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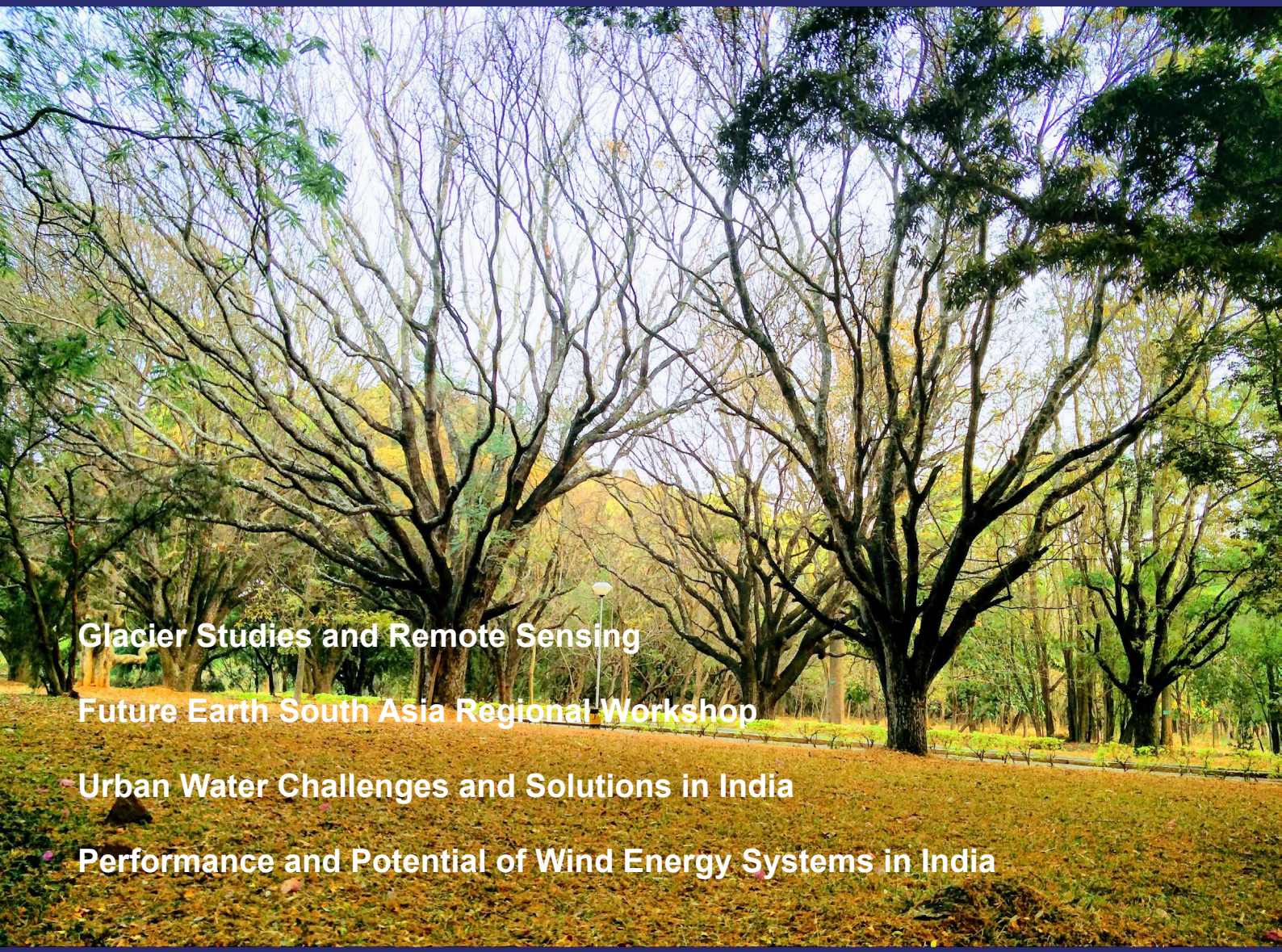
DIVECHA CENTRE FOR CLIMATE CHANGE

Newsletter of the

DIVECHA CENTRE FOR CLIMATE CHANGE



- Glacier Studies and Remote Sensing
- Future Earth South Asia Regional Workshop
- Urban Water Challenges and Solutions in India
- Performance and Potential of Wind Energy Systems in India

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FROM THE CHAIR

Greetings!

Divecha Centre for Climate Change was established at Indian Institute of Science in January 2009 with a generous financial contribution from Arjun and Diana Divecha and the Grantham Foundation for Protection of the Environment.

The primary goal of this Centre is to understand climate variability and climate change, and their impacts on the environment. The Centre continues to pursue experimental and modelling studies in this direction. It has identified technologies to mitigate the severity of climate change in collaboration with entrepreneurs and different engineering departments in Indian Institute of Science. The Centre is also working with Grantham Institute for Climate Change at Imperial College London, on the impact of aerosols on climate and the impact of climate change on water. In addition, the Centre has also undertaken outreach activities to create awareness among students, general public and policy makers about climate change and its consequences. This has been done through workshops, lectures and quiz contests. An annual invited public lecture, called the 'Jeremy Grantham Lecture on Climate Change', has been held for the past seven years. We organize lectures and training courses aiming at capacity building to address issues related to climate variability and climate change. The Centre also provides advice to ministries and departments of the Government of India to develop national and international policies related to climate change.

