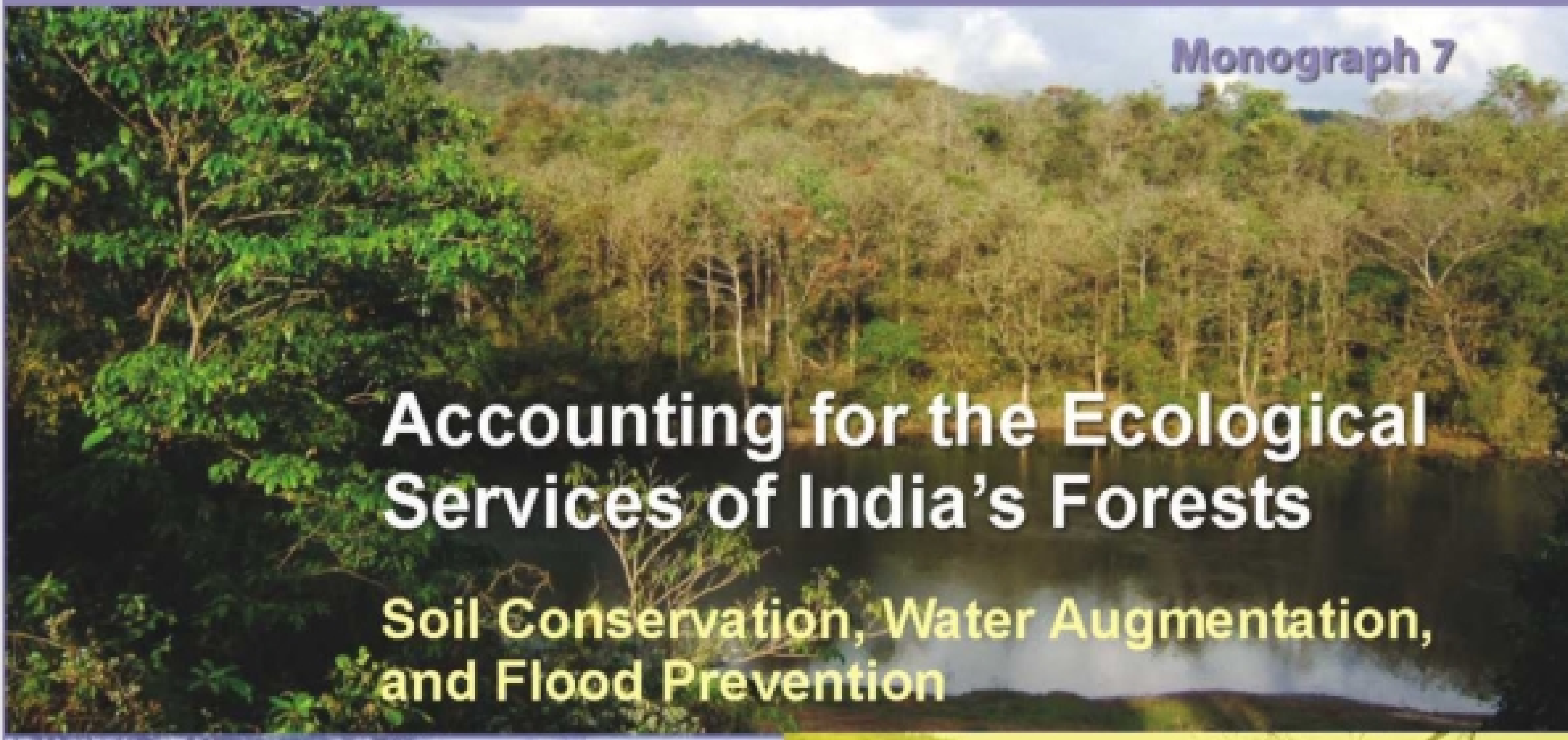
Green Accounting for Indian States and Union Territories Project



Monograph 7

Accounting for the Ecological Services of India's Forests

Soil Conservation, Water Augmentation, and Flood Prevention

gtz

GIST
Green Indian States Trust

Deutsche Bank

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April 2006

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Green Accounting for Indian States and Union Territories Project

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Acronyms

CSO	Central Statistical Organization
CSWCRTI	Central Soil and Water Conservation Research and Training Institute
FRI	Forest Research Institute
GAISP	Green Accounting for Indian States and Union Territories Project
GBIHED	G B Pant Institute of Himalayan Environment and Development
GDP	Gross domestic product
GLASOD	Global Assessment of Soil Degradation
GSDP	Gross state domestic product
ICIMOD	International Centre for Integrated Mountain Development
ISRIC	International Soil Research and Information Centre
NDP	National Domestic Product
NIA	National Income Account
NSDP	Net state domestic product
NTFP	Non-timber forest product
PARDYP	People Resource Dynamics Project
SNA	System of National Accounts
USLE	Universal soil loss equation

Accounting for the ecological services of Indian forests: soil conservation, water augmentation, and flood prevention

Background

In common with most developing nations, India faces many trade-offs in its attempt to reduce poverty and enhance the living standards of its people. There is a need for an empirical basis on which to base policy decisions on trade-offs between the many competing priorities of a developing nation, including inter-generational claims (i.e. trade-offs between the needs of present and future generations). Available measures of development, including the current SNA (system of national accounts) of the United Nations with its primary focus on GDP (gross domestic product) growth rates, do not capture many vital aspects of national wealth, such as changes in the quality of health, changes in the extent of education, and changes in the quality and extent of environmental resources. All of these aspects significantly impact on the well-being of India's citizens generally, and most of these are critical to poverty alleviation specifically, providing income opportunities and livelihood security for the poor. GDP accounts and their state-level equivalents – GSDP (gross state domestic product) accounts – are therefore inadequate as toolkits for comprehensively evaluating the trade-offs encountered by policy-makers in India.

The 'Green Accounting for Indian States and Union Territories Project' ('GAISP') was constituted in 2004 largely in recognition of the reality that though 'GDP growth percentages' are substantially misleading as yardsticks of growth, development, wealth, or well-being, planners, policy-makers, businesses, and the media continue to use them extensively, even uniquely. GAISP proposes to build a framework of adjusted national accounts that represents *genuine* net additions to national wealth. These are sometimes referred to as 'green accounts' in relevant literature. Such a system of environmentally-adjusted NIAs (national income accounts) will not only reflect in economic terms the depletion of natural resources and the health costs of pollution but will also reward additions to the stock of human capital through education. Green accounts for India and its states will provide a much better measure of development than GDP (national income) growth percentages and GSDP (state income) growth measures and will encourage the emergence of *sustainable development* as a focus of economic policy at the operative state level.

GAISP aims to set up top-down economic models for state-wise annual estimates of adjusted GSDP for all major Indian state and Union Territory economies. A top-down or macroeconomic approach is adapted to model adjustments to GDP/GSDP accounts, for two reasons. First, it has the advantage of providing a consistent and impartial national framework to value hitherto unaccounted aspects of national and state wealth and production. Second, it optimizes existing research, which is already extensive but not yet tied together in a manner that makes it useful for policy analysis. The publication of the results and methodology of GAISP will provide a much-improved toolkit for India's policy-makers to evaluate in economic terms the trade-offs they face. It will also engage policy-makers and the public in a debate on the sustainability of economic growth, both at a national level as well as through inter-state comparisons.

The first phase of GAISP comprises the publication of the following eight monographs, each of which evaluates a particular area or related set of areas of adjustments to GSDP accounts.

1. The Value of Timber, Carbon, Fuelwood, and Non-Timber Forest Produce in India's Forests
2. Estimating the Value of Agricultural Cropland and Pasture Land in India
3. The Value of India's Sub-Soil Assets
4. Eco-tourism and Biodiversity Values in India
5. Estimating the Value of Educational Capital Formation in India
6. Investments in Health and Pollution Control and their Value to India
7. Accounting for the Ecological Services of Indian Forests: Soil Conservation, Water Augmentation, and Flood Prevention
8. Estimating the Value of Freshwater Resources in India

All adjustments calculated in these monographs apply to the same set of GSDP accounts (year ended March 2003) and are additive. GAISP's website <www.gistindia.org> will feature a running record of cumulative state-wise adjustments to these GSDP accounts. To a first-order approximation, these adjustments may be added or subtracted as indicated to GSDP growth percentages for 2002/03. The final report of GAISP will summarize and consolidate the work done on these eight monographs and include 'adjusted GSDP' measures for the states and significant Union Territories comprising India, as well as provide a commentary on the policy implications of the results.

Accounting for the ecological services of India's forests: soil conservation, water augmentation, and flood prevention

Introduction

The NIA (National Income Account) is a fundamental macroeconomic variable, which shows the level and performance of economic activities in the economy. The SNA (System of National Accounts) of the United Nations attempts to provide a benchmarked framework for the computation and presentation of national income across all economic activities, so as to make the calculation comprehensive and comparable across nations. A crucial component of the SNA is the estimation of GDP (gross domestic product) where, at the market price, the gross value of all the goods and services accruing to the society is estimated. In the process of GDP estimation, the contribution of natural resources such as forestry, biodiversity, soil, and water generally gets ignored. These natural resources, which have a definite welfare-enhancing role, do not enter into macro-level calculations. This is not due to their poor perceived value nor the fact that their value to society is insignificant; often these resources and their contributions fall outside the domain of the market and hence they remain unpriced and unaccounted for. Hence calculated GDP remains narrow and biased against natural resources. This ultimately means that the GDP, therefore, underestimates the level of welfare that society actually enjoys due to the unrecognized and unappreciated contributions of natural resources. This has further bearing on the conservation strategy for natural resources, where real (natural) wealth continues to get depleted and degraded indiscriminately and insidiously.

A theoretical structure for forest–economy interactions

Forests interact with economies in the following principal ways.

- As a source of timber, renewable in the main but potentially depletable
- As a source of tangible NTFP (non-timber forest products) collected and consumed by households (fuelwood, resin, fruit, leaves, gum, etc.) but not always bought and sold in markets
- As a source of less tangible forest amenities consumed directly either in the present or future (biodiversity-related benefits)
- As a source of environmental services that benefit other productive sectors (such as watershed protection for downstream agriculture, forest-based recreation and tourism)
- As a disposal site for air pollutants that may damage forest health (acid disposition)
- As a sink and source of carbon dioxide, (carbon is stored through forest conservation, or released though forest conversion), increasing levels of which potentially damage other sectors through global climate change

- Forest management as an activity of the governmental and private sectors involving the use of variable inputs (labour and materials) and human capital.

Using this comprehensive list of forest–economy interactions and defining forest-related production in the context of output in the rest of the economy, Vincent (1999) defines adjustments required to be made in NDP (national domestic product) and conventional GDP. While the details of the theory are not reproduced here, we provide the kinds of adjustments Vincent suggests for inclusion.

Adjusted NDP = *conventional GDP* + *non-market values to be added to GDP* – *depreciation of human-made capital* + *net accumulation of natural capital*

Further, changes in the value added by industry and agriculture are to be made to allow for the contribution of the forestry sector. This is in the form of the contribution of forests to pollution disposal and carbon sequestration services, should they accrue to these sectors. Some carbon sequestration services would flow to the rest of the world as well. Alternatively, sectoral accounting can be done and contribution of forestry sector – usually either underestimated or entirely ignored – can be identified and monetized.

Review of some existing studies in India

A considerable quantum of work is ongoing in India on the accounting of environment (air, water, etc.) and natural resources (forest, mineral resources, etc.). Verma (2000) and Chopra and Kadekodi (1997) estimate the dimensions of the value of flow of goods and services from forests in Himachal Pradesh. Stock changes are also recorded to the extent possible. Chopra and Kadekodi (1997) estimate values of timber, non-timber, tourism, and watershed function benefits on the basis of alternative valuation methods. The scope of the functions of forests attempted to be covered is wide and valuation methods vary from market prices to travel cost methods to contingent valuation. This raises the question of additivity, referred to at length by the authors. It also leaves open the issue of integration with the system of NIAs. TERI (The Energy and Resources Institute) (2000) attempted accounting for forests in the state of Goa. TERI has also used the net price method and not gone much beyond a revaluation of timber values of forest stocks and changes in them. Chopra, Bhattacharya, and Kumar (2003) estimate the contribution of the forestry sector to India's GDP. They estimate the forest value for 2001 as 2.2% of the GDP while the conventional account of the Central Statistical Organization puts it as 1.1% of the GDP (CSO 1999). Chopra, Bhattacharya, and Kumar (2003) go far beyond timber and NTFP to capture eco-tourism and carbon sequestration benefits of forests as well. These studies however did not seek to determine economic values or NIA adjustments for the core ecological services of forests, namely, groundwater recharge and the prevention of soil erosion

Table 1

Economic values of intangible benefits of forests, Indian case studies

Intangible benefits	*Annual value*	*Location*	*Methodology used*	*Source*
Recreation/Eco-tourism	Rs 16 197 per hectare (Rs 427.04 per Indian visitor; Rs 432.04 per foreign visitor)	Keoladeo National Park, Bharatpur	Travel cost method	Chopra and Adhikari (2004)
Recreation/Eco-tourism	Rs 20 944 per hectare (Rs 519 per Indian visitor; Rs 495.04 per foreign visitor	Keoladeo National Park, Bharatpur	Contingent valuation method	Murty and Menkhaus (1994)
Recreation/Eco-tourism and other benefits	Rs 23 300 per hectare (Rs 90 per household per year)	Borivili National Park, Mumbai	Contingent valuation method	Hadker *et al.* (1997)
Eco-tourism	Rs 2.95 million (Rs 34.68 per local visitor)	Kalakadu Mundanthurai Tiger Reserve, Tamil Nadu	Contingent valuation method	Manoharan (2000)
Eco-tourism	Rs 676 per hectare (Rs 9.5 per local [Kerala] visitor)	Periyar Tiger Reserve, Kerala	Contingent valuation method, travel cost method	Manoharan (1996)
Soil conservation	Cost of soil erosion @ Rs 21 583 per hectare	Doon Valley	Replacement cost approach	Kumar (2000)
Ecological functions (use value) for local residents	Rs 624 per hectare	Yamuna Basin	Contingent valuation method	Chopra and Kadekodi (1997)
Watershed values (Soil conservation)	Rs 0.2 million per hectare of soil	Lower Siwalik (Yamuna Basin)	Indirect method (reduced cost of alternate technology)	Chopra and Kadekodi (1997)

Source Compiled by authors

and flood damage. This was mainly due to challenges in framing a complex estimation and due to the paucity of relevant data.

