Measuring and valuing ecosystem services: Himalayan mountain context*

The concept of 'ecosystem services' (ES) or 'environmental services' is becoming increasingly popular since the last decade of the 20th century. Several conferences placed ES high on the agenda. The release of the Millennium Ecosystem Assessment (2005) was an important milestone, highlighting the dependence of humans on ecosystems, and stressed the need to better describe, quantify and value (ecologically, culturally and economically) the ecosystem goods and services. Besides resources like food, wood and other raw materials, plants, animals and microorganisms, the ecosystems provide a wide variety of goods and services that enhance human well-being. Examples of ES range from purification of air and water, hydrological regulation, waste assimilation and detoxification, soil formation and fertility maintenance, nutrient cycling, seed dispersal and pollination, maintaining agro-biodiversity, medicinal plants for pharmaceuticals, protection from harmful UV rays, etc. to carbon sequestration and moderation of climate. In spite of the crucial ecological, cultural and economic importance of these ES, ecosystems are continually deteriorating worldwide as the value of ecosystems to human welfare is still underestimated and the ES are not, or only partly, captured in conventional market economics. The benefits provided by natural ecosystems though widely recognized, are poorly understood and quantified.

Himalayan mountains are of critical importance not only to the people of this region, but also to a significant proportion of the global population. Globally, more than half of humanity relies on the freshwater that accumulates in the mountains for a range of consumptive and non-consumptive uses and sustains the benefit of water flows from terrestrial ecosystems. Mountain forests help capture essential atmospheric moisture, to regulate river flow, and to reduce erosion and sedimentation downstream. Similarly, mountain agroecosystems have been providing food security to mankind and maintaining land races of food crops. Therefore, understanding of functions and values of these ecosystems considering the direct, indirect and existence benefits is crucial.

To address the above concerns a brain storming session on ES in the Himalayan mountain context was organized at the G. B. Pant Institute of Himalayan Environment and Development (GBPIHED), Kosi-Katarmal, Almora with the following objectives: (i) to improve the knowledge base on ES and values, and stimulate the integration of this knowledge in planning and decision making for sustainable ecosystem management, and (ii) capacity building of faculty at different institutions/regional universities and NGOs involved in similar kind of studies in the Indian Himalayan Region (IHR). It was expected that through this brain storming, specific areas such as (i) quantification of ecosystem (viz. forests, agroecosystems and aquatic ecosystems) goods and services, (ii) valuation techniques for these goods and services, (iii) integrating natural resources and environmental services, and (iv) environmental income would be covered. In this event about ten identified resource persons and 20 faculty members from different organizations participated. The deliberations were held around three major Himalayan mountain ecosystems and the key lectures to initiate discussion were delivered by the identified resource persons. (i) Forest ecosystem: Madhu Verma, Indian Institute of Forest Management, Bhopal; Seema Purushothaman, Ashoka Trust for Research in Ecology and the Environment, Bangalore; Aniraban Ganguly, TERI, New Delhi. (ii) Aquatic ecosystems: Brij Gopal, School of Environmental Sciences, JNU, New Delhi; T. V. Ramachandra, Centre for Ecological Sciences, IISc, Bangalore. (iii) Agro-ecosystem and livestock component: Uma Melkania and Vir Singh, G.B. Pant University of Agriculture and Technology, Pantnagar. Lectures on 'Methodological issues' were delivered by Sharad Lele, Centre for Interdisciplinary Studies in Environment and Development, Bangalore and Kamal Ray, Burdwan on 'Environmental sustainability of economic reforms: Valuation methodologies of environmental goods'. During this event the other major focus was on mountain-friendly technologies, in a key lecture by H. N. Chanakya *et al.*, Centre for Sustainable Technologies, IISc.

Forest ecosystem

There is a growing concern worldwide on the economic and ecological contributions of forests to the society, and the policy and institutional changes that are required to enable forests to enhance such contributions and in turn reward the conservation communities. There is considerable appreciation around the world regarding the role played by forests in providing important ES such as carbon sequestration, landscape beauty, biodiversity conservation and watershed protection and support to local livelihoods, especially in the context of a developing country. The hydrological services of forests, chiefly water quality and water flow, are among the most valuable ES from the forests. The recently drafted National Environment Policy of India mentions that foremost amongst the ES provided by forests is the role played in the recharging of mountain aquifers, which sustain our rivers.

