world population. Currently, 35.1% of the population is urban (77,437,729 people in 2020).

The average life expectancy for both sexes combined is estimated to be 67.8 years, for females at birth is 68.9 years and for males at birth is 66.8 years. According to the 2017 estimate, the maternal mortality rate is 140 deaths/100,000 live births, Pakistan ranks 61 globally and according to the 2019 data and the neonatal mortality rate in Pakistan is 41.2. The infant mortality rate is estimated to be 55.1 deaths per 1000 live births and deaths under the age of five is estimated to be 68.2 per live births. Major diseases that cause the highest rate of mortality are: Ischemic Heart Diseases, Neonatal Disorders, Stroke, Diarrheal Disorders, Lower Respiratory Infections, Road Injuries, COPD, Cirrhosis, Tuberculosis, Measles, Diabetes.

According to the estimates 78,718,725 persons or 58.75% of adult population (aged 15 years and above) in Pakistan are literate. Accordingly, about 55,259,993 adults are illiterate. The literate adult male population is 71.5% and literate female population is 45.29%. The sex ratio in Pakistan is 103.9 male(s)/female. Fertility rate is estimated to be 3.6 live births per woman in 2020. The nominal (current) Gross Domestic Product (GDP) of Pakistan is $304,951,818,494 (USD) as of 2017.

The air quality in Pakistan is considered to be unsafe, the most recent data indicates the country's annual mean concentration of PM2.5 is 58 µg/m3, is exceeding the recommended maximum of 10 µg/m3 by the World Health Organization’s (WHO) air quality guidelines. Several cities in Pakistan rank prominently among the most polluted cities globally.. Contributors to poor air quality in Pakistan include vehicle emissions, solid waste burning, and industrial emissions. Air pollution is responsible for nearly 22% of premature deaths in Pakistan. More than 5.88% of GDP ($47.8 billion) is the estimated economic burden of air pollution in Pakistan.

About 20% of the whole population of Pakistan has access to safe drinking water. The remaining 80% of population is forced to use unsafe drinking water due to the scarcity of safe and healthy drinking water sources. Drinking water quality is poorly managed and monitored. It is estimated that, 30% of all diseases and 40% of all deaths are due to poor water quality. Diarrhea, a waterborne disease, is reported as the leading cause of death in infants and children in Pakistan. The cost of drinking poor quality water is estimated at Rs 114 billion yearly. Similarly, 20-40 per cent of the total hospital beds in Pakistan are occupied by patients suffering from water-borne diseases (World Wide Fund for Nature [WWF] 2007).

Soil pollution in mainly caused due to heavy trace metals, such as arsenic, cadmium, lead, chromium, nickel, and mercury, are important environmental pollutants, particularly in areas with high anthropogenic pressure. In Sargodha, the highest concentrations of Cd in the soil was found to be 6.74 mg/Kg and the higher values of Cd in soil suggested the possible risk of Cd entering into higher food chain.

Industrial noise in Pakistan is greatest emerging from weaving looms of textile industry, steel mills and airports in the largest cities. It has been officially recorded that Karachi is ranked eighth in world figures for noise pollution. Road traffic noise has been established as the most significant source in the city of Karachi. People suffer from headache, sleeplessness, hypertension, psychological stress, elevated blood pressure and dizziness due to noise.

8.1 COUNTRY OVERVIEW WITH DEMOGRAPHY

Pakistan is bounded to the west by Iran, to the northwest by Afghanistan, to the northeast by China and to the east and southeast by India. The Arabian Sea coast forms its southern boundary. Pakistan sits on the west end of the Great Indo-Gangetic Plain. Around three-fifths of the country's total area consists of rugged mountainous terrain and plateaus, and the remaining two-fifths are a large expanse of flat plains. Several important rivers flow into Pakistan from, or via, the Kashmir Mountains. One of the longest mountain glaciers in the world, Siachen Glacier feeds the Nubra River, a tributary of the Shyok. The many glaciers in this region, especially those of the Karakoram Range, are among the few glaciers in the world that have grown in size since the late 20th century.[1]

8.1.a Demographics

8.1.a.i Population

The current population of Pakistan is estimated to be 221,659,738. The current population is equivalent to 2.83% of the total world population.The population density in Pakistan is 287 per Km^2 (742 people per mi^2) and the total land area is 770,880 Km2 (297,638 sq. miles). Currently, 35.1% of the population is urban (77,437,729 people in 2020).[2]

8.1.b.ii Literacy Rate

According to the estimates 78,718,725 persons or 58.75% of adult population (aged 15 years and above) in Pakistan are able to read and write. Literacy rate for adult male population is 71.5% and for adult female population is 45.29%.

8.1.c.iii Economy

Nominal (current) Gross Domestic Product (GDP) of Pakistan is $304,951,818,494 (USD) as of 2017. Real GDP (constant, inflation adjusted) of Pakistan reached $240,856,714,914 in 2017.GDP per Capita in Pakistan (with a population of

207,906,209 people) was $1,158 in 2017, an increase of $39 from $1,119 in 2016; this represents a change of 3.5% in GDP per capita.[3]

8.2 HEALTH SCENARIO IN PAKISTAN

Life Expectancy: The average life expectancy for both sexes combined is estimated to be 67.8 years**.** For females at birth is 68.9 years and for males at birth is 66.8 years.

Sex Ratio: The total population sex ratio in Pakistan is 103.9 male(s)/female.

Fertility Rate: The Replacement-Level Fertility represents a Total Fertility Rate (TFR) of 2.1: the average number of children per woman needed for each generation to replace itself exactly without the need for international immigration. The current fertility rate for Pakistan in 2020 is 3.425 births per woman, a 1.81% decline from 2019.

Maternal Mortality: According to the 2017 estimate, the maternal mortality rate is 140 deaths/100,000 live births. Pakistan ranks 61 globally.

Neonatal Mortality: According to the 2019 data the estimated neonatal mortality rate in Pakistan is 41.2.[4]

Infant Death and Under the age of five deaths: The infant mortality rate is estimated to be 55.1 deaths per 1000 live births and deaths under the age of five is estimated to be 68.2 per live births.[5]

8.3 SPECIFIC HEALTH ISSUES

8.3.a Magnitude of air pollution and its sources

In accordance with the World Health Organization's guidelines, the air quality in Pakistan is considered unsafe - the most recent data indicates the country's annual mean concentration of PM2.5 is 58 µg/m3, exceeding the recommended maximum of 10 µg/m3 by the World Health Organization's (WHO) air quality guidelines[6]. Globally, Pakistan ranks as the second highest country for annual PM2.5 levels, weighted by city population. Until recently, there was no government monitoring in Pakistan.[7]

8.3.a.i Health Issues due to air pollution:

- Air pollution is responsible for nearly 22% of premature deaths in Pakistan (Shaikh, 2018).

- Mostly in low- and middle-income countries. Burning fuels such as dung, wood and coal in inefficient stoves or open hearths produces a variety of health-damaging pollutants, including particulate matter (PM), methane, carbon monoxide, polyaromatic hydrocarbons (PAH) and volatile organic compounds

(VOC). Burning kerosene in simple wick lamps also produces significant emissions of fine particles and other pollutants.

- Particulate matter is a pollutant of special concern. Smaller-diameter particles (PM2.5 or smaller) are generally more dangerous and ultrafine particles (one micron in diameter or less) can penetrate tissues and organs, posing an even greater risk of systemic health impacts.