According to the IPCC fifth assessment report (AR5), there is a high degree of certainty on the impact of climate change on food security, resulting from changes in the onset and amount of precipitation as well as its temporal and spatial distribution due to increase in temperature, which, in turn, affects the availability of water. The changes in Indian monsoon rainfall, influenced by human activities, have a detrimental effect on agriculture. Often, the links between climate change and food security have been examined in relation to impacts on crop productivity. Studies have indicated a significant decrease in the yield of wheat and rice as a consequence of warming. The impact of increase in temperature largely offsets any increase in yield due to increase in photosynthesis aided by increase in atmospheric carbon dioxide concentration. The demand for water, energy and food is increasing due to rising population, rapid urbanization, change in land-use pattern and uncontrolled growth. In this context, it is important to note that a major fraction of the world's freshwater resources is being utilised for agriculture. Because of the complex linkages between water, energy and food, it is important to engage with diverse decision-makers in government, the private sector, industry and civil society. An understanding of the complex water-energy-food nexus is central to sustainable development, which is one of the goals of the "Future Earth" South Asia regional office located at the Divecha Centre for Climate Change.

S.K. Satheesh

TRAINING ON GLACIER STUDIES AND REMOTE SENSING

In the Indian Himalayas, large quantities of water are stored in the form of seasonal snow, ice and glaciers. Melt water from these sources contribute significantly to the discharge in these rivers flowing in North India, besides the Himalayan Nations. The availability of water from the Himalayan cryosphere will change in the future on account of global warming. The monitoring of Himalayan glaciers is important for assessing the future changes in discharges of the rivers. The estimate of water stored in the glaciers is difficult because of the rugged terrain. Hence remote sensing has emerged as an alternative method for collecting information about glaciers.

Dr. Anil V. Kulkarni, Distinguished Visiting Scientist at Divecha Centre for Climate Change, has been organizing training programs on glaciers and remote sensing for the past seven years. This year, the training program was sponsored by the Science and Engineering Board, of the Department of Science and Technology, Government of India, New Delhi. The duration of the training program was from 19th to 30th June, 2017. We received more than 100 applications from young people all over India. We selected 56 participants representing 34 institutions spread across India, based on the educational qualifications and research objectives of the candidates.

The training was inaugurated by Prof. S. K. Satheesh, Chairman, Divecha Centre for Climate Change. Professors from Divecha Centre for Climate Change (DCCC) and Centre for Atmospheric and Oceanic Sciences (CAOS) delivered numerous lectures. In addition, experts working in the field of cryosphere and remote sensing such as Dr. Satyawali, Deputy Director, Snow & Avalanche Study Establishment (SASE) Chandigarh, Dr. Ajay, Indian Space Research Organization (ISRO), Mr. Babu Govindha Raj K, ISRO, Dr. Krishnan, Indian Institute of Tropical Meteorology, Pune, Dr. Sanjeeva Rao, Department of Science and Technology, Technology Bhavan, New Delhi, were also invited as guest faculty.

Dr. Anil V. Kulkarni speaking during the inaugural session

Many topics were discussed during the training program. Some of them were: impact of climate change on glaciers, morphology of glaciers, paleoglaciation, the distribution of temperature in glaciers, glacier mass balance, and remote sensing. In addition to the lectures, practical sessions were conducted on the estimation of runoff, the estimate of the depth of the glaciers using different techniques, climate change and mass balance, topographic corrections of reflectance, and glacier flow modelling.

A participant receiving the certificate

Participants in the training program

FUTURE EARTH SOUTH ASIA REGIONAL CONFERENCE

A South Asia Regional conference on 'Future Earth' was organized by Divecha Centre for Climate Change and The World Academy of Sciences Regional Office for Central and South Asia (TWAS ROCASA) on 20th and 21st July 2017. The workshop was attended by eminent scientists from South Asia including the chair and members of Indian National Committee on Future Earth, Directors of Future Earth secretariat and ICSU regional office for Asia and Pacific. This conference provided an opportunity to deliberate on regional science needs, science policy interfaces and science society engagement that can lead to a transformation towards global sustainability.

The inaugural session was presided over by Prof. Anurag Kumar, Director of IISc; speakers were Shri A. S. Kiran Kumar, Secretary, Department of Space and Chairman, Indian Space Research Organization (ISRO) and Dr. M. Rajeevan, Secretary, Ministry of Earth Sciences. Prof. Satheesh, Chair, Divecha Centre for Climate Change welcomed Prof. Hein Mallee, Director, Future Earth Asia and Prof. Nordin Hasan, Chairman of Research Advisory Committee, Future Earth Asia. He acknowledged the significant contribution of ISRO and Ministry of Earth Sciences to international science for societal applications. He emphasized that the purpose of this workshop was to engage scientists from the South Asian region to discuss regional science policy needs and strategies for integrating regional efforts. He indicated that the deliberations will lead to development of a strategic document for Future Earth.

The inaugural session of the Future Earth South Asia Regional Conference

Prof. Anurag Kumar asserted that Future Earth will provide the knowledge and support to accelerate transformation towards a sustainable world. Shri A. S. Kiran Kumar highlighted the importance of space applications for harnessing technology for national development. He indicated that the work done at ISRO will provide satellite data to understand

Shri Kiran Kumar, speaking during the inaugural session

the different processes that control Earth's climate. He stressed the need to calibrate and validate the data generated, make newer observations and arrive at mitigation measures for climate change.

Dr. Rajeevan highlighted some of the initiatives taken up by the Ministry of Earth Sciences. He discussed issues related to marine pollution, ocean acidification, and coastal ecosystems. He indicated that an Earth System Model with interactive aerosols, biology, and chemistry is being developed and would be the first Indian model participating in an IPCC Assessment Report. He also deliberated on some of the programs conducted for measuring different parameters of marine and coastal pollution. He concluded his talk by stressing the need to involve social scientists and train students and young researchers in this field. The

Dr. Rajeevan, delivering a talk

inaugural session was concluded with a vote of thanks by Prof. Anil Kulkarni, Distinguished Scientist, Divecha Centre for Climate Change.

In the second session, Prof Hein Mallee, Director, Future Earth Asia, laid strong emphasis on the need for scientists in different disciplines to work together to solve the world's problems.