It must be mentioned, however, that a large number of valuation studies throw considerable light on the magnitude of intangible benefits or ecosystem services accruing from forests. Manoharan (2000) reviews these studies, the methods they use, and the results that they arrive at have been given in Table 1.

Present study

Though various studies and scientific assessments highlight the contribution of the forestry sector in terms of various ecosystem services, not much work has been initiated on the valuation of and accounting for the ecological functions of forest ecosystems. In terms of an accounting framework, therefore, they remain ignored, featuring largely satellite for the forestry sector. Numerous countries have attempted satellite accounting for the forestry sector with extensions in one or the other methodological direction. Norway, Sweden, and the Netherlands among others have gone ahead with partial forest resource accounting (Hultkranz 1992). Several scholars endorse such satellite accounting. Peskin (1989), for example, maintained that stock and flow changes in forests and other environmental resources be treated in a separate table, leaving the basic income accounting table unchanged. Vincent (1999) also opines that it may not be possible or even appropriate to make annual adjustments to NIAs for all aspects. He suggests that satellite accounts take into consideration the most important aspects of forest resources for a particular economy set-up once in four/five years.

Within the category of forest accounts, few studies focus on NTFP, such as fuelwood, fodder and fruit, and resin, even though it has been conceded that forests have amenity values and – at times – these amenity values are higher than timber and non-timber values. Hulkrantz (1992) included both timber and other forest environment resources in his study for Sweden. Ecosystem services are another neglected area though carbon sequestration values of forests have received some attention even in India (Kadekodi and Ravindranath 1997; Ravindranath, Somashekhar, and Gadgil 1997; Haripriya 2001). The forest is one of the most important of our natural and renewable resources. Besides providing economic benefits (accountable) such as timber and carbon sequestration, which are of vital use for mankind, they also offer protection to the other two most important resources—land and water. Environmental quality depends to a great extent on the entire forest ecosystem, encompassing the atmosphere, the climate, the soil, the water mass, and the living organisms.

From the perspective of the ecology and the environment, the importance of forests need not be overemphasized but the part they play in the conservation of soil and water and in the attenuation of floods cannot be overlooked either. To reiterate, the presence of forest prevents soil erosion and moderates the flow of water in catchment areas. These refer to functions such as soil protection, water augmentation (recharging groundwater), flood control/regulation, carbon sequestration, and nutrient recycling that the existence of a preserved forest facilitates. Ecological categories and functions are holistic in nature and somewhat difficult to place completely within a structured system of accounts. At the same time, it is important to account for their economic value to prevent depletion and degradation that may arise due to oversight. The alternative seems to be to set up a system of income–product and capital accounts of the kind attempted in studies such as the contribution of the forestry sector to India's GDP (Chopra, Bhattacharya, and Kumar 2003). This could provide policy guidelines with respect to planning for natural resources at the macro level.

In this monograph, the missing contributions of forests have been accounted for and monetized for 2002/03 in terms of following ecological functions and benefits.

1 Prevention of soil erosion

2 Augmentation of groundwater

3 Flood control

Other benefits of forests, such as carbon sequestration and the provision of timber, fuelwood, and NTFP have been estimated in earlier paper (Monograph 1 under the GAISP series), and the biodiversity values of forests are the subject of a later paper (Monograph 5 of the GAISP series).

Prevention of soil erosion

Soil erosion: Indian scenario

India's cultivable tropical/subtropical land has been conducive to the flourishing of fabulously rich civilizations, owing to the production of abundant food, fibre, fodder, and fuel materials. Khoshoo and Tejwani (1993) note that the dispossessed landlords ruthlessly destroyed all the forests before they handed over their lands to the government. Today, as a result, hardly any area in India is free from the hazard of soil erosion. India's total land area is about 297.319 mha (million hectares). Out of this, 169.569 mha is cropland. Land utilization statistics are available for 92.7% of the total geographical area of 328 mha. Net sown area in 1992/93 was about 68.28 mha, of which 66.9% was devoted to food grain production during 1993/94 (GoI 2003).

Before the establishment of the Ministry of Environment and Forests, the Ministry of Agriculture furnished all relevant information regarding soil erosion and degradation in India. In the 1950s, the ministry reported that 145 mha of land was in need of soil and water conservation measures (MoA 1968). Bali (1975) estimated that 175 mha of land was degraded (69.5 mha critically and 106 mha severely). About 64% of the soil erosion is due to water-borne erosion alone. In another study, Dhruvnarayana and Ram Babu (1983) found that about 5334 MT (million tonnes) of soil is eroded every year. The country's rivers carry approximately 2062 MT of soil. Of this, about 29% is lost to the sea, 10% is deposited in reservoirs, and 61% is transported from one place to another.

In more recent studies, Singh, Babu, Narayana, *et al.* (1992) have estimated soil erosion for India using the USLE (universal soil loss equation) and soil erosion maps at a scale of 1:6 000 000. The maximum area of degradation falls into the moderate category while the minimum area comes under the very severely eroded category. The ISRIC (International Soils Research and Information Centre), under the aegis of the UNEP (United Nations Environment Programme) has also conducted studies for soil degradation in India under the project GLASOD (Global

Table 2

Soil erosion and sediment estimates, India (million tonnes)

	Estimates based on annual value of		
Particulars	*Soil loss*	*Rainfall*	*Discharge*
Total soil erosion	5334	–	–
Total sediments loads of rivers	–	1296	2062
Total sediment deposition in reservoirs	–	480	338

Source CSWCRTI (1999)

Assessment of Soil Degradation). GLASOD has used 26 units of maps and 33 records for assessment of all types of soil degradation for India. GLASOD studies also take into account other studies done by the Government of India and individual experts. However, due to the difference in severity measurements, other estimates may vary from the GLASOD estimates by a factor of two, sometimes more (FAO 1994).

India's total soil loss situation is computed on the basis of the following assumed data (Vohra 1982).

1 Geographical area: 328 mha

2 Average annual rainfall: 1175 mm (47 inches)

3 Total annual river discharge: 164.5 mha per m

Table 2 presents the total soil erosion value based on this data and regression equations (Appendices I and II). Clearly, out of a total value of 5334 MT of soil loss (16.35 tonnes per ha [hectare]), the rivers carry approximately 2062 MT (Singh *et al.* 1992).

Estimation of soil loss prevented by forests in India

Prevention of soil erosion by forests

Experiments conducted in plots of the CSWCRTI (Central Soil and Water Conservation Research and Training Institute), Dehra Dun, (conducted through its stations across the country) have yielded a large number of observations. For example, in a study in the Nilgiris area, the effects of the vegetative cover of the natural degraded shola forest and of the converted man-made forests in small catchments with an undulating topography of 10%–20% slope have been studied since 1968 after the first calibration period for nine years (1957–65) before felling the shola forest and the second calibration period for three years (1965–67) after felling the forest in three plots (0.09 ha each), leaving one plot (also 0.09 ha) with the forest intact as control. During the first calibration period, the average annual rainfall was 1361 mm with the run-off ranging from 0.01% to 0.05% and there was absolutely no soil loss owing to the good canopy, good undergrowth, dense leaf-litter, high humus content, and consequent high interception and infiltration rate in the shola forest. However, for the same region at the same slope (10%–20%), the soil loss for the bare land was found to be 12.5 tonnes per ha per annum. At this

Table 3

Run-off and soil loss under treated and untreated micro-watersheds, 1999–2002

Year	Rainfall (mm)	*Run-off* (percentage of rainfall)			*Soil loss* (tonnes per hectare)		
		*W1**	*W2**	*W3**	*W1**	*W2**	*W3**
1999	180.5	10.5	16.2	32.4	20.8	26.0	46.5
2000	150.8	3.5	14.6	14.7	12.9	23.2	36.4
2001	209.8	4.9	16.9	40.8	10.6	13.1	56.6
2002	78.0	6.1	11.8	20.4	NR	NR	NR
Average	154.3	6.3	15.5	29.4	14.8	20.8	46.5

W1 – micro-watershed fully treated with forest cover; W2 – micro-watershed partially treated with forest cover; W3 – untreated micro-watershed; NR – No recharge

Source CSWCRTI (2000)

rate, it is evident that forests prevent soil erosion (with respect to bare land or no forestland), especially in the southern and south-western states of India. As mentioned, forests interrupt raindrop velocity and prevent soil erosion, which is perhaps India's most serious environmental problem currently. In ecological science, forest influence on soil is well established. For example, broad-leafed forests significantly prevent soil erosion.

The CSWCRTI's experiments in the Himalayan foothills also suggest that treated watersheds with particular forest types significantly reduce soil loss (Table 3). Since the land is alluvial and at a higher slope, the differential soil loss is 31.7 tonnes per ha per annum (46.5 – 14.8). It is clear that bare land has the highest run-off with respect to any forest type. In another study in 1969, the influence of artificially raised forests of eucalyptus on run-off and soil loss was studied on a micro-watershed in Doon valley and monthly run-off and peak discharge prediction equations were developed (Appendix II). These equations of the situation before and after reforestation revealed that it had resulted in the reduction of run-off by 28% and of peak rate of discharge by 73% as compared to the non-forested area.

To arrive at the picture of erosion prevented by forests with respect to bare land, representative experiments from different part of India have been compiled. Studies are primarily from the CSWCRTI and GBIHED (G B Pant Institute of Himalayan Environment and Development), Almora, PARDYP (People Resource Dynamics Project) research jointly with ICIMOD (International Centre for Integrated Mountain Development), Kathmandu. These studies are for different forest types with varying degrees of land slopes and soil types. In all cases, average annual value of rainfall, run-off, and soil loss have been taken into consideration. Invariably, experimental plots have been designed for controlled and uncontrolled areas but other geomorphologic aspects remain the same, so that differences in soil loss can be attributed to forest cover. Again, within the forest, the type of forest matters—a broad-leafed forest has

Table 4

Soil loss prevented by dense forest, 2001

State/Union Territory	*Dense forest* (million ha)	*Soil loss prevented* (million tonnes)	*Soil loss prevented* (million kg)
Andhra Pradesh	2.58	32.28	32283.75
Arunachal Pradesh	5.39	66.28	66282.43
Assam	1.58	19.46	19455.07
Bihar	0.34	4.14	4144.19
Chhattisgarh	3.79	46.55	46554.52
Delhi	0	0.05	46.70
Goa	0.18	2.23	2231.25
Gujarat	0.87	10.66	10659.12
Haryana	0.11	1.40	1399.83
Himachal Pradesh	1.04	12.82	12817.24
Jammu and Kashmir	1.18	14.56	14561.19
Jharkhand	1.18	14.49	14486.22
Karnataka	2.62	32.70	32695.00
Kerala	1.18	14.72	14715.00
Madhya Pradesh	4.44	54.55	54547.94
Maharashtra	3.09	38.62	38617.50
Manipur	0.57	7.02	7017.59
Meghalaya	0.57	6.98	6981.95
Mizoram	0.89	10.98	10982.34
Nagaland	0.54	6.63	6628.00
Orissa	2.80	34.38	34377.59
Punjab	0.15	1.90	1903.72
Rajasthan	0.63	7.77	7769.74
Sikkim	0.24	2.94	2938.54
Tamil Nadu	1.25	15.62	15623.75
Tripura	0.35	4.26	4256.03
Uttar Pradesh	0.90	11.02	11017.99
Uttaranchal	1.90	23.38	23379.27
West Bengal	0.63	7.80	7799.23
Andaman and Nicobar Islands	0.66	8.24	8241.25
Chandigarh	0	0.01	6.15
Dadra and Nagar Haveli	0.02	0.19	185.58
Daman and Diu	0	0	2.46
Lakshadweep	0	0.03	33.75
Pondicherry	0	0.04	43.75
Total	41.68	514.69	514685.61

Source Compiled by authors on the basis of FSI Reports of 2001, 2003, and 2005

better ability to check erosion than, say, a pine forest. However, a dense forest of pine cover would prove as effective as a broad-leafed forest. This is clearly suggested by a scientific study conducted by GBIHED, Almora (along with ICIMOD, Kathmandu) on a small micro-watershed in the hills of Bheta Gad, Uttaranchal, aimed at studying the effect of forest vegetation in preventing soil erosion. The study, which stretches for four years, records the soil erosion activity of the watershed and compares the results with another erosion plot covered with broad-leafed forest. It is easily inferred that soil loss prevented by the forest is quite substantial at approximately 12.295 tonnes per ha per annum. This rate of prevented erosion has been adopted for estimation of erosion benefits in India's northern and north-eastern states. Table 4 summarizes soil loss calculated from the forest cover (dense) obtained from the FSI, 2005 report.

