Biodiversity and climate change: sustainable development perspective*

Healthy ecosystems constitute a healthy planet. Thus, ecosystem restoration is a win–win strategy crucial to attaining the sustainable development goals (SDGs) of the United Nations. The ongoing climate change is unequivocally anthropogenic and, together with other stressors like deforestation, land degradation, biological invasion, etc. has resulted in species loss and a shift in landscape dynamics. The carbon cycle and water cycle, arguably the two most important large-scale processes for life on Earth, depend on biodiversity at genetic, species, and ecosystem levels and can provide feedback to climate change. Geomatics and data analytics have revolutionized our understanding of the impacts of climate change and ecosystem responses. The effects of climate change are particularly experienced in fragile ecosystems like the Himalayas, which harbours rich biodiversity and supports several dependent communities. Climate extremes and natural hazards are becoming more prevalent, especially in vulnerable ecosystems. Joining hands with experts from various science arenas such as ecology, oceans, cryosphere and atmosphere, it would be easier to build climate change-resilient ecosystems as nature-based solutions to realize SDGs and net-zero targets.

The Third International workshop on Biodiversity and Climate Change held recently had witnessed the participation of over 230 participants from diverse domains. The workshop was held to specifically address some of the key topics such as understanding feedback between climate change and biodiversity, balancing bioresource management and socio-economic development, how cryospheric changes in the polar regions and high mountains affect biodiversity, water cycle and global climate, predicting and managing natural hazards and extreme weather events, understanding the intricacies between terrestrial and marine bio-geochemical cycles, and the ways forward to achieve the net-zero targets through nature-based solutions. Considering

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the above key issues, the workshop had seven themes/technical sessions: (i) Biodiversity and land cover dynamics, (ii) Geomatics and data analytics, (iii) Forest and agricultural resources and biotechnology, (iv) Extreme weather events and natural hazards, (v) Global cryosphere and the Himalaya, (vi) Biogeochemistry – terrestrial and marine and (vii) Nature-based solutions and net-zero targets.

The event began with four tutorials on the first day: (i) species distribution modelling using machine learning, (ii) soft techniques in environmental geochemistry and sediment analysis, (iii) geomatics and data analytics using open source-Google Earth Engine, and (iv) a hierarchy of glacier models. On the second day, the inaugural ceremony began with a welcome address by K. Kumar, followed by an overview of the workshop by M. D. Behera (IIT Kharagpur) in relation to its themes and key questions. S. K. Dube (Advisor at IIT Kharagpur) talked on the journey of Centre for Ocean, River, Atmosphere, and Land Sciences (CORAL) in the frontier domain of climate change. B. Pani (University of Delhi, Delhi) emphasized the compliance of the National Education Policy with climate studies. This was followed by talks by T. Meloth (National Centre for Polar and Ocean Research (NCPOR), Goa), S. K. Behera (Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan), and V. P. Singh (Texas A&M University (TAMU), USA). The inaugural addresses were delivered by M. Mohapatra (India Meteorological Department (IMD), Delhi) and V. K. Tewari (IIT Kharagpur) on the theme of the workshop.

The first plenary talk was given by Singh, who elaborated on the feedback between water resources and climate. Mohapatra emphasized the increasing extreme weather and climate events, while D. Ray (West Bengal Forest Department, Kolkata) spoke on forest biodiversity and conservation of the Sundarbans ecosystems. Behera talked about the prediction of monsoon patterns in the face of climate change and its impacts on crop yield. E. Sharma (Ashoka Trust for Research in Ecology and the Environment (ATREE), Bengaluru) proposed an integrated approach for sustainability through research policy and governance, while Meloth highlighted climate change impacts on the

Third Pole. K. Clem (Victoria University of Wellington, New Zealand) discussed the tropical drivers of Antarctic climate variability and extremes. S. Nayak (National Institute of Advanced Studies (NIAS), Bengaluru) highlighted various climate risks to wetland ecosystems and emphasized the sustainable blue economy. A. Orr (British Antarctic Survey, University of Cambridge, UK) talked about the interaction of fine-scale dynamics and microphysics in a Himalayan valley, while D. Bromwich (Ohio State University, USA) discussed Antarctica and polar prediction. C. Biradar (Centre for International Forestry Research (CIFOR)-International Centre for Research in Agroforestry (ICRAF), Delhi) stressed agroforestry systems as nature-based solutions for climate change mitigation.