- Exposure to indoor air pollutants can lead to a wide range of adverse health outcomes in both children and adults, from respiratory illnesses to cancer to eye problems.[8]

8.3.a.ii Covid-19 and its impact on air pollution:

Air pollution levels across geographies have reduced considerably due to reduced fossil fuel consumption in transportation, industries and power plants along with reduction in other sources of pollution. Last few weeks data for Pakistan has shown that the lockdown in Pakistan has resulted in a drastic drop in pollution level in many cities across the country.[9],[10]

Poor fuel quality and increasing vehicle concentration have been blamed as the primary cause of poor air quality in Pakistan, and the drastic decrease in vehicular mobility has cut down a major proportion of urban emissions.[11]

8.3.a.iii Psycho social and economic burden of air pollution:

Pakistan air pollution has an annual PM 2.5 average of 74.3 µg/m³. More than 5.88% of GDP ($47.8 billion) is the estimated economic burden of air pollution in Pakistan. Ambient air quality problems tend to be most severe in urban areas, where population, pollution sources, automobiles, and industry are most concentrated. In Pakistan, more than 35% of the population lives in urban areas, most of them in cities of more than 1 million inhabitants. Air pollution is associated with increased respiratory illness and premature mortality. By 2005, the direct cost of the damage associated with outdoor air pollution was estimated at 1.1% of Pakistan's GDP or US$1.07 billion. At that time, more than 22,600 deaths per year were directly or indirectly attributable to ambient air pollution in Pakistan, of which more than 800 are children under five years of age (World Bank 2006, 2008).

Outdoor air pollution alone caused more than 80,000 hospital admissions per year, nearly 8,000 cases of chronic bronchitis, and almost 5 million cases of lower respiratory cases among children under five. (WHO 2011).

These PM2.5 concentrations are estimated to cause over 9,000 premature deaths each year, representing 20% of acute lower respiratory infection (ALRI) mortality among children under five years of age, 24% of cardiopulmonary mortality, and 41% of lung cancer mortality among adults 30 or more years of age in these cities. About 12% of the deaths are among children under five years of age and 88% are among adults. Nearly 80% of the deaths are in Karachi. PM concentrations are also the estimated cause of 59% of chronic bronchitis cases in these cities, or a total of nearly 185,000 cases, and nearly 33,000 hospital admissions, over 645,000 emergency room visits, over 1.6 million cases of ALRI in children, over 100 million restricted activity days, and over 300 million respiratory symptoms annually. These annual health effects represent 203,000 DALYs, of which 97,000 are from premature mortality and 106,000 from morbidity.

8.3.a.iv Measures to mitigate air pollution:

- A national monitoring network offering data granularity and coverage in more cities is critically important to better understand emission sources and drive action.
- Current anti-smog measures include stricter emission standards on factories, as well as fining heavily polluting vehicles and farmers burning crop stubble.
- Implementation of well-targeted interventions could possibly improve ambient PM2.5 air quality in Karachi by 40–50% over the next 10–15 years.
- A strategy and action plan to control PM emissions from road vehicles will need to address in-use vehicles, and new and imported second hand vehicles entering the roads.
- Adapting the art of more efficient pollution/emission control technologies for the industries, power generation facilities and transport vehicles to reduce their emission load and pollution.
- Fast-track deployment of new Hydro-cracking refineries as well as installation of Diesel Hydro-desulphurisation (DHDS) units in existing local refineries to move towards Low Sulphur fuels, while renegotiating import contracts to opt for cleaner Euro-6 gasoline and diesel.
- Switch our transportation system from being biased towards promoting privatised modes of transportation to better public transportation facilities and systems.
- Develop Non-Motorised-Transportation (NMT) systems such as walking and cycling as modes for movement for citizens rather than vehicles.
- Invest aggressively in cleaner and renewable energy sources.

8.3.b Magnitude of water pollution and its sources

About 20% of the whole population of Pakistan has access to safe drinking water. The remaining 80% of population is forced to use unsafe drinking water due to the scarcity of safe and healthy drinking water sources. Drinking water quality is poorly managed and monitored.

The primary source of contamination is sewerage (fecal) which is extensively discharged into drinking water system supplies. The secondary source of pollution is the disposal of toxic chemicals from industrial effluents, pesticides, and fertilizers from agriculture sources into the water bodies. The drinking water quality and quantity are very low because of poor treatment of deteriorated water and old sanitation system in urban areas.[12]

The release of toxic chemicals from urban communities and industries without any treatment into water bodies deteriorates water quality and also causes adverse effects to human beings.

8.3.b.i Health issues due to water pollution:

- Anthropogenic activities cause waterborne diseases that constitute about 80% of all diseases and are responsible for 33% of deaths. (Daud et al. 2017).

- It is estimated that, 30% of all diseases and 40% of all deaths are due to poor water quality. Diarrhea, a waterborne disease, is reported as the leading cause of death in infants and children in Pakistan while every fifth citizen suffers from illness and disease caused by the polluted water

- Approximately 60 million people are at risk of being affected by high concentrations of arsenic in drinking water; the largest mass poisoning in history (Guglielmi 2017). (Rahman et al. 2018).

- In most of the cities of Pakistan, the elementary source of provision is ground water supply, which contains various pathogens including many viral, bacterial, and protozoan agents causing 2.5 million deaths from endemic diarrheal disease each year.[13]

- The main reasons of waterborne diseases in drinking water are the addition of municipal sewage and industrial wastewater at different points of the water distribution network as well as lack of water disinfection and water quality monitoring at treatment plants.

- Diseases such as cholera, typhoid, dysentery, hepatitis, giardiasis, and cryptosporidiosis and guinea worm infections represent about 80% (including diseases due to sanitation problem) of all diseases and are responsible for 33% of deaths.

- In major cities of Sindh and Punjab, about sixteen percent of people are exposed to more than 50 ppm of arsenic. Higher concentration of fluoride above permissible limits causes a trouble in major areas of Baluchistan, Punjab, and Sindh. The dental fluorosis diseases are commonly found in Sindh, Punjab, and Khyber Pass.

- The concentration of nitrate (NO_3) was found above the permissible limits causing blue baby syndrome in bottle fed babies. The average daily intake of potassium (K) by adults was noted to be less than 0.1% through water. Diseases such as hypertension, kidney diseases, heart problem, muscle weakness, bladder weakness, and asthma may be caused due to K level decreasing in blood and increase in level may cause cysts, reduced renal function, rapid heartbeat, and improper metabolism of proteins. The major source of sodium (Na) is the deposition of minerals into the water.

- Major health problems were reported as gastroenteritis (40%–50%), diarrhea (47%–59%), dysentery (28–35%), hepatitis A (32%–38%), hepatitis B (16%–19%), and hepatitis C (6-7%) by respondents. In southern Sind, waterborne diseases such as diarrhea, vomiting, gastroenteritis, dysentery, and kidney problem are caused by polluted drinking water.[14]

8.3.b.ii Economic burden of water pollution:

An estimated 250,000 child deaths occur each year as a result of water-borne diseases. Inadequate quantity or quality of water and lack of sanitation facilities result in diseases such as diarrhea, typhoid, intestinal worms, and hepatitis. The cost of drinking poor quality water is estimated at Rs 114 billion yearly. Similarly, 20-40 per cent of the total hospital beds in Pakistan are occupied by patients suffering from water-borne diseases (World Wide Fund for Nature [WWF] 2007). Owing to the unavailability of safe drinking water and sanitation services, the effects are not only seen on human health but also on economy. Environmental degradation costs Pakistan Rs 365 billion a year.[15]

8.3.b.iii Measures to mitigate water pollution:

- An effective National Water Policy and management is needed to conserve and enhance water resources, minimize drinking water pollution, and improve the country’s water supply with proper sewerage facilities.