South India

Average soil loss during 2000–04 on bare land (tonnes per ha per year) = [9.385054 + 9.514319 + 29.253003 + 1.195635] / 4 = 12.337

North India

Average soil loss during 2000–04 on broad-leafed forest = 0.0424
Loss prevented by forest (tonnes per ha per year) = 12.337 – 0.0424 = 12.295

(Appendices III, IVA, IVB, IVC, IVD, IVE)

For the given dense area of different states of India in 2001, soil loss has been estimated by simply multiplying the differential soil loss prevented by the presence of forest to existing forest areas (in ha).

This has been done state-wise for 2001/02. Open forest and scrubs also prevent erosion, depending upon soil types, gradient velocity of rainfall, etc. but they are not as effective as dense forests. Therefore, the estimation of soil loss benefit provided by the forest is, at best, a conservative one (Table 5).

Estimation of economic value of prevented loss

There are two approaches to value soil loss. The first approach is the productivity loss approach where it is assumed that other factors (climate, pests, diseases, fertilizer rates, crop management, technology, etc.) remaining the same, the yield of crops gets reduced due to erosion. It should be noted that only on-site impact has been considered here. Off-site impacts of soil erosion, in terms of siltation of reservoirs and other downstream damages (fisheries, navigation, etc.), could be significant but have not been considered due to paucity of reliable data and time constraints. Due to the lack of well-established yield–erosion relationship for different parts of India, we have avoided this approach and opted for the second approach, known as the resource value of soil loss. Under this, soil is considered as the supplier of vital nutrients. Artificial fertilizers are used as a marketed proxy for valuation of nutrients lost due to erosion. However, resource value of soil differs from the replacement cost approach, under which the depletion of nutrients is in terms of annual marginal cost of their replacement. Resource value is based on the cumulative depletion of soil nutrient content due to erosion. It is cumulative so as to account for the erosion progressively impairing the quality of soil over time, increasingly limiting the soil's potential uses. Generally, it has been found that only major nutrients like nitrogen (N), potassium (K), phosphorous (P), and organic matter are taken into account. Minor nutrients like magnesium, calcium, organic material, etc. are ignored. Stocking (1987) calculated the economic cost of eroded soil for Zimbabwe in terms of the three major nutrients (N, P, K). Here we consider only N, P, K, and organic matter for 2001/02. These are the estimates of the soil loss prevented by the forest (not the cumulative loss). This

Table 5

Soil loss prevented by dense forest, 2003

State/Union Territory	*Dense forest* (million ha)	*Soil loss prevented* (million tonnes)	*Soil loss prevented* (million kg)
Andhra Pradesh	2.44	30.47	30473.75
Arunachal Pradesh	5.35	65.77	65765.02
Assam	1.30	16.03	16028.62
Bihar	0.30	3.72	3720.18
Chhattisgarh	3.90	47.91	47906.42
Delhi	0.01	0.06	63.91
Goa	0.13	1.57	1568.75
Gujarat	0.63	7.80	7798.01
Haryana	0.05	0.64	639.08
Himachal Pradesh	0.90	11.03	11031.50
Jammu and Kashmir	1.05	12.90	12900.81
Jharkhand	1.17	14.36	14355.95
Karnataka	2.25	28.08	28076.25
Kerala	0.96	12.04	12035.00
Madhya Pradesh	4.18	51.43	51425.05
Maharashtra	2.84	35.48	35483.75
Manipur	0.65	8.04	8035.20
Meghalaya	0.65	7.98	7977.44
Mizoram	0.75	9.20	9202.75
Nagaland	0.57	7.01	7013.90
Orissa	2.82	34.62	34620.93
Punjab	0.07	0.91	913.15
Rajasthan	0.45	5.53	5525.58
Sikkim	0.24	2.90	2902.90
Tamil Nadu	1.20	15.01	15008.75
Tripura	0.50	6.20	6201.53
Uttar Pradesh	0.60	7.37	7369.08
Uttaranchal	1.84	22.64	22640.64
West Bengal	0.60	7.43	7429.31
Andaman and Nicobar Islands	0.63	7.86	7855.00
Chandigarh	0	0.01	11.06
Dadra and Nagar Haveli	0.01	0.18	178.21
Daman and Diu	0	0	2.46
Lakshadweep	0	0.02	15.00
Pondicherry	0	0.02	21.25
Total	39.06	482.20	482196.19

Source Compiled by authors

approach, however, might yield the upper range of the value, as it happens to be a comprehensive assessment of nutrient loss.

Estimation of nutrient loss has been attempted for the calculation of annual nutrient loss through sediment losses. Average concentration of different soil nutrients – total nitrogen, total phosphorous, total potassium, total calcium, and organic carbon – in run-off soil (mg per g) under different land-use categories has been adopted as per Pandey, Pathak, and Singh (1984) in the Doon valley and Nilgiri areas (Table 6). The dense forest area in different states of India has been multiplied by the soil loss prevented by the forest. For calculation of nutrient loss, the average concentrations of N, P, K, and organic matter in dense forest have

Table 6

Concentration of nutrients (mg per g) in run-off

Land use	*Nitrogen (N)*	*Phosphorous (P)*	*Potassium (K)*	*Organic carbon*
Dense forest	2.32	0.044	8.25	22.50

Source Pandey, Pathak, and Singh (1984)

been considered. The average concentration of nutrients has been multiplied by the estimated soil loss in each state. The loss of nutrients has been summarized in Table 7.

Table 7

Estimation of nutrient loss (N, P, K, organic matter), 2001

	Nutrients (million kg)			
State/Union Territory	*N*	*P*	*K*	*Organic matter*
Andhra Pradesh	74.90	1.42	266.34	726.38
Arunachal Pradesh	153.78	2.92	546.83	1491.35
Assam	45.14	0.86	160.50	437.74
Bihar	9.61	0.18	34.19	93.24
Chhattisgarh	108.01	2.05	384.07	1047.48
Delhi	0.11	0	0.39	1.05
Goa	5.18	0.10	18.41	50.20
Gujarat	24.73	0.47	87.94	239.83
Haryana	3.25	0.06	11.55	31.50
Himachal Pradesh	29.74	0.56	105.74	288.39
Jammu and Kashmir	33.78	0.64	120.13	327.63
Jharkhand	33.61	0.64	119.51	325.94
Karnataka	75.85	1.44	269.73	735.64
Kerala	34.14	0.65	121.40	331.09
Madhya Pradesh	126.55	2.40	450.02	1227.33
Maharashtra	89.59	1.70	318.59	868.89
Manipur	16.28	0.31	57.90	157.90
Meghalaya	16.20	0.31	57.60	157.09
Mizoram	25.48	0.48	90.60	247.10
Nagaland	15.38	0.29	54.68	149.13
Orissa	79.76	1.51	283.62	773.50
Punjab	4.42	0.08	15.71	42.83
Rajasthan	18.03	0.34	64.10	174.82
Sikkim	6.82	0.13	24.24	66.12
Tamil Nadu	36.25	0.69	128.90	351.53
Tripura	9.87	0.19	35.11	95.76
Uttar Pradesh	25.56	0.48	90.90	247.90
Uttaranchal	54.24	1.03	192.88	526.03
West Bengal	18.09	0.34	64.34	175.48
Andaman and Nicobar Islands	19.12	0.36	67.99	185.43
Chandigarh	0.01	0	0.05	0.14
Dadra and Nagar Haveli	0.43	0.01	1.53	4.18
Daman and Diu	0.01	0	0.02	0.06
Lakshadweep	0.08	0	0.28	0.76
Pondicherry	0.10	0	0.36	0.98
Total	1194.07	22.65	4246.16	11580.43

Note Loss of nutrients pertains to 2001/02.
Source Compiled by authors

Losses arising out of soil erosion at the national level are either absent or at the most highly speculative. Kumar (2004) estimates the cost of soil erosion for the Doon valley, which is at the current price, using two approaches: productivity loss and resource value. Singh, Vasisht, and Mathur (2003) estimate the cost of land degradation for 17 major Indian states (although the basis of the data remains Punjab) as 12 288 rupees per ha per annum at the current price (1995/96). Estimation of soil erosion and subsequent economic loss demands a large number of data sets over sufficient time experience, which is why it has not evolved as a field of study in several developing countries.

Our present study follows the replacement cost approach. On the basis of soil loss figures obtained for 2001, we arrive at the total major nutrient loss, which Indian forests prevent. Here again, we account for the saving by dense forests only. Open forest and scrubs do not help that much in prevention of soil erosion although they do play positive roles. Quantification of that saving of soil is extremely difficult due to paucity of data.

The major nutrients lost due to soil erosion are N, P, K, and organic matter. Lost nitrogen can be replaced by urea (46% N); although other fertilizers can also replenish lost nitrogen, only urea is considered here as it contains the maximum concentration of nitrogen when compared to ammonium sulphate (20.6% N) and calcium ammonium nitrate (25% N). Phosphate is supposed to be replaced by DAP (diammonium phosphate) (18-46-0). Potash has been replenished by muriate of potash (60% K_2O). The loss of organic matter is replenished with the help of farmyard manure, at an average national price of approximately Rs 0.50 per kg (exclusive of Central and state sales tax and local taxes). Fertilizer prices are generally administered and controlled, and vary from state to state depending upon sales and other taxes. Prices of DAP and muriate of potash have been decontrolled since August 1992. Table 8 gives the value of potential nutrient loss, obtained at the prevailing market price of nutrients gathered from the data published by the Fertilizer Association of India (2003/04) (Appendix V). Table 9 and Table 10 provide a glimpse of soil loss and economic value for each state of India for 2001/02 and 2003/04, and Table 11 compares the economic loss prevented in 2003 with the corresponding value in 2001, based on successive bi-annual FSI survey estimates of dense forest.

Augmentation of groundwater by forest

Forest and watershed management have increasingly come into focus as tools for water recharging and conservation. In a simple hydrological cycle model, the circulation of water from the ocean to the atmosphere, from the atmosphere to the land surface, and from the land surface to the ocean is a complex process. The presence or absence of forests, especially dense forest, has a profound impact on the hydrological process. Figure 1 illustrates the impact of deforestation on the hydrological cycle.

Table 8

Estimation of nutrient loss (N, P, K, organic matter), 2003/04

	Nutrients loss (million kg)			
State/Union Territory	*N*	*P*	*K*	*Organic matter*
Andhra Pradesh	70.70	1.34	251.41	6856.59
Arunachal Pradesh	152.57	2.89	542.56	14797.13
Assam	37.19	0.71	132.24	3606.44
Bihar	8.63	0.16	30.69	837.04
Chhattisgarh	111.14	2.11	395.23	10778.94
Delhi	0.15	0	0.53	14.38
Goa	3.64	0.07	12.94	352.97
Gujarat	18.09	0.34	64.33	1754.55
Haryana	1.48	0.03	5.27	143.79
Himachal Pradesh	25.59	0.49	91.01	2482.09
Jammu and Kashmir	29.93	0.57	106.43	2902.68
Jharkhand	33.31	0.63	118.44	3230.09
Karnataka	65.14	1.24	231.63	6317.16
Kerala	27.92	0.53	99.29	2707.88
Madhya Pradesh	119.31	2.26	424.26	11570.64
Maharashtra	82.32	1.56	292.74	7983.84
Manipur	18.64	0.35	66.29	1807.92
Meghalaya	18.51	0.35	65.81	1794.92
Mizoram	21.35	0.40	75.92	2070.62
Nagaland	16.27	0.31	57.86	1578.13
Orissa	80.32	1.52	285.62	7789.71
Punjab	2.12	0.04	7.53	205.46
Rajasthan	12.82	0.24	45.59	1243.26
Sikkim	6.73	0.13	23.95	653.15
Tamil Nadu	34.82	0.66	123.82	3376.97
Tripura	14.39	0.27	51.16	1395.35
Uttar Pradesh	17.10	0.32	60.79	1658.04
Uttaranchal	52.53	1.00	186.79	5094.14
West Bengal	17.24	0.33	61.29	1671.59
Andaman and Nicobar Islands	18.22	0.35	64.80	1767.38
Chandigarh	0.03	0	0.09	2.49
Dadra and Nagar Haveli	0.41	0.01	1.47	40.10
Daman and Diu	0.01	0	0.02	0.55
Lakshadweep	0.03	0	0.12	3.38
Pondicherry	0.05	0	0.18	4.78
Total	1118.70	21.22	3978.12	108494.14

Note Loss of nutrients pertains to 2003/04.
Source Compiled by authors

In the modified forest hydrological cycle, the precipitation falls on the vegetative cover, which is first intercepted by the forest's canopy or the leaf cover area, thus reducing the intensity of rainfall. Thereafter, the water reaches the ground along the stem (in what is called stem flow) and also falls directly on to the ground. It is then absorbed from the soil by vegetation roots and – at high humidity levels – moves out from the leaves into the atmosphere through the process of transpiration. Of the water that falls directly on to the land surface, some evaporates back into the atmosphere and some goes away as surface run-off. Evapo-transpiration

