linkages, (iii) underlining the need for better synthesis and adequate dissemination of knowledge available on multiple subjects, (iv) creation of a web-based platform (http://gbpihedenvis.nic.in/HimYRF-2014) as a beginning of knowledge network and for sharing of information, and (v) request GBPIHED or any other organization to continue providing base support for organizing similar meets.

A total of 74 young researchers (24 women, 50 men), representing 30 institu-tions across 12 Indian Himalayan states, and engaged in research in diverse disciplines, attended the meet. Selected senior mentors and resource persons were drawn from various organizations to facilitate and moderate the proceedings of the meet.

1. National Action Plan on Climate Change, GoI, 2008; http://pmindia.nic.in/pg01-52.pdf

2. Negi, G. C. S., Rawal, R. S., Sharma, S., Kumar, K. and Dhyani, P. P., *Curr. Sci.*, 2014, **106**(5), 659–660.

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MEETING REPORT

MP-TRACS crops*

Climate change will have a major impact on agriculture in tropical countries like India. However, these impacts are highly crop-specific, and climate projections for impact assessment and adaptation need to be considered at the precision, accuracy and reliability required for a given class of crops. Unfortunately, very little is known in this regard for the economically important crops characterized by secondary metabolites, like tea, rubber, aromatic and medicinal plants, coffee and spices (TRACS). While efforts are on at several national agencies, the critical issues of the methodology for adopting climate change scenarios, and interfacing with crop processes, have not yet received the required attention. Further, such assessments need to be integrated with all the major components like crop, pollinator, disease and constraints due to primary resources as well as demand. These issues are particularly acute for TRACS crops. Thus, there is need for an integrated decision support system for such crops.

A national discussion meeting was therefore organized with the primary goal of creating a common platform of knowledge synergy for addressing outstanding issues related to modelling and projections for the special class of TRACS crops. Seven organizations participated

in the meeting, with the following broad themes for discussion: (a) Enhanced production of TRACS crops with immediate and tangible benefits to farmers. (b) Enhancing sustainability and eco-compatibility of TRACS crops under different scenarios of climate change in the next 50 years. (c) Development of a comprehensive and integrated decision support system for TRACS crops.

The importance of the topic of the meeting was put in clear perspective by P. S. Ahuja (CSIR), in his inaugural address. Highlighting some of the major national initiatives by CSIR and other agencies like Indian Council of Agricultural Research (ICAR) in the areas of crop and ecosystem modelling, Ahuja emphasized the need for initiating a multi-sectorial and multidisciplinary approach for modelling and projection of agro-economic crops through a core group of scientists. In this context he appreciated the participation by a large number of delegates representing different agencies and domains, and the sizable participation of scientists from C-MMACS (CSIR-4PI), Bengaluru and the holistic nature of the proposed programme. He particularly emphasized data coverage, data quality and accurate forecasting for crop management. Noting that modelling has assumed a critical role essentially in all branches of science and engineering, Shyam Chetty (C-MMACS and NAL, Bengaluru) emphasized the intricacies involved in modelling complex systems like crop–climate processes. He emphasized the need for a core group like the one assembled for the meeting to provide

India with unique advantages through an effective national collaborative programme.

In his overview of the objective and approach of the meeting, P. Goswami (C-MMACS) briefly traced the major events leading to the current event, beginning with the presentation to the Planning Commission (in January, 2011) on a Network Initiative on Sustainability, Climate Adaptation and Mitigation. He also emphasized that the C-MMACS team had developed several process models like crop disease (capsule rot of cardamom), malaria and energy; these models, including their computer codes, have been developed in-house and the results published in high-impact journals like *PLoS ONE* and *Nature Scientific Report*. He identified creation of reliable and crop-specific climate projections at regional level in India as the biggest challenge and the most critical gap. In the long term, a critical need is mapping of changes in geographical distribution of potential areas of TRACS production under climate change; in the short term, new and improved technologies need to be identified and incorporated.

The meeting then discussed the major themes for a comprehensive programme; the deliberations under these sessions are outlined below.

In the session 'climate change: issues and challenges in spices, aromatic and medicinal crops' several scientists highlighted critical and specific issues related to spices and aromatic and medicinal crops. Ajay Divakaran (Indian Cardamom Research Institute (ICRI), Kailasanadu)

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*A report on the National Discussion Meeting on Modelling and Projections for Spices, Aromatic and Medicinal Plants, Coffee and Tea held at the CSIR Centre for Mathematical Modelling and Computer Simulation (Repositioned as CSIR-4PI), Bengaluru.

highlighted the role of meteorological variables like relative humidity and soil temperature and outlined the impact of climate change on cardamom cultivation, such as through increasing incidents of pests. The potential threat to many medicinal and aromatic plants (MAPs) due to impact of climate change was discussed by D. D. Patra (CIMAP, Lucknow), who highlighted some of the MAP species that may be affected due to climate change in terms of secondary metabolites, phenological processes, delay in flowering, etc. Rakesh Kumar (IHBT, Palampur) focused on the decadal change in ecosystem dynamics due to climate change in the Himalayan region, and emphasized the need for efforts in modelling the impact of climate change on biomass and phenology.

