HIMALAYAN FOREST ECOSYSTEM SERVICES

Incorporating in national accounting

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Kyoto : Think Global, Act Local

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Front Page Concept :

The map on the cover indicates the flow of Forest Ecosystem Services from a part of the Himalayan region to the Gangetic plains (light green portion). The three arrows shown in the map indicate this flow.

About Kyoto : Think Global, Act Local

The main goal of the Kyoto; Think Global, Act Local project is to be able empower local community forest groups in the Himalayan region to access funds under the UNFCCC and Kyoto Climate Change. Initiated in 2003, this multinational project is being leaded by University of Twente, The Netherlands (Dr. Margaret Skutsch) and regionally coordinated by ICIMOD, Nepal (Dr. Kamal Banskota). In Uttarakhand state of India, CHEA is the implementing it with Prof. Surendra P. Singh as Principal Investigator, Dr. Pushkin Phartiyal (Community Participation Specialist) and Dr. Ashish Tewari (Scientific Investigator). This publication is an effort for sharing of research carried under the project.

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Thanks are due to CHEA, it's council and Dr. Andreas Schild, Director General, ICIMOD, Nepal for their constant support for implementation of the Kyoto Think Global Act Local Project in Uttarakhand.

Uttarakhand : The grandeur of high snow clad mountains (above). Collection of firewood by women in a Himalayan village (below).

Foreword

One of the major changes which we were able to bring about in the developmental policies and procedures of the newly carved out state of Uttaranchal, now Uttarakhand, in year 2000, was to make our rural developmental strategy forest-centric. Consequently, the designation of the Agriculture Production Commissioner, the APC, was changed to the Forest and Rural Development Commissioner, or FRDC. It was not mere cosmetics and the central concept was to re-visit forests and forestry from all possible angles, including their potential of creating income generation opportunities for the local/rural house-holds. This line of thinking ultimately culminated in what came to be known as the CDH Plan, or the Conservation, Development and Harvesting Plan in so far as the development of medicinal and aromatic plants was concerned. Imprint of this policy shift is traceable in many a schemes and institutions which have since been created in the state. As arguably the last Himalayan State, Uttarakhand was expected to trigger innovative initiatives for conservation of its rich forest wealth keeping in view their significance for 500 million people living in the Great Gangetic doab. For a long time there has always been a lurking demand for a tangible economic incentive in our national accounting system. It was but natural for Uttarakhand to spearhead a demand through a Memorandum when the first opportunity presented itself in the form of a presentation before the Twelfth Finance Commission (TFC). Interestingly, the three newly formed states of Jharkhand, Chattisgarh and Uttaranchal took their birth between two Finance Commissions, thus depriving each of them major maintenance allocations made to the states by each Finance Commission.

As we were looking for relevant propositions for the Twelfth

Finance Commission I came to know about an international research project "Kyoto Think Global Act Local", managed in a number of developing countries of Africa and Himalayan countries, including India under the leadership of Dr. Margaret Skutch from University of Twente, the Netherlands. This research project focused on: (i) carbon sequestration by community managed forests, (ii) enabling local people to measure carbon sequestration by forest, and (iii) make a claim for payment. CHEA, the Indian partner of the project was contacted, discussions were held with Prof. S.P. Singh, the then professor of Botany, Kumaon University, who was the principal investigator, and his associates Dr. Pushkin Phartyal and Dr. Ashish Tewari, mainly on various implications of giving a value to a standing forest. These deliberations resulted in constituting a Task Force of Experts for dealing with carbon issues of the state, with Prof. S.P. Singh as the Co-ordinator. This very Task Force of Experts' services were soon utilized for developing a Memorandum for consideration of the Twelfth Finance Commission (TFC), making a strong plea reflecting the forest eco-system services provided by the Himalayan States in particular and all the forests in general. When I formally approached Prof. S.P. Singh with this proposal, as the visit of the XII Finance Commission was imminent, this resulted in a flurry of activities, in intensive exchange of notes and ideas, and ultimately into the Additional Memorandum for the XIIth Finance Commission of India, in a record two weeks' time!

This Additional Memorandum to the TFC, presented on behalf of the Government of Uttaranchal/Uttarakhand, was so forceful and well-argued that I shared it with all other Chief Secretaries of the nine Himalayan States and states with predominant share of forest area, requesting each of them to add to this their very own arguments when presenting their own respective cases before the TFC. I do, however, wonder as to what extent they were able to improve upon it at all but most of them did thank me for the gesture ! When the Award of the Twelfth Finance Commission was announced we were more than pleased to see our efforts resulting in a recommendation for a substantial transfer of resources to the forest rich states for maintenance of their forests. Acceptance of the recommendations of the TFC has resulted in transfer, for the first time in the history of India, of Rs. 1,000 crores for the maintenance of existing forests, on a pro-rata basis viz. on the basis of recorded area of forests as validated by the Forest Survey of India. If one is not mistaken this provision of Rs. 1,000 crores for the period of next five years must represent one of the few major payments for the eco-system services by the forests in the entire world by any country.

I am indeed delighted to see that Professor S.P. Singh has further developed the draft, presented to the Twelfth Finance Commission as the Additional Memorandum, into a book and CHEA has undertaken the task of publishing it for the benefit of all those interested in forest conservation, the eco-system services that emanate from them and economic incentives which are logically required for sustaining conservation activities. Being naturally very happy to have played a very modest role in leveraging a substantial sum for the maintenance of our forests, courtesy the yeoman efforts made by Prof. S.P. Singh and his colleagues in the Task Force, I do hope that the process of policy change would not stop here but be galvanized further spurred by this initial success into in-depth researches on the various aspects of eco-system services and development of appropriate strategies for conservation in general.

In passing, let me hasten to add that a similar realization for a change in policy, on the development finance side, has also manifested itself, if the Mid Term Assessment of the Tenth Five Year Plan (MTA), is any indication. And, it says:

"Environment sustainability is not an option but an imperative. Clean air, pure water, conservation of forests and wild life and generation of greenery are the essentials for a healthy environment. Prevention of degradation of land, controlling floods and droughts, preventing desertification, conservation of fragile eco-systems, prevention of deforestation, conserving bio-diversity and mitigating water and air pollution, all present challenges for planners and policy makers." (Mid -Term Assessment, Tenth Plan, Planning Commission of India, page 427)

Planning Commission documents also acknowledge that " the preservation of forests...is an environmental public good, generating positive externalities for multiple stakeholders beyond the local level. There are costs, including opportunity cost, associated with forest preservation, which are borne by local stakeholders while benefits accrue to dispersed groups of stakeholders (the country and the world at large). For example, the ban on green felling has meant that many states with large forest cover have had to forego revenues from this source. If regional balance is to be encouraged by leveraging the innate strengths of the less developed states, there is no reason why these already relatively backward states alone should bear the country's economic burden of environmental conservation. Consideration need to be given, " adds the Planning Commission Mid Term Assessment report, " to evolve a suitable mechanism to compensate, in some way, these backward states with a high proportion of land under verified forest cover, for providing this public good. This would be a pro-equity entitlement that would create a level playing field and reduce the inherent economic disadvantages of backward, forested states." (MTA, Planning Commission of India, pages: 506-507)

Having successfully played a seminal role in highlighting the important part played by our forests in providing life-sustaining eco-system services to the country, through the two most important instruments of our national accounting system, namely the Finance Commission and the Planning Commission, I am sanguine that the present publication would carry the agenda forward and generate interest in planners, decision-makers and the academia. I avail this opportunity to congratulate and thank Prof S.P. Singh and his colleagues for highlighting the importance of eco-system services rendered by the forests and mountains in India and pioneering insightful researches which are bound to impact on the economies and welfare of several backward and mountainous regions of the country.

R.S. Tolia
Chief Information Commissoner, Uttarakhand

Summary

Resulting from interactions between biotic and abiotic components of ecosystems, ecosystem services sustain and fulfill human life and without them economics of the world would grind to a halt. Some of the common ecosystem services associated with forests are hydrologic regulation, climatic control, soil formation, carbon sequestration and recreation. The cost of products such as foodgrains, hydroelectricity and drinking water would be much higher if ecosystem services were fully accounted for in monetary terms. At present consumers do not pay for the services of ecosystems that are used to produce goods and services enjoyed by humans. Because of this natural ecosystems are liable to degrade and eventually collapse, leaving future generations with depleted natural capital and fewer options. In a major exercise by a team of economists and ecologists the monetary value of global ecosystem services was estimated at least, at $ 33 trillion, which was about as much as the then global GDP (in 1994).

Both ecology and economic valuation of ecosystem services are still in infancy. Here we have made the first approximations of values of Himalayan forest ecosystem services, primarily based on the estimates of Costanza et al. (1997) for temperate and tropical forests. While applying their values, we have kept in view that the ecological characters of the Himalayan forests are closer to tropical than temperate forests. As for carbon sequestration estimates,

they are fairly reliable. Our estimates of forest carbon pool in Indian Himalaya is about 5.4 billion t (forest biomass + forest soil), which is about equal to the annual carbon emission from fossil fuels in Asia. The total value of forest ecosystem services flowing from Uttarakhand is about 2.4 billion dollars/yr, or Rs. 107 billion/ yr, and at Indian Himalayan level it is Rs. 943 billion/yr.

Because of the river connections, the ecosystem services flowing from Uttarakhand have played a principal role in shaping the rise of culture in the great Gangetic plains, inhabited by nearly 500 million Indians. Therefore, it is important that the Himalayan forests are conserved, and people living in Himalayan regions given appropriate economic incentives for their conservation efforts. Whatever success the people of the Himalayan regions have achieved, they have been able to do so without enjoying facilities of modern energy sources. The economic gains for providing ecosystem services to downstream areas could be used to supply cooking gas or electricity at an affordable cost. The value of ecosystem services could be at least reflected in national accounting systems, particularly while transferring money from the center to states. Getting payment for maintaining standing forests would be a great advancement in the area of conservation.