Prof Hein Mallee delivering a talk

The Monsoon Asia Integrated Regional Study (MAIRS) initiative is working towards sustainability in Asian regions;

the Sustainability Initiative in the Marginal Seas of South and East Asia (SIMSEA) focuses on seas and coastal area in Asia and the MANGO (Monsoon Asia and Oceania Networking Group) initiative is a regional monsoon-specific research project in Asia.

Prof. Nordin Hasan, Chairman of the Research Advisory Committee, Future Earth Asia indicated that the key principle of Future Earth research program is to link Earth System research to global sustainability, promote integration, regional engagement, capacity building and networking. He emphasized the need for a more nimble system to achieve global sustainability in an era of increasing change.

Prof Nordin Hasan, delivering a talk

This was followed by talks focusing on some of the core activities at the Future Earth South Asia Regional Office. Prof. S. K. Satheesh recounted the course of events that took place since the inception of the Future Earth program in July 2016. Prof. J. Srinivasan outlined on the MAIRS regional project program of Future Earth and its activities. Subsequent talks described programs on glaciers and water challenges, urban water challenges, wind energy and policy.

Prof V. K. Dadhwal, leading the discussion

The third session was chaired by Prof V. K. Dadhwal, Director, Indian Institute of Space Science and Technology.

Prof. K. Krishnamoorthy, Chair, Indian National Committee for Future Earth, delivered a talk on the national committee and its core objectives. These include promotion of science, and coordination between scientific institutions, academia and the government. He requested the scientists and policymakers to act through the national committees to undertake scientific work of national and international importance.

Dr. Madhu Verma, Centre for Ecological Services and Management, Indian Institute of Forest Management (IIFM), Bhopal, elaborated on the environmental conservation and sustainable development of ecosystems in relation to Future Earth. She gave a brief overview of IIFM's contribution to the valuation of ecosystem services.

Dr. Thamban Meloth, ESSO-National Centre for Antarctic and Ocean Research, Ministry of Earth Sciences, Vasco da Gama, Goa, highlighted the ongoing research program at Antarctica to understand the current status and

Dr. Madhu Verma (Left) and Dr. R. R. Yadav (Right) delivering their talk on the first day

dynamics of Antarctic ice shelves and to decipher their response towards to climate change. Dr. R. R. Yadav, Wadia Institute of Himalayan Geology, Dehradun, elaborated on the regional aspect of climate change in the northwest Himalaya and Karakoram. He showed how past climate records indicate anthropogenic impacts.

Lecture by Dr. Sanjeev Bagai

The next session started with a special lecture by Dr. Sanjeev Bagai, Vice Chairman, Director and Dean, Manipal Hospital, Dwarka (MHDPL), on the "Hazards of Plastic on Health and Ecosystems: Air, Water and Soil".

He presented statistics on the Indian pediatric disease, morbidity and mortality. He gave insight on the health hazards caused due to Bisphenol-A (BPA), a harmful chemical compound found in plastics. He showed how leaching of BPA has serious toxic effects. He concluded his talk by highlighting the need to ban plastics.

This was followed by a session on the nexus perspective as driver of sustainable development, organized by CDD Society, whose work includes providing solutions across the spectrum from treating waste water to remediation of lakes.

Ms. Clara Nicolai leading the nexus discussions

Ms. Clara Nicolai discussed sustainable development goals (SDGs) in terms of clean water and sanitation, good health and wellbeing, sustainable cities and communities, gender equality, zero hunger and responsible consumption and production.

Mr. S. Vishwanath, Biome Environmental Solutions, discussed wastewater and the nature of its informal reuse in Bengaluru. He discussed the farming crisis arising from decline in groundwater tables and an increase in waste water seepage. This untreated waste water that flows into the main river system has been reused for agriculture. He emphasized the need for a risk management approach using the Sanitation Safety Plan developed by WHO to reduce the impact of wastewater and measures to prevent wastewater from polluting fresh water sources. Mr. Rajendra Shrestha, Environment and Public Health Organization (ENPHO), Kathmandu, Nepal, presented case studies on productive reuse and resource recovery done in Nepal. He spoke on the FSTP (Faecal Sludge Treatment Plant) project and its uses in irrigation, biogas fuel and compost. He pointed out that this topic has been introduced as a curriculum in schools. He expressed the need for a comprehensive research program on application and impact of treatment and transformation of waste in farming that includes proper monitoring.

Mr. C. Rohit, Department of Sanitation, Water and Solid Waste for Development, EAWAG, talked about the role of small-scale sanitation to advance SDGs in South Asia. He highlighted the need to reduce the proportion of untreated wastewater and substantially increase recycling. He discussed small scale technologies that are used in treatment of waste water such as constructed wetlands and soil filtration, and activated sludge processes. He provided a glimpse of the national and state level policies used in sanitation He presented an overview of the design, installation and operation of sewage treatment infrastructure.

On the second day, the session started with a talk by Dr. M. V. R. Seshasai, Deputy Director, Earth and Climate Sciences Area, NRSC, Hyderabad, on “National Remote Sensing Centre and Future Earth”. He discussed the conceptual framework of National Information system for Climate and Environmental Studies (NICES) and discussed its main objectives and activities. He stressed the need for concerted efforts on local, regional and global scales and that of putting information from satellites to use in understanding the Earth-Climate-System.

This was followed by a special lecture given by Dr. H. Paramesh, Pulmonologist, Lakeside Hospital, Bangalore, on the impact of air pollution on health. He presented an estimate of morbidity and mortality of non-communicable diseases in India. He elaborated on some measures to mitigate outdoor air pollution. He indicated the need for community oriented programs and the need for legal activism.