Madhu Verma presented a case study on 'Economic valuation of forests of Himachal Pradesh', and mentioned that having faced impact of degradation in upstream catchments in many parts of the world, explicit value is being placed on these services and real payments are being generated for forest owners and managers, acting as incentives for conservation. On the other hand, compensation has been demanded from the agencies who are converting forest land for non-forestry purposes. She mentioned that since August 2002, the Himachal Pradesh

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(HP) government has issued a notification regarding imposition of one-time levy for loss of environmental values on user agencies against forest land diverted towards non-forest use. The one-time levy has been fixed at Rs 8 lakhs per ha where forest density is >10% and Rs 5 lakhs per ha for other forest areas where density is <10%. This levy is in addition to the compensatory afforestation and cost of catchment-area treatment, and rehabilitation of dumping sites wherever applicable. The amount thus collected is meant for compensating the communities whose benefits shall be lost in forest diversion. Seema Purushothaman in her deliberations on 'Socio-economic valuation of natural resource use: Evolving paradigms', highlighted the fact that economic valuation of environmental goods and services has evolved both in terms of objectives and techniques. Valuation exercises are practised in macro and micro-economics to determine sustainable scale, optimum allocation and resource use efficiency of natural capital. Through three case studies she provided insights on (i) quantification of pharmaceutical value of biodiversity and land use valuation, (ii) adoption of the approach in an empirical context in a dry deciduous forest in Central India, and (iii) valuation of land use in forest peripheries.

Aquatic ecosystem

Aquatic ecosystems sustain life on earth, regardless of mankind's understanding of the biology, chemistry and geology involved. Wetlands inhabit a transitional zone between terrestrial and aquatic habitats, and are influenced to varying degrees by both. They differ widely in character due to regional and local differences in climate, soil, topography, hydrology, water chemistry, vegetation and other factors. Wetlands provide habitats and support a diverse range of biodiversity (e.g. in 1 m^2 of coral reef there can be up to 3000 species). Wetlands undertake important biological and ecological processes, including life support systems, i.e. water and carbon cycles. Hence, they are important for hydrological functions, and economic, social, spiritual and cultural development.

Highlighting the importance of aquatic systems, Brij Gopal in his presentation on 'Valuation and management of Himalayan aquatic ecosystems for their ecosystem services', provided a detailed overview of ES offered by lakes and wetlands in the Himalayan mountains and pointed out that valuation of the ES of the aquatic ecosystem is a complex issue as several hydrological variables such as duration, frequency, amplitude of variation and timing of water in the system, besides geomorphic features of their basin, determine the ecosystem goods and services. Further valuation must take into account the downstream benefits as well, as the ES provided by them are of far greater magnitude and significance to the downstream populations. The sediments transported by the rivers are not just an economic resource but, besides determining the habitats and biodiversity of the downstream areas, influence the regional climate (through regulating sea salinity). He also emphasized the cultural significance of water bodies, as all rivers, lakes and springs have religious and spiritual values since historical times. T. V. Ramchandra in his presentation entitled 'Appraisal of aquatic ecosystem services' underlined that valuation is further complicated by the fact that all aquatic ecosystems interact with, and are dependent upon, their terrestrial catchments. He maintained that the valuation of ES, and therefore the management of aquatic ecosystems for the sustainability of these services should be made on a river-basin scale. Management of Himalayan aquatic ecosystems must avoid maximizing gains from their ES in a manner that will have far-reaching irreversible consequences for downstream services.

Agroecosystems

These are known for the dynamic process of carbon sequestration. Agroecosystems can contribute to manage the soil carbon pool more effectively. Soil carbon pool is twice as big as the biomass carbon pool. Uma Melkania in her presentation on 'Issues of ecological economics and ecosystem services in the agroforestry system in Himalayan mountains', described the interlinkages of mountain farming system with forests, grasslands, livestock components and underlined the need for considering watershed as a planning unit for conservation and management of resources to maximize the ES. Vir Singh in his presentation on 'Livestock-mediated agro-ecosystem services in the Himalayan mountains', stressed upon the fact that agroforestry systems, orchards, silvi-pastoral systems and all other types of food production systems in order to keep thriving, need inputs generated by livestock, especially dung/manure and energy (draught power) as well as the invisible services rendered by them. Thus, livestock do extend their services to accelerate the process of CO_2 absorption into plant biomass and soil carbon pools. Amita Shah provided inputs on maintenance of diversity, reduction of run-off and flooding, and diversified income as the three ES of agroecosystems. J. C. Kuniyal, in his inputs on cold desert agroecosystems of HP, took into account the impacts of agroecosystem on the surrounding ecosystems.

In the quest for sustainable development of hilly regions of India, it is important to use sustainable technologies, techniques and practices as vehicles that gradually bring about development that can qualify a criteria set for sustainability. Such a filtration process is essential today because it is perceived that indigenous or traditional technologies and practices fail the criteria of profitability while the currently marketed technologies and practices are obsessed with 'short-term profitability', often measured merely on yardsticks such as returns on investment and therefore pass the criteria of sustainability. Fair evaluation of technologies can happen where criteria of ecology, environment, human and knowledge resources are included in the evaluation process. In the above context, H. N. Chankya presented the experience of 'Participatory technology development on coffee bioreactors' as an example of a process where the above issues are addressed at the grassroots level, enabling informed choices as well as gradual development of local resource base.