Introduction

The last century has seen more dramatic changes in human history than any other of the past. Doubling in agricultural land, four-fold increase in human population, 14-fold increase in economy, 15-fold increase in energy use, and 17-fold increase in carbon dioxide emission are some of the examples of these changes (Peterson et al. 2003). The climate change induced by the increased emissions of green house gases (carbon dioxide, nitrous oxide, methane, chlorofluro-carbons and others) is real and has begun to touch us. Human activities have increased carbon dioxide concentration in the atmosphere from 280 to 380 ppm (in 2005) in less than two centuries, and global temperatures by 0.75 ^{O}C in the past century (Folland et al. 2001). Present CO_2 level is higher than at any time during last 6,50,000 years. Though some people still question it, the weight of evidences in favour of global warming is so large that it is no more possible to ignore it. The rise in global sea level by 20 cm, and six times more use of Thames Barrier which protects London from flooding down of the Thames estuary, diminution of snow packs and some of the longest and largest glaciers of the world in the Himalaya, and decrease in the yields of apple in some areas of Himalaya due to the inadequate winter chilling, and incidents of subsiding buildings because of the thaw of ground beneath them in Alaska are a few examples of the warning of this global crisis (see box 1). It is already a greater crisis than the global terrorism (King 2000). Nearly 35,000 deaths in the

Box 1. A few evidences of climate change

Rise in CO_2 concentration is well established so is its linkage with temperature.

Temperature rise by 0.75° C during the industrial period, and sea level rise by 20 cm.

Leaf production hastened by 6 days and leaf fall delayed by a similar number of days globally.

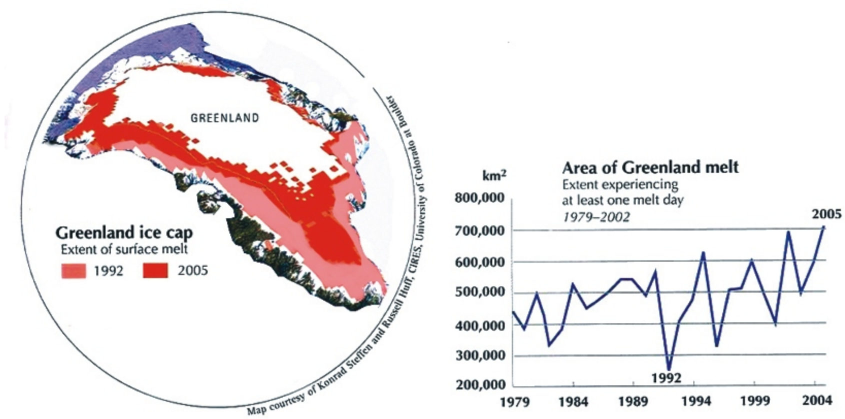
22 out of 35 non-migratory butterfly species in Europe shifting their ranges to north by 35-40 km.

Reduction in the hunting season of polar bears (with adverse consequences on health and reproduction) because of decline in Arctic sea ice.

Retreat of mountain glaciers in Andes, Himalaya and Alps; Siberia melting; breaking away of Larsen B ice-shelf from Antartic Penniusula; melt of permafrost in Alaska, causing buildings and roads to subside.

Extreme weather incidents: over 50° C temperature at many places in India and Pakistan in 2003; 1,800 deaths and million stranded due to floods in Bangladesh in 2004; about 35,000 death in heat wave of 2003 in Europe.

Uneasy and turbulent oceans.



Changes in Greenland ice cap between 1992 and 2005 an evidence of climate change

heat wave of 2003 in Europe and expected massive species extinction are possibly dire warnings of the likely collapse of some of the societies, if the crisis of global warming were not to be averted.

The countries of the world are seeking international commitment to reduce the emissions of CO_2 and other greenhouse gases under the Kyoto Protocol. It provides an economic process that puts a value on not emitting CO_2 and enables countries to trade carbon emissions. Under the Clean Development Mechanism (CDM) of Kyoto Protocol there is a provision to derive monitory benefits from developed countries to support certain forestry operations in developing countries, such as carbon sequestration through afforestation and reforestation. In a way, this is a mechanism to get payment for providing an ecosystem service of global significance. Such a concept can be applied on a regional or country-scale, to compensate the regions sequestering carbon.

It must be recognized that there are many more precious services that emanate from the earth's ecosystems, and along with natural capital stocks that produce them, they are critical to the functioning of our life-support system and human welfare. In a comprehensive analysis, Costanza et al. (1997) estimate the current economic value of the services provided by the earth's ecosystems at least at US$ 33 trillion per year. Most of these services are not part of the market system and are ignored and underdeveloped.

Rationale of valueing ecosystem services

Ecosystem services result from interactions between biotic and abiotic components of ecosystems (Singh 2002) (Fig.1). Daily (1997) defines them as conditions and processes

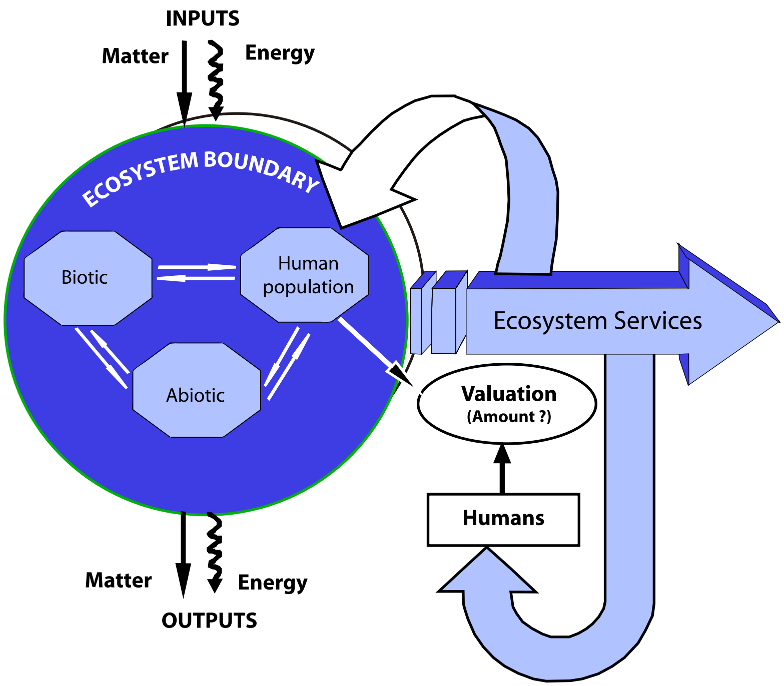


Fig. 1. Interaction between abiotic and biotic components of ecosystems results in many ecosystem processes, which sustain and fulfill human life. They are called ecosystem services. They always flow, but are treated as services only when they serve humans. (from Singh 2002)

through which ecosystems and species in them sustain and fulfill human life. Some economists treat ecosystem services (ESs) as components of nature enjoyed, consumed, or used for human well being (Boyd and Banzhaf 2006). According to them ESs are things or characteristics, not functions or processes which are not end products, they are intermediate to the production of final services. Accordingly, costs of products such as agricultural crops, hydroelectricity, and domestic water supply in cities (the supply of which depends partly on upstream ecosystems services) would be much higher if ecosystem services were accounted for in monetary terms. At present the final consumer does not pay for these inputs. This has two consequences. First, there is an equality problem: why should the products, which are consumed mainly by urban populations, be subsidized at the cost of the

A dense oak forest in the watershed of Pinder river. An oak forest not only makes precious soil, it is also a source of rich biodiversity.

people of rural areas where ecosystems are conserved. Second, there is a danger that the people of rural areas may eventually decide to stop conserving ecosystems, in favour of short term local benefits, which would be disastrous in many ways, and extremely expensive, if not impossible to reverse. Thus, efforts are required to do their valuation at all spatial

Maha Kali River at Jauljibi, Dharchula. Rivers are not only source of water, but they also serve the society by providing several other ecosystem services, including giving scenic beauty to the region.

* The un-numbered pictures show various aspects of ecosystem services and related things.

scales (local, regional, national and global), and identify the regions from where they flow and those who are the beneficiaries. There would be a need to develop appropriate mechanisms of money transfer from the consumers of the eco-services to the producers of these. The market does not perform this transfer at present, therefore this function needs to be taken over by the state. In the case of Himalayan states, which are providers of ecosystem services, the most appropriate mechanism would appear to be a centre-state money transfer in which the funds from general revenue at national level (representing the consumers) is ploughed back via the states into forestry and other eco-services at the local level in the Himalayas, such that the local people may obtain tangible, financial returns for their efforts. Obviously, each country needs to prepare itself to address the problems of global change, by giving value to regions important for its ecological security. For example, in case of Himalayan states it may be important for local people to have access to modern energy sources to enable them to keep forest conserved. Suitable mechanisms would be required to ensure that the local communities have share in the money that is transferred from centre to the states.

First approximations of the value of forest ecosystem services

Though the valuation of ecosystem services emanating from the forests and other ecosystems of Himalaya is still in its infancy, and may require several years of research, we are in a position to make first approximations, good enough to make a plea for taking measures to better reflect them in our accounting systems. In this article on the Himalayan states, I have depended more on Uttaranchal, largely because of the better understanding of its ecosystems. Ecosystem services (ESs), are divisible into three categories with regard to our ability to make their estimates, viz., (i) ESs for which approximate values are already available for some forests and can be easily estimated for others e.g., carbon sequestration by forests; (ii) ESs which are quantifiable by developing suitable methods, e.g., hydrological regulation, and generation of soil fertility; and (iii) ESs which are proven, but inestimable at a regional or larger spatial scales because of several confounding factors, e.g., effects of forest cover on the regional climate. We have presented two sets of data: (i) Carbon value of forests, compiled from various sources, particularly those generated by ecologists of Kumaun University, Nainital. (ii) Aggregated value of all ecosystem services using the estimates generated by Costanza et al. (1997). We have also provided reasonably reliable information in support of our argument that due consideration should be given to the forest-rich states of the country while making centre-state financial transfers.