Table 9

Economic value of nutrient loss (million rupees), 2001/02

	Economic value of nutrient loss				
State/Union Territory	*N*	*P*	*K*	*Organic matter*	*Total*
Andhra Pradesh	786.43	23.04	1978.91	363.19	3151.57
Arunachal Pradesh	1614.64	47.30	4062.95	745.68	6470.57
Assam	473.93	13.88	1192.55	218.87	1899.23
Bihar	100.95	2.96	254.03	46.62	404.56
Chhattisgarh	1134.07	33.23	2853.68	523.74	4544.72
Delhi	1.14	0.03	2.86	0.53	4.56
Goa	54.35	1.59	136.77	25.10	217.81
Gujarat	259.66	7.61	653.38	119.92	1040.57
Haryana	34.10	1.00	85.81	15.75	136.66
Himachal Pradesh	312.23	9.15	785.66	144.19	1251.23
Jammu and Kashmir	354.71	10.39	892.56	163.81	1421.47
Jharkhand	352.88	10.34	887.97	162.97	1414.16
Karnataka	796.45	23.33	2004.12	367.82	3191.72
Kerala	358.46	10.50	901.99	165.54	1436.49
Madhya Pradesh	1328.79	38.93	3343.65	613.66	5325.03
Maharashtra	940.72	27.56	2367.16	434.45	3769.89
Manipur	170.95	5.01	430.16	78.95	685.07
Meghalaya	170.08	4.98	427.98	78.55	681.59
Mizoram	267.53	7.84	673.19	123.55	1072.11
Nagaland	161.46	4.73	406.28	74.56	647.03
Orissa	837.44	24.53	2107.26	386.75	3355.98
Punjab	46.37	1.36	116.69	21.42	185.84
Rajasthan	189.27	5.55	476.27	87.41	758.50
Sikkim	71.58	2.10	180.13	33.06	286.87
Tamil Nadu	380.59	11.15	957.7	175.77	1525.21
Tripura	103.68	3.04	260.88	47.88	415.48
Uttar Pradesh	268.4	7.86	675.37	123.95	1075.58
Uttaranchal	569.52	16.69	1433.09	263.02	2282.32
West Bengal	189.99	5.57	478.07	87.74	761.37
Andaman and Nicobar Islands	200.76	5.88	505.17	92.71	804.52
Chandigarh	0.15	0	0.38	0.07	0.60
Dadra and Nagar Haveli	4.52	0.13	11.38	2.09	18.12
Daman and Diu	0.06	0	0.15	0.03	0.24
Lakshadweep	0.82	0.02	2.07	0.38	3.29
Pondicherry	1.07	0.03	2.68	0.49	4.27
Total	12537.70	367.32	31548.94	5790.21	50244.21

Source Compiled by authors

is the term used to describe the combined effects of evaporation and transpiration. Part of the water falling on the surface is utilized in enhancing soil moisture to its field or saturation capacity. Only the residual water goes into recharging the groundwater table. This process can be represented by a simple water balance equation (Equation 1).

$$P = E + R + F + GW \tag{1}$$

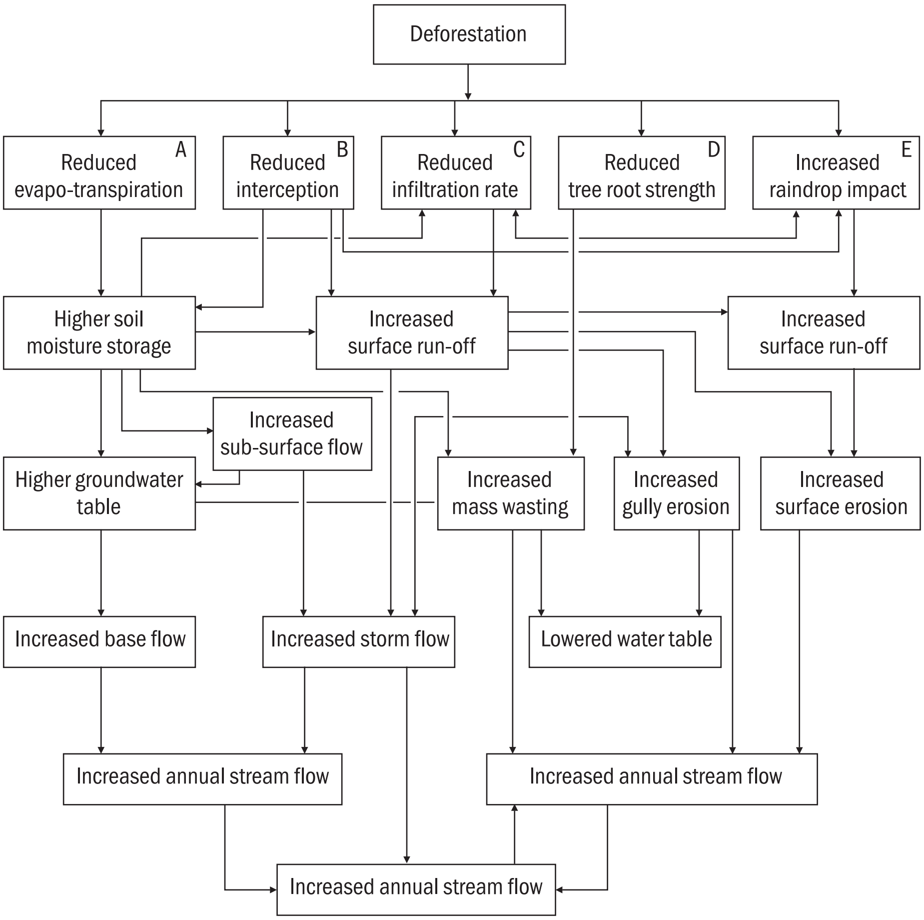

Figure 1

Likely hydrological changes following deforestation

Source Adapted from NIH (1986)

where 'P' is precipitation, 'E' is evapo-transpiration, 'R' is run-off, 'F' is moisture required to saturate the soil to field capacity, and 'GW' is groundwater recharge.

Rainfall is the most important component of the water balance equation. In India, rainfall is the most important source of groundwater recharge. In the absence of adequate vegetative growth, most of the rainfall gets converted into run-off and surface flows. The forest surface protects the soil from the direct impact of rainfall and also acts as a sponge. Forest litter also reduces rainfall impact and helps water absorption into the ground.

Run-off is that portion of rainfall, which moves down the stream, channel, rivers, or ocean as surface sub-surface flows. It is the most difficult variable to analyse and calculate considering that it is a function of soil type, area, vegetative cover, intensity of rainfall, topography, slope, etc. Deriving the run-off coefficient and total run-off from numerous studies under various soil types cover and vegetative area, we arrive at a broad conclusion about run-off rate in different forest types of India (Appendices VIA, VIB, and VIC). The following assumptions are made in using the method to estimate run-off.

Table 10

Economic value of nutrient loss (million rupees), 2003

	Economic value of nutrient loss (million rupees)				
State/Union Territory	*Nitrogen*	*Phosphorus*	*Potassium*	*Organic matter*	*Total*
Andhra Pradesh	742.34	21.75	1867.96	342.830	2974.88
Arunachal Pradesh	1602.04	46.94	4031.23	739.856	6420.07
Assam	390.46	11.44	982.51	180.322	1564.73
Bihar	90.62	2.66	228.04	41.852	363.17
Chhattisgarh	1167.00	34.19	2936.54	538.947	4676.68
Delhi	1.56	0.05	3.92	0.719	6.25
Goa	38.21	1.12	96.16	17.648	153.14
Gujarat	189.96	5.57	478.00	87.728	761.26
Haryana	15.57	0.46	39.17	7.190	62.39
Himachal Pradesh	268.73	7.87	676.20	124.104	1076.90
Jammu and Kashmir	314.26	9.21	790.79	145.134	1259.39
Jharkhand	349.71	10.25	879.98	161.504	1401.44
Karnataka	683.94	20.04	1721.00	315.858	2740.84
Kerala	293.17	8.59	737.72	135.394	1174.87
Madhya Pradesh	1252.71	36.70	3152.23	578.532	5020.17
Maharashtra	864.38	25.32	2175.07	399.192	3463.96
Manipur	195.74	5.73	492.54	90.396	784.41
Meghalaya	194.33	5.69	489.00	89.746	778.77
Mizoram	224.18	6.57	564.11	103.531	898.39
Nagaland	170.86	5.01	429.93	78.906	684.71
Orissa	843.37	24.71	2122.18	389.485	3379.75
Punjab	22.24	0.65	55.97	10.273	89.13
Rajasthan	134.60	3.94	338.70	62.163	539.40
Sikkim	70.71	2.07	177.94	32.658	283.38
Tamil Nadu	365.61	10.71	920.00	168.848	1465.17
Tripura	151.07	4.43	380.14	69.767	605.41
Uttar Pradesh	179.51	5.26	451.71	82.902	719.38
Uttaranchal	551.53	16.16	1387.81	254.707	2210.21
West Bengal	180.98	5.30	455.40	83.580	725.26
Andaman and Nicobar Islands	191.35	5.61	481.49	88.369	766.82
Chandigarh	0.27	0.01	0.68	0.124	1.08
Dadra and Nagar Haveli	4.34	0.13	10.92	2.005	17.40
Daman and Diu	0.06	0	0.15	0.028	0.24
Lakshadweep	0.37	0.01	0.92	0.169	1.47
Pondicherry	0.52	0.02	1.30	0.239	2.08
Total	11746.30	344.13	29557.42	5424.706	47072.56

Source Compiled by authors

1 Rainfall occurs at uniform intensity over the entire watershed (forest) area)

2 Run-off rate is the same for the entire forest area.

Estimation of rechargeable groundwater potential is a complex process. Groundwater recharge depends on various factors other than rainfall; these include evapo-transpiration, soil moisture characteristics, topographic slope, land-use pattern of the area, period before and after the rainfall, and actual rainfall. Weekly evapo-transpiration rates vary from 20 mm in northern India to almost 70 mm in places in central

Table 11

Economic value of nutrient loss in soil erosion prevented by dense forest

	Economic value of nutrient loss (million rupees)		
State/Union Territory	*Total value in 2003* (million rupees)	*Total value in 2001* (million rupees)	*Change in economic value over 2003–2001*
Andhra Pradesh	2974.880	3151.57	–176.690
Arunachal Pradesh	6420.066	6470.57	–50.504
Assam	1564.732	1899.23	–334.498
Bihar	363.172	404.56	–41.388
Chhattisgarh	4676.677	4544.72	131.957
Delhi	6.249	4.56	1.689
Goa	153.138	217.81	–64.672
Gujarat	761.258	1040.57	–279.312
Haryana	62.390	136.66	–74.270
Himachal Pradesh	1076.904	1251.23	–174.326
Jammu and Kashmir	1259.394	1421.47	–162.076
Jharkhand	1401.444	1414.16	–12.716
Karnataka	2740.838	3191.72	–450.882
Kerala	1174.874	1436.49	–261.616
Madhya Pradesh	5020.172	5325.03	–304.858
Maharashtra	3463.962	3769.89	–305.928
Manipur	784.406	685.07	99.336
Meghalaya	778.766	681.59	97.176
Mizoram	898.391	1072.11	–173.719
Nagaland	684.706	647.03	37.676
Orissa	3379.745	3355.98	23.765
Punjab	89.133	185.84	–96.707
Rajasthan	539.403	758.50	–219.097
Sikkim	283.378	286.87	–3.492
Tamil Nadu	1465.168	1525.21	–60.042
Tripura	605.407	415.48	189.927
Uttar Pradesh	719.382	1075.58	–356.198
Uttaranchal	2210.207	2282.32	–72.113
West Bengal	725.260	761.37	–36.110
Andaman and Nicobar Islands	766.819	804.52	–37.701
Chandigarh	1.084	0.60	0.484
Dadra and Nagar Haveli	17.395	18.12	–0.725
Daman and Diu	0.238	0.24	–0.002
Lakshadweep	1.469	3.29	–1.821
Pondicherry	2.079	4.27	–2.191
Total	47072.560	50244.21	–3171.654

Source Compiled by authors

Maharashtra (such as Jalagaon). While normal rainfall for India as a whole is around 1100 mm, its duration and intensity vary from place to place. Western Rajasthan receives about 300 mm of rainfall, while the Western Ghats receive 2200 mm on an average. The Indian subcontinent features a variety of soil types (alluvial, red, black, laterite, desert, etc.) and forest types (from pine forests in the Himalayas to shola and bluegum in the Western Ghats). Each tree species has a different interception process of rainfall and transpiration rates. Temperatures range from 10 °C to over 40 °C in the same area in a year. Arid zones have different characteristics and recharge methodologies. These conditions further limit the threshold values of rainfall required to affect groundwater recharge. The influence of artificially raised forests of the fast-growing species of eucalyptus for fuel and paper pulp in a short duration of 10 years on run-off and soil loss in the Doon valley has been acknowledged as the benchmark study conducted by CSWCRTI.

Infiltration is the process by which water enters the surface sub-soil and becomes part of the groundwater. Infiltration capacity has a positive correlation with soil porosity and organic matter content, which is provided by leaf litter and vegetative growth in the forest. Wisseman and Lee (1980) has reported infiltration capacity for bare and vegetative growth (Appendix VII). In India, infiltration rates under various forest covers have been estimated by the CSWCRTI and the FRI (Forest Research Institute), Dehra Dun (Appendices VIIIA and VIIIB). Eckholm (1976) states that cutting of tropical forests has caused wells, springs, streams, and even rivers to dry off in the lean season.

In this monograph, standard methods have been used to calculate groundwater recharge. Most methods discussed are empirical in nature, based on scientific studies done by various scientists and researchers across the country. Equations 2 and 3 give some of the relationships between rainfall and recharge that they have arrived at.

Chaturvedi Formula

$$R = 1.35\ (P-14)^{0.5} \qquad (2)$$

where 'R' is groundwater recharge, 'P' is precipitation in inches, and $P>15$ inches

Sehegal Formula (also called Amritsar Formula)

$$R = 2.5\ (P-16)^{0.5} \qquad (3)$$

for rainfall between 28 and 30 inches for last 20 years

Computation of differential water recharge between forest area and non-forest area

Water/hydrological balance methods have been used here to calculate the additional recharge facilitated by the forest. In this method, it is assumed that the precipitation quantum left over after evapo-transpiration, surface run-off and saturation of soil is available for groundwater recharge. This follows from Equation 1.