Special lecture by Dr. H. Paramesh

The next two sessions included brief presentations from South Asian participants. Dr. Arabinda Mishra, Senior Social Scientist, International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal, gave a talk on sustainable development challenges in the Hindu Kush Himalayas (HKH). He stressed that the Himalayas were a global asset not only for providing water, food and energy to people living there but also to people living downstream.

Dr. A. Thevakaran, Department of Physics, University of Jaffna, discussed climate change projections over Sri Lanka. He argued that Sri Lanka was one of the most hazard prone countries in South Asia due to its complex topography and monsoonal climate. Dr. Rekha Nianthi, Department of Geography, University of Peradeniya, Sri Lanka, presented on the national adaptation plan for climate change impacts in Sri Lanka. She presented how climate change can shift boundaries of agro-ecological zones in Sri Lanka. She showed some scientific evidence about climate change in Sri Lanka.

Dr. Zahid Hameed, Maldives Meteorological Service, presented a brief overview of the climate variability in Maldives. Dr. Nadiruzzaman, Bangladesh, presented a case study on big data in understanding climate change migration using mobile phones. He showed how mobile phones can be used to unravel the hidden migration and mobility patterns in climate stressed regions. Dr. Shakeel Ahmed, CSIR-National Geophysical Research Institute, Hyderabad, discussed the use of helicopter systems to monitor groundwater. He emphasized the need for a knowledge base on groundwater. Dr. N. Raghuram, Professor and Dean, School of Biotechnology, GGS Indraprastha University, New Delhi, discussed the impact of nitrogen fertilizers on the environment and climate. He presented various scenarios on emission of nitrogen and also how to mitigate them.

In the final session, there was interaction among all participants on the strategic plan for the future activities in the regional office. Prof. Hein Mallee, appreciated the issues discussed in the meeting. Prof. Nordin Hasan, appreciated the enthusiastic participation of young scientists in the future earth program. The session concluded with Prof. K. Krishnamoorthy thanking all the participants for their feedback.

URBAN WATER WORKSHOP IN DIVECHA CENTRE

Divecha Centre hosted a workshop on "Water Challenges and Solutions in India, with focus on Urban Water", on July 31st and August 1st, 2017, in collaboration with Interdisciplinary Centre for Water Research (ICWaR) in IISc and the Sustainable Water Future Programme (Water Future) of Future Earth. The main goal of the workshop was to seek wide-ranging inputs on water challenges and solutions, as a prelude to development of a Water Solution Laboratory.

The Water Solution Laboratory will be a collaborative project, involving IISc and various organizations working on water in Bangalore and elsewhere in India, as well as Water Future and their global network of partners. The goal of this laboratory is to address major water challenges being faced by India in a variety of areas, and is motivated by Sustainable Development Goal 6 ("Ensure availability and sustainable management of water and sanitation for all"). The discussions that began with this workshop are aimed at creating a unique institution to solve local problems and increase the number of solution providers in the water sector. Following the workshop, Divecha Centre has initiated dialogue with ICWaR in IISc and other organizations in Bangalore with expertise on water issues, such as Ashoka Trust for Research in Ecology and Environment, for identifying the initial areas of focus for the lab and next steps in its development.

The Future Earth team at the workshop was led by Prof. András Szöllősi-Nagy, who chairs the Sustainable Water Future Programme and UNESCO's International Hydrological Programme. The inaugural session included a talk by Mr. M. N. Vidyashankar, former chairman of Bangalore Water Supply and Sewerage Board (BWSSB). Participants were drawn from academia, research, government, civil-society, and non-governmental organizations working on water issues. The workshop comprised sessions titled "Context: global & local water challenges and transformation towards a sustainable water future", "Understanding water

Prof. András Szöllősi-Nagy addressing the participants

solutions from different perspectives", "Application of Water Solution Laboratory in India: Identifying the main areas of focus", "Methods & Technologies for Water Solution Laboratory", "Framework for Identifying Solutions", and "Towards implementing Solution Laboratory in India". A wide range of topics related to urban water were discussed, and several disciplines (in water science and engineering as well as social sciences) were represented at the workshop.

It was decided at the workshop and discussions following it that the solution laboratory would work to reduce the gap between science, policy and governance. Comprehensive assessments of water challenges led by local experts would be an important activity. Knowledge sharing and collaborative thinking could be facilitated by the lab, with the lab seeking to bridge knowledge and practice. It's major characteristics would be strategic thinking, integrated study and interdisciplinary nature. Stakeholders' involvement and participation was identified as crucial to its success, and they would be involved in advisory capacity at the outset. It was suggested that the lab would play a catalytic role in long term strategic planning and fostering a multidisciplinary problem-solving culture. Matching solutions with problems, and knowledge assessment and dissemination would be important. The water-food-energy nexus is becoming increasingly important, and solution laboratory would play a role in addressing this area. Government, researchers, civil society groups, builders, planners, lake rejuvenation groups, students, and entrepreneurs would be stakeholders in the solution laboratory.

In a concluding session, the broad relevance of the lab to various areas of interest to the Government of India were discussed. These include developing knowledge about effective water systems essential to the government's Smart Cities Mission, facilitating dissemination of innovative solutions, capacity building in water management, managing health impacts of water use, meeting sustainable development goals, providing knowledge to the government for negotiating water treaties, bridging science and decision-making, and leveraging international funding to solve the country's water challenges.

Participants who attended the urban water workshop

WORKSHOP ON PERFORMANCE AND POTENTIAL OF WIND ENERGY SYSTEMS IN INDIA

A workshop on the "Performance and Potential of Wind Energy Systems in India" was held at Divecha Centre for Climate Change on 22nd and 23rd August, 2017. The workshop included participants from industry, research institutes, academic institutions, and decision makers. The two-day workshop began with a welcome address by Prof. S. K. Satheesh, Chairman, Divecha Centre for Climate Change. He highlighted the need to examine the performance of wind power plants in order to ensure that India achieves the ambitious target of 60GW set for 2022. Dr. V. Rao Kotamarthi of Argonne National Laboratory, U.S.A., indicated the need for industry-university collaborations to improve the accuracy of wind forecasting. The role of wind power from off-shore sites was discussed by Dr. M. V. Ramana Murthy of National Institute of Ocean Technology and Harsh Pandit of Suzlon Energy Ltd.