Carbon-sink value of forests

Nearly 20-25% of the annual atmospheric increase of about 8 billion t of carbon is a consequence of deforestation, which results in the depletion of the carbon-sink (Fig. 2). Therefore, conservation of forests, including those under the control of local communities in developing countries, is an important component of overall climate strategy. Forest sinks represent much cheaper and easier solution to the build-up of the atmospheric carbon. However, carbon sequestration by existing forests, including those managed by local communities are not eligible for carbon trade under the Kyoto Protocol largely because technical difficulties that were foreseen in accurate measurement and verification of carbon gains. Under the Kyoto Protocol only afforestation (plantations on land where forests did not exist) and reforestation (plantation on land which was cleared before 1990) are eligible for carbon trade. However, avoidance of deforestation by conserving forests is more effective solution to the atmospheric rise of CO_2, as what matters is the carbon pool size in a forest, not the rate at which carbon cycles through it. Indeed, plantations would bind carbon rapidly,

Forest cover in Nainital is still dense. Though the lake has great recreational value, tourists also give importance to adjoining forests.

but they may take 40-50 years to accumulate amounts equal to that are stored in the existing forests.

It has been argued that land use changes acceptable under the Protocol should also include soil carbon sequestration, and changes in carbon emitted as a result of afforestation, reforestation and deforestation activities. Carbon loss from

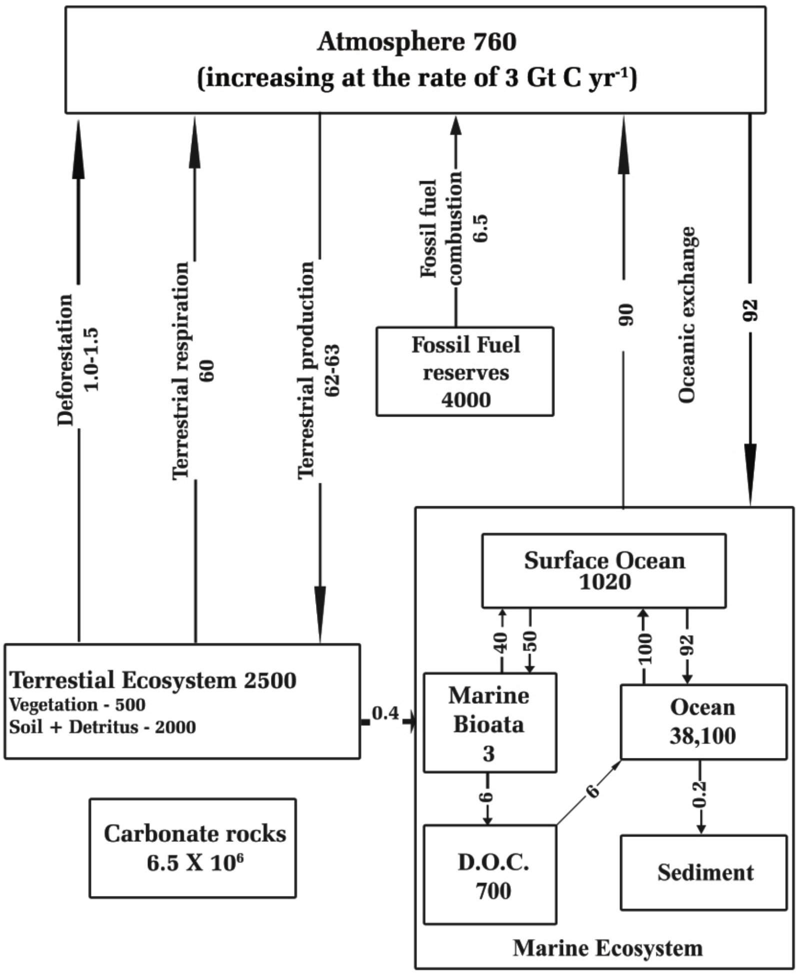


Fig. 2 Global carbon cycle during the 1990s as described in Grace et al, (2001). The stocks shown in boxes are in billions of tonnes of C (GT C); arrows indicate fluxes, Gt C Yr^{-1}. C in atmosphere is increasing at the rate of 3 Gt C Yr^{-1}. DOC is dissolved organic carbon.

soil following deforestation can be very high, particularly in the Himalaya, where slopes are steep, immature and subject to three monsoon months of heavy rainfall.

At global scale, soil holds more carbon than the atmosphere and biomass combined (see in Zobbagy and Jackson 2000), and is therefore important for managing global carbon budget. Since deforestation often results in a rapid soil erosion and chemical breakdown of soil organic matter, the carbon cost of deforestation needs to take this into account as

Community managed banj oak forest at Lamgara, Almora. It sequesters a considerable amount of carbon apart from being a source of firewood and fodder.

well as the carbon in trees. Indeed it has been shown that the total cost of lost carbon due to deforestation is far greater, in dollar terms, that the cost of raising plantations (Korner, 2001). Plantations, although, may contribute to the prevention of deforestation and long-term carbon fixation in biomass, they certainly cannot substitute for the forest, which provides many services which a plantation cannot. Under the Kyoto Protocol the role of existing forests in carbon strategy was excluded because of reasons other than those based on scientific knowledge.

In view of the above we have considered both, the existing carbon reserve or pool in the forests and the rate of carbon sequestration. Data on changes in carbon reserves may help to evaluate the amount of carbon loss avoided by conservation measures. While doing so, we have included carbon of both biomass and soil pool wherever data are available. Being away from atmospheric interaction, the deep soil carbon is effectively sequestered, and the recognition of its value gives importance to certain deep rooted species, such as the common Himalayan oak (*Quercus leucotrichophora*), which otherwise are not valued.

Carbon sequestration in Uttarakhand

In Uttarakhand and several other Himalayan states most of the forest loss currently occurs as a consequence of forest degradation, in which forest stock declines without decrease in area. This represents a form of chronic disturbance (Singh 2002) in which the biomass removal on a given day is invisible, generally in form of a few human loads of firewood, fodder, and forest floor litter for manuring. Whole tree cutting generally does not occur. Because of grazing of domestic animals seedlings stop becoming saplings and saplings seldom become trees. The lopping of leafy branches reduces seed setting, and as trees become progressively denuded, they stop even regenerating foliage. The land is eventually left with a large collection of stems and their large leafless branches. They represent carbon stocks that keep on diminishing. The incessant pressure of the slow biomass removal, trampling and grazing do not give respite to the forest to recover, and it may degrade for the lack of regeneration even when biomass removal is within the

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* It might be helpful to give definitions of 'forest', 'afforestation' and 'reforestation', as defined in the Marrakech Accord:

- Forest is defined as "a minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30%, and with trees with the potential to reach a minimum height of 2-5 metres at maturity in sity"
- Afforestation is defined as "the direct human-induced conversion of land that has not been forested forland that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources".
- Reforestation is defined as "the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, and land that was forested but that been converted to non-forested land".

carrying capacity with regard to net primary productivity. Trampling and litter removal, in a long run, deplete soil carbon and damage roots. Somehow, forest degradation, the main cause of depletion of carbon in developing countries, is hardly referred to under the Kyoto Protocol. There the carbon loss is generally referred to as the decline in forest area resulting from tree cutting.

Table 1. Carbon in different forest ecosystem types of Uttarakhand. Forest area based on remote sensed data of P.S. Roy and P. Joshi (unupbl.), in which biomass and productivity were determined by actually harvesting trees and carbon by measuring concentration in each component. Their estimates based on six undisturbed forest stands of all major types along an attitudinal gradient of over 2000 m were adjusted for disturbed conditions in the region by multiplying with a correction of 0.63, derived from Singh and Singh (1992). For soil, the depth was extended from 30 cm (measured by Rana et al., 1992) to 150 cm (measured by Ashish Tewari and Bhupendra Jina, unpubl. data). The total carbon sequestration value at the rate of US$ 13 per t C (which is the average of rates prevailing in 2004) is US$ 85.91 million of Rs. 3.82 billion (US $1=Rs. 44.5). M=Million; t = metric tonne; C = Carbon.

Forests Type	Area (km^2)	Carbon				
		Biomass Pool	Forest loor Litter (Mt)	Soil pool (150 cm) (Mt)	NPP ($t\ ha^{-1}$)	Net Accumulation in biomass ($Mt\ yr^{-1}$)
Tropical conifer (pine)	5418	33.4	1.74	61.71	3.14	1.43
Temperate conifer	6017	37.1	1.9	68.54	3.49	1.59
Temperate broad leaved	7809	119.3	2.39	111.95	4.72	2.29
Moist deciduous	3027	54.4	0.30	15.10	1.85	0.92
Dry deciduous	695	12.5	0.07	3.47	0.42	0.21
Sub Tropical(sal)	562	10.1	0.05	2.80	0.34	0.17
Total	**23528.05**	**266.96**	**6.48**	**263.58**		**6.61**

In relatively undisturbed forests of various types in Uttarakhand, such as sal (*Shorea robusta*), pine (*Pinus roxburghii*)and oaks (*Quercus spp.*) forests, generally carbon sequestration rate in total biomass ranges between 4.0-5.6 t C ha^{-1} yr^{-1}, which are reasonably close to values reported for tropical forests. However, these high rates are not found everywhere. Largely because of forest degradation, at regional scale a range of 2.52-3.53 t C ha^{-1} yr^{-1} is common. Low values of carbon sequestration are also likely to occur on steep slopes with shallow sandy soils, along rivers where dry deciduous forests with stunted trees are common. The amount of carbon accumulated in total forest biomass in the state is 6.61 million tones (M t) annually (Table 1), valuing Rs. 3.82 billion at the rate of US$ 13 per t carbon (Table 1).