- Bottled drinking water: Although this seems to be an expensive option, keeping in view the higher concentration of arsenic (50 μg/L) (Guglielmi 2017), fecal , bacterial, and other contamination in drinking water (Sahoutara 2017), it is time to switch to the bottled drinking water.

- Reforestation: Annually, Pakistan loses approximately 2.1% of its forests. If this rate continues, Pakistan will run out of forests within the next 50 years (Randhawa 2017).

- Glacier conservation: Outside the polar region, Pakistan has the highest numbers of glaciers (> 7200) than any other country (Khan 2017).

- Restoring lakes

- Regulating tube-wells drilling[16]

- Awareness: In Pakistan, water is free and therefore no attention has been given by the public to its conservation. Both on the print and electronic media, awareness is needed for water conservation.

- Prevention of groundwater contamination to a greater extent.

- Reusing treated wastewater for irrigation purposes.

8.3.c Soil Pollution

Magnitude of Soil Pollution and its sources: Trace heavy metals, such as arsenic, cadmium, lead, chromium, nickel, and mercury, are important environmental pollutants, particularly in areas with high anthropogenic pressure. In addition to these metals, copper, manganese, iron, and zinc are also important trace micronutrients. The presence of trace heavy metals in the atmosphere, soil, and water can cause serious problems to all organisms, and the ubiquitous bioavailability of these heavy metal can result in bioaccumulation in the food chain which especially can be highly dangerous to human health. Sediment analyses play a crucial role in assessing the degree of heavy metal pollution and the resulting health risk associated with the food chain.

The daily As intake from food stuffs in As affected (irrigated with lake water) and unaffected (irrigated with canal water) area was found to be 343.5 and 144.7 μg/day in adults, respectively.[17]

8.3.c.i Health issues related to soil pollution:

- Heavy metals are of great concern because of their toxic properties and some heavy metals are also essential for the survival and health of humans. However, for these heavy metals (either essential or toxic) the health risk requirement requires consideration of toxicity from excessive exposure.

- In a study conducted (Arain et al.) it showed that 30–40% people of the Bobak village (near Manchar Lake, Sindh) were suffering from rough skin with black dots and arsenical skin lesions, especially on face, arms, and feet, possibly due to overexposure of high arsenic contents. Another study revealed that 61 to 73% people of villages on the bank of Manchar lake suffer from chronic arsenic toxicity like melanosis and keratosis.[18]

- People have also experienced clinical features like respiratory problems, anemia, gastrointestinal problems, muscles cramps, and weakness.

- Due high level of lead in the blood, neurological, physiological, and behavioral problems were also observed in the exposed population.

- Exposure to Cadmium especially in children is observed to have bone resorption, suggesting a direct osteotoxic effect with increased calciuria.

8.3.c.ii Economic Burden of Soil Pollution:

Climate change is affecting almost all the sectors of our economy particularly water resources, energy, health, biodiversity, with a major impact on agricultural productivity. This is due to changes in temperature, adverse effect on land and water resources and enhanced frequency and intensity of natural hazards such as droughts and floods. Dry land areas, such as arid and semi-arid regions are most vulnerable to these changes; such regions are already facing significant water shortages and temperatures are already close to their tolerance limits. The increasing temperatures increase crop stresses (thermal and moisture stresses), change irrigation water requirements, and increasing the risk of pests and diseases. Sustenance of agriculture sector and agri-based industries depend upon ample and steady supply of water for irrigation.[19]

8.3.c.iii Measures to mitigate soil pollution:

Some of the measures to mitigate soil pollution in Pakistan would be:

- It has been proposed that organic farming can reduce the level of some negative externalities from (conventional) farming.
- A feasible way to reduce land pollution in Pakistan would be to implement recycling centers of large capacity.
- Bio remediation, where microorganisms are used to consume the pollution-causing compounds as well as electromechanical systems for extracting chemicals, and containment of chemicals by paving over the tainted area.[20]
- Use of bio-fertilizers and organic fertilizers.
- Tackling salinity.
- Growing drought and salt tolerant crops
- Implementing the necessary policies required

8.3.d Noise Pollution

8.3.d.i Noise pollution and its sources:

Industrial noise in Pakistan is greatest emerging from weaving looms of textile industry, steel mills and airports in the largest cities. For instance, average noise levels in a textile mill in Karachi were found to vary between 85 and 112 dB. In the sheet metal industry, 8% of workers had noise-induced hearing impairment. Another study of Karachi textile workers found that 22% of those exposed to noise had noise-induced hearing loss compared to 2% of controls. Exposure to noise in day to day life leads to mood changes, anxiety, sleep disturbance and reduced work efficiency. Also, causes Titinnus.[21]

8.3.d.ii Measure to mitigate noise pollution:

Traffic authorities should initiate measures to reduce the noise levels in the city particularly at high noisy places. Noise meters should be installed on major noise producing intersections. When these noise meters indicate noise levels above 90 dB (permissible level) traffic should be diverted to other areas to reduce noise level.[22]

ANNEXE: FIGURES, TABLES AND GRAPHS

Table 1: Demographics of Pakistan

2020 world percentage	**2.81%**
2020 population rank	**5**
Growth rate	**2.0%**
Density	**287/Km2**
Area	**770,880Km2**
Capital city	**Islamabad**
Region	**South Asia**
Government	**Government of Pakistan (GoP)**

Fig 1: Life expectancy in Pakistan (1955-2020)

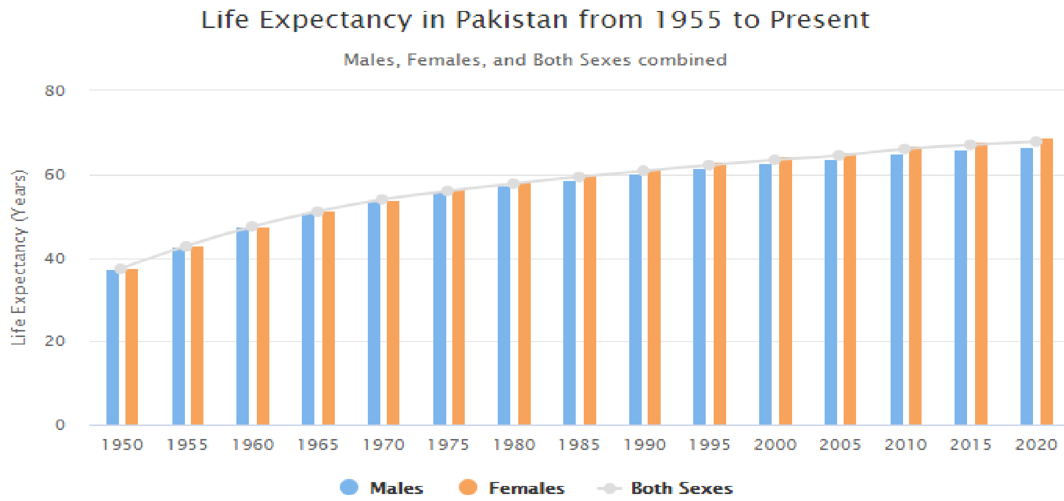


Fig 2: Maternal mortality rate. Pakistan ranks 61 globally.

