major decision-makers in the use and conservation of the natural resources around them and a balanced approach is essential for safe-guarding the national interests and welfare of the people. The national interest, he observed, is to protect the territorial integrality of the nation and promote economic development. Major concerns for development, according to Mibang, are imbalance in developing new economic regions, inappropriate planning, rapacious approach to natural resources that ignores the customary laws evolved over centuries to sustain them for posterity. When communities apprehend danger of misappropriation of their natural resources, they show resistance. Mibang further underlined that the state bears the responsibility for creating normal living conditions for the people, conserve and rationally use the natural resources for an inclusive development that ensures preservation of culture. He also voiced his concerns over the poor representation of people from the NER in Parliament, suggesting that a better representation will ensure more development in the region.

Ramesh Negi (Chief Secretary of Arunachal Pradesh) remarked that the natural resources are facing challenges from the point of their use and conservation. He observed that over the centuries, changing priorities of humans and their lifestyle, are dislocating the symbiotic relation between communities and the environment. Therefore, a continued intellectual debate among stakeholders, i.e. communities, academicians, researchers, planners, administrators and civil societies is essential for appropriate policies and plans for development. He observed that contradictions in the society for environment and development while balancing profit and greed are the important decisions to be made, the traditional value system, which imbibes cultural values should be strengthened for a well-framed developmental approach. Cultural values, Negi stressed, are the major strength for development of a society. Omkar Singh (Department of Environment and Forests, Government of Arunachal Pradesh) mentioned that a more articulate interaction between communities and planning bodies is required for effective conservation and development. Community participation and suggestions, he remarked, play an important role in conservation projects. Emphasizing on the rich biodiversity of the NER and the need for inventorying the biodiversity of the region, P. K. Samal (GBPIHED, North East Unit) mentioned that discovery of new species is common in the region and the Unit itself has discovered four new species of fishes *Erethistoides senkhiensis*, *Glyptothorax dikrongensis*, *Pseudolaguvia viriosa* and *Garra magnidiscus*, during the last 5–6 years.

The participants in the deliberations agreed that development paradigm in the NER must focus on sustainable socio-economic development and livelihood security, conservation of biological diversity and ecological security, adaptation/mitigation of climate change impacts and developing appropriate policy and stakeholder's need-based research and capacity building. Further, the gap between the region and the rest of the country in terms of various developmental outcomes, productivities and capacities of people and institutions is large and growing, and has to be bridged. Even within the region, there are vast differences, particularly between populations living in the hills and the plains, and between those living in the towns and villages. Given the vast disparities within the region, a development strategy will have to be evolved depending upon prevailing resources, conditions and needs and priorities of the people. Further, the development strategy for the various tribes in the region will have to be participatory and should be calibrated in their own setting. The long-term vision of development, therefore, will include biodiversity conservation and sustainable development through facilitation and strengthening of community initiatives. The envisaged initiatives will keep in view practical methodologies for addressing ecological concerns through appropriate technological interventions, enhanced livelihoods for local communities and development of protocols to economically benefit the locals from wildlife conservation so as to promote long-term commitment towards biodiversity conservation. Focus should also be on enhanced capacity, engagement and cooperation of local communities and community institutions in biodiversity conservation to 'ensure environmental sustainability', one of the eight renewed commitments to human development adopted in the Millennium Declaration of 2000 by the member states of the United Nations. The approach should also necessitate wider networking with organizations, institutions, government departments and bodies and credible NGOs working in the region.

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MEETING REPORT

Ecosystem monitoring and forest census studies in South Asia*

Intact tropical forests cover 13.9 million sq. km worldwide, or 24% of tropical land area. They are the most productive terrestrial ecosystems on Earth[1] with high priorities for biodiversity conservation[2]. These forests store a substantial amount of carbon in biomass and soil, and they also regulate the transfer of carbon into the atmosphere as carbon dioxide (CO_2) (Figure 1). Knowledge of the sign and magnitude of the stocks and flows of carbon and biomass within global forests is of importance in the context of climate change[2]. Intact tropical forests in Amazonia and Africa have been increasing in biomass and thereby absorbing ~12% of current anthropogenic CO_2 emissions, but the continuity of this biomass carbon sink remains uncertain[1,2].

