

Innovation-led, business-allied, service-centric, foresight-based, multi-linear technology delivery and adoption models should replace or complement the existing public sector-led extension systems. However, skill development and confidence-building among stakeholders is required to achieve the last mile delivery.

(16) Besides food security, nutritional security is an essential element in the zero hunger goal. Producing nutrient-rich crops (food and fruit crops) and vegetables would go a long way in the sustainable diversification and intensification of cropping systems. Promotion of cultivation of pulses and leguminous vegetables through creation of 'pulse villages' supported by 'pulse Panchayats' is an important step. Agronomists have also to identify under-utilized crops that are rich in nutrients and niches in the cropping systems where they could be introduced. Additionally, use of protected agriculture with hydroponics, aeroponics, vertical farming, etc. in the urban and peri-urban areas would help in providing nutritious food.

(17) There are serious gaps in understanding the skill needs of the agricultural sector. Therefore, a mission mode approach is needed to identify and priori-

tize the skill needs, and institutionalize these in imparting knowledge to the youth. Agriculture needs quality youth, but the current AR4D (Agricultural Research for Development) agenda is an incremental innovation and not attractive to them. Therefore, there is need for transformational innovation through transdisciplinary and trans-stakeholder approaches at different levels, i.e. redesigning agricultural education system for entrepreneurship, and not just for research and extension. Vocational training, inclusion of agronomic education in school curriculum, especially on climate-smart, organic farming and farming system-based farmers' participatory approach for technology generation, transfer and adoption are needed to ensure faster growth in agriculture.

(18) In order to promote the development of farmers-led skills as well as protect their rights, it is necessary to recognize and further promote these innovations. It is also desirable to blend the farmers' innovations with modern scientific knowledge and properly up-scale them for the benefit of the farming community.

(19) Farmers' income can be doubled by adoption of integrated approach

involving new abiotic and biotic stress-tolerant genotypes, low-cost, efficient, water harvesting technology, timely inputs and credit support, nutrient scheduling on the basis of soil health card, and smart mechanization of agricultural practices. Therefore, large-scale demonstrations on integrated approaches involving farmers are necessary to achieve this target.

(20) A standing committee was constituted for holding the dialogue for the next International Agronomy Congress in a country other than India in order to make it a global event.

To realize the above goals, we the agronomists of India and elsewhere hereby adopt the Delhi Declaration and resolve to work together with all stakeholders for sustainable management of natural resources, environment, energy and livelihood security, to achieve the zero hunger challenge.

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MEETING REPORT

Challenges and knowledge gaps in ecological sciences*

As a science, the subject of ecology is relatively young, although India's ecological concerns are rooted deep in our civilization as evidenced in Vedic literature. In the modern context, the subject has grown enormously and many potential areas have been identified. However, there are still a number of challenges and knowledge gaps. A symposium was organized to address these issues which was attended by about 250 delegates from all over the country. Inaugurating the symposium, Manju Sharma (National Academy of Sciences, India (NASI), Allahabad) highlighted the need for linking ecological sciences with appropriate policies for societal benefits. She stressed upon the need for ecologically viable

scientific solutions to rejuvenate our rivers, and emphasized that rejuvenation of the Ganga is possible only through multifarious approaches interfacing domains of science. She also highlighted the innovative initiatives taken by NASI under Ganga research programme. Archana Thakur (UGC, New Delhi) shared her views on the emergent need and relevance of innovative ecological research in science and social realms. The symposium witnessed 8 technical sessions, including a plenary lecture, 4 keynote lectures, 12 invited talks, 11 oral and over 100 poster presentations.

In the plenary lecture, Rup Lal (University of Delhi) explained the significance of metagenomics to address microbial perspectives in ecology. He reiterated that the boom in sequencing technologies and advances in the development of high-throughput tools/techniques based on nucleic acids/proteins have substantially

up-scaled the studies enhancing our understanding of molecular microbial ecology. He also shared his experiences with the human microbiome project and advocated that the composition of the human microbiome is intricately linked with human health and diseased states. T. K. Adhya (KIIT University, Bhubaneswar) furthered the ecological role of plant-microbe interactions. In addition to rhizosphere and phyllosphere, the microenvironments of plant include endorhiza (root), anthosphere (flower), spermosphere (seeds) and carposphere (fruit). Manipulation of these microenvironments reduces the incidence of plant diseases, chemical inputs, emission of greenhouse gases (GHGs) and enhances agricultural production. Using the coastal wetlands of Chilka Lake, he demonstrated the dynamics of colonization pattern for root-associated microbiome, wherein each root niche plays a selective

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role in the microbiome assembly, and consequently, the performance of the host plant. He demonstrated that there were site-specific physico-chemical factors which played a key role in determining the community structure and function.