The third day witnessed over 190 presentations, including 18 keynotes. A. A. Khuroo (University of Kashmir, Srinagar, Jammu and Kashmir) talked about data synthesis for biodiversity science, while S. Sharma (Govind Ballabh Pant (GBP)-National Institute of Himalayan Environment (NIHE), Leh, Ladakh) spoke on soilless cultivation in the trans-Himalayan cold desert of Ladakh to enhance productivity for climate change adaptation. S. Sundarapandian (Pondicherry University, Puducherry) discussed the importance of natural forests in carbon storage, while B. R. Parida (Central University of Jharkhand, Ranchi, Jharkhand) talked about retrieving surface soil moisture using synthetic aperture radar and optical sensor data. B. K. Bhattacharya (Space Applications Centre (SAC)-Indian Space Research Organisation (ISRO), Ahmedabad) elaborated on applications of remote sensing in measuring land surface temperature and evapotranspiration, while C. P. Singh (SAC-ISRO, Ahmedabad) talked about monitoring phenology and changes in alpine ecosystems using geomatics. P. C. Pandey (Shiv Nadar University, Greater Noida, Uttar Pradesh) discussed wetland vegetation mapping and chlorophyll sensitivity analysis using drone data. M. Jena (Berhampur University, Berhampur, Odisha) spoke on the taxonomy of coccoid algae *Coelastrum* through polyphasic approaches and explained molecular approaches for accurate identification. S. C. Sahu (Maharaja Sriram Chandra Bhanjadeo University, Mayurbhanj, Odisha)

mentioned that temperature rise could decrease forest productivity in tropical forests. S. V. Pasha (NIAS, Bengaluru) demonstrated an appropriate field sampling approach for remote sensing-based biomass studies.

R. Joshi (GBP-NIHE, Sikkim Regional Centre, Gangtok, Sikkim) delivered an invited talk on air temperature lapse rates across the Himalayan arc, while S. Sahoo (Punjab Remote Sensing Centre, Ludhiana, Punjab) discussed groundwater depletion-induced land subsidence analysis using a PsInSAR-based approach. P. S. Ranhotra (Birbal Sahni Institute of Palaeosciences, Lucknow, Uttar Pradesh) elaborated upon the vegetation change in relation to the post-Last Glacial Maximum to Holocene in the western Himalayas and mentioned that a decline in tree-line shift in the last century could be associated with a rise in temperature. H. Biswas (Council of Scientific and Industrial Research-National Institute of Oceanography, Goa) talked about reassessing phytoplankton community structure from the central Arabian Sea, while R. K. Sarangi (SAC-ISRO, Ahmedabad) talked about ocean productivity and stressed linking satellite data with models for biogeochemistry studies. N. Sahu (Indira Gandhi National Tribal University, Amarkantak, Madhya Pradesh) discussed the eco-physiological investigations and the challenges associated with climate modelling. J. Kuttippurath (IIT Kharagpur) talked on sustainable and nature-based solutions to reduce atmospheric pollution, while C. S. Reddy (National Remote Sensing Centre-Indian Space Research Organisation, Hyderabad, Telangana) emphasized the need for interdisciplinary strategies for invasive species management and mitigating climate change.

The following recommendations and conclusions emerged from the workshop: A blend of traditional science with modern approaches is needed to achieve the SDGs. A successful climate action plan requires reliable and accurate data, which calls for active monitoring and more detailed observations on ecosystem dynamics, biosphere–atmosphere feedbacks, phenological shifts in different groups of organisms, their differential responses to changing environmental conditions, time-series analyses, etc. Spatial data science offers several opportunities for monitoring land-cover changes, threat and vulnerability assessments, and identification of resilient patches for conservation. With the ongoing UN Decade on Ecosystem Restoration, the conservation of existing forests and other ecosystems requires prime attention to prevent them from becoming extinct. Taking advantage of advances in remote sensing, modelling, artificial intelligence, biotechnology, and nanotechnology would help mitigate some of the extant challenges (pollution reduction, bioremediation, etc.), and aid in better prediction and prevention/preparedness for extreme weather events and natural disasters. It is also important to continually refine/update the existing models with changing trends in climate and the influx of new data from observations/syntheses. In brief, the adoption of integrated, nature-based approaches with equity-based partnerships among all the stakeholders is the way forward to achieve the SDGs.

A valedictory function was held at the end of the day to mark the formal conclusion of the workshop, wherein A. A. Dharwadkar (Geological Survey of India, Lucknow), B. Pradhan (University of Technology Sydney, Australia), and Sharma delivered the valedictory talks. R. K. Sahoo (Indian Railway Traffic Services, Kharagpur) explained the green initiatives undertaken by the Ministry of Railways, Government of India, to combat climate change. The best presenters were selected, and prizes were given to them by B. Chatterjee (IIT Kharagpur). Behera concluded the event with encouraging words on the path ahead and thanked all the dignitaries, participants and sponsors.

On the fourth day, a field trip to the Sundarbans, West Bengal, was arranged to realize the innumerable ecosystem services (ecotourism, livelihood benefits, blue carbon sequestration, etc.) offered by the mangrove ecosystems. The participants were deeply concerned about the fragility of such important ecosystems and discussed mangrove conservation and restoration efforts. The trip provided another opportunity for pondering key ecological questions, paving ways for on-the-spot open discussions and networking. Overall, this workshop proved to be a suitable platform for not only debating and deliberating on the research findings and recommendations but also giving an enthralling experience on biodiversity–climate change feedback in the live laboratory of the Sundarbans.

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