Soil carbon pool on deep soil sites is as large as the biomass carbon pool, but we do not know the rate of sequestration in the soil. However, loss of soil carbon following the cutting of forest can be considerable in Himalaya because of immature topography, steep slopes and high geological activity level. A preliminary study carried out in Lamgarha block of Almora District indicates that forest degradation may lead to soil loss at the rate of up to 3 t C ha^{-1} yr^{-1}.

The major conifers at the regional level are *Pinus roxburghii* in lower altitudes and silver fir (*Abies pindrow*), blue pine (*P. wallichiana*) and deodar (*Cedrus deodara*) in higher altitudes. Broad leaved forests in which oaks (*Quercus luecotrichophora*, *Q. floribunda* and *Q. semecarpifolia*) dominate are also major accumulators of carbon (Table 1.)

Carbon associated with increase in forest area

T.P. Singh (unpubl.) has recently used the data on increase in forest area in Uttarakhand to estimate carbon sequestration.

The major points of the same are as follows:

1. On the basis of State of Forest Report (SFR) 2001, the area of dense forest (over 40% crown density) increased by 117400 ha, from 1,784, 900 ha in 1999 to 1,902,300 ha in 2001. And during the same period the area of open forest decreased by 49600 ha.
2. The carbon content in the biomass of the increased area of dense forest category was estimated as 22,951,700 t and decrease in carbon amount as a consequence of decrease in open forest areas as 6,328,960 t in open category. To be on the safer side only 20% of the increase in forest cover was taken, as the remaining portion was speculated due to the difference in methods of forest cover estimation between the two assessment years. FSI recently has developed methods to assess forest cover down to 1 ha (Saxena et al. 2003).
3. At the rate of US$ 13 t^{-1} C, the value of increased carbon (16.6 M t) in biomass is US$ 216.1 million or Rs. 906 billion. It gives an annual value of Rs. 4.8 billion.

Carbon sequestration in community forests of Uttarakhand

Under an international project, Kyoto-Think Global Act Local, led by the University of Twente, the Netherlands an attempt is being made by the investigators of CHEA (Central Himalayan Envirnment Association) to enable the local people to measure and monitor carbon sequestration in community forests (called “Van Panchayats”, they are managed by village level forest councils) of Lamgarha block of Uttarakhand, and to make a claim for payment for carbon services (Singh S.P., Tewari Ashish and Phartiyal P., Unpubl.) Data collected for three years show that these forests on average are sequestering carbon at the rate of 3.7 t C ha^{-1} yr^{-1} (Table 2).

This is not an inconsiderable amount given the fact that the people depend on their VP forests for extracting biomass for firewood, fodder and litter. It may be pointed out that forest floor litter is the main source of nutrients for crops grown in

An evenaged banj oak forest under the management of Dhaili, Van Panchayat, Almora. People believe that water in village stream increased with the establishment of this oak stand.

Biomass measurements at Dhaili Van Panchayat, Lamgara, Almora. It is possible to train local people to undertake some of the responsibilities of measuring carbon sequestration by forests.

Table 2. Carbon stock and sequestration rates in a few community forests (Van Panchayats, VPs) of Lamgarha block of Uttarakhand (from Singh SP, Tewari A and Phartiyal P., unpubl.)

Uttarakhand, India	**Carbon stock ($t\ ha^{-1}$)**			**Mean sequestration rate ($t\ C\ ha^{-1}\ yr^{-1}$)**
	Year 1	**Year 2**	**Year 3**	
Dhaili VP forest				
Even aged banj oak forest	172.1	176.5	179	3.4
Dense mixed banj oak forest	255.7	260.2	264	4.2
Mixed banj oak chir pine degraded	18.8	20.8	23.25	2.2
Mean C- stock			**155.4**	
Toli VP forest				
Young banj oak with chir pine forest	156.9	161.2	165	4.05
Chir pine forest with bushy banj oak	58.9	62.4	65	3.05
Young pure chir pine forest	69.5	74.0	78	4.25
Mean C- stock			110.26	
Guna VP forest				
Young pudre chir pine forest	-	10.3	14.1	3.8
Mixed banj oak forest	-	154.0	158.4	4.4
Mean C- stock			**86.2**	
Mean C- sequestration rate across the forests				**3.7**

mountains. Clearly, the community level efforts are contributing to forest conservation. In contrast, in an area of 2865 ha in Uttaranchal where communities were not playing their role in forest management, Rathore et al. (1997) found depletion in carbon stock of biomass at the rate of about 5 $t\ yr^{-1}$ over a period of 16 years, though there was only a small reduction in forest area. This is a good example of the amount of carbon that can be saved by local people managing their forests effectively. People of the study villages conserve their community forests generally by (i) protecting forest by employing guards on payment or by providing voluntary service; (ii) enforcing rotational grazing;(iii) collection of only fallen wood for cooking purpose; and (iv) participating in controlling fire. Though some leakages take place as occasionally people collect biomass from government forests, they are not large enough to severely affect carbon sequestration at the regional level. However, to sustain both carbon forestry and biomass extraction to meet the daily needs of firewood, fodder and litter community forests must be of sufficiently large sizes. If managed properly, about 3 ha of forests can meet the demands of biomass associated with 1 ha of cropfield and about 8-10 persons. Not all community forests are of this size, however, consequently degradation in them is quite common.

Situation at Indian Himalayan level

In the entire Indian Himalayan region it is estimated that forests sequester about 65 million t carbon annually in aboveground biomass alone. The value of this carbon sequestered annually in aboveground forest biomass is estimated as US$ 843 million or Rs. 37.5 billion (Table3). Between the two principal divisions of Indian Himalaya, western Himalaya is about 25% larger geographically than north eastern Himalaya, but with regard to forest area western Himalaya is 2.6 times smaller than the eastern Himalaya. In the Kashmir region of western Himalaya, alpine meadows dominate. Therefore, forests in north eastern region accumulate nearly three times more carbon each year than in the western region.

The size of soil carbon pool of alpine meadows (Table 4) is quite large (about 3 billion t). The alpine meadow communities have much larger root: shoot ratio than grasslands of lower altitudes. Sites where drainage is poor,

Table 3. Carbon sequestered in forest (aboveground) of Western Himalayan and North-eastern Himalayan regions, as estimated by Anil Tewary (unpubl.) The total economic value of carbon sequestered was calculated @ US$ 13 t-14 yr-1. (WH =Western Himalaya, NEH = North-eastern Himalaya, NPP =net primary productivity, NA=net accumulation).

	Geographical Area (km^2)	Forest Area (km^2)	Unit area (km^2) NPP (t C yr^{-1})	NA	NA (t C yr^{-1})	Total forest area NA (yr^{-1})
			Low			
WH	331393	63046	317.91	158.96	10021532	130.3
NEH	262179	166917	379.55	189.77	31676421	411.8
			High			
WH	331393	63046	568.24	284.12	17912671	232.9
NEH	262179	166917	901.95	450.98	75275520	978.6
			Mean			
WH	331393	63046	415.72	207.86	13104893	170.4
NEH	262179	166917	620.01	310.00	51744902	672.7
TOTAL	**593572**	**229963**	**1035.73**	**517.87**	**64849795**	**843.0***

*** Rs.37.5 billion**

peatlands develop, where carbon keeps on accumulating year after year. With global warming humans may migrate into alpine meadows, and convert them to agricultural fields. Conservation of these ecosystems warrants immediate attention, as their disturbance may emit large amount of CO_2. Our rough estimate of total carbon pool in the entire forest area of Indian Himalaya is about 5.4 billion t C (forest biomass + soil) which is approximately equal to the annual carbon emission from fossil fuels in Asia. The potential upper bound of carbon store of Himalaya (forest biomass +soil) is speculated to be about 700 t ha^{-1}. Values like this are approached by old growth forest stands, which still remain in remote mountain areas. They emphasise that the Himalayan region has a great potential to store carbon, and old growth forests should be valued from this standpoint, apart from their importance from biodiversity standpoint.

Table 4. Soil carbon in alpine meadows of the three Western Himalayan states. Based on a study in meadows of Uttaranchal by Singh et al. (1995).

Western Himalayan States	Area of alpine meadows (km^2)	Carbon in soil of alpine meadows (billion t)
Jammu and Kashmir	57567	2.49
Uttarakhand	6835	0.30
Himanchal Pradesh	4632	0.20
Total	**69034**	**2.99**

Forest ecosystem services other than carbon sequestration

In this section we deal with ecosystem services other than carbon sequestration, such as soil formation and water regulation (Table 5.) Some of them, such as genetic resources are of global significance, while many such as soil erosion control are useful to local people or are of national and continental significance.

Our ecological knowledge for managing ecosystem services(ESs) is still limited (Kremen 2005). The Millennium Ecosystem Assessment (2003) has given a summary of ecosystem services, components and processes of ecosystems that provide them, and feasibility for ecological studies (Box 2.)

Watershed services

Forests affect both water quality (total as well as seasonal variations), and water quantity. Forests vegetation has a large "sponging effect", soaking up and storing rainwater, and releasing it gradually later on. Consequently, a forested watershed reduces the impact of downstream flood or drought. This ecosystem service is of great local and regional significance, but is not easily manageable.

The impact of forest communities and habitats primarily depends on whether evapotranspirational loss is more or less than the water retained by the sponging effect. The sponging effect of the forest is largely because of the organic matter generated by aboveground and belowground litter, pores, tunnels, and slits created by dead roots and soil fauna.