The primary focus of session-III was on coffee, tea and rubber. On tea, R. M. Bhagat (TTRI, Jorhat) discussed issues and challenges in tea production in North East India related to climate change, and pointed out the role of weather parameters like rainfall and temperature in the major tea-growing areas of Assam. B. Radhakrishnan (UPASI, Valparai) discussed how some of the minor pests are turning out to be major and vice versa. He emphasized that many weather parameters limit productivity, and weather informatics through crop–weather model would be useful. Emphasizing that coffee was a crop sensitive to weather and climate, Y. Raghuramulu (Central Coffee Research Institute, Chikmagalur) outlined the impact of climate change on coffee production; he also emphasized the need for short-term strategies like better farming practices and use of weather informatics in India. James Jacob (Rubber Research Institute of India, Kottayam) emphasized the different impacts of climate change on rubber yield in different agro-climatic regions, and suggested that mathematical models be used to predict future shifts in rubber cultivation due to climate change, whereas satellite-based remote sensing can be used for real-time monitoring of diseases of rubber.

Session-IV was primarily devoted to the potential of weather and climate informatics for TRACS crops. It was emphasized that relevant and adequate data on crop and weather processes were a critical requirement. Referring to data requirements for weather variables, S. Himesh (C-MMACS) presented the design and operation of the Climate Observation and Modelling Network (COMoN), and highlighted some of the important points related to data optimality, data quality and analysis. He mentioned that the Network now consists of 26 multi-level, multi-variable profilers which cover many parts of India. K. V. Ramesh addressed the evidence of impact of climate change on TRACS crops over India, and presented some results to highlight the significant trends in various crops, including tea and coffee over the Indian region. He emphasized the uncertainties in climate simulations and projections, especially over India; using analysis of multi-model IPCC climate data, he showed that the CMIP5 had little progress over CMIP3 in simulation of the Indian monsoon and emphasized the need for identifying reliable climate projections. The potential role and current status of seasonal forecasting were outlined by K. C. Gouda (C-MMACS). He also outlined the methodology and validation of forecasts made by C-MMACS of seasonal rainfall and date of onset of monsoon, and emphasized the critical roles such forecasts can play in agricultural planning. He also presented some exploratory results on dynamical crop simulation. Referring to the need for weather informatics stressed by several participants, V. Rakesh (C-MMACS) highlighted the pioneering efforts of C-MMACS in high-resolution (village cluster level) forecasting over Karnataka, and presented several results for validation of rainfall forecasts at Hobli level. He also outlined the relevance of weather informatics to TRACS crops, and presented the impact assessment of hobli-level forecast in scheduling of irrigation and pesticides application to the crops. Emphasizing that any effort in enhanced production should also be sustainable, E. V. S. Prakasa Rao (C-MMACS) emphasized the sustainability of agricultural systems in a changing climate and pointed out the implications of climate change and related factors to agricultural production. He stressed that terrestrial carbon sequestration by the TRACS crops is an additional socio-economic benefit.

In the panel discussion, a concept/proposal for modelling and projection for TRACS crops was initiated with emphasis on multi-sectorial synergy towards development of a modelling platform. The panel discussed the desirability and feasibility of such a proposal and its relevance to the TRACS crops. It also discussed the major components of such a proposal and task-sharing policies for timely implementation of the project. Various models for execution of the project were also explored. It was agreed that without a comprehensive and well-coordinated effort, the TRACS agricultural sectors will be increasingly vulnerable to various effects of climate change. At the same time, a proper inclusion of climate change into TRACS can significantly improve India's domestic and international performance in terms of these economically important crops. At the same time, inclusion of relevant weather forecasts and informatics can provide immediate and tangible benefits to farmers.

The participants identified the major challenges as real-time observed data, crop processes as a function of weather variables and identification of the vulnerable as well as potential regions for TRACS crops with future projection. The participants also emphasized the importance of data optimality and information on the specific range and threshold values of atmospheric and environmental variables relevant to the crop. In addition to resolution and continuity, use of multi-source data, and especially remotely sensed data and management of data are important for development and validation of the model which will be helpful for forecasting and future projection of the crops.

The participants felt that an integrated modelling platform, though challenging, was feasible because of the generic nature of modelling which can be applied to a wide variety of crops; for example, a climate projection, with crop-specific validation can be effectively used by a number of agencies. The meeting recommended development of a multi-agency programme on modelling and projection for tea, rubber, aromatic and medicinal plants, coffee and spices (MP-TRACS). With validated and quantified assessment for multiple scenarios for proactive planning for comprehensive knowledge-based adaptation, MP-TRACS will be a versatile tool for decision support.

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