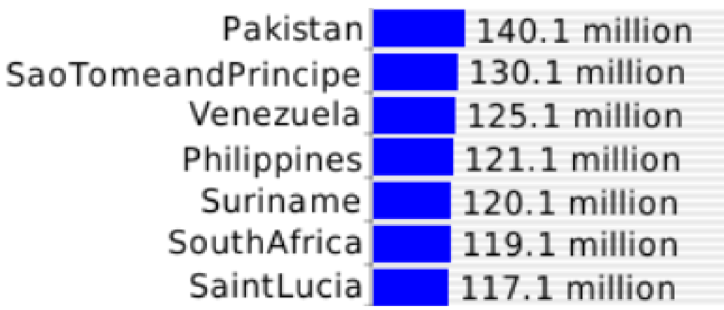


Fig 3: Neonatal mortality in Pakistan

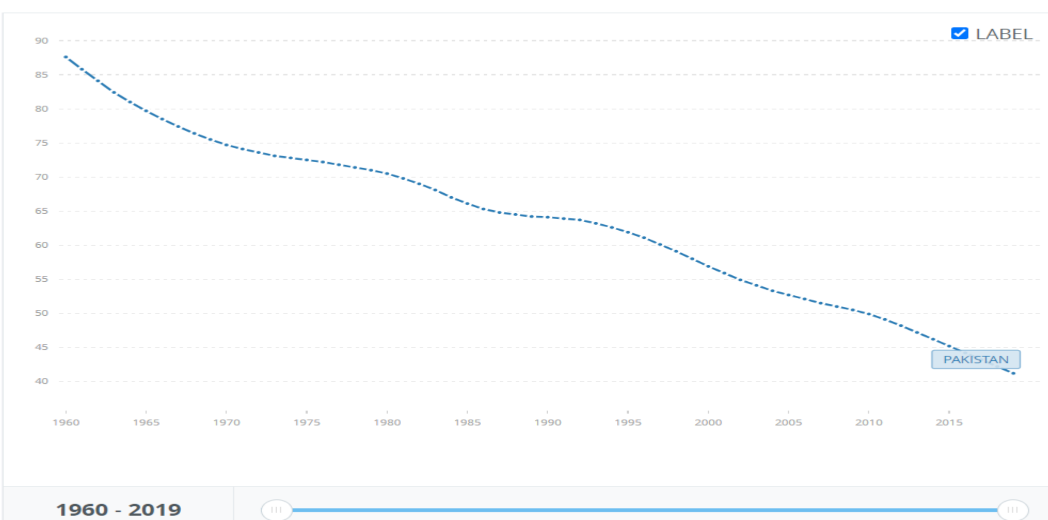
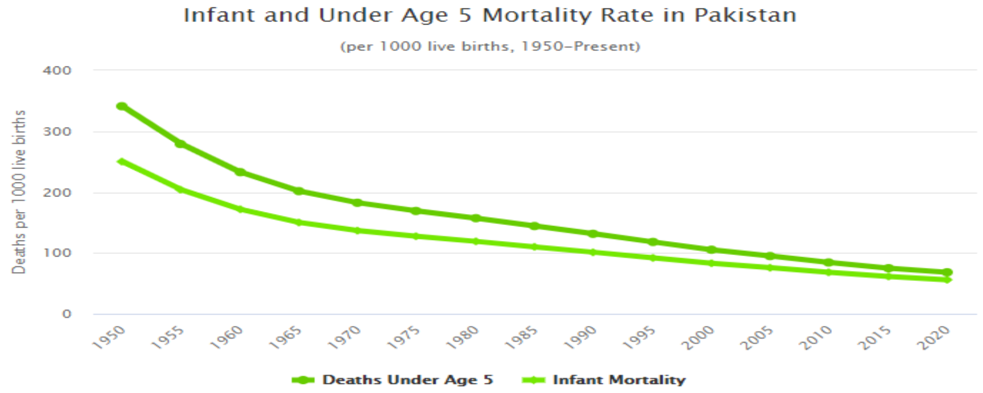


Fig 4: Infant and Under age 5 mortality



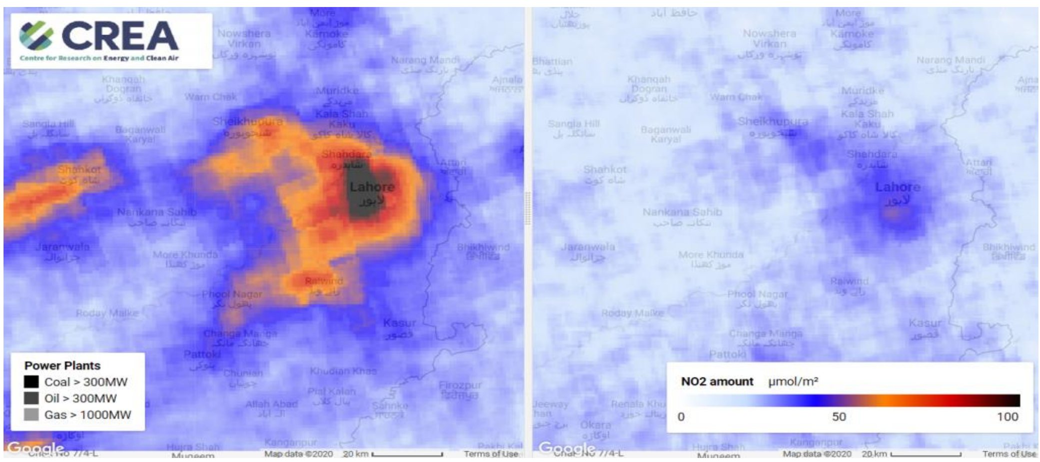
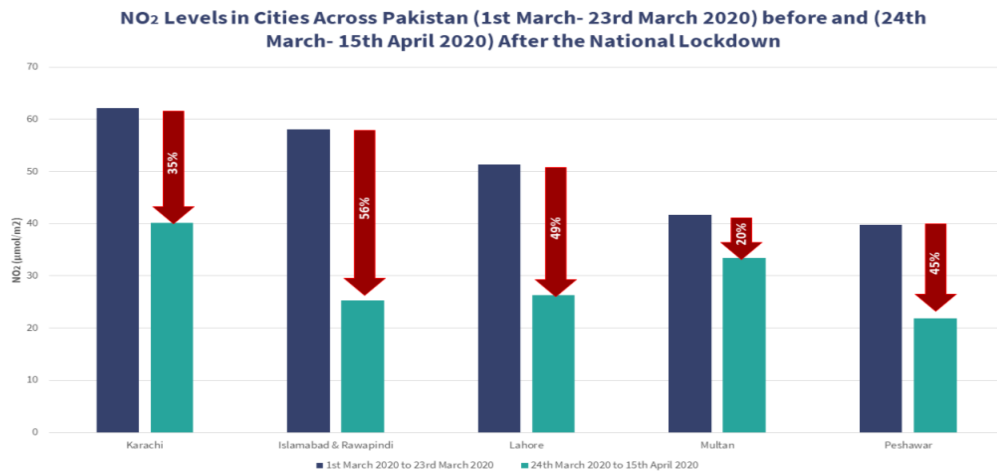


Fig 5: PM 2.5 for 2019

PM2.5: µg/m³	2019 Annual AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Karachi	40.2	86.7	42.1	32.4	18.2	16.1	18.1	23.3	22.2	28.5	44.9	67.1	75.9
Lahore	89.5	199.1	110.3	73.6	62.5	53.7	44.5	39.9	40.9	54.7	104.6	134.9	182.7
Faisalabad	104.6	223.0	128.3	82.0	59.1	56.5	46.3	54.2	58.4	66.5	92.0	148.5	226.2
Gujranwala	105.3	220.4	127.4	86.4	70.9	65.8	53.3	59.2	48.8	67.4	107.6	144.9	217.3
Peshawar	63.9	81.2	44.3	28.6	53.7	44.4	56.4	52.8	41.4	60.9	75.2	77.9	113.5
Islamabad	35.2	37.0	24.9	18.6	17.2	14.6	20.5	31.7	29.8	42.9	40.0	48.8	96.3