Forests cause rain, in some areas they may account for most of the annual rainfall. Forests like Sahel improve water quality by decreasing soil erosion and filtering pollutants from water. About 3,400 public water systems in the USA alone depend on forested watershed services.

Apart from the consumptive uses, water quantity influences several recreational activities, such as fishing, boating and

Box. 2 Ecosystem services, classified according to the Millennium Ecosystem Assessment (2003), and the ecosystem service providers with some modifications. Spatial scale indicates the scale (s) of operation of the service.

Service	Components /processes of ecosystem providing services	Spatial scale	Potential to undertake ecological study and measurement
Aesthetic, cultural	All biodiversity	Local-global	Low
Ecosystem goods	Diverse species	Local-global	Medium to high
UV protection	Biogeochemical cycles	Global	Low

Purification of air	Micro-organisms, plants	Regional-global	Medium
Flood and drought mitigations	Vegetation	Local-regional	Medium
Climate stability	Vegetation	Local-global	Medium (carbon sequestration rate easy to measure
Pollinations	Insects, birds, mammals	Local	High (measure pollen deposition per visit; fruit/seed set with/without organisms)
Pest control	Invertebrate parasitoids and predators	Local	High (pest dilution and parasitism rates.
Purification of water	Vegetations, soil micro-organisms, aquatic micro-organisms, aquatic invertebrates	Local-regional	Medium to High (measure useful indicators)
Detoxification and Decomposition of wastes	Leaf litter and soil invertebrates; soil Micro-organisms; aquatic micro-organisms	Local-regional	Medium; dung burial rate
Soil generation and soil fertility	Leaf litter and soil invertebrates; soil-micro-organisms; nitrogen-fixing plants; plant and animal production of waste products	Local	Medium (measure soil depth and soil carbon and nutrients)
Seed dispersal	Ants, birds, mammals	Local	High (measure distance from source)
Colonization of bare sites and succession	r-strategist species	Local	High (measure in terms of cost of raising plantations

rafting. Contingent Valuation Methods (CVM) and Travel Cost Methods (TCM) have been used to estimate the marginal values of additional hectare-meter of water required to augment low seasonal flows in streams. The other non-consumptive use of stream flows include electricity generation. Forests by controlling soil erosion improve the functioning of turbines (e.g., marginal value). Then, there are passive use values of stream flows, as many habitats, species and conditions depend on them, and there are people who are willing to pay for the maintenance of stream flows (e.g., $95 per household per year for natural stream flow of 11 Colorado rivers). People have been found to value the knowledge that the habitats, species and conditions depending on water flow are preserved. Such people, however, may never directly experience them.

Forest ecosystems contribute to water quality by detoxifying environment (accomplished by soil and litter invertebrates and microbes) and removing pollutants (pesticides, heavy metals, nutrients and other) and preventing erosion of hill slopes and silt deposition in downstream water bodies.

The young and rising Himalayan ranges are highly susceptible to landslips and erosion. The Ganga-Brahmaputra river system carries the higher sediment load than any other river system in the world (Wasson 2003). Since the Himalayan states heavily depend on hydroelectric projects for energy generation which requires clean water, addressing the problems of silt load is very important (Thandani 2006). Turbid water with high concentration of silt is also not good for fishes. The vegetation cover shelters soil from the force of rain, and a complex of roots, mycorrhizal sheaths, litter, humus and activities of soil organisms helps retaining water, soil and nutrients.

A Himalayan river carrying huge amount of silt. The heavy silt load often interferes with hydroelectricity generation. Forests reduce the silt content of river to a certain extent.

One way of measuring the value of water purification function of forests in a watershed is the cost of constructing and operating water treatment plants to purify water. The 8 million people of the New York city receive water form the 32 km^2 Catskill watershed. In 1990S the people decided to spend $ 1.4 billion to protect the watershed and thus keep water quality high. By doing so they saved $ 4-6 billion at the cost of constructing a new water treatment plant, and $ 300 million per year to operate it. There are a few more examples of people choosing to protect watershed forests instead of constructing new water filtration plant (e.g., Sterling forest watershed in case of New Jeresy, Bull Run watershed in case of Oregon, Portland Maine, see in Krieger 2001). In these cases money actually spent to protect watershed could be taken as an appropriate measure of the value of water purification services.

Deterioration of water quality reduces recreational and passive use values associated with water. People are attracted to clean flowing water of rivers, not the turbid water of the rainy season.

Climate stability and forests

Forest communities and habitats play a major role in regulating regional and global climate. Impact of the Amazonian forest on regional climate over wide spatial scales is well known. Climate model simulations of the replacement of forests with grasses and shrubs indicate conspicuous reduction in evapotranspiration. Its consequences include substantial warming of the surface, and the inhibition of convection in the atmosphere, regional precipitation and cloud cover. Furthermore a large scale deforestation in Amazon may also cause changes elsewhere. The changes may include cooling of Europe and warming during winters in Asia (Foley et al. 2007). Because forest covers go up to great heights (3000-4000 m altitudes) in the Himalaya, their impact on the climate of the subcontinent could be profound. Furthermore, the high wall of trees in

A forested landscape ranging from mountains to adjacent plains. One would like to stop and enjoy this science beauty; a few may pay so that it is conserved.

Himalaya contributes to high humidity level in adjacent plains through the release of water vapours.

In an urban setting, forests can be used to reducing cooling costs. According to an estimate 100 million trees could reduce $ 1 billion worth energy costs annually in developed countries.

Removal of the atmospheric CO_2 by forests is cheaper than any technological method. Conservation of the existing forests and raising new plantations are crucial for carbon sequestration.

Biodiversity services

The biodiversity related forest services may include the following:

- Ensuring a wealth of potentially precious genetic material for breeding purpose to improve yields of crops and livestock, to produce pharmaceuticals and biotechnological devices to improve crop yields, and to reduce the use of chemical pesticides in agriculture.
- Giving shelter to many species that keep potential agricultural pests in check.
- Providing pollination services to many crops. A study has shown that forests by promoting bee fauna contribute to the yield of coffee.
- New bare lands resulting from landslips and fires are immediately colonized by pioneers such as alder (*Almus spp*) and poplars (*Populus ciliata*) in Himalaya. Alders are good facilitators, speeding up natural succession. An alder can form a new forest within 8-10 years.

Cultural and heritage values

Several studies (see in Krieger 2001) carried out in the USA indicate that, at least rich people value forests for their aesthetic attributes. They may attach value to the knowledge

A coniferous forest surrounding a temple. Religion often contributes to forests conservation and flow of ecosystem services.

that a forest exists. In these studies, generally people's willingness to pay for the protection of forests has been estimated. People have given value for various attributes of nature: high density of large trees in forests, roadless forest areas, healthy forests and wilderness, existence value for old-growth forest to protect spotted owl, or other threatened species. In these studies generally contingent valuation method has been used.

Apart from the above services, forests contribute substantially to soil formation, and they differ in their rates to generating soil. This precious service is difficult to measure, and is generally not the part of common persons perception.

A few estimates of services

Though we know that economics of the earth would grind to a halt without ESs, their values in money terms have been estimated only recently because ecosystem valuation is difficult and fraught with uncertainties. One of the most

The reservoir of Dhauliganga hydroelectric power station. Improvement in watershed services can greatly prolong the reservoir life.

comprehensive exercises of this kind was carried out by Costanza et al. (1997), which involved a group of 13 experts with backgrounds ranging from economics to ecology. They considered 17 types of ESs across various ecosystem types, including 13 from forests (Table 5.) Costanza et al.(1997) synthesized previous studies based on a wide variety of methods of environmental economics and used their own wherever necessary. Commonly applied methods of economic valuations are briefly described in annexure 1.

In order to make estimations of total value of ESs they considered the total global extents of ecosystems and classified them into 16 primary categories, such as coastal areas, open areas, tropical and temperate forests and grasslands. Valuation of each type of ecosystem and each of ecosystem service was done separately. Though the figures of Costanza et al. (1997) are global, from them one could draw some conclusions for the Himalayan area. For Himalayan forests, we used the mid-points (Table 6) of the values estimated for tropical forests (US$ 2007/ha/yr) and temperate/boreal forests (US$ 302/ha/yr). In terms of species richness, the Himalayan forests are closer to temperate forests, but in terms of ecosystem functioning they are closer to tropical forests (Zobel and Singh, 1997).

The River Alakhnanda at Rudraprayag still with clean water. People in urban areas of plain have not seen clean river for several generations.

Since the latter factor is more important in relation to ecosystem services, by taking mid-point values we are underestimating the value of the Himalayan ESs. We thought it would be safe to take a conservative value. As shown in Table 6, with an average value of about 1150 dollars/ha/yr the total value of the ESs from the forests of Uttarakhand (area 2352700 ha, P.S. Roy and P. Joshi, unpubl. data) is approximately 2.4 billion dollars/yr or 107 billion Rupees/yr, and for the entire forested Indian Himalayan region it is estimated at about Rs. 943 billion. Of these, the carbon sequestration service accounts for only a small fraction, 5%. We do not know to what extent Costanza et al. (1997) considered carbon sequestration and whether it was part of

Organically raised crops in the higher Himalaya. Many people may pay more for food derived from organically grown crops. Furthermore, this form of cultivation keeps other ecosystems free from toxics.

climatic regulation or biogeochemical cycle or both. As far as we know, at the time they undertook their study carbon sequestration was not valued as it is being valued under the

Ecosystem Service	Value in US\$ ha^{-1} yr^{-1} (US\$ = Rs. 44.5)
Climatic regulation	167.6
Disturbance regulation	2.3
Water regulation and water supply	5.2
Erosion control	114.6
Soil formation	11.6
Nutrient cycling	429.6
Waste treatment	102.7
Biological control	2.3
Food production	50.7
Raw material	164.0
Genetic resource	18.5
Recreation	78.6
Cultural	2.3
TOTAL	**1150**

Table 5.