The contribution of South Asian ecosystems to the global carbon budget is

*A report on 'Ecosystem Monitoring and Forest Census Research in South Asia' held on 19 and 20 May 2014 at the National Centre for Biological Sciences, Bengaluru.

still poorly known because of the heterogeneity of ecosystem types in this ancient and dissected landscape. South Asia presents a wide range of climates from monsoon-induced high precipitation areas in the upper reaches of the Western Ghats (up to 7000 mm at some locations) to drier tracts along the eastern footslopes that support diverse vegetation types ranging from high-elevation shola (montane) forests[3] to aseasonal lowland rainforests in Sri Lanka. The mountains of the South have a critical effect on climate throughout the subcontinent, capturing the southwest monsoon rains to provide conditions for rainforest vegetation on the southwestern coasts and maintaining 'rain shadow' dry climates to the east through a Föhn Effect[4,5]. Therefore, these mountains affect the livelihoods of millions of people. The Western Ghats rainforests, known locally as wet evergreen forests, predate the rise of the Himalayas and are well known for their high biodiversity and species endemicity[4,5]. Along with the central dry forests and east coast ecosystems, South Asia is home to a substantial fraction of the plant, fish, herpetofauna, bird and mammal species of the subcontinent[6].

South Asia has a long tradition of forest census research, stretching back at least to the Indian network of preservation plots (initiated in 1906 with a plot at Saranda, Bihar, India[7]) and linear tree increment (LTI) plots (from 1929)[8]. Sri Lanka initiated its first forest inventory in 1956 (ref. 9) and has built a strong tradition in forest conservation[10] with protected areas covering 22% of the area of the country, a higher proportion than most other Asian nations[11].

The rise of international plot networks and the acceleration of research in this field, especially since the 1980s, has had a hugely stimulating effect on tropical ecology in general[12]. Forest census plots originally intended simply for local timber resources management have been pressed into service worldwide as global 'forest carbon observatories' (e.g. the Smithsonian Institution's Forest Global Earth Observatories ForestGEO[13]) to answer 'big ecology' questions about the ecosystem processes that control our biosphere[14]. The more recent rise of the international climate change agenda has only added urgency to these endeavours as humans have become the major force shaping the biosphere endangering the planetary support system on which we all depend[15].

In view of South Asia's long tradition of expertise with forest census plots, a two-day conference on ecosystem monitoring and forest census research was held in Bengaluru. The conference attracted a wide cross-section of Indian, Sri Lankan and foreign expertise on relevant forest ecology and conservation issues.

Sixty participants, including students, researchers and eminent scientists from several Indian institutes/organizations, University of Oxford, UK, and University of Peradeniya, Sri Lanka attended the conference. The conference included a training workshop on day 1 followed by talks on current directions in tropical forest science and monitoring. The training workshop focused on introducing participants to standardized, internationally accepted forest census protocols developed by long-term ecosystem monitoring networks such as ForestGEO[16] and the Red Amazónica de INventarios FORestales Global Ecosystems Monitoring network (RAINFOR-GEM)[17], as well as techniques of database management and GIS. Sessions were led by Toby Marthews and Sam Moore (University of Oxford, UK (UoO)) and Suranjan Fernando (University of Peradeniya, Sri Lanka (UoP)).

Thirteen talks featured findings from forest monitoring networks across the globe, methodological issues and visions for building large-scale forest monitoring networks in South Asia.

Yadvinder Malhi (UoO) drew on findings of the RAINFOR and RAINFOR-GEM networks that focus on the carbon dynamics of forest plots and emphasized the need for a comparable network in South Asia to enable pan-tropical comparisons of the terrestrial carbon cycles. Sam Moore (UoO) presented early data from recently established RAINFOR-GEM plots in West Africa, highlighting the importance of monitoring both disturbed and pristine forests. This theme was further emphasized by Toby Marthews (UoO), whose data from Malaysia showed how net primary productivity (NPP) and carbon allocation varied along a disturbance gradient. Anand Osuri (National Centre for Biological

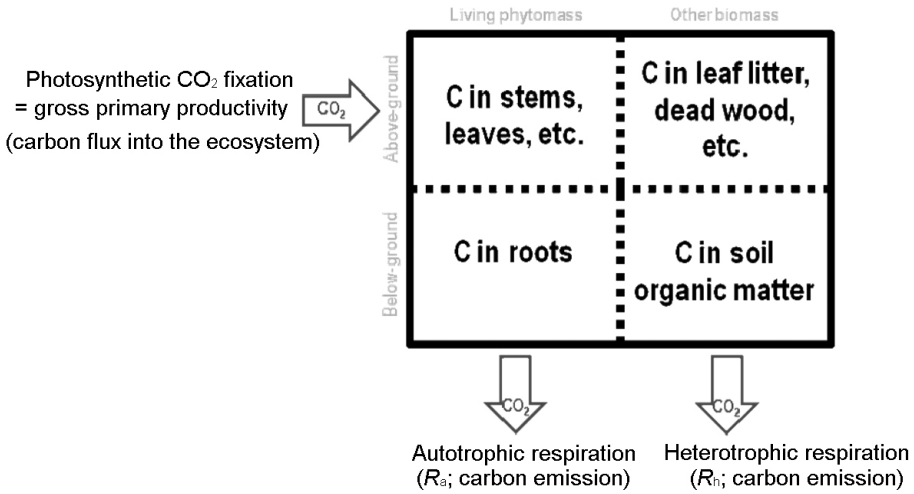

Figure 1. A forest carbon (C) budget composed of fluxes into (deposits) and out of (withdrawals) the ecosystem carbon stock (in a forest context, these flows are predominantly in the form of CO_2).