Table 12 gives the approximate calculations of groundwater recharge figures in India. The data for rainfall (R) for different geographic areas has been taken from the *Compendium of Environment Statistics* (CSO 1998). Evapo-transpiration data (E) has been obtained from *Evaporation Data of Observatories* (IMD 1980). Root constant (F) is the variable, which depends on land use in the catchment area of the recharge. It is assumed that recharge is possible only when the soil moisture deficit is completely nullified. In our study, the Root constant / soil moisture deficit is compiled from various studies carried out in India, the approximate values for which are tabulated in Table 13.

The figure for run-off coefficient has been calculated using Appendices VIA and VIB. Due consideration has been given to soil type, land use, and general slope of the area to get the most approximate value of the run-off coefficient, which is the most complex parameter in the water balance equation.

The differential values of water recharge for forest and non-forest area reveal the role of the forest in water recharge, assuming that other bio-geo-physical factors remain the same. In Table 14, water recharge has been estimated for the states with significant forested area. The price of water varies across states and uses (agriculture, industry, households - see Appendix X) and has been estimated in Table 15 at the estimated *financial cost* (see Appendix IX) from Bhatia, Kumar, Misra *et al.* (2000). However, our estimation of the forests' water recharge function is at the *opportunity cost* of water of Rs 4.5 per m^3 from the aforementioned study – that is, the economic cost of procuring water, exclusive of any distribution or environmental costs. It may be noted that the *full cost* of water from this study, including environmental and distribution costs is higher, at Rs. 8.5 per m^3.

Flood control

Floods are the most frequent natural disasters and cause damage in terms of not only human life but also physical property. Floods also cause diseases and displacement of humans on a large scale. Some plausible causes of floods are high intensity of rainfall over a particular region and alterations in the natural drainage of the river basin area by its being converted to human settlement, necessitating deforestation. Of the above, the link between deforestation and floods has been found to be very significant (CSE 1999). Ecologists believe that forest acts as a sponge, absorbing large quantities of water during the rainy season. Dense vegetation slows down water movement, reduces surface flow, and facilitates water infiltration into the ground. The leaves catch rainfall on the forest canopy while the leaf litter on the floor intercepts rain flow and protects the soil. It also helps water infiltrate better into the soil, until soil saturation capacity is reached. Only after that does the excess water get converted into surface run-off. If the rainfall intensity is very high, then the very infiltration capacity of the system is reduced and even afforestation cannot make much of a difference to the overall flood situation.

Table 12

Groundwater recharge figures for different states of India

State	*Rainfall* (mm)	*Evapo-trans-piration* (mm)	*Soil type*	*Surface moisture/ root constant* (mm)	*Run-off* (percentage in mm of rainfall)	*Groundwater recharge* (mm)	*Remarks*
Andhra Pradesh							
Telangana	800	480	Black	200	1–2	104	Forested area
Coastal Andhra Pradesh	609	374	Alluvial	150	9–10	31	Eastern Ghats
Rayalseema	372	–	Red	200	–	No recharging	Arid zone
Madhya Pradesh							
East Madhya Pradesh	1145	628	Red	250	2–4	222	Forest
West Madhya Pradesh	922	510	Black	200	5–10	112	Plain
Maharashtra							
Konkan Western Ghats	2804	700	Laterite, red	300	50–60	262	For laterite specific yield = 2%–4%
Madhya Maharashtra	745	480	Black	200	3–4	65	Semi-dry
Marathwada	717	402		200	1–2	80	
Vidarbh	978	538	Red, black	300	1–2	140	Forest area
Bihar							
Bihar	1005	565	Alluvial	200	10–15	136	Plain
Jharkhand	1078	490	Red	200	15–20	188	Forest area
Tamil Nadu							
North Tamil Nadu	360	300	Red			No recharge	
South Tamil Nadu	323	300	Laterite, alluvial, red			No recharge	
Rajasthan							
Western Rajasthan	330	NA	Desert	120	Nil	33	Desert
Eastern Rajasthan	680	440	Red, black	100	2–4	80	Semi-forested
Uttaranchal	1147	479	Mountain				20%–30% slopes
Grass covers		500		332	20–30	236	
Bare soil		400		676	50–60	29	
Forest		500		240	20–25	307	
Himachal Pradesh	921	450	Mountain				20%–30% slopes
Forest		450		202	20–30	169	
Grass cover		450		150	20–30	104	
Punjab	499	370	Alluvial	70	1–2	50	
Haryana	513	37	Alluvial	70	1–2	63	
Orissa	1177		Red				
Central Orissa	1177	617	Red	300	3–10	156	Forest
Coastal Orissa	1177	660	Red	200	10–15	197	
Karnataka							
Coastal Karnataka	3178	600	Laterite	300	50–60	372	Western Ghats
South interior Karnataka	703	460	Red	100	4–8	108	
North interior Karnataka	476	400	Red	100	2-4	No recharge	
Gujarat							
Saurashtra and Kutch	543	400	Black, alluvial	100	Plain	43	Alluvial soil
South and north Gujarat	1060	480	Black	300	10-15	190	Semi-forested
West Bengal	1097	520	Alluvial	200	5-10	309	Plain
Assam	1901	600	Alluvial	250	10-15	322	Flood plain
Arunachal Pradesh	2037	600	Mountain, red	300	30-40	290	Hilly areas
North eastern states	1247	450	Red	300	30-40	190	Hilly areas

Source Computed by the authors on the basis of Karanth 1987; Lerner *et al*. 1990; Lal and Subba Rao 1981; Singhal *et al.* 1997; Negi 1998 and 2002; Simmers 1988, Rawat and Rawat 1995, and Central Water Commission 2002.

Table 13

Land use and root constant

Land use	*Root constant*
Annual crop such as paddy; grassland	100 mm
Semi forest / open forest area	200 mm
Forest cover	300 mm

Source Simmers (1988)

Table 14

Differential water recharge by dense forest

	Water recharge (mm)		
State	*Forest area*	*Non-forest area*	*Difference* (mm)
Andhra Pradesh	104	31	73
Madhya Pradesh	222	112	110
Maharashtra	65	140	75
Bihar	188	136	52
Rajasthan	83	30	53
Uttaranchal	307	93	214
Himachal Pradesh	169	40	129
Orissa	156	117	39
Karnataka	108	50	58
Gujarat	150	43	107
Assam	300	99	201
Kerala	325	227	227
West Bengal	309	216	93
Arunachal Pradesh	322	229	93
Manipur	190	57	133
Meghalaya	190	57	133
Tripura	190	57	133
Nagaland	190	57	133

Note The water recharge differential has been computed for the monsoon period (June to September).

Hence, the overall impact of forests on flood management depends upon various factors, including type of forest, intensity and duration of rainfall, and general topography of the area. As a thumb rule, forest area (dense) is a critical determinant of flood intensity and frequency. A study by the CSWCRTI found that volume of run-off reduced by 28% following afforestation, while peak run-off decreased by 73%. A good forest cover, especially in the hilly region of the Himalayas, is the best bet to reduce floods in the plain (Merz 2004).

Here, we have compiled the average damage due to floods in terms of crops, cattle, human life, and public utilities, using data sourced from the Rashtriya Badh Ayog. The damage figures available at current prices (Appendix II) have been deflated by the WPI (wholesale price index) in the base year 1970/71. The WPI has been constructed on the basis of data available from the Reserve Bank of India (RBI 2004).

Table 15

Economic value of differential water recharge (due to dense forest only), 2001 and 2003

	2001			*2003*		
State/Union Territory	*Dense forest area* (million ha)	*Total extra water recharge* (million m^3)	*Value* (million rupees)	*Dense forest* (million ha)	*Total extra water recharge* (million m^3)	*Value* (million rupees)
Andhra Pradesh	2.58	188.54	56.56	2.44	177.97	53.39
Arunachal Pradesh	5.39	717.30	215.19	5.35	711.70	213.51
Assam	1.58	318.18	95.45	1.30	262.14	78.64
Bihar	0.34	17.53	5.26	0.30	15.74	4.72
Chhattisgarh	3.79	416.68	125.00	3.90	428.78	128.63
Delhi	0	NA	NA	0.01	NA	NA
Goa	0.18	NA	NA	0.13	NA	NA
Gujarat	0.87	92.80	27.84	0.63	67.89	20.37
Haryana	0.11	NA	NA	0.05	NA	NA
Himachal Pradesh	1.04	134.53	40.36	0.90	115.79	34.74
Jammu and Kashmir	1.18	NA	NA	1.05	NA	NA
Jharkhand	1.18	61.29	18.39	1.17	60.74	18.22
Karnataka	2.62	151.70	45.51	2.25	130.27	39.08
Kerala	1.18	267.22	80.17	0.96	218.56	65.57
Madhya Pradesh	4.44	488.22	146.47	4.18	460.27	138.08
Maharashtra	3.09	231.71	69.51	2.84	212.90	63.87
Manipur	0.57	75.94	22.78	0.65	86.96	26.09
Meghalaya	0.57	75.56	22.67	0.65	86.33	25.90
Mizoram	0.89	118.85	35.65	0.75	99.59	29.88
Nagaland	0.54	71.73	21.52	0.57	75.90	22.77
Orissa	2.80	109.09	32.73	2.82	109.86	32.96
Punjab	0.15	NA	NA	0.07	NA	NA
Rajasthan	0.63	33.51	10.05	0.45	23.83	7.15
Sikkim	0.24	31.80	9.54	0.24	31.41	9.42
Tamil Nadu	1.25	72.49	21.75	1.20	69.64	20.89
Tripura	0.35	46.06	13.82	0.50	67.11	20.13
Uttar Pradesh	0.90	191.85	57.56	0.60	128.31	38.49
Uttaranchal	1.90	407.09	122.13	1.84	394.23	118.27
West Bengal	0.63	59.02	17.71	0.60	56.22	16.87
Andaman and Nicobar Islands	0.66	38.24	11.47	0.63	36.45	10.93
Chandigarh	0	NA	NA	0	NA	NA
Dadra and Nagar Haveli	0.02	NA	NA	0.01	NA	NA
Daman and Diu	0	NA	NA	0	NA	NA
Lakshadweep	0	NA	NA	0	NA	NA
Pondicherry	0	NA	NA	0	NA	NA
Total	41.68	4416.94	1325.08	39.06	4128.60	1238.58

NA – not available

Source Compiled by authors

For calculating total flood damage, we have added damage caused to four categories.

1 Population (human lives) lost

2 Heads of cattle lost

3 Damage to crops and houses

4 Damage to public utilities

Appendix XI tabulates data pertaining to these variables from 1950 through 2003. For categories 1 and 2, only numbers are given, while for categories 3 and 4, the value is given in rupees per annum. The monetary value of human lives is derived through simple calculations.

To get a realistic but representative statistical value of life, average per capita income of 20 000 rupees at current price has been multiplied by average remaining age (40 years). Let us say this figure is 'A'. Subsequently, this value 'A' has been discounted by average rate of discount of 4% to get the current value of a human life in the current year. This figure is 391 000 rupees.

To get the current value of cattle (livestock), a small primary survey was done in the Ghazipur dairy, Delhi, and livestock owners in Tamil Nadu, Uttar Pradesh, West Bengal, and Gujarat were contacted to find out the prices of different types of livestock. Based on the feedback, an average figure of 10 000 rupees was taken to represent the average value of a head of cattle depending on breed, age, milking capacity, and so forth.

Then, in each given year, the number of human and cattle lives lost was multiplied by the respective current value. Then that value was deflated by the WPI to arrive at the true value in the corresponding year. Since categories 3 and 4 were already given in rupees (Appendix XI) for their corresponding year at current prices, these values were also deflated by the WPI to arrive at their value at current prices.

The WPI data was taken from the *Report on Currency and Finance, 2002*, published by the Reserve Bank of India. Since the WPI series was started afresh twice in 1983/84 and 1993/94 to account for the revision of price index, the data was spliced to get a continuous series with 1970 as the base year. This data was then used as the deflator to correct the series and achieve the true values in each year. This damage has been explained by regressing it over deforestation (dense forest) to find out the trend of flood damage as a consequence of deforestation. The coefficient comes out as 178.15 with negative sign, which is expected as these two variables move in inverse direction (Table 16). This average all-India trend has been used to convert the increase in flood damage due to decline in forest area (dense only) by a hectare. The regression coefficient suggests a significant negative correlation between dense forest area and flood damage (Tables 17 and 18). Decrease in each hectare of forest (dense) increases the value of flood damages by 8125.75 rupees per annum.

Based on a number of studies done in India (CSWCRTI 1999–2004), the quantity of rainfall intercepted by the forest is approximately 35%, of which 20% is due to the forest canopy, 10% due to the vegetative cover, and 5% due to leaf litter. Of the 80% rainfall (through fall and stem flow) that reaches the ground, 15% is lost again to evaporation (10% through ground vegetation, 5% through leaf litter). This indicates the total interception capacity of the forest as 35% (Appendices VIIIA and VIIIB). The increased detention storage of forest soil helps retard flood intensity.

However, if it rains for longer, there may not be a significant difference in the infiltration rates of forest and non-forest areas.