Annual value of various forest ecosystem services of Uttarakhand. Values were calculated from various parameters given for forests in Costanza et al.(1997).

Kyoto Protocol. Costanza et al. (1997) did not consider certain services like natural colonization of bare sites by plants and subsequent succession which play an important role in the

State	Area (km^2)				Value of ESs as of 1994(US$1=Rs. 44.5)	
	Total Geographical Area of the State	Dense forests	Open forests	Forest area for ESs	Billion US$	Billion Rs.
Himanchal Pradesh	55673	6656	2892	8102	0.93	41.46
Uttarankhand	53485	18245	5283	20887	2.40	106.89
Jammu and Kashmir	222235	16156	13814	23063	2.65	118.02
Arunachal Pradesh	83743	57756	11091	63302	7.28	323.95
Assam	78438	14517	9171	19103	2.20	97.76
Manipur	22327	5936	11448	11660	1.34	59.67
Mizoram	21081	3786	14552	11062	1.27	56.61
Meghalaya	22429	5925	9708	10779	1.24	55.61
Nagaland	16579	5137	9027	9651	1.11	49.39
Tripura	10486	2228	3517	3987	0.46	20.40
Sikkim	7096	2363	755	2741	0.32	14.02
Total	**593572**	**138706**	**91257**	**184334**	**21.20**	**943.33**

Table 6. A summary of values of ecosystem services (ESs) emanating from the forests of Himalayan states. "Forests area for ESs", is equal to the dense forest plus half of the area of open forest.

Table7. Values of ecosystems services of alpine meadows of the three Western Himalayan states. The values are derived from Costanza et al. (1997). The modifications include: waste treatement values were not considered because the Himalayan meadows are generally beyond human habitation and the food production values were halved as these meadows are not used intensively as rangelands. Thus, per ha value of ESs of these meadows is US$ 123.

Alpine Western Himalayan States	Area of alpine meadows (Km^2)	Carbon in Soil as of 1994 meadows (t)	Value of ESs of alpine meadows (US$ 1=Rs. 44.5)	
			Million US $	Million Rs.
Uttarakhand	6835	29392.1	0.8	3.74
Jammu and Kashmir	57567	247536.0	0.71	31.51
Himanchal Pradesh	4632	19917.6	0.6	2.54
TOTAL	69034	296845.8	0.85	37.79

Himalayan region where landslips erosion and other soil mass movements are frequent. Though meadows are not great service providers (Table 7), their role is considerable in the westernmost Himalayan state of J&K where they spread over millions of hectares. Furthermore, these meadows are going to be the hub of social and ecological activities with rising global temperatures, because of the upward march of humans and many species of plants and animals.

Sharing of Ecosystem services

Ecosystem services are always in flow- they were flowing even when there were no humans on the earth. However, their use and valuation depends on humans living both inside and outside the ecosystems, otherwise they are merely bio-physical components. Therefore, it is important to identify and map areas generating ESs and people utilising them.

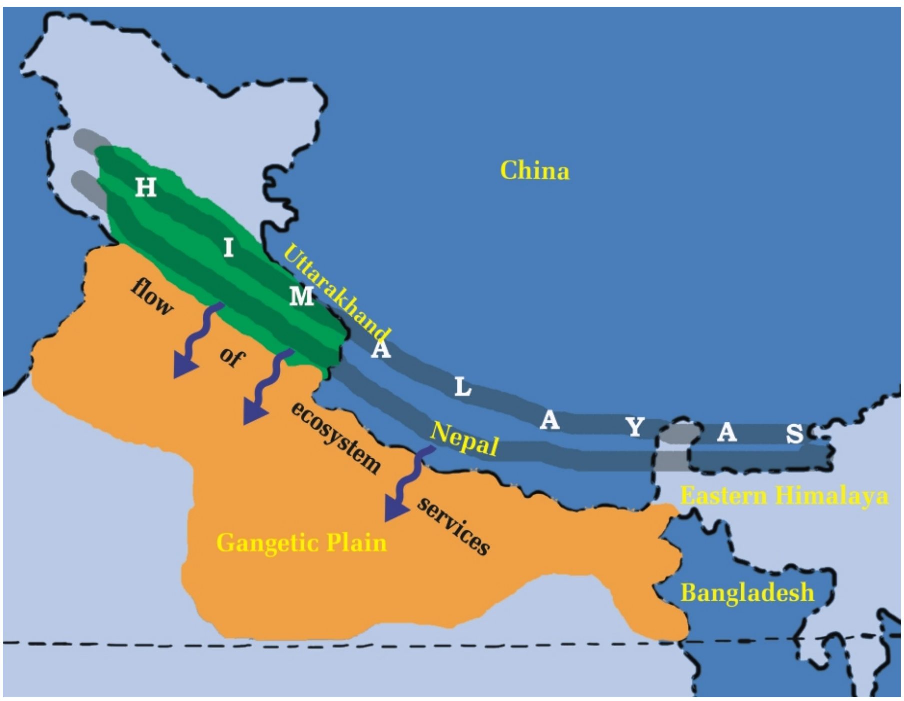

Fig. 3 Forest of western Himalaya, particularly of Uttarakhand provide Ecosystem services (Ess) to the Great Gangetic-Plains where more than 500 million people live. Strips are indicate mountain ranges.

Because of the river connections, the ESs flowing from Uttarakhand have played a major role in shaping the rise of culture in the Great Gangetic Plains (GP), at present inhabited by about 500 million Indians (Fig.3). The valuation of ESs emanating from a region also depends on this kind of connections, more the people in the receiving zone the more is the value of services flowing from the service providing zone. There is no such large receiver zone in the case of other Himalayan states (Fig.3). The ESs of Arunanchal Pradesh, which is rich in highly diverse forests, is by far the highest but

The highly productive and populated Bageshwar valley. Cities heavily depend on ecosystem services emanating from adjoining rural areas.

a certain part of it is only a biophysical abstract because of the associated receiving zone is small. Most of its ESs are of global and local significance. In contrast, in the case of Uttarakhand, the receiving zone is very large and productive, therefore regional significance of ESs is high. Obviously, it is not possible to make useful estimates of the values of ESs an ecosystem simply by transferring values from similar ecosystems studied elsewhere.

Though the Gangetic Plains owes its origin to geological processes, the ESs such as the generation of soil fertility, hydrological regulation, and other services flowing through the watercourses emanating from Uttarakhand have a great nursing effect. Although it has not been possible yet to give estimates of ESs flowing from Uttarakhand to Gangetic plains, there are certain evidences as given below that testify their value:

1. Higher water status in lowland forest ecosystem than in highlands despite lower precipitation and higher evaporation loss due to warmer temperatures. Though the sal forest in the plains receives 100 cm less rainfall than the forests in Nainital catchment, its (sal forest) water potentials both in soil and trees are significantly higher largely because of the downstream movement of water, soil and nutrients.
2. Increase in proportion of sand and gravel in downstream areas subsequent to deforestation in upstream areas.
3. The grasslands in plains adjacent to mountains are among the most productive ecosystems of the world.
4. The 3-4 km high walls of forest cover in Himalaya contribute significantly to the productivity of crops grown in the Gangetic plains by providing humid conditions. Source are the vapours emanating from evapotranspiration from vegetation.
5. In many parts of the world (e.g., western coastal United States) the ecosystem productivities are much lower in plains than in adjacent mountains (Zobel et al. 2001). In some regions, forest vegetation in mountain is surrounded by deserts in plains. In contrast, in the plains adjacent to Himalaya productivity is generally greater than in the mountains indicating a massive downstream flow of ecosystem services. The forest cover of Himalaya

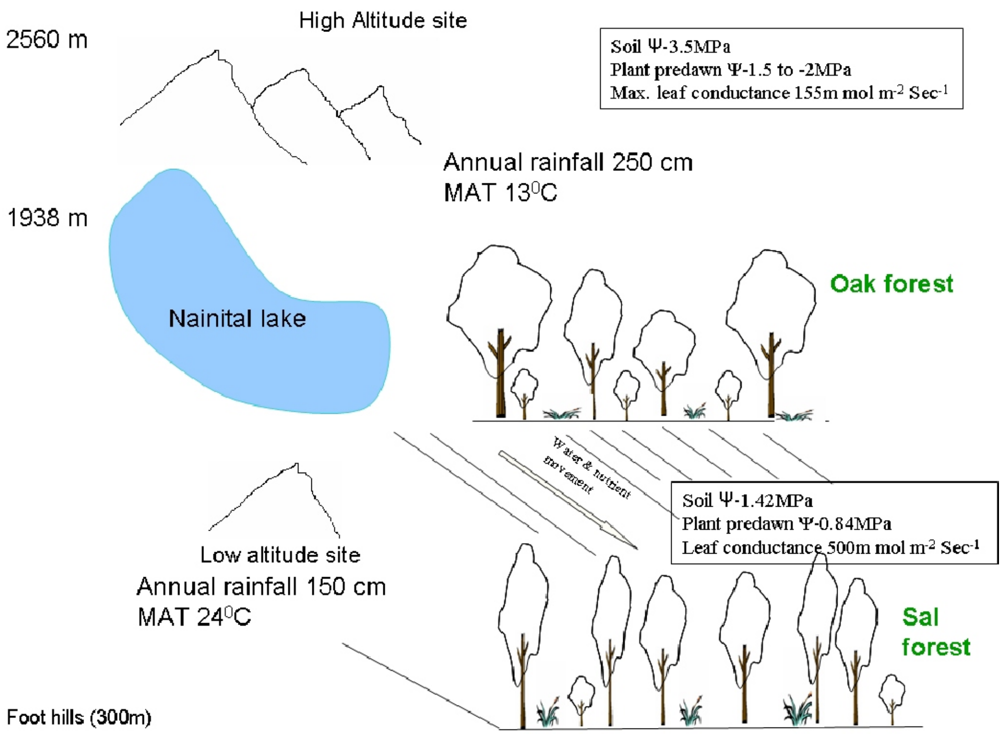

Fig..4 A depiction showing water potential ( ) of sal and oak forests

might play a significant role in creating humid conditions in plains.