Fig 6: Covid-19 and its impact on Air pollution

Fig 7: Map showing NO_2 reductions over Lahore before (1st March- 23rd March 2020) and after (24th March- 15th April 2020) the national lockdown announcement



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9. Health Sensitization in Sri Lanka

9. Health Sensitization in Sri Lanka

SUMMARY

Sri Lanka, formerly Ceylon, is an island country lying in the Indian Ocean and separated from peninsular India by the Palk Strait. It has a maximum length of 268 miles (432 km) and a maximum width of 139 miles (224 km). Colombo is the executive and judicial capital of Sri Lanka. Sri Jayewardenepura Kotte, a Colombo suburb, is the legislative capital. The current population of Sri Lanka is 21,430,438. The urban population is 18.4 % of the total population (3,945,488 people) and the population density in Sri Lanka is 341 per Km2

Maternal mortality rate is 36 deaths/100,000 live births and neonatal mortality rate was reported to be 4.5% in 2018, according to the World Bank. The infant mortality rate is 6.4 deaths per 1000 live births and under the age of five mortality rate is 7.3 deaths per 1000 live births. The average life expectancy at birth for both sexes combined is 77.6 years, for females it is 80.7 years and for males is 74.3 years.

The majority of its people are poor, live in rural areas, and depend on agriculture for their livelihood. The nominal (current) Gross Domestic Product (GDP) of Sri Lanka is $87,357,205,923 (USD) as of 2017. According to estimates 14,737,231 persons or 92.64% of adult population (aged 15 years and above) are literates. The total sex ratio in Sri Lanka is 95.4 male(s)/female. The fertility rate in Sri Lanka is 2.177 births per woman, a 0.77% decline from 2019. The public expenditure on health as percentage of GDP is 1.68% and per capita public expenditure on health is U.S.$ 68 as on 2016.

Diseases that cause the highest number of mortalities in the country are: Ischemic Heart Diseases, Stroke, Diabetes, Asthma, Alzheimer's Disease, Lower Respiratory infect, COPD, Self- harm, Chronic kidney disease, Cirrhosis.

The AQI (Air quality Index) for Sri Lanka is considered to be Moderate (51-100). The average air quality for PM2.5 in 2019 was 78µ/g, which was two times above the WHO exposure recommendation.

The most important air pollutants are: PM2.5, PM10, ground-level ozone (O3), carbon monoxide (CO), sulfur oxides (SO x), nitrogen oxides (NOx), and lead (Pb). PM, CO, SO x, NOx, environmental tobacco smoke (ETS), formaldehyde and polycyclic organic matter are the pollutants found indoors. Indoor air pollution remains a large threat as 66% of the population use biomass for cooking. Use of inefficient stoves and biomass, poor ventilation and absence of chimneys, tobacco smoke, volatile organic compounds, asbestos, pesticides, kerosene, mercury and biological pollutants are some of the indoor air pollutants. The air quality has been deteriorating mainly in the urban areas due to stagnant and low dispersion of air pollutants generated by vehicles, thermal power plants, Industries, open burning of waste, resuspension of road dust, refineries, biomass burning and other commercial activities within the country.

Ambient air pollution attributable death rate (per 100 000 population) is 27 in Sri Lanka. Second hand smoke (SHS) is a common source of Indoor Air Pollution in Srilanka, according to the Global Youth Tobacco Survey of 2007, 65.9 % (95% CI, 62.1 - 69.5) of Sri Lankan school children (aged 13 – 15 years) reported that they have been exposed to Second hand smoke in public places.

Water pollution mainly results from domestic activities, agriculture and industries. Algal blooms are the most dominating source for the originating of eutrophication. When the organic contents of the water body increases, it causes oxygen depletion and effects aquatic life. People die every year from water-borne diseases such as typhoid, cholera, kidney diseases, paratyphoid fever, Dysentery, Jaundice, Amoebiasis and Malaria.

Soil erosion in Sri Lanka is a serious problem. It has numerous impacts on crop productivity, economic growth, income distribution, food production and long-term environmental stability. About 70% percent of Yala rainfall and 50-55% of Maha rainfall are erosive. In many areas, new lands are cleared for agriculture, settlement and other developmental activities, without investigation of suitability for the purpose. This has resulted environmental degradation, loss of natural resources, such as soil and water, inefficient economic exploitation and ultimately, poverty.

In a study conducted in Colombo, Sri Lanka, the LA eq (8 hrs) within Colombo ranged 76.6 to 84.0 dB; well above the Sri Lankan recommendation of 63.0 dB (an increase of 13.3 to 21.0 dB), and the WHO recommendation of 55.0 dB (an increase of 21.6 to 29.0 dB).

Main sources of community noise include road traffic, rail and air traffic, and construction. Other community noise pollution sources include; religious establishments, car alarms, emergency service sirens, mechanical equipment, fireworks, compressed air horns, electric appliances, audio entertainment systems, electric megaphones, and public address systems such as loud speakers. Health effects due to excessive noise can range from mild effects such as annoyance to more serious effects such as noise induced hearing loss and Ischemic heart disease. Exposure to loud noise can also cause high blood pressure, heart disease, sleep disturbances, and stress. Many children who are exposed to loud noise, have been found to suffer from stress and other problems, such as impairments in memory, attention level, and reading skill.

9.1 COUNTRY OVERVIEW WITH DEMOGRAPHY

Sri Lanka, formerly Ceylon, island country lying in the Indian Ocean and separated from peninsular India by the Palk Strait. It has a maximum length of 268 miles (432 km) and a maximum width of 139 miles (224 km). Colombo is the executive and judicial capital of Sri Lanka. Sri Jayewardenepura Kotte, a Colombo suburb, is the legislative capital. The majority of its people are poor, live in rural areas, and depend on agriculture for their livelihood. A roughly triangular mountainous area known as the Central Highlands occupies the south-central region of Sri Lanka and is the heart of the country. This highland mass is surrounded by a diverse plain, the general elevation of which ranges from sea level to about 1,000 feet (300 metres). This plain accounts for about five-sixths of the country’s total area. The Central Highlands have a highly dissected terrain consisting of a unique arrangement of plateaus, ridges, escarpments, intermontane basins, and valleys[1]

9.1.a Demographics

9.1.a.i Population

The current population of Sri Lanka is 21,430,438**.**

The population density in Sri Lanka is 341 per Km^2 (884 people per mi^2) in a total land area of 62,710 Km2 (24,212 sq. miles). The urban population is 18.4 % of the total population (3,945,488 people in 2020).[2]

9.1.b.ii Literacy Rate

According to estimates 14,737,231 persons or 92.64% of adult population (aged 15 years and above) in Sri Lanka are able to read and write

9.1.c.iii Economy

- Nominal (current) Gross Domestic Product (GDP) of Sri Lanka is $87,357,205,923 (USD) as of 2017.

- GDP Growth Rate in 2017 was 3.31%, representing a change of 2,643,858,692 US$ over 2016, when Real GDP was $79,903,861,972.

- The Gross Domestic Product (GDP) in Sri Lanka was worth 84.01 billion US dollars in 2019, according to official data from the World Bank and projections from Trading Economics. The GDP value of Sri Lanka represents 0.07 percent of the world economy.[3]

9.2 HEALTH SCENARIO IN SRI LANKA

Life Expectancy: The average life expectancy at birth for both sexes combined is 77.6 years. Life expectancy for females at birth is 80.7 years and for males is 74.3 years.