Conclusion

Forest ecosystems provide numerous benefits to humans. Many of these evade quantification and, in many cases, doing so carries with it the problem of double counting. For example, the forest's slope stability function in any case would get accounted for through enhanced agricultural productivity. However, accounting for distinct ecological functions of forests would not only correct the misallocation of sectoral benefits but also induce efficiency while taking decisions with respect to budgetary resource allocation for their conservation vis-à-vis other demands on the same funds. In this monograph, we have attempted to account for three functions of forests – (1) soil conservation (prevention of soil erosion), (2) water augmentation, and (3) avoidance of flood damage – on broad ecological criteria and indicators. On a geological scale, they might be related to each other, may even overlap, but in the short run, this accounting and subsequent summation of the value would help in evoking the economic rationale for forest conservation. It is logical to assume that if the forest area is not disturbed, the national total value of ecological benefits – 103.76 billion rupees in 2001 – would recur every year to the society forever (infinite time). Therefore, in this study, the annuity value of the forest's ecological services has been estimated at a 4% rate of discount (Equation 4; Tables 19 and 20).

Table 16

Summary output of regression

Regression statistics	
Multiple R	0.60
R^2	0.36
Adjusted R^2	0.34
Standard Error	1122.45
Observations	31.00

ANOVA	df	SS	MS	F	Significance F
Regression	1	20913548.46	20913548.46	16.60	0.0003269
Residual	29	36536980.73	1259895.89		
Total	30	57450529.18			

	Coefficients	*Standard error*	*t-stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	8303.89	1676.08	4.95	0	4875.93	11731.86
Dense forest	–178.15	43.73	–4.07	0	–267.59	–88.72

Decrease in each hectare of forest (dense) causes the value of flood damages to increase by 8125.75 rupees per annum (detailed results in Tables 17 and 18)

Source Compiled by authors

Table 17

Data set on dependent variable (flood damage, million rupees) and independent variable (forest area, million ha)

Year	*Value of livestock and humans deflated by the wholesale price index* (million rupees)	*Other damage* (million rupees) *at base year price*	*Total damage* (million rupees)	*Dense forest* (million ha)
1970	49.99	23.47	73.46	46.451
1971	44.57	54.47	99.04	46.451
9172	75.35	14.99	90.34	46.451
1973	357.52	64.83	107.00	46.451
1974	45.63	81.17	126.80	46.451
1975	62.34	66.55	128.89	46.451
1976	192.68	128.00	320.68	36.001
1977	1513.88	182.12	490.00	36.001
1978	563.76	220.45	784.21	36.001
1979	1349.72	109.00	850.00	36.001
1980	281.23	176.38	457.61	36.001
1981	312.20	274.50	586.70	36.001
1982	741.94	395.86	1137.80	36.001
1983	636.95	644.79	1281.74	36.105
1984	571.73	528.11	1099.84	36.105
1985	326.78	1167.83	1494.61	36.105
1986	326.96	1141.21	1468.17	37.801
1987	659.85	846.00	1505.85	37.801
1988	1122.67	1638.05	2760.72	38.471
1989	541.29	914.39	1455.68	38.471
1990	866.50	716.30	1582.80	38.571
1991	417.28	709.54	1126.82	38.571
1992	727.45	1754.83	2482.28	38.581
1993	1837.64	1866.11	3703.75	38.581
1994	854.54	1147.76	2002.30	36.761
1995	494.92	2559.41	3054.33	36.761
1996	1042.75	2180.40	3223.15	31.357
1997	623.64	2137.47	2761.11	31.357
1998	1709.59	4676.12	6385.71	31.357
1999	259.27	1741.17	2000.44	31.357
2000	1155.10	1469.49	2624.59	34.790

Source Compiled by authors

$$\text{Annuity value, } X = A/r \qquad (4)$$

where ‘A’ is the current value and ‘r’ is the rate of discount (4%).

Following the concept of user’s cost (Hicks 1920) and necessary adjustments in the gross accounted value, the forest’s contributions in terms of ecological services (depreciation of natural capital) along with other adjustments have been made in Table 21. It is clear that for states like Arunachal Pradesh, Assam, Himachal Pradesh, Jammu and Kashmir, and Mizoram the loss on account of these ecological functions is significantly high as a proportion of their state domestic product. They also

Table 18

Estimate of flood avoidance benefits of forest

	2001			*2003*		
State/Union Territory	*Dense forest area* (million ha)	*Avoided flood damage* (million rupees)	*Effective avoided flood damage* (million rupees)	*Dense forest area* (million ha)	*Avoided flood damage* (million rupees)	*Effective avoided flood damage* (million rupees)
Andhra Pradesh	2.58	20964.44	7337.55	2.44	19826.83	6939.39
Arunachal Pradesh	5.39	43797.79	15329.23	5.35	43472.76	15215.47
Assam	1.58	12838.69	4493.54	1.30	10563.48	3697.22
Bihar	0.34	2762.76	966.96	0.30	2437.73	853.20
Chhattisgarh	3.79	30796.59	10778.81	3.90	31690.43	11091.65
Delhi	0	0	0	0.01	81.26	28.44
Goa	0.18	1462.64	511.92	0.13	1056.35	369.72
Gujarat	0.87	7069.40	2474.29	0.63	5119.22	1791.73
Haryana	0.11	893.83	312.84	0.05	406.29	142.20
Himachal Pradesh	1.04	8450.78	2957.77	0.90	7313.18	2559.61
Jammu and Kashmir	1.18	9588.39	3355.93	1.05	8532.04	2986.21
Jharkhand	1.18	9588.39	3355.93	1.17	9507.13	3327.49
Karnataka	2.62	21289.47	7451.31	2.25	18282.94	6399.03
Kerala	1.18	9588.39	3355.93	0.96	7800.72	2730.25
Madhya Pradesh	4.44	36078.33	12627.42	4.18	33965.64	11887.97
Maharashtra	3.09	25108.57	8788.00	2.84	23077.13	8077.00
Manipur	0.57	4631.68	1621.09	0.65	5281.74	1848.61
Meghalaya	0.57	4631.68	1621.09	0.65	5281.74	1848.61
Mizoram	0.89	7231.92	2531.17	0.75	6094.31	2133.01
Nagaland	0.54	4387.91	1535.77	0.57	4631.68	1621.09
Orissa	2.80	22752.10	7963.24	2.82	22914.62	8020.12
Punjab	0.15	1218.86	426.60	0.07	568.80	199.08
Rajasthan	0.63	5119.22	1791.73	0.45	3656.59	1279.81
Sikkim	0.24	1950.18	682.56	0.24	1950.18	682.56
Tamil Nadu	1.25	10157.19	3555.02	1.20	9750.90	3412.82
Tripura	0.35	2844.01	995.40	0.50	4062.88	1422.01
Uttar Pradesh	0.90	7313.18	2559.61	0.60	4875.45	1706.41
Uttaranchal	1.90	15438.93	5403.62	1.84	14951.38	5232.98
West Bengal	0.63	5119.22	1791.73	0.60	4875.45	1706.41
Andaman and Nicobar Islands	0.66	5363.00	1877.05	0.63	5119.22	1791.73
Chandigarh	0	0	0	0	0	0
Dadra and Nagar Haveli	0.02	162.52	56.88	0.01	81.26	28.44
Daman and Diu	0	0	0	0	0	0
Lakshadweep	0	0	0	0	0	0
Pondicherry	0	0	0	0	0	0
Total	41.68	338600.00	118510.00	39.06	317229.28	111030.25

@ 35% of the total damage, as entire flood damage can never be mitigated by forestry alone (Appendices VIIIA and VIIIB)

Source Compiled by authors

happen to be the forest-rich states of India which have experienced significant decline in the forest area over the period 2001–03 covered in FSI surveys. Conversely, some north-eastern states (Manipur, Meghalaya, Nagaland, Tripura) which showed increases in dense forest cover between 2001 and 2003 FSI surveys attract positive adjustments to their GSDP, so we recognize that if there are still any issues related to survey data quality or consistency, then they would feed into our calculations.

Table 19

Value of ecological services rendered by Indian forests, 2001 (million rupees)

State/Union Territory	*Value for nutrient loss*	*Value for water recharge*	*Flood benefits*	*Total*	*Annuity value*
Andhra Pradesh	6420.31	848.43	7337.55	14606.29	365157.25
Arunachal Pradesh	13181.66	3227.85	15329.23	31738.74	793468.50
Assam	3869.05	1431.81	4493.54	9794.4	244860.00
Bihar	824.16	78.885	966.96	1870.005	46750.13
Chhattisgarh	9258.35	1875.06	10778.81	21912.22	547805.50
Delhi	9.29	0	0	9.29	232.25
Goa	443.73	0	511.92	955.65	23891.25
Gujarat	2119.79	417.6	2474.29	5011.68	125292.00
Haryana	278.39	0	312.84	591.23	14780.75
Himachal Pradesh	2548.98	605.385	2957.77	6112.135	152803.38
Jammu and Kashmir	2895.8	0	3355.93	6251.73	156293.25
Jharkhand	2880.89	275.805	3355.93	6512.625	162815.63
Karnataka	6502.09	682.65	7451.31	14636.05	365901.25
Kerala	2926.39	1202.49	3355.93	7484.81	187120.25
Madhya Pradesh	10848.01	2196.99	12627.42	25672.42	641810.50
Maharashtra	7679.91	1042.695	8788	17510.605	437765.13
Manipur	1395.6	341.73	1621.09	3358.42	83960.50
Meghalaya	1388.51	340.02	1621.09	3349.62	83740.50
Mizoram	2184.07	534.825	2531.17	5250.065	131251.63
Nagaland	1318.12	322.785	1535.77	3176.675	79416.88
Orissa	6836.71	490.905	7963.24	15290.855	382271.38
Punjab	378.6	0	426.6	805.2	20130.00
Rajasthan	1545.18	150.795	1791.73	3487.705	87192.63
Sikkim	584.39	143.1	682.56	1410.05	35251.25
Tamil Nadu	3107.11	326.205	3555.02	6988.335	174708.38
Tripura	846.4	207.27	995.4	2049.07	51226.75
Uttar Pradesh	2191.16	863.325	2559.61	5614.095	140352.38
Uttaranchal	4649.46	1831.905	5403.62	11884.985	297124.63
West Bengal	1551.04	265.59	1791.73	3608.36	90209.00
Andaman and Nicobar Islands	1638.95	172.08	1877.05	3688.08	92202.00
Chandigarh	1.22	0	0	1.22	30.50
Dadra and Nagar Haveli	36.91	0	56.88	93.79	2344.75
Daman and Diu	0.49	0	0	0.49	12.25
Lakshadweep	6.71	0	0	6.71	167.75
Pondicherry	8.7	0	0	8.7	217.50
Total	102356.13	19876.23	118510	240742.4	6018559.00

Source Compiled by authors

Tables 22 and 23 provide the details of the differences between annuity value of the forest's ecological services in 2002/03 over 2001/02. This difference also shows the magnitude of loss of ecological capital unaccounted and unadjusted.

The ecosystem benefits of forests remain somewhat hazy; this study hopes to clarify the issue and raise some new ones. Along with benefits like the provision of timber and NTFP as well as benefits of carbon sequestration, an articulation of these ecological benefits would make the conservation argument more emphatic and guide decision-makers to use the ecology judiciously. Needless to add, in a resource-scarce country

Table 20

Value of ecological services rendered by Indian forests, 2003 (million rupees)

State/Union Territory	*Value for nutrient loss*	*Value for water recharge*	*Flood benefits*	*Total*	*Annuity value*
Andhra Pradesh	6060.35	800.87	6939.390500	13800.61	345015.14
Arunachal Pradesh	13078.77	3202.65	15215.466880	31496.89	787422.17
Assam	3187.63	1179.63	3697.216250	8064.48	201611.91
Bihar	739.84	70.83	853.203750	1663.87	41596.84
Chhattisgarh	9527.21	1929.51	11091.648750	22548.37	563709.22
Delhi	12.71	0	28.440125	41.15	1028.75
Goa	311.98	0	369.721625	681.70	17042.54
Gujarat	1550.80	305.51	1791.727875	3648.03	91200.82
Haryana	127.09	0	142.200625	269.29	6732.27
Himachal Pradesh	2193.85	521.06	2559.611250	5274.52	131862.91
Jammu and Kashmir	2565.60	0	2986.213125	5551.81	138795.33
Jharkhand	2854.98	273.33	3327.494625	6455.80	161395.12
Karnataka	5583.56	586.22	6399.028125	12568.80	314220.08
Kerala	2393.41	983.52	2730.252000	6107.18	152679.55
Madhya Pradesh	10226.96	2071.22	11887.972250	24186.15	604653.68
Maharashtra	7056.70	958.05	8076.995500	16091.75	402293.64
Manipur	1597.97	391.32	1848.608125	3837.90	95947.45
Meghalaya	1586.48	388.49	1848.608125	3823.57	95589.33
Mizoram	1830.16	448.16	2133.009375	4411.32	110283.11
Nagaland	1394.86	341.55	1621.087125	3357.50	83937.43
Orissa	6885.11	494.37	8020.115250	15399.60	384989.88
Punjab	181.60	0	199.080875	380.68	9517.02
Rajasthan	1098.88	107.24	1279.805625	2485.92	62148.02
Sikkim	577.30	141.35	682.563000	1401.21	35030.20
Tamil Nadu	2984.81	313.38	3412.815000	6711.01	167775.13
Tripura	1233.31	302.00	1422.006250	2957.31	73932.78
Uttar Pradesh	1465.50	577.40	1706.407500	3749.30	93732.56
Uttaranchal	4502.57	1774.04	5232.983000	11509.59	287739.70
West Bengal	1477.47	252.99	1706.407500	3436.87	85921.69
Andaman and Nicobar Islands	1562.13	164.03	1791.727875	3517.88	87947.07
Chandigarh	2.20	0	0	2.20	55.00
Dadra and Nagar Haveli	35.44	0	28.440125	63.88	1597.00
Daman and Diu	0.49	0	0	0.49	12.25
Lakshadweep	2.98	0	0	2.98	74.50
Pondicherry	4.23	0	0	4.23	105.75
Total	95894.92	18578.70	111030.248000	225503.87	5637596.70

Source Compiled by authors

such as India, this accounting would prove to be a handy tool for justifying the additional investment required for this sector, which remains ignored otherwise.