Sciences (NCBS), Bengaluru) presented his work on rainforest fragments in the Kodagu region of Karnataka, indicating that relative to contiguous forests, fragments showed pervasive losses of large-seeded tree species and stored a disproportionate amount of carbon in a few large individuals, with implications for carbon dynamics in these systems in the future. T. R. Shankar Raman and Divya Mudappa (Nature Conservation Foundation, Mysuru), drawing on over a decade of experience with the restoration of degraded tropical forest fragments in the Anamalai region of the southern Western Ghats, spoke both of the critical importance of fragments in sustaining wildlife populations and faunal diversity across this region, as well as the logistical challenges of sustained long-term restoration. Ghazala Shahabuddin (Ambedkar University, Delhi), studying community-managed oak-pine forests in the Western Himalayas, suggested that anthropogenic resource extraction from these forests is associated with decline in tree basal area and tree density in these forests, as well as the progressive invasion of pine into these systems. She emphasized the need for long-term monitoring programmes to understand the current and future impacts of these changes in oak-pine dynamics.

Using small plot inventories across the Western Ghats, Priya Davidar (Pondicherry University, Puducherry) showed that seasonality was a major driver of diversity and distribution patterns of rainforest trees across the latitudinal gradient of these mountains, with aseasonal southern sites harbouring highest tree diversities. At a smaller geographic scale, with data from 18 one-hectare long-term plots across a rainfall gradient within the Mudumalai Tiger Reserve, H. S. Dattaraja (Centre for Ecological Sciences (CES), Indian Institute of Science (IISc), Bengaluru) showed that rainfall was a major correlate of plant community structure and diversity, as well as post-drought mortality, with species being lost at higher rates from the wetter regions of this gradient following the 2003–2006 drought. At a site-specific scale, Nimal Gunatilleke (UoP), using data from the 25 ha forest dynamics plot in Sinharaja, Sri Lanka, showed that local species assemblages, particularly the presence of endemics, were primarily driven by topographic habitat factors and spatially structured processes such as dispersal limitation. At an even more localized scale, Sandeep Pulla (CES, IISc), combining long-term plot data from Mudumalai with modelling approaches, presented evidence for neighbourhood-scale abiotic resource niche differentiation between competing tree species as a factor that stabilizes tree communities over time.

With data from the dry tropical forests of Mudumalai Tiger Reserve (MTR), southern India, Rutuja Chitra-Tarak (CES, IISc), showed that seasonal swelling and shrinkage of trees are likely to cause major biases in estimation of wood growth from tree diameter census in such dry ecosystems. She emphasized the need for identification of better proxies to estimate this bias, which is a vital factor in understanding growth–climate relationships and carbon metrics of dry forest systems.

Jayashree Ratnam (NCBS) highlighted that although India has a diverse range of forest types across a large climatic gradient of rainfall and temperature, there is a paucity of long-term forest monitoring sites that collect data on forest carbon metrics and match data collection protocols to international networks. Thus, the contribution of India's forests to regional and global carbon cycles, and the current and potential responses of these ecosystems to future climatic changes, remain poorly known[18]. In this context, the establishment of a network of protocol-matched sites that capture the diversity of forest types and environmental gradients across the Indian region is an urgent scientific priority. Ratnam then introduced the NCBS-led attempt to bridge this gap through the initiation of a Long-term Ecosystem Monitoring Network (LEMoN-India), using a bottom-up, grassroots approach. As part of this initiative, six 1 ha long-term monitoring plots have been set up across different forest types in the country thus far, and it is envisioned that such a network will grow in a collaborative model with different institutions and researchers taking responsibility for the establishment of additional sites.