Sex Ratio: The total population ratio is 95.4 male(s)/female.[4]

Fertility Rate: The current fertility rate for Sri Lanka in 2020 is 2.177 births per woman, a 0.77% decline from 2019.**Maternal Mortality:** 36 deaths/100,000 live births (2017 est.) country comparison to the world. **Neonatal Mortality:** The neonatal mortality rate in Sri Lanka was reported to be 4.5% in 2018, according to the World Bank.

Infant Mortality and Under the age of five deaths: The infant mortality rate is 6.4 deaths per 1000 live births and under the age of five mortality rate is 7.3 deaths per 1000 live births.[5] **Disease Prevalance:** The disease prevalence that causes the highest number of deaths are:[6] Ischemic Heart Diseases, Stroke, Diabetes, Asthma, Alzheimer's Disease, Lower Respiratory infect, COPD, Self- harm, Chronic kidney disease and Cirrhosis.

9.3 SPECIFIC HEALTH ISSUES

9.3.a Magnitude of Air Pollution and its sources

The AQI for Sri Lanka is considered to be Moderate (51-100). The average air quality for PM 2.5 in 2019 was 78µ/g, which was two times above the WHO exposure recommendation.

Sri Lanka ranks 25 globally in Air pollution in 2019 and the most polluted city is Colombo, Western with 78µ/g in 2019.[7] The most important air pollutants are: PM2.5, PM10, ground-level ozone (O_3), carbon monoxide (CO), sulfur oxides (SO_x), nitrogen oxides (NO_x), and lead (Pb) which are found in the ambient air (also known as "criteria pollutants").

PM, CO, SO_x, NO_x, environmental tobacco smoke (ETS), formaldehyde and polycyclic organic matter are found indoors.[8] Indoor air pollution remains a large threat as 66% of the population use biomass for cooking. Use of inefficient stoves and biomass, poor ventilation and absence of chimneys, tobacco smoke, volatile organic compounds, asbestos, pesticides, kerosene, mercury and biological pollutants are some of the indoor air pollutants.

9.3.a.i Health Related Issues due to Air Pollution:

- Subclinical effects of air pollution, such as temporary deficits in lung function or pulmonary inflammation, may occur in most of those people exposed while mortality may occur in a few. It is usually the more susceptible who suffer from more severe effects.[9]

- Several population groups are more vulnerable to the effects of air pollutants, such as, those who are innately more susceptible to the effects of air pollutants than others, those who become more susceptible as a result of environmental, social and personal behaviors, and those who are simply exposed to unusually large amounts of air pollutants.[10].

- Many pollutants act together in a series of partly inter-related biological mechanisms which result in a range of adverse health outcomes.[11]

- Indoor air pollution from combustion of solid fuels for cooking and space heating is one of the ten most important risk factors contributing to the global burden of disease. The World Health Organization (WHO) estimated that the number of deaths attributable to Indoor Air Pollution in Sri Lanka in 2004 was 4300.[12]

9.3.a.ii COVID-19 Pandemic and its impact on Air Pollution: Air pollution in Sri Lanka's urban areas has decreased by up to 75% during the lockdown imposed in response to the COVID-19 pandemic.[13] Most industries and commercial enterprises have also stopped their activities, which minimizes wastewater and solid waste generation and reduces methane, H2S, and other related air pollutant emissions.

9.3.a.iii Future Prediction for Sustainability:

Robust research studies should be designed to generate individual exposure data, identify and evaluate determinants associated with air pollution exposures and to quantify the public health effects of such exposures in Sri Lanka. Public health impact of outdoor air pollution control activities should be assessed to monitor and modify such mitigation activities. Modifying existing regulatory practices based on findings of robust research studies, strict adherence to regulations at community and household level and identifying new mitigation strategies can play a key role in minimizing the impact of air pollution on health.[14]

9.3.a.iv Measures to mitigate Air pollution:

- Measures have been taken to reduce outdoor air pollution due to vehicular emissions. The National Policy on Urban Air Quality Management was adopted in 2000.

- The phasing out of leaded gasoline in June 2002, introduction of low sulphur diesel in January 2003, banning the importation of Two Stroke Three-wheelers in 2008, and initiation of vehicular emission testing programme in the year 2008 are some key steps that have been taken to control urban outdoor air pollution in Sri Lanka.

- The permissible ambient air quality standards for selected air pollutants were for the first time enacted under the National Environmental (Ambient Air Quality) Regulations of 1994.

- With the publication of WHO air quality guidelines in 2005, air quality standards for Sri Lanka, including standards for PM_{10} and $PM_{2.5}$, were amended and gazzetted in August 2008.[15]

9.3.b Magnitude of Water Pollution and its Sources

In Sri Lanka, water pollution mainly results from domestic activities, agriculture and industries. Less amount of people have access to municipal water. At the same time, local authorities do not monitor water quality well. Algal blooms are the most dominating source for the originating of eutrophication. When the organic contents of the water body increases, it causes oxygen depletion and effects aquatic life.[16] Water Quality Amount of Dissolved Oxygen (mg/l): Excellent 8.0 – 9.0; Slightly 6.7 – 8.0; Moderately Polluted 4.5 – 6.0; Highly polluted < 4.5.

9.3.b.i Health Related Issues due to Water Pollution

Pollution of water resources is another serious environmental problem in Sri Lanka. People die every year from water-borne diseases such as typhoid, cholera, kidney diseases, paratyphoid fever, Dysentery, Jaundice, Amoebiasis and Malaria.

9.3.b.ii Covid-19 Pandemic and its impacts on Water pollution:

Sri Lanka's lockdown has also seen a decline in marine pollution. We have observed that plastic pollution on the beaches has gone down by 40% while nitrate and phosphate levels have decreased by 30%. Around 80% of marine pollution originates on land, and different types of plastic comprise most of it. Huge garbage patches float on the waves, toxic microplastics are eaten by fish and work their way up the food chain, and chemical pollutants create dead zones with low oxygen and cause algal blooms that can kill fish and contaminate ecosystems.

The lockdown measures have helped reduce air and marine pollution, at least for a limited time. The pandemic offers an opportunity to look at a cleaner, healthier, less polluted world, if only for a brief window of time.[17]

9.3.b.iii Measures to mitigate water pollution:

Proper sewage treatment and management.

- Proper method of trash disposal.

- Avoiding direct dumping of waste into water bodies.

- Reduction in excessive use to pesticides, herbicides and fertilizers

- To enforce polluter pays principle for water pollution due to industrial activities and other polluters.

- Reduce fertilizer leaching and eutrophication.

9.3.c Magnitude of Soil Pollution and its sources

The land area of Sri Lanka is 65,610 km2 (Survey Dept., 2007). Of this, nearly two million hectares are used for agricultural purposes (Dept. of Census and Statistics, 2016).

The average size of a small-holding in Sri Lanka declined by 64% over the last 56 years, from 1.3 ha in 1946 to 0.47 ha by 2002 (Dept. of Census and Statistics, 2002), while 66% of cropland is rain-fed, therefore, increasingly vulnerable to impacts of climate variability and climate extremes. Soil erosion in Sri Lanka is a serious problem. It has numerous impacts on crop productivity, economic growth, income distribution, food production and long-term environmental stability.

Soil erosion in a Maha season can be as high as 54 t ha-1 from chena lands (Dharmasena, 1992a). About 70% percent of Yala rainfall and 50-55% of Maha rainfall are erosive. Annual erosivity in the central dry zone ranges from 116 t m ha-1 (in Maha Illuppallama) to 162 t m ha-1 (in Kantale), and 55-65% of annual erosive rains occur during the Maha season (Dharmasena, 2003). Rain-fed farming areas in dry and intermediate zones become less productive because proper soil conservation measures are not being adopted, indicating that the mismanagement of land and improper land uses are the main causes for accelerating soil erosion.