Ms. Jane Jose of Southern Regional Load Dispatch Centre, India, discussed the need for forecasting, scheduling and imbalance handling in one renewable energy sector. Mr. Chandrashekharaiah of State Load Dispatch Centre, India, highlighted the role of hydropower to take care of the variability of wind power generation. Dr. Zakir Rather of Indian Institute of Technology, Bombay, India, discussed the impact of wind power on grid stability. Mr. Malolan Cadambi of Greenshore Energy Pvt. Ltd., India, spoke on estimating the off-shore wind resources from satellite data and combining off -shore wind power plants with desalination plants. A panel discussion that followed highlighted the need for strengthening the grid and more accurate forecasting of wind power. Dr. Raghavendra Ashrit of National Centre for Medium Range Weather Forecasting, India, discussed forecast products for renewable energy application. Mr. Amresh Khosla of Manikaran Analytics, India, explained the role of post processing of the wind speed data to arrive at an accurate wind energy forecast. The panel discussion on wind forecasting discussed the need for combined use of weather forecast model and machine learning to forecast wind energy generation. The need for quality controlled data assimilation and bias correction in the weather forecast model was also highlighted.

On the second day, Mr. Neeraj Kuldeep of Council on Energy, Environment and Water, India, indicated the need to move to a market driven approach in the wind sector and advocated the need for wind power plants in regions with low wind speed. Dr. Sue Haupt of National Centre for Atmospheric Research, U.S.A., emphasized the need for higher accuracy in wind energy prediction. She discussed the Dynamic Integrated Forecast System (DIFS) used by them for forecasting wind energy, which assimilates data from wind turbines along with the wind speed forecasts from various numerical models to provide better wind energy forecast. Dr. V. Rao Kotamarthi of Argonne National Laboratory, U.S.A. highlighted the need for high performance computing for wind forecasting. He discussed the need for modelling across different scales for different applications. Dr. Jim Wilczak of National Oceanic and Atmospheric Administration (NOAA), Boulder, U.S.A.,

discussed the role of data assimilation and model parameterization.

Dr. P. Mukhopadhyay of Indian Institute of Tropical Meteorology, India, presented recent initiatives in forecasting of wind using a high resolution model. He stressed the need for extensive site level validation of critical model parameters to achieve better accuracy in forecasting. Mr. Vinayak Mamodkar of ILAB-E Renewables Pvt. Ltd., India, stressed the need for a more holistic approach and collaborative framework to deliver reliable energy to the customer. Mr. J. Bastin of National Institute of Wind Energy, India, discussed the wind potential in India. He mentioned the importance of data from more than eight hundred national wind monitoring stations in India. Dr. Indradip Mitra of Indo-German Energy Program, India, spoke about the large scale integration of renewable energy in India. He introduced the concept of "Virtual Power Plants" to manage grid stability with higher renewable penetration. He spoke about the experience in Germany, with grid management where the renewable energy penetration is very high.

Mr. Krishna Kumar Swaminathan of GE Global Research, India, discussed wind energy forecasting from a machine learning perspective. He mentioned that creating a digital twin for the wind power plant can result in better accuracy in forecasting. Ms. Anasuya Gangopadhyay of Divecha Centre for Climate Change, spoke about the impact of spatial variation in wind generation of Karnataka. She showed that there was good scope for geographical smoothing of diurnal variation among different wind power plants in Karnataka.

In the concluding session, the need for better forecasting of wind generation and maintaining grid stability with increasing renewable penetration was stressed. The necessity to develop new wind mill designs to take into account the monsoonal wind regime in India was highlighted. The development of wind power plants at off-shore sites was proposed. This will be possible only if wind energy potential at off-shore sites is mapped accurately.

Participants who attended the wind energy workshop

RESEARCH HIGHLIGHTS

VULNERABILITY OF THE FORESTS OF MEGHALAYA TO CLIMATE CHANGE

About 80% of the geographic area of Meghalaya is covered by forests and tree cover. Meghalaya is a part of the Indo-Myanmar global biodiversity hotspot and home to diverse plant and animal groups. A study was carried out at the request of the state government to assess the current state of the forests and biodiversity and the likely impact of climate change. We assessed the structure (tree count, carbon stock, basal area, and canopy cover), and composition (tree biodiversity) of the forests using data from around 200 plots spread all across the state. We assessed the changes, from 2000 to 2016, in the structure of the forests using high-resolution satellite data supported by ground verification. We modelled the future impact of climate change on vegetation by using high resolution downscaled climate data and a dynamic vegetation model. In total we created 24 new GIS layers of information for the forests.

Figure 1 shows the change in Normalised Difference Vegetation Index (NDVI) over 16 years (2000 to 2016) within the forest boundary. It shows that about 50% of the forests in Meghalaya, especially in the north and west Garo hills, have experienced increased disturbance (negative NDVI).