6. Resumption of crop cultivation in the plains immediately after scooping out one meter soil for brick making is testimony to build up of soil fertility, derived from "natural subsidy" of ecosystem of services from mountains.
7. Crop cultivation in the Gangetic plains for several thousands of years without widespread degradation is made possible because of the ongoing replenishment of soil and its fertility from the mountains. Problems of soil erosion are unheard in most of the Gangetic plains.

Extensive crop cultivation in the Gangetic plain, partly depends on replenishment of soil fertility by the forests of mountain areas.

The above indirect evidences suggest that a considerable amount of ESs created in Uttarakhand flows to Gangetic plains, the grain bowl of India (Table 8.) Thus, it is safe to conclude that the services created in Uttarakhand that benefit the adjacent plains are worth more than Rs. 5000 crores (taken as about half of the Rs. 10,000 crores of ESs created in Uttarakhand). Thus, a mechanism of monitory compensation should be developed by the nation to enable the Himalayan people to sustain their conservation activities, and not turn into an exploitative community by effecting such landuse changes which are counter to carbon sequestration and flow of other services within and outside the region.

Moderation of regional climate

Generally, people's concerns have centred on how climatic changes will affect species and modify ecosystems. However, species and ecosystem are not mere “slaves” of the

Table 8. A set of forest ecosystem services flowing from Himalayan regions with spatial scale of benefits and possible financial arrangement.

Forest ecosystem services (ESs)	***Identification of qualitative aspects of ESs***	***Spatial scale benefited and example of benefits***	***Possible financial solutions for enabling the UA people to conserve forests***
Carbon sequestration	Rate of C sequestration; differences among forest types.	Global; mitigation of global warming	Substituting the present firewood subsidy by cooking gas/electric/solar energy at affordable costs; inclusion of C savings under employment guarantee scheme of the state.
Soil formation	Replenishment of soil fertility in cropfields. Use of forest litter in the cropfield soil maintenance, control of erosion, and C, water and nutrients storage in soil.	Local, National, and Global	Justifying a demand for infrastructural support and capacity building for eco-friendly enterprises, such as eco-tourism, and those based on organic agriculture and other niche-products
Hydrologic regulation	Water filtration by forests, spring discharge; control on overland flow; contribution to river flows	Local and National	Justifying access of rural women to modern energy sources
Climatic amelioration	Role of forests in water circulation through evaportranspiration, and consequent contribution of water vapours to humidity rise, temperature moderation, and agricultural productivity.	Local, National and Global	A better reflection in national accounting
Recreation	Eco-tourism based on forest, wildlife, lakes, rivers, glaciers and cultural traits (rafting, angling, etc.)	Local, National and Global	Payment is already there; but needs to be scaled up by creating & enabling favorable environment with the support of central government.
Providing habitat for NTFP's (e.g.,mushrooms, lichens, resins); and the maintenance of organic agriculture and native crop diversity	Numerous NTFPs are being used, some even without any acknowledgement; sustainability of organic culture is largely forest based, and crop diversity is dependent on forest- derived soil organic matter	Local and Regional	Working out a strategy to maximize profits on a sustainable basis at collectors level in case of NTFPs; commercialising organic agriculture; and raising awareness about the true-value of forests
Colonization of bare sites by early successional species (e.g., *Alnus nepalensis, Populus ciliata, Coriaria nepalensis*)	Forest stands are developed within no time on lanslips and land deposits. They are not only source of timber, but also control soil erosion and generate fertility	Local and Regional	Efforts would be required to reduce fragmentation of the stands constituted by colonizing species through participatory approach.

environmental changes, the structure and functioning of ecosystems can greatly modify the environmental changes themselves. For example, in general, deforestation increases albedo and reduces roughness of residual vegetation, leaf area index and rooting depths of plants (see Foley et al. 2003).Decrease in rainfall and net warming are likely to follow deforestation. In view of this, the role of forest cover on the Himalayan slopes in controlling the climate of the Indian sub-continent needs to be investigated. The high humidity of the Gangetic Plains in part is due to the forest cover of the Himalaya. Delhi's humidity, for example is high considering that from the standpoint of precipitation it is a semiarid place. Evapotranspiration from a forest is process which improves the growth of nearby plants by providing vapours. Somehow, hydrological services seldom give importance to vapour flows from forests and other vegetation. In contrast to the temperate region mountains where forest cover is limited to 1000-1500 m altitudes, in the Himalayan region forests clothe the slopes beyond 3000 m altitudes. A high humidity level plays a significant role in promoting growth of both cultivated food crops as well as trees. A few scientists have separated vapour-service (referred to as green water) from liquid water (blue water) service, and pointed out that the vapours contributions are generally ignored. Valuation of these services is difficult because several other factors can mask their effects, nevertheless they are real, and important.

Cropfield soil organic matter

In the Himalayan states, majority of agriculture is forest-based and farmers still cultivate native crop varieties (e.g., in Western Himalayan states 39 crops species and over 150 crop varieties are still grown), particularly in remote areas, thus contributing to the conservation of their genetic diversity and evolutionary processes. Eastern Himalayan states are known

Litter collected from forest floor ultimately ends up as organic manure to cropfields.

Organically grown crops in rain fed terrace fields contribute to maintaining crop diversity for cultivating a diverse group of crops in which legumes are prominent. This represents a human-assisted ecosystem service of global significance. Much of the crop diversity is managed in rain-fed areas by small and poor farmers with the support of organic matter derived from forests (forest floor litter is used as manure). However, the maintenance of crop biodiversity by local people has, by and large, remained unnoticed though several agencies get financial support in the country for undertaking this task. In fact, the transfer of litter from forest floor to cropfields represents a human-assisted supply of ecosystem service of a major local significance. The organic matter is not only the source of nutrients, it also helps retaining soil moisture, and reduces erodibility, thereby improves water quality in downstream areas. The collection of forest litter limits the intensity of forest fires.

Soil carbon increases in cropfields are known to range from 0.1 to 1 t ha -1 yr-1 due to conservation practices (Paustian et al. 2006). The Himalayan agricultural fields can be used as potent carbon sinks through adoption of additional practices as given below:

- Lowering the frequency and intensity of soil tillage.
- Including more hay and leguminous crops in annual rotations.
- Using more of high-residue-yielding crops and reducing fallow periods.
- Restoration of degradation sites, such as landslips and degraded forests.
- Use of forest litter with a slow rate of decomposition.

Soil tillage increases the rate of soil organic matter decomposition (including the conversion of C to CO_2) by making soil warmer and breaking soil aggregates (Reicosky 1997). No-till, a practice in which a narrow slot is cut for sowing seeds, and weeds are removed by application of herbicides, is reported to increase soil carbon at the rate of 20% over a period of 20 years time (Ogle et al. 2005).

Justification for the payment for providing ESs

A country requires a balanced mix of ecosystems, of which some take care of food production and others which give ecological security to it. The ecosystems that dominate in the Himalayan states belong to the second category. It is because of their ecological services that India has one of the largest areas under productive ecosystem (agricultural land) in the world.

Whatever success the people in mountains have achieved in conserving their forests, they have been able to do so without any access to modern energy sources. On an average, the per capita CO_2 emission from fossil fuels is 0.1-0.2 t yr - in the Himalayan region (based on data of Nepal and Bhutan), and

A woman on a tree collecting leaf fodder. A wealthy India has enough resources to address its issue of women drudgery.

1.1 t capita^{-1} yr^{-1}(1996) for India. Since vehicular CO_2 emission is large and much of the increase in vehicle number has occurred after 1996, India's current per capita CO_2 emission should be already much higher than 1 t yr^{-1}.

From the equity point of view alone, the poor people in the Himalayan states should be given support to have alternatives to biomass fuel, so that they have some modern content in their lives. It involves also the issue of gender equity, for it is the women who suffer most due to the lack of support from the centre to these areas. They do all the hard work of collecting resources including biomass for cooking, and thus live a hard life exposed to very unhygienic conditions. A high quality car carrying tourists can be seen on roads in the Himalayan region where women still climb trees for collecting low quality fodder for their low quality animals, a practice that might have persisted since the Stone Age. According to a report, 1.6 million women die prematurely in the world because of the pollution created by the use of biomass for cooking. In an economic model based on consumptive traits and power of technology (which is being followed worldwide), it is unfair to keep their lifestyle still of the Stone Age. Steps should be taken to replace the use of firewood by modern energy sources, so that the forests continue to generate ESs, including carbon sink benefits, and the women in Himalayan region have a better health condition and time for childcare (Table 9). Evidently, the economic support for ESs that people generate by conserving forests can be used to supply modern energy such as LPG and electricity at an affordable cost. The present subsidy of firewood (in practice people collect firewood from even reserved forests, if community forests are unable to meet their demands) could be replaced by the subsidy of LPG or other modern energy sources to enable communities to conserve their forests. When firewood is thus replaced the carbon sink and other ESs are strengthened.

Table 9. Impact of replacing firewood with cooking gas in Himalaya where women spend many hours on collecting firewood, fodder, litter and water each day.