Delegates from different institutions/regional universities and NGOs (Indian Council for Forestry Research and Education, FRI, Dehra Dun; Vivekananda Parvatiya Anusandhan Sansthan, Almora; Wildlife Institute of India, Dehra Dun; Faculty from Forestry and Botany Departments, Kumaun University, Naini Tal; Garhwal University, Srinagar and Gurukul Kangri University, Hardwar; GBPIHED scientists and researchers) participated in the discussions and highlighted the need for capacity-building on

valuation methodologies and putting their studies in the ecological economics framework. The GBPIHED scientists made brief presentations about the R&D work being carried out on the subject and invited inputs from the resource persons. The major follow-up points that emerged were: (i) collaborative studies between centres of excellence on natural sciences, economics and social sciences, particularly on methodologies for quantification of ES and economic valuation of ES; (ii) developing expertise on ecological aspects of ES and their measurement/quantification; and (iii) using ecological science as a tool to better manage the environment.

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MEETING REPORT

Insect genetics and genomics on the fast track*

Beginning in 1908, a tiny fly *Drosophila melanogaster* changed the course of genetic experiments by providing the first mutant gene, *white eye*. Not satisfied with collecting mutants, scientists sequenced the entire genome of the fly in 2000, to herald an era of insect genomics. Today researchers work on more than a hundred insect maps, analyse 37 whole genome sequences and nearly two million ESTs of different insects, and a dozen insect species have been given a dose of foreign gene by means of transgenesis. Such enormous and diverse research data generated by genomics, were just as expected from the most diverse group of living organisms on our planet, the insects.

As a result, the number of research publications has exponentially grown, making it difficult for a non-specialist to follow the developments. Although the internet and e-mail have aided in getting TOCs and reprints, gaining knowledge about frontier insect genetics and genomics research from its practitioners is the best impetus a researcher can get. The Centre for DNA Fingerprinting and Diagnostics, Hyderabad in the thick of advances accomplished in silkmoth genetics and genomics (Figure 1), played host to 25 invited speakers from nine countries to present an account of their current research in the field of insect genetics and genomics. Various aspects of as many as 30 insect species (Table 1) were covered during the symposium by means of oral and poster presentations grouped under seven broad topics, as reported in the following sections.

*A report on the 'International Symposium on Insect Genetics and Genomics' organized during 9–11 January 2006 by J. Nagaraju, Centre for DNA Fingerprinting and Diagnostics (CDFD), India and Toru Shimada, University of Tokyo, Japan and held at CDFD.

Genetic mapping

Contrary to a widespread misconception of the genomic era, genetic maps remain indispensable even in organisms with completely sequenced genomes. Either a physical map is nonexistent, or in physically mapped genomes gaps in clone coverage, lost DNA fragments and dislocated fragments contribute significantly to erroneous mapping. In the absence of comprehensive annotation of the sequenced genomes, it has been realized that to overcome these problems, as well as to improve overall mapping accuracy, comparing and integrating physical maps with genetic and cytogenetic maps is obligatory. Marian Goldsmith (University of Rhode Island, USA) set the stage by reviewing the status of molecular linkage maps in silkworm, including integration of different genetic maps, and genetic and physical maps. She also listed the genes that need immediate attention for map-based cloning and analysis. A case in point was illustrated by K. Kadono-Okuda (National Institute of Agrobiological Sciences, Japan) concerning EST-map-based cloning of *Bombyx mori* densovirus resistance gene *nsd2*, which does not express in cell lines. Holocentric nature of *B. mori* chromosomes make them difficult to identify and genetic maps may contain errors of location. Ken Sahara (Hokkaido University, Japan) used genomic tools such as BAC–FISH to correct and fine-tune genetic linkage maps of *B. mori* (e.g. chromosomes 8, 13, 16 and 18). Christian Schlötterer (Veterinary University, Austria) presented the concept of hitch-hiking mapping in the context of population genomics of fruit fly. He sounded caution against the stochasticity of mapping experiments due to involvement of multiple factors. For instance, demography affects pattern of variation in X-chromosome and autosomes of *Drosophila*.

Comparative genomics

Comparative studies on genome sequences among insects, worms and vertebrates can point to taxa-specific genes. Newly sequenced organisms such as *B. mori* can complement *Drosophila* as a model organism, as much of our knowledge of endocrinology, reproduction, behaviour and immunity derives from studies in Lepidoptera. As many basic physiological processes of insects are conserved through evolution, a comparative study will help further elucidate the function of gene homologues. Further, comparing at the molecular level elucidates what makes Lepidoptera, for instance, different from other insects, as many of these newly identified genes are potential candidates for targets of lepidopteran-selective insecticides. David Heckel (Max Planck Institute of Chemical Ecology, Germany) introduced the topic by elaborating on the importance of *B. mori* genome sequence information on comparative genomics of Lepidoptera. The central theme of his talk was, however, about the limitations of the current genomic data in understanding lepidopteran genetics, for which Heckel suggested better integration of maps and sequencing of a second lepidopteran, *Helicoverpa* sp. Kazui Mita (National Institute of Agrobiological Sciences) detailed first-hand information on WGS, cDNA collection and physical-map