It was decided that every effort would be made to support and continue the development of a regional network of long-term monitoring plots across the savannas and forests of South Asia. While the ongoing initiatives of the LEMoN-India network and the multiple 1 ha plots at Mudumalai and Sinharaja form potential nodes for this network, its ability to deliver regional-scale information for South Asia will depend on the addition of multiple sites that capture the range of forest types and climatic gradients in the region (see Marthews *et al.*[17] for a discussion of logistical challenges and criteria for locating plots along regional gradients). Such a network will not only be critical for baseline information at the regional scale, but will also represent a deep infrastructural investment that will catalyse the growth of ecosystem science for this region. It will also enable the exploration of important questions about the impacts of anthropogenic and climate drivers on ecosystem processes at regional scales in South Asia. As envisioned, the growth of this network will be both bottom-up, with interested individuals and groups undertaking to set up protocol-matched plots in ecosystems that are easily accessible to them, as well as top-down, through efforts to raise network-level funding for this monitoring programme. Finally, there is also a need for similar regional networks for other terrestrial biomes such as grasslands as well as marine ecosystems.

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ACKNOWLEDGEMENTS. We thank UKIERI–UGC collaborative grant to Oxford University and NCBS (UKIERI UGC Thematic Partnership UGC-2013-14/056), for this conference and workshop.

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MEETING REPORT

Somatic embryogenesis and bioreactors*

Production of homogeneous quality planting material to the farmers is one of the major constraints in coconut productivity. The present annual production of coconut seedlings, through conventional techniques, is unable to meet the annual requirement of quality planting materials. Rapid multiplication of coconut through *in vitro* techniques, therefore, is of paramount importance. However, coconut is highly recalcitrant to *in vitro* culture.

Tissue culture of plantation crops was initiated at the Indian Council of Agricultural Research-Central Plantation Crops Research Institute (ICAR-CPCRI), Kasaragod three decades back and repeatable *in vitro* protocols have been developed for oil palm (seedling meristematic column) and arecanut (inflorescence culture). Efforts for developing a protocol for *in vitro* regeneration of coconut using plumular explants were initiated in 2000. Even though plantlets have been regenerated and successfully established in the field, a commercial-scale protocol has not been achieved and conversion of somatic embryos into plantlets has remained one of the major bottlenecks.

Recognizing its importance, ICAR has incorporated development of a commercially viable coconut tissue culture protocol as one of the flagship programmes of ICAR-CPCRI in the XII Plan period. In this connection, a brainstorming session was organized at ICAR-CPCRI.

In his presidential address, George V. Thomas (ICAR-CPCRI) stressed upon the role of biotechnology as a solution to problems confronting conventional methods. He gave a brief history of tissue culture work taken up at the Institute since 1970s and emphasized the importance of having a commercially viable tissue culture protocol in coconut. He hoped that the brainstorming session would be purely business-like, where innovative ideas could be discussed in detail.

In the inaugural address, T. Janakiram (ICAR) lauded the efforts made by the Institute for developing coconut embryo culture technique, which has received international acclaim from Bioversity International. He also highlighted the point that a repeatable tissue culture protocol would be the only solution for production of homogenous planting material on a large scale. He also suggested exploring the possibility of a public–private partnership to commercialize the coconut tissue culture protocol after the technique had been perfected.

Sugatha Ghosh (Coconut Development Board) emphasized that the current multiplication rate of 1 : 1 (one seed to one palm) in coconut should be modified to at least 1 : 20 using rapid multiplication protocols without compromising on quality, to meet the demand of 10 million quality planting materials of coconut per year, of which only 3–3.5 million could be met by conventional techniques. He suggested formation of a network approach, through collaborative efforts, to achieve success in the development of a tissue culture protocol in coconut, with a dedicated team led by CPCRI, and with possible funding from ICAR, CDB, DBT and BIRAC.

Anitha Karun (ICAR-CPCRI) spoke about the current status of plumule culture in coconut. Achievements made in this area, including procedure for excision of shoot meristem directly from the zygotic embryo, hastening *in vitro* culture period and identification of best performing palms and seasons for collection of explants were also discussed. Presence of genotypic differences in response to *in vitro* culture, low rate of somatic embryo formation, conversion of somatic embryos into plantlets, and formation of abnormal somatic embryos were the major constraints.

M. K. Rajesh (ICAR-CPCRI) gave a talk on deciphering somatic embryogenesis in coconut through molecular approaches. He gave a concise picture on the progress made in understanding somatic embryogenesis pathway in coconut through bioinformatics and transcriptomic approaches.

Working on *Santalum album* (sandal wood) and ghanera (*Nothapodytes foetida*), Devanand P. Fulzele (BARC, Mumbai) observed that conversion of somatic embryo into plantlets was always a challenge in recalcitrant species.

*A report on the Brainstorming session on 'Somatic Embryogenesis and Use of Bioreactors' organized by ICAR-Central Plantation Crops Research Institute, Kasaragod on 2 August 2014.