M. P. Sharma (ICAR-Indian Institute of Soybean Research (IISR), Indore) shared his experiences of harnessing AM fungi in sustainable management of crop and soil by optimizing a highly reproducible Arbuscular Mycorrhiza (AM)-signature biomarker, and quantifying neutral and phospholipid fatty acids in soil and roots. The study identified 16 : 1 ω 5 ester-linked fatty acid as a biomarker for assessing AM fungal biomass; 16 : 1 ω 5 neutral lipid fatty acid to estimate mycorrhizal spore counts and 'glomalin', an AM fungal glycoprotein that stabilizes soil aggregates and carbon pool.

A. K. Joshi (International Maize and Wheat Improvement (IMWIC), New Delhi) focused on the need for climate smart agriculture (CSA) as a solution to cope with increasing food demands under changing climate scenario. CSA broadly works on three parameters: sustainably increasing agricultural productivity and farmers' income, adaptation to climate change, and reducing GHG emissions. He advocated the need for climate smart approaches such as climate-resilient varieties, technologies that save water, nutrients and other inputs, weather-based insurance, use of information technology that provides weather-based and agri-based advisories and capacity development. T. Damodaran (ICAR-Central Soil Salinity Research Institute (CSSRI), Lucknow) contemplated on harnessing the rhizosphere ecology for sustainable production of horticultural crops in salt-affected areas. He pointed out that habitat-specific microbial consortia of nitrogen fixers, P-solubilizers, growth promoters, siderophore and antibiotic activity for growth promotion enhance crop productivity in saline and sodic environment.

P. Verma (National Institute of Plant Genome Research (NIPGR), New Delhi) discussed the recent advances in plant-fungal pathogen interactions exploring novel insights for effectors and their targets. He presented the 34.6 megabase genome sequence of *Ascochyta rabiei* and predicted 10,596 protein-coding genes that encode large and diverse inventories of secretory proteins, carbohydrate-active enzymes, transporters and primary/secondary metabolism enzymes, reflecting its

necrotrophic lifestyle. Analysis identified a novel PEXEL-like effector, PEC25, indispensable for *A. rabiei* virulence. D. Vyas (H. S. Gour University, Sagar) advocated that enhanced patchiness in niche specificity by dominant woody perennials favours diversity of mushrooms in Patheria forest, Madhya Pradesh.

Vivekanand (Malaviya National Institute of Technology (MNIT), Jaipur) discussed the importance of bioenergy as a sustainable option for future energy needs and waste management. The energy needs are likely to increase from the current 17.7 to 28 TW by 2050. He advocated the use of agro-industrial residuals and non-food plant biomass as a sustainable, renewable and alternative feedstock for energy generation. Pretreatment of lignocellulosic biomass using thermal hydrolysis/steam explosion will make it an environment-friendly and efficient source of bioenergy.

South Asia is considered as a hot spot of black carbon (BC). More than half of ~8 Mt of BC released into the atmosphere annually originates in the Indo-Gangetic Plains. Through observational and modelling studies, S. N. Tripathi (IIT, Kanpur) elaborated the consequences of large radiative forcing associated with BC and brown carbon aerosols in the Indo-Gangetic Plains. He showed increased rainfall due to cloud invigoration under high aerosol loading and changes driven by absorbing aerosol-induced perturbations in near-surface energy budget with short- and long-term climatic implications.

S. K. Mishra (IIT, BHU, Varanasi) identified that obstructions in flow path (exploitation for hydropower generation and excessive withdrawal) and the resulting reduction in stream flow are the major constraints reducing dilution effect, and consequently, enhancing water quality degradation in the Ganga. S. N. Upadhyay (IIT, BHU) elaborated the status of Ganga pollution and control efforts. Currently, only one-third of the total sewage is treated before being discharged into the River. He drew attention towards improper solid waste management facilities, deforestation, inadequate storm-water drainage systems and increasing agricultural run-off, which are important non-point sources that need proper management. P. M. Prasad (IIT, Kanpur) pointed out that the economic agents exploit the river resources for their livelihood beyond natural regenerative and assimila-

tive capacities, and that there is a need to adopt judicious use for sustainable livelihood. S. Nayak (BBA University, Lucknow) identified that the issues linked with property right regimes, lack of participatory approaches and unequal access to land and water resources are the principal causes of environmental quality degradation which need policy intervention.

R. K. Singh (NIDM, New Delhi) mentioned that ~60% of the land mass in India is prone to earthquakes, over 40 m ha to floods, ~8% of the total area to cyclones, and 68% of the area is susceptible to drought. To manage disasters, the Government of India has taken initiatives such as constitution of high-powered committees, enactment of The Disaster Management Act 2005, creation of new institutions and assigning new roles to the existing institutions. He highlighted that disaster management needs to be tackled through integrated planning adopting a multi-hazard and multi-sectoral approach. R. R. Yadav (Wadia Institute of Himalayan Geology (WIHG), Dehradun) while analysing climate and conflict of Mughal invasion asserted that climate-driven crop failure for years to decades was the leading cause of human conflicts. Based on palaeoclimate records he showed that vast variability in climatic extremes and associated disparities in the availability of resources in Kabul, the ruling territory of Zahir-ud-din Muhammad Babur Padshah Ghazi (Babur), lured him to invade and conquer India which enjoyed climatic-driven agricultural prosperity in the early 16th century.