Some farmers and land owners in Sri Lanka are using their land sustainably, based on generations of experience. However, many others are not doing so. In many areas, new lands are cleared for agriculture, settlement and other developmental activities, without investigation of suitability for the purpose. This has resulted environmental degradation, loss of natural resources, such as soil and water, inefficient economic exploitation and ultimately, poverty. The best use for land depending on economic, social, political and cultural conditions, but as importantly, on soil characteristics and their response to use.[18]

9.3.c.i Health impacts due to Soil Pollution:

- The health issues can be induced directly (vegetables and fruits) and indirectly (animal pathway) entering the food chain, further affecting the ingestion of pathogenic organisms, ingestion of nutrient-deficient crops contributing to malnutrition, undernutrition and food insecurity, and thereby contaminating water through soil leaching.

- There are large numbers of metals and metalloids included under the category of heavy metals: Cd, As, Pb, Ni, Zn, Cu and Hg. Some agricultural practices are commonly considered as major sources of adding heavy metals to the environment. It has been reported that agriculture is one of the fundamental sources of heavy metal pollution in coastal areas of Sri Lanka.[19]

- Consumption of contaminated food has been taken into account as the primary pathway for human exposure to potentially toxic heavy metals.

- Cadmium is one of the well-established nephrotoxicants, both with acute and chronic exposures.

- Chronic Arsenic poisoning among people living in many areas of the world has been reported as it may cause different life-threatening diseases. Increased exposure to Arsenic causes a significant increase of renal diseases.[20]

9.3.c.ii Economic Burden of Soil Pollution:

A computable general equilibrium model incorporating soil erosion is developed to analyze the impacts of various policy reforms in Sri Lanka. Our analysis establishes three important results. First, economic losses from soil erosion in Sri Lanka are substantial. Second, trade liberalization reforms increase national income and marginally reduce soil erosion. Third, while trade liberalization has a positive impact on soil erosion, complementary policies which directly target soil erosion, such as tax/subsidy incentives, are needed to minimize social losses from soil erosion.[21]

9.3.c.iii Measures to mitigate Soil Pollution:

- Reducing the use of fertilizers.

- Rehabilitating the degraded agricultural lands. Land degradation due to soil erosion and decline in soil fertility is a major issue in the central highlands of Sri Lanka with 50% of agricultural lands in a degraded condition.

- Leaving all the crop residues in the field; Practicing conservation tillage that leaves residues on the soil surface; Applying organic materials as manures or mulch; Adapting inter-cropping and relay cropping and leaving weed residues on the surface; all this will reduce soil erosion; increase the infiltration rate; reduce water loss through evaporation; reduce soil temperature; improve seed germination; increase organic matter content in the surface soil layer; improve the soil stability; stimulate soil biological activity; increase soil aeration; facilitate biological pest control; and suppress weed growth.

- Soil erosion is a serious threat to agricultural production mainly because of two reasons, firstly, it takes a long period of time to recognize that the land is being degraded due to soil erosion. Secondly, the problem of soil erosion problem is usually addressed by looking at the consequences, rather investigating and treating the cause of problem.

- Various models have been developed to simulate the likely incidence of erosion; would-be effects; agronomic, as well as engineering measures, to mitigate the problem; and the farming system approach to productive and sustainable management of 13 dry zone farm lands. Agricultural development projects have emphasized soil conservation as a major component in their work plans.[22]

9.3.d Magnitude of Noise Pollution and its Sources

In a study conducted in Colombo, Sri Lanka, the LA eq (8 hrs) within Colombo ranged 76.6 to 84.0 dB; well above the Sri Lankan recommendation of 63.0 dB (an increase of 13.3 to 21.0 dB), and the WHO recommendation of 55.0 dB (an increase of 21.6 to 29.0 dB). These levels translate into increase of sound pressure level by 21.4 to 794.3 times above the recommendations on the logarithmic scale of dB.

Main sources of community noise include road traffic, rail and air traffic, and construction. Among these sources of noise, road traffic is probably the most serious and pervasive type of noise pollution. Fast growing vehicle population in towns in the recent years, has resulted in considerable increase in traffic on roads causing alarming noise pollution and noise level increases with traffic volume in an exponential manner (Marathe 2012). The source of most outdoor noise in Colombo is mainly due to construction and transportation which includes vehicle noise and rail noise. Other community noise pollution sources include; religious establishments, car alarms, emergency service sirens, mechanical equipment, fireworks, compressed air horns, electric appliances, audio entertainment systems, electric megaphones, and public address systems such as loud speakers. Commercial activities in residential areas are increasingly creating noise nuisance to the public.[23]

9.3.d.i Health impacts of Noise Pollution:

Health effects due to excessive noise can range from mild effects such as annoyance to more serious effects such as noise induced hearing loss and Ischemic heart disease.

Exposure to loud noise can also cause high blood pressure, heart disease, sleep disturbances, and stress. These health problems can affect all age groups, especially children. Many children who are exposed to loud noise, have been found to suffer from stress and other problems, such as impairments in memory, attention level, and reading skill.[24]

9.3.d.ii Measures to mitigate Noise pollution:

- The Motor Traffic (Vehicular Horn) Regulations passed by the Parliament recently enabled the Commissioner General of Motor Traffic to carry out tests to ensure that motor vehicles are maintained to comply with the permissible noise levels.

- All forms of community noise in the city is regulated by the City Public Health Department under public nuisance act and the construction noise is regulated by the City Planning Division and the City Public Health Department.

- To minimize the noise emission due to construction activity and Ground vibration and Air blast over pressure due to blasting and compaction activity.

- Environmental noise level measurements should be carried out generally in accordance with the methods laid down in National Environmental (Noise Control) Regulation 1996 No 924/12 dated 23.05.1996 and ISO 1996 (Part 1, 2, 3) and - 4142: 1990.[25]

ANNEXE: FIGURES, TABLES, GRAPHS

Table 1: Demographics of Sri Lanka

2020 world percentage	0.27%
2020 population rank	58
Growth rate	0.612%
Density	341/Km2
Area	62,710 Km2
Capital city	Colombo
Region	South Asia
Government	Government of Sri Lanka (GoSL)

Fig 1: Urban and rural population of Sri Lanka (1955-2020)

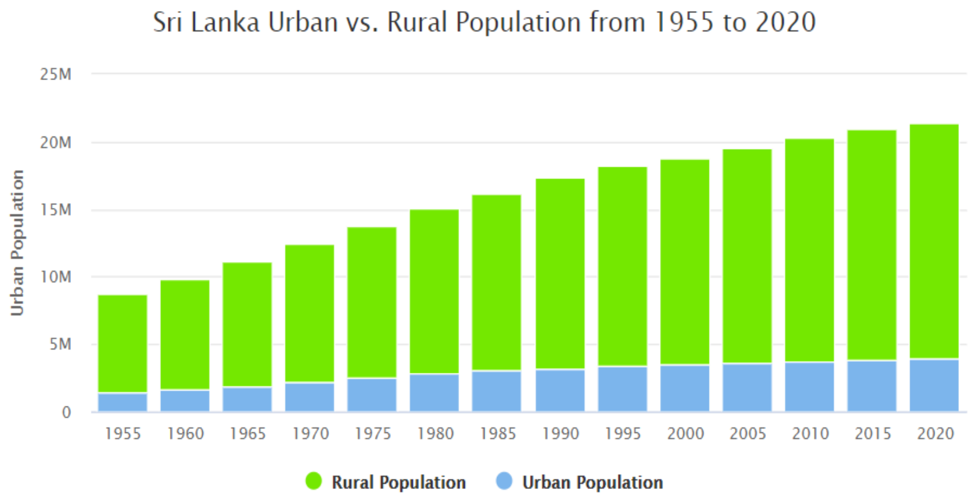


Fig 2: Life expectancy in Sri Lanka (1955 – 2020)