Table 21

Change in annuity value of ecological services over 2003–2001 in Indian forest (million rupees)

	Annuity Value		*Change in annuity value over*
State/Union Territory	*2001*	*2003*	*2003–2001*
Andhra Pradesh	365157.25	345015.14	–20142.11
Arunachal Pradesh	793468.50	787422.17	–6046.33
Assam	244860.00	201611.91	–43248.09
Bihar	46750.13	41596.84	–5153.28
Chhattisgarh	547805.50	563709.22	15903.72
Delhi	232.25	1028.75	796.50
Goa	23891.25	17042.54	–6848.71
Gujarat	125292.00	91200.82	–34091.18
Haryana	14780.75	6732.27	–8048.48
Himachal Pradesh	152803.38	131862.91	–20940.47
Jammu and Kashmir	156293.25	138795.33	–17497.92
Jharkhand	162815.63	161395.12	–1420.51
Karnataka	365901.25	314220.08	–51681.17
Kerala	187120.25	152679.55	–34440.70
Madhya Pradesh	641810.50	604653.68	–37156.82
Maharashtra	437765.13	402293.64	–35471.49
Manipur	83960.50	95947.45	11986.95
Meghalaya	83740.50	95589.33	11848.83
Mizoram	131251.63	110283.11	–20968.52
Nagaland	79416.88	83937.43	4520.55
Orissa	382271.38	384989.88	2718.51
Punjab	20130.00	9517.02	–10612.98
Rajasthan	87192.63	62148.02	–25044.61
Sikkim	35251.25	35030.20	–221.05
Tamil Nadu	174708.38	167775.13	–6933.25
Tripura	51226.75	73932.78	22706.03
Uttar Pradesh	140352.38	93732.56	–46619.81
Uttaranchal	297124.63	287739.70	–9384.92
West Bengal	90209.00	85921.69	–4287.31
Andaman and Nicobar Islands	92202.00	87947.07	–4254.93
Chandigarh	30.50	55.00	24.50
Dadra and Nagar Haveli	2344.75	1597.00	–747.75
Daman and Diu	12.25	12.25	0
Lakshadweep	167.75	74.50	–93.25
Pondicherry	217.50	105.75	–111.75
Total	6018559.00	5637596.70	-380962.30

Source Compiled by authors

Table 22

Adjustments in the national accounts for the year 2002/03

State	GSDP 2002/03	NSDP 2002/03	Value for nutrient loss	Value for water recharge	Flood benefits	Total benefits (4+5+6)	Loss in annuity value in 2003 over 2001	Loss in annuity value in 2002/03 (8*1/2)	ESDP (3-9)	ESDP / NSDP (10/3)	Loss as a per cent of NSDP (9/3*100)
1	2	3	4	5	6	7	8	9	10	11	12
Andhra Pradesh	1607684.0	1439754.0	6060.4	800.9	6939.39	13800.61	20142.11	10071.06	1429682.95	0.99	0.70
Arunachal Pradesh	19450.5	17395.1	13078.8	3202.7	15215.47	31496.89	6046.33	3023.165	14371.94	0.83	17.38
Assam	354314.2	317208.0	3187.6	1179.6	3697.22	8064.48	43248.09	21624.05	295583.96	0.93	6.82
Bihar	897150.2	787033.0	3594.8	344.2	4180.70	8119.68	6573.79	3286.895	783746.11	1.00	0.42
Goa	77711.0	67356.0	312.0	0	369.72	681.70	6848.71	3424.355	63931.65	0.95	5.08
Gujarat	1382850.0	1144047.0	1550.8	305.5	1791.73	3648.04	34091.18	17045.59	1127001.41	0.99	1.49
Haryana	658372.0	579374.0	127.1	0	142.20	269.29	8048.48	4024.24	575349.76	0.99	0.69
Himachal Pradesh	159460.0	142024.0	2193.9	521.1	2559.61	5274.52	20940.47	10470.24	131553.77	0.93	7.37
Jammu & Kashmir	147495.0	128052.0	2565.6	0	2986.21	5551.81	17497.92	8748.96	119303.04	0.93	6.83
Karnataka	1139292.0	1004063.0	5583.6	586.2	6399.03	12568.81	51681.17	25840.59	978222.42	0.97	2.57
Kerala	761819.0	696021.0	2393.4	983.5	2730.25	6107.18	34440.70	17220.35	678800.65	0.98	2.47
Madhya Pradesh	1132756.0	974607.0	19754.2	4000.7	22979.62	46734.52	21253.10	10626.55	963980.45	0.99	1.09
Maharashtra	2951911.0	2632253.0	7056.7	958.1	8077.00	16091.75	35471.49	17735.75	2614517.26	0.99	0.67
Manipur	35312.0	32047.8	1598.0	391.3	1848.61	3837.90	–11987.00	–5993.48	38041.28	1.19	–18.70
Meghalaya	43429.0	38422.7	1586.5	388.5	1848.61	3823.58	–11848.80	–5924.42	44347.12	1.15	–15.42
Mizoram	17687.2	16346.1	1830.2	448.2	2133.01	4411.33	20968.52	10484.26	5861.84	0.36	64.14
Nagaland	36793.6	34272.0	1394.9	341.6	1621.09	3357.50	–4520.55	–2260.28	36532.28	1.07	–6.60
Orissa	446844.5	387373.0	6885.1	494.4	8020.12	15399.60	–2718.51	–1359.26	388732.26	1.00	–0.35
Punjab	707508.7	629677.5	181.6	0	199.08	380.68	10612.98	5306.49	624371.01	0.99	0.84
Rajasthan	873717.5	768878.0	1098.9	107.2	1279.81	2485.93	25044.61	12522.31	756355.70	0.98	1.63
Sikkim	11527.3	10386.5	577.3	141.4	682.56	1401.21	221.05	110.525	10275.98	0.99	1.06
Tamil Nadu	1537287.0	1367809.0	2984.8	313.4	3412.82	6711.01	6933.25	3466.625	1364342.38	1.00	0.25
Tripura	60616.9	56603.4	1233.3	302.0	1422.01	2957.32	–22706.00	–11353.0	67956.42	1.20	–20.06
Uttar Pradesh	1796015.0	1568625.0	5968.1	2351.4	6939.39	15258.90	56004.73	28002.37	1540622.64	0.98	1.79
West Bengal	1671371.0	1537807.0	1477.5	253.0	1706.41	3436.87	4287.31	2143.655	1535663.35	1.00	0.14
UTS	767080.0	706390.0	1620.2	164.0	1848.61	3632.82	4230.43	2115.215	704274.79	1.00	0.30
Total	19295454.6	17083825.1	95894.9	18578.7	111030.25	225503.90	380805.60	190402.80	16893422.33	0.99	1.11

Source Compiled by authors

Appendix I

Estimation of soil loss

Sediment data for 21 rivers of the Himalayan region and for 15 rivers of the non-Himalayan region, along with data on catchment area, average annual discharge, and rainfall was reported by Gupta (1975), Rao (1975), and Chaturvedi (1978). Ram Babu, *et al.* (1978) (quoted in CSWCRTI, Annual report, 1999) computed the average annual erosion index values El30, in tonnes per hectares for various regions across the country. Based on this data, the following statistical relationships were observed (Equations 1–5).

$$Y = f\,(x1, x2) \qquad (1)$$

where 'y' is sediment in million tonnes

$$Y = f\,(x) \qquad (2)$$

where x is annual total run-off in million hectares metres

$$Y = f\,(x1, El30) \qquad (3)$$

$$x1 = \text{catchment area (million hectares)} \qquad (4)$$

$$x2 = \text{average annual rainfall (mm)} \qquad (5)$$

Based on the above observations and statistical relationships, the following relationships were developed for calculating sediment load in rivers (Equations 6–8).

$$Y = 0.014\ x_1^{0.84} x_2^{1.37} \ (R^2 = 0.82) \qquad (6)$$

$$Y = 19.52\ x^{0.84} (R^2 = 0.70) \qquad (7)$$

$$Y = 342 \times 10^{-6}\ x_1^{0.84} El_{30}^{1.65} \ (R^2 = 0.84) \qquad (8)$$

To calculate the sediment load in reservoirs, the following regression equations were developed (Equations 9 and 10).

$$Y = 5.5 + 11.1X \qquad (R^2 = 0.64) \qquad (9)$$

$$Y = 5.3 + 12.7Xw \qquad (R^2 = 0.72) \qquad (10)$$

where 'w' is the weighted factor of reservoirs

Source Dhruvnarayana and Rambabu (1983)

Appendix II

Influence of forests on run-off and soil loss in the Doon Valley

The following Equations 1 through 4, mapping the situation before and after the treatment of reforestation in 'W1', reveal that reforestation results in reduction, from the treated watershed 'W1', of run-off by 28% and of peak rate of discharge by 73% by 1973 compared to 'W2'. This favourable influence of the raised eucalyptus in reducing run-off, peak rate of discharge, and consequently soil loss is attributed mainly to the dense and luxurious undergrowth of the light crown of eucalyptus trees.

Run-off

$$Y = 1.19\,X - 0.2 \quad (r = 0.94) \tag{1}$$

significant at 1% level with a degree of correlation, where X is monthly run-off (mm) from W1 and Y is the monthly run-off (mm) from W2

Peak discharge

$$Y = 1.674\,X - 0.009 \quad (r = 0.9) \tag{2}$$

significant at 1% level with a degree of correlation, where X is peak run-off rate (cumec) or discharge from 'W1' and 'Y' is peak run-off rate from 'W2'.

In 1969, W1 was cleared of bushwood vegetation and planted with eucalyptus species whereas 'W2' was left undisturbed. Data analysis for the following five years revealed the following changes in the respective equations.

Run-off

$$Y = 0.92\,X - 2.5 \quad (r = 0.88) \tag{3}$$

where X is the monthly run-off (mm) from W2 and Y is the monthly run-off (mm) from 'W1' (treated)

Peak discharge

$$Y = 0.875\,X - 0.0077 \quad (r = 0.94) \tag{4}$$

where X is peak run-off rate from W2 (untreated) and Y is peak rate of run-off from W1 (treated)

Appendix III

Physico-chemical characteristics of erosion plots in Bheta Gad watershed

Characteristics	*Pine forest*	*Rain-fed agriculture*	*Degraded land*	*Grassland*	*Bare plot*
Slop/aspect	*SE*	*E*	*S*	*E*	*E*
CEC (Meq/l)	8.680	10.240	12.160	13.240	13.20
pH	6.390	6.160	6.840	6.340	6.34
OM (%)	2.820	2.550	1.640	2.560	2.55
Total nitrogen (%)	0.143	0.236	0.098	0.162	0.161
Carbon–nitrogen ratio	11.500	6.280	9.700	9.020	9.21
Available phosphorus (kg/ha)	39.500	32.300	34.800	32.400	33.30
Available potassium (kg/ha)	229.000	286.000	137.000	270.000	276.00
Infiltration rate (cm/hour)	5.800	5.700	10.600	6.000	6.10
Bulk density (g/cm^3)	1.430	1.220	1.010	1.290	1.25
Soil texture	SL	SL	LS	SL	SL
Sand (%)	63.000	63.000	73.000	64.000	68.00
Silt (%)	22.000	25.000	16.000	24.000	25.00
Clay (%)	15.000	11.000	11.000	12.000	07.00
WHC (%)	30.800	33.900	26.600	32.800	31.40

Meq/l – milligram-equivalent per litre; CEC – cation exchange capacity; OM – organic matter; SL – sandy loam; LS – loamy sand; WHC – water holding capacity

Sources ICIMOD (2000) and Banskota and Sharma (1995)

Appendix IVA

Erosion plot event data for bare land areas (2001)

Watershed: Bheta Gad
Erosion plot no.: EP6
Name: Bare land
Location: Gewar

Elevation: 1620 m
Average slope (°): 21.0
Slope aspect: EN
Year: 2001

Month	*Run-off* (m^3 per ha)	*Soil loss* (tonnes per ha)
January	0.000000	0.000000
February	0.000000	0.000000
March	0.000000	0.000000
April	0.000000	0.000000
May	0.000000	0.000000
June	0.000000	0.000000
July	2246.280000	0.574103
August	2721.460000	0.621532
September	0.000000	0.000000
October	0.000000	0.000000
November	0.000000	0.000000
December	0.000000	0.000000
Total	4967.740000	1.195635

Sources ICIMOD (2000–04); PARDYP (1998–2004)

Appendix IVB

Erosion plot event data (2002)

Watershed: Bheta Gad
Erosion plot no.: EP6
Name: Bare land
Location: Gewar

Elevation: 1620 m
Average slope (°): 21.0
Slope aspect: EN
Year: 2002

Month	*Run-off* (m^3 per ha)	*Soil loss* (tonnes per ha)
January	16.640000	0.017242
February	226.026000	0.867653
March	122.880000	0.253093
April	113.720000	0.375888
May	201.320000	1.969854
June	45.312000	1.403650
July	254.380000	3.954329
August	594.044000	20.188587
September	118.704000	0.222707
October	0.000000	0.000000
November	0.000000	0.000000
December	0.000000	0.000000
Total	1693.026000	29.253003