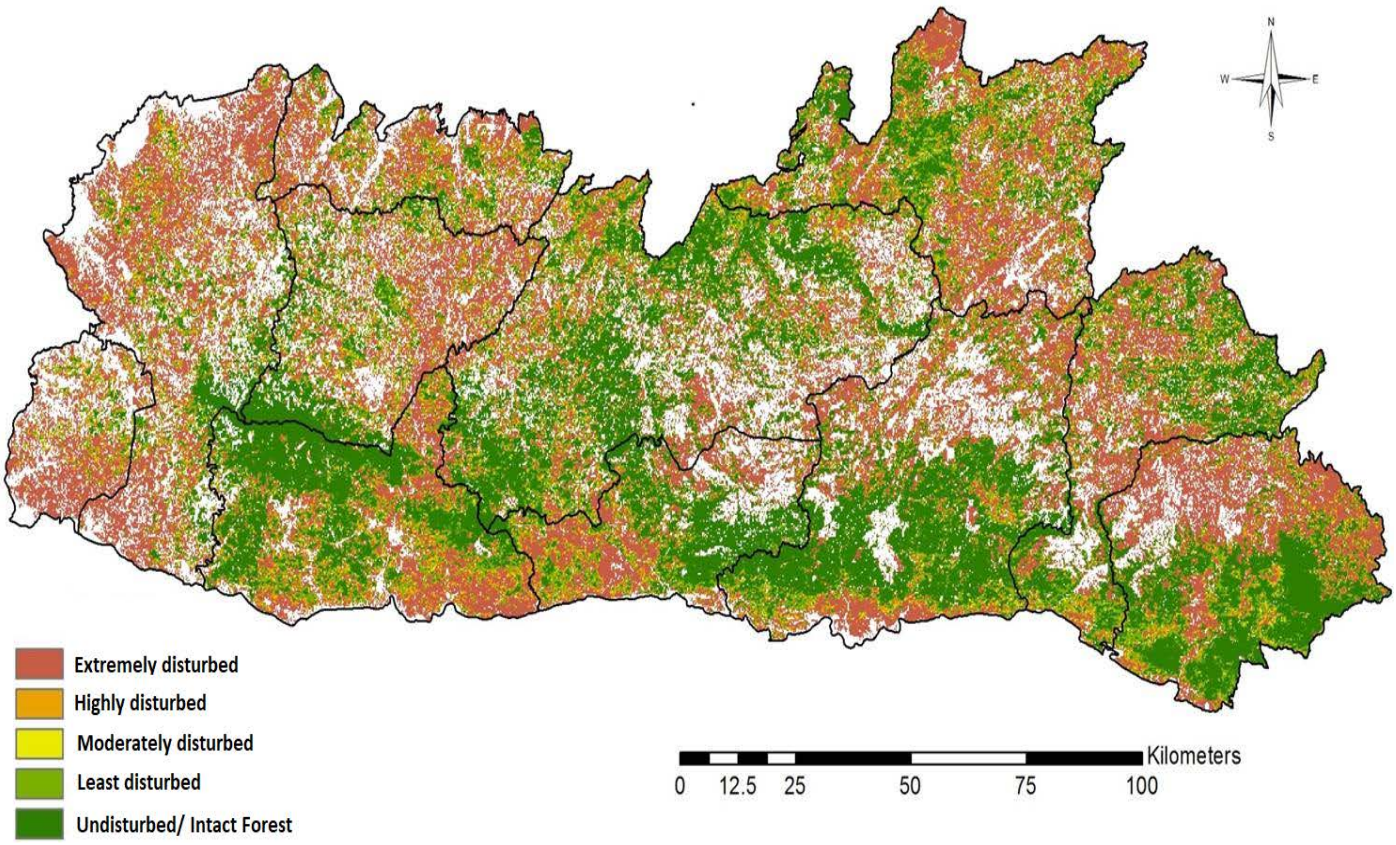


Figure 1: Extent of disturbance in Meghalaya forests as assessed from the change in NDVI

Our field-based analysis suggests an average carbon density of about 55 tonnes carbon per hectare (tC/ha) in the state, which is much higher than the estimates published by forest survey of India (17 tC/ha). The species richness in

The report released by Shri. R.M. Mishra (Left), Minister of Information Technology and Communications and Dr. M Ampareen Lyngdoh (Right), Development Commissioner Govt. of Meghalaya

our sample plots showed wide variation from single species per plot in degraded forests to almost 30 species per plot in highly dense evergreen forests. Richness of species in the forests is estimated to be high in West Garo hills and parts of Jaintia Hills, and low in districts of West Khasi Hills and Ri-Bhoi.

The vulnerability of the Meghalaya forests was identified using the methodology proposed by IPCC, 2013. Our inherent vulnerability index suggests that currently about 25% of the total forested area in Meghalaya has high or very high vulnerability. About 64% of the forested area in the state is estimated to have low inherent vulnerability, indicating higher resilience in these areas and making them suitable for forest conservation related activities. Forests of North Garo Hills and Ri-Bhoi are the districts with most vulnerable forests in the state, while the forests in East Jaintia Hills and East Khasi Hills are the most resilient.

In this report we conclude that a promising way to protect forests from the effects of future climate is to make them more resilient to the stresses of today's climate. Thus we argue that inherent vulnerability should be given preference in planning current adaptation policies in the state. We further argue that strengthening the structure and composition of forests, and augmenting the biodiversity in the state, will not only manage current vulnerabilities and weaknesses of the

forest systems in the state but at the same time will also make these forests more resilient to future climatic stresses. We also recommend that the impact and vulnerability information must be used in the forest working plans and in planning of afforestation programmes in the state.