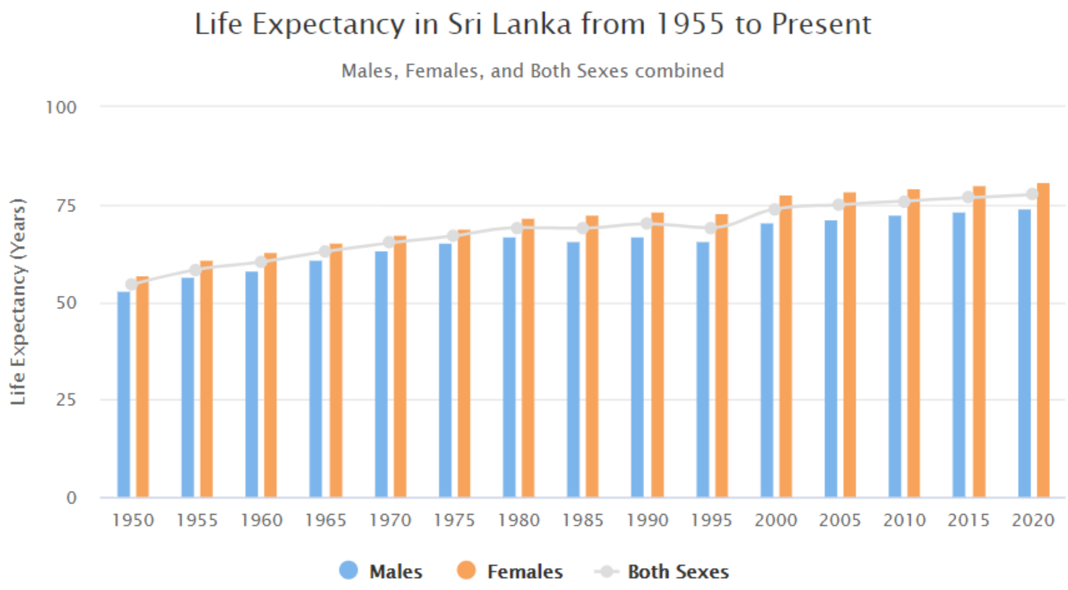


Fig 3: Infant and Under age 5 mortality in Sri Lanka

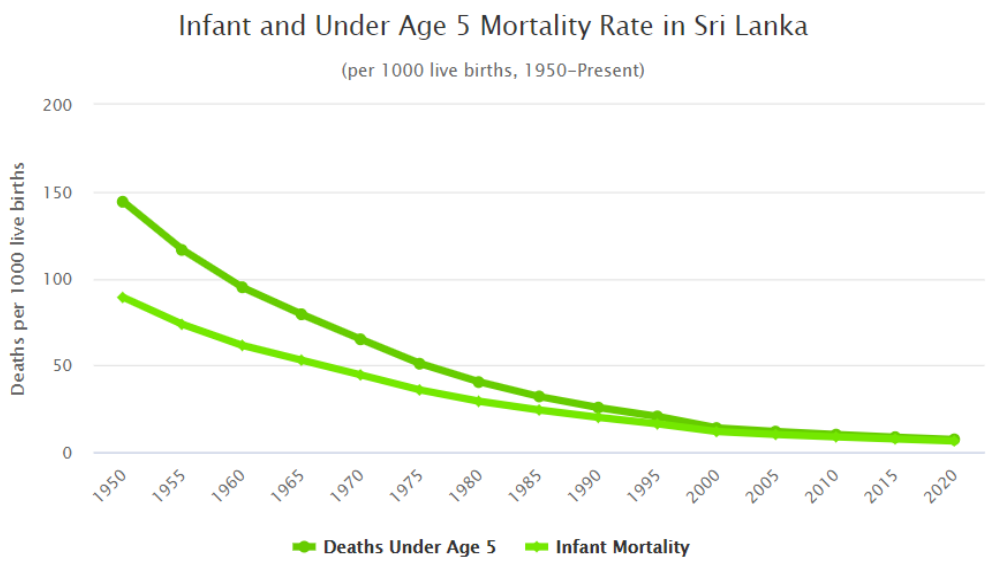


Fig 4: Major diseases and mortality rate (2007- 2017)

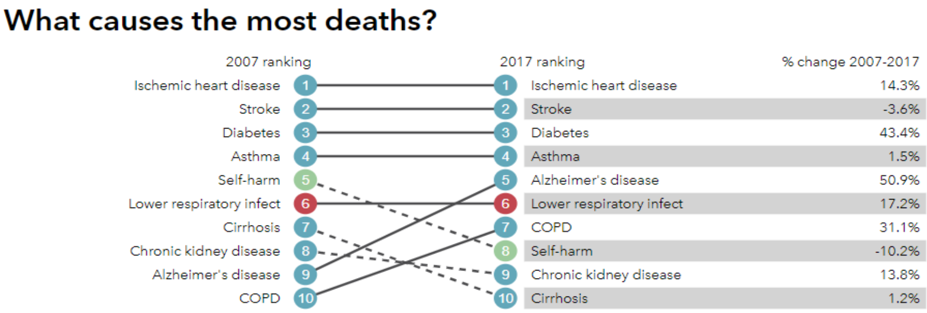
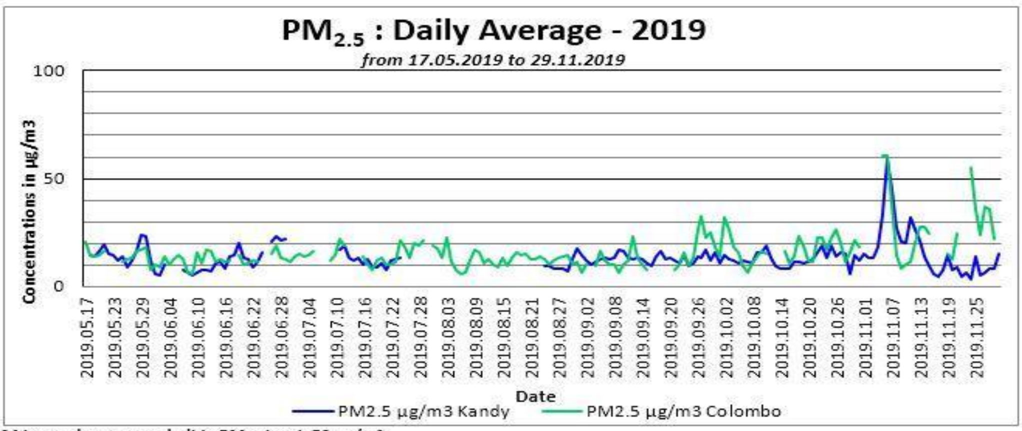


Fig 5: *PM2.5 daily average variation during the period of 17.05.2019 to 29.11.2019 in Kandy and Colombo City Areas*



24 hr maximum permissible $PM_{2.5}$ level: 50 µg/m³

Table 2: Permissible Noise level according to the Sri Lanka control regulations

Zone	Noise Level dB (A)	
	Day Time	**Night Time**
Low Noise Zone	55	45
Medium Noise Zone	63*	50
High Noise Zone	70	60
Silent Zone	63	45
Construction Zone	75	50

(*) The noise level should not exceed 60 dB (A) inside existing houses, during day time

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