	Cooking energy	
	Firewood	**Cooking gas (LPG)**
Women drudgery	Severe	Low
Kitchen pollution and health risk	Severe (16 million women die prematurely each year globally)	Negligible
Effect on Carbon sequestration and other ecosystem services	Adverse	Favorable
Opportunity for developmental processes	Low	High
Carbon saving	Low	High
Distance from source	Short	Long
Effect on fossil fuel stock	Little	Little
Availability of raw material for biofuels	Little	Substantial
Other justification	None	Indian allowed to increase CO2 emission
Overall sustainability	Low	High

If the poor of the Himalayan states are allowed to have access to LPG, it would add less than 0.5% of greenhouse gas emission, but carbon sequestration through forests conserved may be several folds higher.

A 0.5% increase in efficiency of India's automobile fleet is likely to free-up nearly sufficient fuel energy for cooking needs of the poor in the Himalaya. Rather than excluding such a subsidy of LPG, some of this nature's one time gift ought to be actually reserved to fulfil our obligation to bring the health and welfare of all people to a reasonable level, and to enhance the capacity of the Himalayan forests to supply ecosystem services. A country like India should take advantage of the present agreement of Kyoto Protocol, under which they can increase CO_2 emissions. Repairing forest sinks by using cooking gas at afforadable prices can be one such step.

Conclusions

The data presented above on ecosystem services of the Indian Himalayan forests are only rough estimates, and need to be taken as the first approximations. However, they are good enough to establish that ecosystem services provide an important portion of the total contribution to human welfare in our country. In case we fail to give adequate weight to them in our accounting systems, current and continued human welfare may be drastically affected. The total ecosystem services flowing from the Himalayan region, according to our estimates, of about Rs. 943 billion yr^{-1}, accounts for nearly one-third of the GDP of the country. “If ecosystem services were actually paid for, in terms of their contribution to the country's economy” (quoted from Costanza et al. 1997), the price of commodities depending on ecosystem services would be much higher. Seeing the huge value of ecosystem services it would be impractical to think that they would be incorporated *per se* into national accounting systems. However, decision makers can initiate steps to better reflect the values of ecosystem services and natural capital in centre-to-state transfer of grants. There is a need to “greening the budget' and giving full value to the services of forests at the national level (Singh, 2003). Even a crude estimation of goods drawn from forests would indicate that they contribute far more than 1% to the national economy (Singh, 2003). The states which have taken measures to conserve their ecosystems to achieve continued flow of the services need to be given enough economic incentives to enable their people to conserve their forests. By compensating for ecosystem services in monitory terms, the decision makers would contribute to bringing about a major qualitative change in the conservation approach.

With the growing consumptive traits, the country with its huge population is soon going to be a major CO_2 emitter among the countries of the world, even if per capita emissions were low. Since as per our economic policy, we are not going to slow down the increasing per capita CO_2 emission, we need to promote the health of our sinks. In a tropical country like India with high mean temperatures (an associated changes in precipitation pattern), even a limited warming can exceed the tolerance limits of organisms, including humans and ecosystems in which they live.

In some of the Himalayan states, such as Uttarakhand, community forestry has been strongly institutionalized, and issues of ecosystem services can directly affect their economic condition and processes leading to the empowerment of local people. Recognition of ecosystem services in national policies may enable the local people to own carbon trade and other ecological enterprises, and hence to play a far greater role in conservation activities.

The financial support for the Himalayan states would essentially be used to (i) maintain the flow of ecosystem services to the rest of the country on a sustainable basis, and (ii) therefore, improve the quality of life without jeopardizing the national ecological security.

Annexure

Annexure 1: Approaches and methods for estimating economic value of forest ecosystem services (Ess)

We need to estimate economic value of forest ESs to decide whether a forest should be logged for timber or conserves so that people continue to receive ecosystem services. If the monetary value of ecosystem services is more than that of the timber, its conservation is justified in economic terms. The problem is that few ESs have established monetary values. Then, monetary value of a given ecosystem type would vary from one region to another. Another problem is while benefits of timber is enjoyed by small fairly cohesive groups of people of current generation the costs of foregone ESs are borne by larger, dispersed groups, including of future generations. Therefore, decision are often made in favour of groups interested in timber.

While considering forest ESs, studies vary in number of categories recognized. Costanza et al. (1997) recognized 14 types of services. Nearly 75% of total value of forests in their study was due to climatic regulation, waste treatments and food production. This pattern is unlikely to apply to Himalaya where people's needs and dependence on ESs are different. In Himalaya, as an example, soil stabilization may be very important. Krieger (2001) grouped ESs into 8 categories, which appear to be quite handy is use. The following description is based on that.

Value of ESs services to a great extent depends on people's perception and attitudes. For example, forestry professionals in Uttarakhand now give far more importance to forest ESs than they did only a couple of years ago. A study of North Carolina conducted by Schaberg et al. (1999)

showed that people ranked five ESs as following oxygen, habitat for endangered species, stable forest cycles, and climate stability. It is quite possible that some of them may not find place is five most important ESs that people in a Himalayan state perceive. In fact, most people hardly give value to the nature's role in waste treatment, which Costanza et al. (1997) considered second most important service in economic terms.

ESs valuation methods

Some of the methods of calculating economic value of ESs are as following:

Travel Cost Methods. This is a commonly used method, generally applied to recreational and other site-specific activities or resources that involve expenditure on travel. For example, people visit lakes, forests and other wilderness sites, and often they do not pay to enter and use them. However, they incur expenditure on travel to visit them. Based on information on relationship between the number of visits over time (visitation rates) and distance traveled, demand for the site visited is calculated. The demand function permits determination of consumer surplus estimates of the economic value of that site. This method thus considers actual behaviour of people, i.e., the costs they incur on a thing or for a purpose. Using this methods the recreational value of Nainital lake and forests was estimated at about 5 million rupees.

Contingent valuation

In contingent valuation method actual behaviour of people is not observed for measuring economic values of ESs. In this people are asked what they would be willing to pay for a non-market ecosystem service. This method relies on questionnaires or interviews, in which a market-like situation is presented to people and they express a monetary value for well described non-market ecosystem services (Mitchell and Carson 1987). For example, municipality may ask whether citizens would vote for or gainst a referendum that would increase taxes to raise a fund for watershed treatment so that drinking water quality is improved. This may involve raising plantations along a river to check soil erosion or inflow of pollutants, or constructing check dams to regulate stream flow. Responses across the sampled people are taken to estimate demand and economic value.

Hedonic valuation

Like travel cost method, in this method also actual cost that people incur on a thing or for a purpose is considered for estimating economic value of ecosystem services. Application of the hedonic method is possible to a situation where the price of a good reflects access to ecosystem services or goods. For example, in a city air quality may vary from one place to another, and difference in house prices may reflect that. That is prices are higher where air is cleaner. This difference occurs only where buyers are aware of the difference in air quality on the prices of houses from other factors that affect house prices. Then a sale price of houses that is attributable to air quality is estimated. Data on the observed willingness to pay for air quality (as an addition to the price of a houses) are taken to calculate a demand function for air quality (Freeman 1979). This is turn gives an estimate of the consumer surplus that is associated with different levels of air quality (see in Krieger 2001).

Similarly, buyers may pay more for a house facing a lake or forest than one with no such attractive views, provided they care for that.

Averting expenditure

Of the various averting expenditure methods (also called defensive methods), one method relies on cost of technological substitutes for some ecosystem services. For example, a municipality may substitute the water purification service of a forested watershed with a water treatment plant. The cost of water treatment plant used to avert or prevent the loss of an ecosystem service with a substitute gives one measure of the value of the service (Freeman 1993). Remember that only when expenditure is actually made to create the substitutes, it is considered a valid estimate of ecosystem service. In case of New York city's, $ 1.4 billion was spent to protect watershed and water purification services it generated. By spending this amount, $ 6-8 billion was saved, as the new treatment plant's cost. The city chose to treat the watershed, which was the less expensive alternative. Thus the cost incurred on watershed treatment to avert the deterioration in water quality is taken as the value of watershed services. This value is thus represents actual expenditure, rather than the maximum willingness to pay. The averting method thus represents the lower end of the scale with regard to the value of ESs. First, because the method relies on expenditure for the least cost alternative. Second, technological alternatives seldom fully replace an ecosystem service. For example, a water treatment plant can provide clean water for municipal use but not for recreational activities, and fish habitat (Krieger 2001).

Benefits transfer

In this, value estimates for ESs in one location or setting are used to estimate value in another location or setting. The validity of transfer of estimates depend an how similar are locations or settings, and how correctly original estimates were calculated. Since value transfer is inexpensive and easy, it is widely used.

Commercial value

In all above methods market prices for ESs are not available, but in some cases they are available, and are usable. For example, fishesh with well-defined market prices. Thus the present commercial value of a wetland for fish yield can be calculated as the present price of the fish that wetland would yield in future when it is provided protection. Clearly, this measure would only be partial, because it does not consider its other values such as recreational and water regulational values.

Gross expenditure

The gross expenditures incurred to enjoy ESs is a common method, particularly in relation to recreational activities. Total expenditures on travel, equipment and supplies for a fishing trip are taken as value of fishing. However, it is only an indication of the importance of a given recreational activity, it does not give economic value as defined by consumer surplus. Furthermore, it does not estimate demand curves and maximum willingness to pay.

Economic impact

A national park or a wilderness area attracts visitors to the region it is located. The visitors directly impact local economy through their spending on food, lodging and supplies. Measures of these impacts include income, profits, employment and tax revenue. Thus, several local businesses are directly affected by tourist activity, and they in turn directly affect businesses that supply them goods and service (e.g., the firm that supplies food products or kitchen appliances to a hotel). Both direct and indirect economic impacts of tourism induce additional impacts, such as increased spending by workers and additional income and jobs supported by that spending. All these when combined can be taken as total economic impact of tourism on a local economy. However, it cannot be considered economic value as defined by consumer surplus.

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