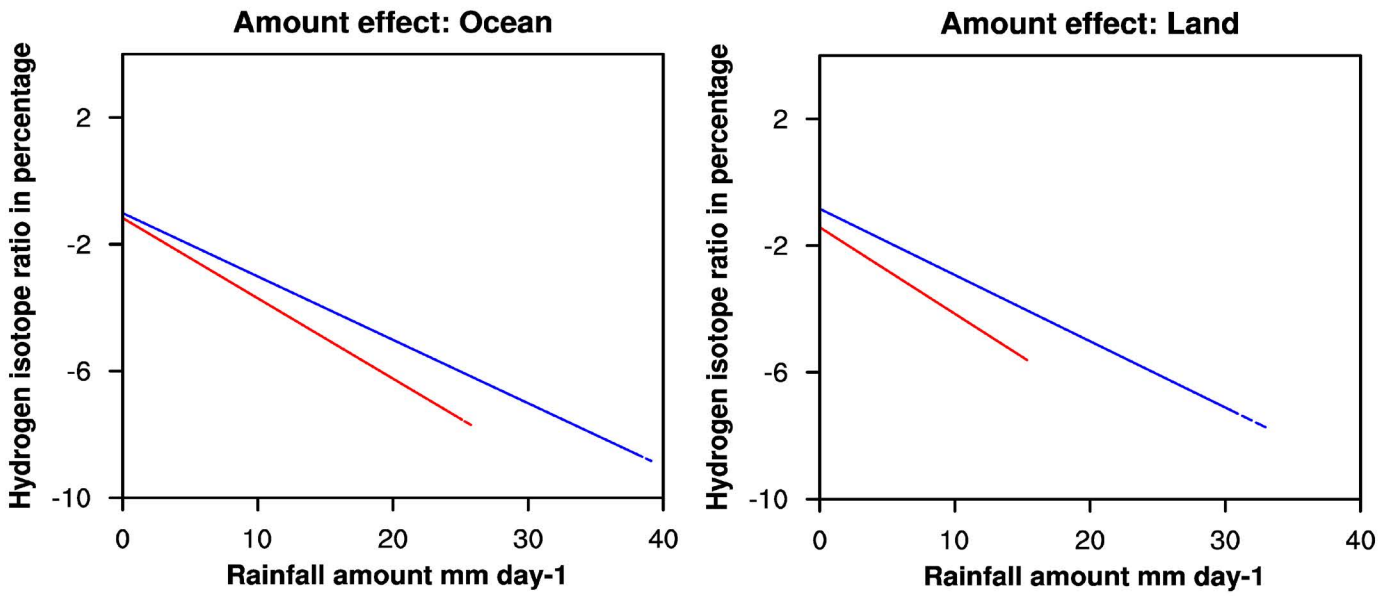
Reference: Chaturvedi, RK; Ravindranath N.H et al (2017) Vulnerability of the Forests and Biodiversity of Meghalaya to Climate Change. Report Submitted to the Government of Meghalaya.

DEEP CONVECTION AND THE ISOTROPIC RATIOS IN TROPICAL RAINFALL

Isotopes are elements with the same atomic numbers but different masses. Water is composed of one oxygen atom and two hydrogen atoms. The oxygen atom has two major stable isotopes in nature. They are 16O (abundance 99.75%), and the heavier 18O (abundance 0.20%). Hydrogen has two isotopes 1H (abundance 99.98%) and deuterium 2D (0.01%). During evaporation lighter molecules evaporate preferentially and hence vapor becomes depleted in the heavier isotope. During condensation the heavier molecules condense preferentially. The heavier isotope ratio in water is reported as a deviation from a standard sample of water with a known isotope ratio. In the tropics, regions with larger rainfall show depletion in the heavier isotope of oxygen or hydrogen. Hence the measurement of the concentration of the heavier isotope of oxygen or hydrogen in rainwater can be used to infer the amount of rainfall. Trees and cave deposits (called stalagmites) preserve the history of past rainfall. Hence we can reconstruct past rainfall based on this evidence.

Recent observations suggest that the extent of depletion of the heavier isotope depends on convective rainfall, and not total rainfall. To understand this issue better, we used a climate model to assess the relation between the deep convective rainfall and the depletion of the heavier isotopes. In the climate model, the total tropical rainfall is the sum of deep convective (85%), shallow convective (3%) and large-scale rainfall (12%). We reduce the contribution of deep convective rainfall in a controlled manner. We find that with the reduction in deep convection, the heavier isotopes of hydrogen, and hence the isotope ratios increase. This amount effect is estimated as the magnitude of the regression slope between long-term monthly precipitation amount and hydrogen isotope ratios in rain over tropics. Thus, our study indicates that the analysis of isotope ratios in rainfall could be a powerful tool to improve convective parameterization schemes in climate models.

Our study also implies that changes in convective activity and relative proportions of rainfall types over a region in the past could introduce uncertainties in the estimated rainfall. More positive values of isotope ratios in proxy records may imply a reduction in deep convection rather than a reduction in total rainfall.



The relation between isotope ratio and rainfall amount. Red indicates baseline simulation and blue indicates deep convective rainfall reduced by 60%

Reference: Tharammal, T., Bala, G. and Noone, D., 2017. Impact of deep convection on the isotopic amount effect in tropical precipitation. Journal of Geophysical Research: Atmospheres, 122(3), pp.1505-1523

MULTI-CRITERIA SUSTAINABILITY ASSESSMENT OF COAL AND SOLAR POWER GENERATION IN INDIA

India has embarked on an ambitious program to expand solar power plants to a total installed capacity of 100 GW by 2022. Most people assume that electrical energy from a coal power plant is less expensive. In this study, Mitavachan and Srinivasan compare coal and solar power generation with respect to a set of seven sustainability criteria. The analysis shows that electrical power from solar plant is more affordable than power from coal. Further, it is observed that solar power is far better than power from coal when environmental extend such as global warming, air pollution and water footprint are considered. The study estimates that coal power plants emit 23 times more greenhouse gas emissions, cause 28 times more air pollution, consume 40 times more water and lead to 15 times more external costs to society than solar power plants in India. Further, both the power sources are comparable when seen from land transformation, land occupation and levelized costs (LCOE) perspectives. It is only in reliability that solar power plants with 16-24% capacity utilization factor (CUF) lose out to coal power plants which have 50-74% CUF. This study highlights the importance of decision making in the Indian energy policy arena based on multi-criteria assessments employing life cycle perspective.