R. M. Borges (IISc, Bengaluru) provided experimental evidence of water-stress hypothesis, suggesting that plants facing water stress gain a selective advantage by nocturnal flowering to reduce water loss through evapotranspiration, leading to larger flowers that provide more nectar to support pollinators. Her observations provide new perspective in plant-pollinator co-evolution.

S. K. Barik (CSIR-NBRI, Lucknow) stressed that an integrated approach connecting modelling, molecular and chemical ecology will help in understanding ecological complexities, assessing the impact of disturbances and climate change on species survival, succession, invasion, carbon sequestration and population interactions. Ecologists must strive to apply integrated approach for solving contemporary environmental challenges.

The symposium resolved to: (a) integrate modelling, molecular and chemical ecological approaches for a more comprehensive understanding of ecological complexities, shifts in functional attributes and ecosystem responses to stresses. (b) Microbiomes are important modifiers of functional attributes and need to be systematically studied at individual as well as community level. (c) Microbe–root interactions and gene manipulation should be integrated in a holistic manner

for sustenance and better yield of agricultural crops under changing climate conditions and other stresses. (d) Rejuvenation and restoration of the Ganga require integration of ecological studies with innovative technologies and sewage treatment-associated management plans.

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MEETING REPORT

Quaternary environments and climates*

An international brainstorming session/workshop on Quaternary Environments and Climates was held to promote the exchange of existing information and knowledge related to climate change uncertainties, past evidences and future adaptations. Several aspects such as global temperature rise, warming of oceans, sea-level changes, adaptive responses of species and extreme weather conditions were addressed. Societal impact of the climate change on human health, landscape, agriculture, biodiversity, etc. was also discussed. The chief guest Nayanjot Lahiri (Ashoka University, Haryana) pointed out several interesting sequences and events emphasizing ‘How do great discoveries take place?’ Nineteen experts from various organizations in India and abroad had gathered to discuss on various issues related to climate. The first technical section focused on the overall view of the research work carried out by scientists in Birbal Sahni Institute of Palaeosciences (BSIP), Lucknow. Scientists and research fellows of BSIP involved in the study of climate, ecology and vegetation of the past discussed their research direction and strategies. Four technical sessions and two workshops were organized to provide answers to these following questions: (1) What is Anthropocene in Indian/South Asian perspective and what are the typical Anthropocene markers? (2) What are the forcing factors

governing monsoonal climate: tropical versus polar? (3) Quantification of past climate/ecological changes – an emphasis on uncertainty in proxies/models? (4) What are the subtleties, nuances and uncertainties of chronological constraints?

The complex social–ecological interactions in the Anthropocene and lack of multi-decadal records represent an important gap in information that hinders the development of the research agenda. Combining the records with conventional sources of historical information from instrumental monitoring records, official statistics and enumerations, remote sensing, archival documents, cartography and archaeology would produce an evolutionary framework for reconstructing integrated regional histories. Several keypoints were addressed during the meeting: (1) The unprecedented climate extremes that we may expect in the future? (2) Relevant climate metrics for extreme impacts on ecosystems and societies. (3) Capability to predict extreme climate impacts. (4) Assessment of the vulnerability of the coupled social–ecological system. (5) Coping with extreme environmental conditions. (6) The resistance, resilience, and adaptation of ecological and societal systems to extremes.

John Dearing (Southampton University, UK) conducted a workshop in which the strategies for complex social–ecological interactions in the Anthropocene were discussed. R. J. Wasson (National University, Singapore) deliberated views related to changing hydro-climate over the Himalaya, extreme events and policy stand. The importance of calibrating oxygen isotope anomaly for volume effect in calcium carbonate deposits (e.g. spele-

them) for its better usage to quantify past rainfall was discussed with R. Ramesh (NISER, Bhubaneswar). A review of various forcing factors/internal feedbacks impacting monsoonal precipitation in India was provided by P. D. Naidu (National Institute of Oceanography (NIO), Goa). Suitability of climate models for understanding changing environment over the Indian Himalayan Region was presented by A. P. Dimri (JNU, New Delhi). He underlined the importance of improvised parameterization of models in the wake of fine-scale sub-regional processes. U. K. Shukla (BHU Varanasi) presented the geological history of Varanasi city vis-à-vis Ganga plain. S. S. Naik (NIO, Goa) elucidated pH and temperature changes recovered from Antarctica and the Arabian Sea spanning Holocene to Anthropocene. D. S. Singh (Lucknow University) presented his work on the Gangotri glacier, to quantify Anthropocene changes using black carbon inventories. Parth S. Chauhan (IISER Mohali) presented a succinct review of human evolution over the subcontinent by focusing on past human adaptations. S. K. Manjul (ASI, New Delhi) presented an overview of archaeological finds recently unearthed from 4MSR, Rajasthan, an Indus site revealing amazing craft and culture of ancient human settlers between ~2600 and 1900 BCE and migration paths of the Harappans, arguably linked to changing climate (monsoon) era.

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