Reference : H Mitavachan and J Srinivasan, Multi-criteria Sustainability Assessment of Coal and Solar Power Generation in India, **Current science (In press**)

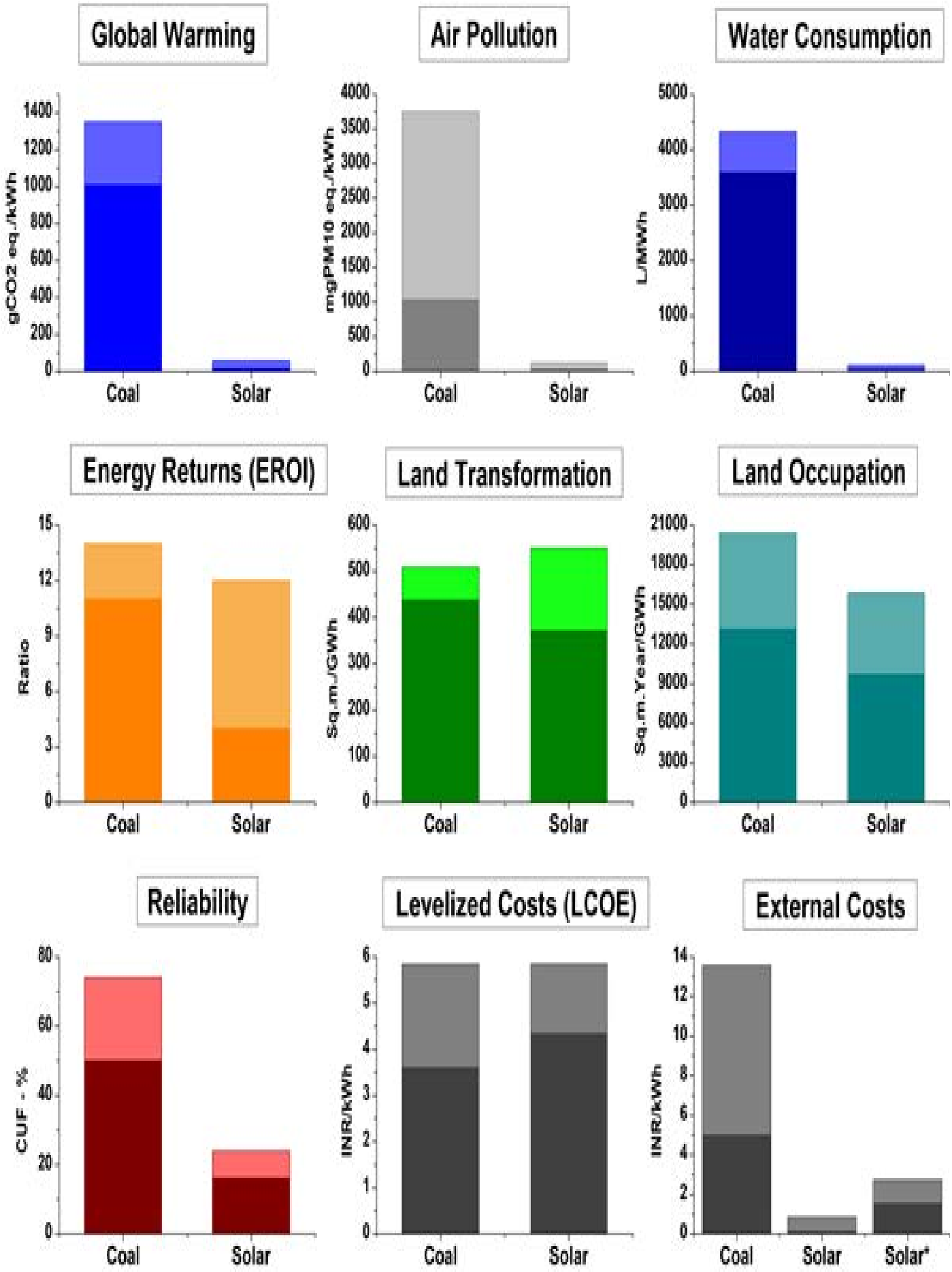


Figure: Comparative performance of coal and solar power generation with respect to different sustainability indicators in Indian context. The lighter shades represent the higher bound values.

THE PERFORMANCE OF A 20 kW SOLAR PHOTOVOLTAIC SYSTEM AT INDIAN INSTITUTE OF SCIENCE

A 20 kiloWatt (peak) solar photovoltaic system was established at Indian Institute of Science in April 2013. The system has produced around 80 kWh/ day for the past four years. The annual energy generated was around 29 MWh (MegaWatt hours). The monthly energy generated was above 3 MWh in March and around 1.6 MWh in July. The analysis of the performance of this system has provided new information regarding the performance of such systems in India.

The temperature of the solar module plays an important role in the energy output of the system. The annual average module temperature was around 45°C. In summer, module efficiency decreased by 0.08% per degree rise in module temperature. In the monsoon season, the efficiency reduced by 0.04% per degree rise in module temperature.

In post monsoon period, it reduced by 0.06% per degree rise in module temperature. In winter the module did not exhibit much drop in the efficiency. This is because of intermittent natural cooling that took place at the surface of the modules due to lower ambient temperatures.

20 kW Solar power system at IISc.

A mathematical model was developed to predict the yield from a solar photovoltaic plant based on the weather forecast at the location. This model can be deployed in the management of distributed energy generation systems consisting of SPV systems. The deviations of this model from the measured values are around 15% for most of the days. The methodology adopted to develop the model can be used in any location. This model is simple to adopt as it uses performance data from a SPV system installed at a specific location and weather forecast data available in the public domain. Hence, it would be a powerful tool for private solar power producers availing net-metering facility.

References :

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