Sources ICIMOD (2000–04); PARDYP (1998–2004)

Appendix IVC

Erosion plot event data (2003)

Watershed: Bheta Gad
Erosion plot no.: EP6
Name: Bare land
Location: Gewar

Elevation: 1620 m
Average slope (°): 21.0
Slope aspect: EN
Year: 2003

Month	*Run-off* (m^3 per ha)	*Soil loss* (tonnes per ha)
January	42.544000	0.076579
February	326.484000	0.856315
March	166.200000	0.839230
April	0.000000	0.000000
May	0.000000	0.000000
June	120.629000	1.009749
July	789.952000	3.662536
August	564.284000	3.069910
September	0.000000	0.000000
October	0.000000	0.000000
November	0.000000	0.000000
December	0.000000	0.000000
Total	2010.093000	9.514319

Sources ICIMOD (2000–04); PARDYP (1998–2004)

Appendix IVD

Erosion plot event data (2004)

Watershed: Bheta Gad
Erosion plot no.: EP6
Name: Bare land
Location: Gewar

Elevation: 1620 m
Average slope (°): 21.0
Slope aspect: EN
Year: 2004

Month	*Run-off* (m³ per ha)	*Soil loss* (tonnes per hectare)
January	71.256000	0.079585
February	0.000000	0.000000
March	0.000000	0.000000
April	0.000000	0.000000
May	19.326000	0.020292
June	375.588000	2.710951
July	471.304000	3.771108
August	604.310000	2.803118
September	0.000000	0.000000
October	0.000000	0.000000
November	0.000000	0.000000
December	0.000000	0.000000
Total	1541.784000	9.385054

Sources ICIMOD (2000–04); PARDYP (1998–2004)

Appendix IVE

Erosion plot event data for broad-leafed forest areas (average for 2000, 2001, 2002, 2003, 2004)

Watershed: Bheta Gad
Erosion plot no.: EP8
Name: Broad-leafed forest
Location: Sauli

Elevation: 1620 m
Average slope (°): 20.1
Slope aspect: E
Year: 2000-04

Month	*Surface run-off* (m³ per ha)	*Soil loss* (tonnes per hectare)
January	0.0000	0.0000
February	0.0000	0.0000
March	0.0000	0.0000
April	0.0000	0.0000
May	0.0000	0.0000
June	0.0000	0.0000
July	151.1440	0.0104
August	133.9200	0.0251
September	17.4240	0.0069
October	0.0000	0.0000
November	0.0000	0.0000
December	0.0000	0.0000
Total	302.488	0.0424

Sources ICIMOD (2000–04); PARDYP (1998–2004)

Appendix V

Market prices of nutrients

	1995/96			2001/02				
Particulars	*(Kharif)*	*(Rabi)*	*2000/01*	*Before 28 February 2002*	*28 February 2002*	*2002/03*	*2003/04*	*2004/05*
Fertilizer and food grain prices (rupees per kg)								
Nutrient prices (rupees per kg)								
N based on urea	7.22	7.22	10.00	10.00	10.50	10.50	10.50	10.50
P_2O_4 based on SSP	14.29 to 17.66	16.25 to 18.21	15.63 to 21.88	15.63 to 21.88	15.63 to 21.88	16.25 to 21.88	16.25 to 21.88	16.25 to 21.88
DAP, K	16.96 to 18.48	18.11 to 19.45	15.43	15.43	16.22	16.22	16.22	16.22
Complex (NP/NPK)	19.67 to 31.18	20.11 to 30.08	16.31 to 28.08	16.31 to 28.08	17.57 to 29.72	17.57 to 29.72	17.57 to 29.72	17.57 to 29.72
K_2O based on MOP	6.03 to 7.57	7.00 to 8.00	7.09	7.09	7.43	7.43	7.43	7.43

Source FAI (2004)

Appendix VIA

Value of C in the rational equation

Vegetative cover and slope	*Soil texture*		
	Sandy loam	*Clay and silt loam*	*Stiff clay*
Cultivated land			
0%–5%	0.30	0.50	0.60
5%–10%	0.40	0.60	0.70
10%–30%	0.52	0.72	0.82
Pasture land			
0%–5%	0.10	0.30	0.40
5%–10%	0.16	0.36	0.55
10%–30%	0.22	0.42	0.60
Forest land			
0%–5%	0.10	0.30	0.40
5%–10%	0.25	0.35	0.50
10%–30%	0.30	0.50	0.60

Source Annual Report of the CSWCRTI, Dehra Dun 1999

Appendix VIB

Run-off under various covers in different soil types

Treatment	*Run-off as percentage of rainfall*
Dhulkot silty clay loam, 9% slope, alluvial soil Dehra Dun, rainfall 1250 mm	
Grass cover	27.1
Bare and ploughed fallow	59.6
Pueraria hirsute	21.2
Eulaliopsis binata	
Alluvial soil, 2% slope, Vasad rainfall 791 mm	
Forest	2.1
Bidi tobacco	26.0
Black soil, 1% slope, Kota rainfall 657 mm	
Natural cover (forested land)	0.4
Sorghum (kharif)	2.4
Cultivated fallow	3.7
Red chalka soil, 3% slope, Deccan rainfall 700 mm	
Cultivated fallow	16.6
Natural cover	9.5
Red soil, 5% slope, rainfall 1129 mm	
Natural cover	1.5
Paddy	3.5
Medium black soil, 1.18% slope Sholapur, rainfall 607 mm	
Shola forest	1.3
Bare fallow	19.8
Shallow cultivation	22.5
Deep laterite soil, 25% slope Ootacamund, rainfall 1295 mm	
Natural cover	1.3
Potato (on contour)	2.3

Sources Tejwani, *et al*. (1975); Gupta, Khan, Agarwal, *et al.* (1966); Verma, *et al*. (1968); Singh, Dayal, and Bhola (1967); Narain, Verma, and Singhal (1980); Srinivas and Rao (1983); Rai (1980); Bhushan and Om Prakash (1982) (Cited in CSWCRTI, 1999, 2001, 2003)

Appendix VII

Vegetative cover and infiltration

Infiltration is the process by which rainwater enters the surface soil or groundwater table. Decay of tree roots and their penetration under a forest results in changes in the physical and chemical properties of the soil. The presence of leaf litter and vegetation in forested land increases the organic matter of the soil, making it more conducive to infiltration. Table 1 gives the infiltration capacity of bare and vegetated area.

Table 1

Texture infiltration capacity (mm per ha)

Type of soil	Bare soil	Vegetated
Clay	0–5	5–10
Clay loam	5–10	10–20
Loam	10–15	20–30
Sandy loam	15–20	30–40
Sand	20–25	40–50

Source Wisseman and Lee (1980)

Table 2

Forest and groundwater recharge

Land type/forest Infiltration rates (mm per hour)	*First hour*	*Second hour*	*Third hour*
Rice fields	27	19	18
Fallow	35	19	18
Sal forest	89	59	58
Shola forest	56	40	15

Studies on black cotton soil in the Bellary region showed the infiltration rates under forest cover, natural grassland, and terraced cultivation as 52.6 mm per hour, 30 mm per hour, and 14 mm per hour, respectively. Studies at FRI Dehra Dun report the initial infiltration rates under eucalyptus, sal, chri, teak, bamboo plantation, and grassland as 54 mm per hour, 21.4 mm per hour, 12 mm per hour, 9.6 mm per hour, 9.6 mm per hour, and 7.6 mm per hour, respectively. These studies indicate that infiltration rates are higher in forests than in other vegetation types. This is due to the increased organic material in the soil, which promotes the activity of microorganisms. Forests also deplete soil moisture capacity through greater transpiration through their leaves, thereby increasing water infiltration.

Appendix VIIIA

Summary of studies in India on interception by forest canopies

Species	*Stand density* (trees per ha)	*Interception* (percentage of rainfall)
Acacia nilotica	–	26 .0
Acacia modesta	–	21.2
Acacia catechu	574	28.5
Dalbergia sissoo	–	13.3
Shorea robusta	1678	25.3
Alistonia scholaris	1675	26 .0
Pinus roxburghi	1156	22.1
Tectona grandis	472	20.8
Eucalyptus hybrid	1658	11.5

Source CSWCRTI (1999–2004) Annual Reports

Appendix VIIIB

Interception by leaf litter

Litter under interception	As percentage of rainfall	Remarks
Shorea robusta	9.1	(The interception was higher
Tectona grandis	8.9	with lower amounts and
Pinus	7.6	intensities of rainfall)
Dendrocalamus strictus	5.6	

Source Gupta *et al*. (2000)

The above study indicates that interception by tree cover varies from 12% to 38% in the six species that were studied. On an average, therefore, 20% of the rainfall is intercepted by forests. For interception by ground vegetation, no detailed studies are available but it can be conservatively estimated as 10%. If we take 5% as the average interception by the forest ground leaf litter, then the total rainfall intercepted by forests adds up to 35%. Based on these studies, it is understood that interception loss by forests is a function of type of vegetation, rainfall, and climatic conditions. Rainfall of low intensity results in more interception losses by the forest. In times of higher rainfall, the interception losses become insignificant and forest cover has little impact on the development of major floods.

Appendix IX

Cost of water procurement

Type of cost	*Cost* (rupees per m^3)
Financial cost	0.3
Opportunity cost	4.5
Economic cost	5.8
Environmental cost	2.7
Full cost	8.5

Source Bhatia, Kumar, Misra, *et al.* (2000)

Appendix X

Domestic and industrial water rates in Delhi, Chennai, and Hyderabad

	Delhi (1995)		*Madras (1990)*		*Hyderabad (1992)*	
	m^3 per month	*Rupees per m^3*	*m^3 per month*	*Rupees per m^3*	*m^3 per month*	*Rupees per m^3*
Domestic	0–20	0.35	0–50	1.00	0–15	30.00
	>20	0.70	>50	2.00	15–25	2.50
					>50	3.00
Non-domestic	0–50	3.00	0–50	3.00	0–20	100.00
	>5	5.00	50–100	4.00	20–50	5.00
			>100	5.00	>50	7.00
Industrial	0–50	5.00		7.00	0–200	200.00
	50–100	6.50			200–500	7.50
	>100	8.00			>500	10.00

Source Dinar and Subramanian (1997)

Appendix XI

India: statement showing damage due to floods/heavy rains during 1953–2002

			Damage to crops		Damage to houses					
Year	Area affected (million ha)	Population affected (millions)	Area (million ha)	Value (crore rupees)	Numbers	Value (crore rupees)	Cattle lost (numbers)	Human live lost (numbers)	Damage to public utilities (crore rupees)	Total damages to crops, houses and public utilities (crore rupees)
1953	2.290	24.280	0.930	42.08	264924	7.420	47034	37	2.900	52.400
1954	7.490	12.920	2.610	40.52	199984	6.561	22552	279	10.150	57.231
1955	9.440	25.270	5.310	77.80	1666789	20.945	72010	865	3.980	102.725
1956	9.240	14.570	1.110	44.44	725776	8.047	16108	462	1.140	53.627
1957	4.860	6.760	0.450	14.12	318149	4.979	7433	352	4.270	23.369
1958	6.260	10.980	1.400	38.28	382251	3.896	18439	389	1.790	43.966
1959	5.770	14.520	1.540	56.76	648821	9.418	72691	619	20.020	86.198
1960	7.530	8.350	2.270	42.55	609884	14.309	13908	510	6.310	63.169
1961	6.560	9.260	1.970	24.04	533465	0.889	15916	1374	6.440	31.369
1962	6.120	15.460	3.390	83.18	513785	10.655	37633	348	1.050	94.885
1963	3.490	10.930	2.050	30.17	420554	3.701	4572	432	2.740	36.611
1964	4.900	13.780	2.490	56.87	255558	4.588	4956	690	5.149	66.607
1965	1.460	3.610	0.270	5.87	112957	0.195	7286	79	1.070	7.135
1966	4.740	14.400	2.160	80.15	217269	2.544	9071	180	5.736	88.430
1967	7.120	20.460	3.270	133.31	567995	14.264	5827	355	7.857	155.431
1968	7.150	21.170	2.620	144.61	682704	41.112	130305	3497	25.373	211.095
1969	6.200	33.220	2.910	281.91	1268660	54.423	270328	1408	68.112	404.435
1970	8.460	31.830	4.910	162.78	1434030	48.606	19198	1076	76.441	287.827
1971	13.250	59.740	6.240	423.13	2428031	80.241	12866	994	129.113	632.484
9172	4.100	26.690	2.450	98.56	897301	12.460	58231	544	47.174	158.194
1973	11.790	64.080	3.730	428.03	869797	52.482	261016	1349	88.489	569.001
1974	6.700	29.450	3.330	411.64	746709	72.434	16846	387	84.942	569.016
1975	6.170	31.360	3.850	271.49	803705	34.097	17345	686	166.050	471.637
1976	11.190	50.460	6.040	595.03	1745501	92.160	80062	1373	201.495	888.685
1977	11.460	49.430	6.840	720.61	1661625	152.290	556326	11316	328.948	1201.848
1978	17.500	70.450	9.960	911.09	3507542	167.574	239174	3396	376.100	1454.764
1979	3.990	19.520	2.170	169.97	1328712	210.606	618248	3637	233.627	614.203
1980	11.460	54.120	5.550	366.37	2533142	170.851	59173	1913	303.283	840.504
1981	6.120	32.490	3.270	524.56	912557	159.630	82248	1376	512.314	1196.504
1982	8.870	56.010	5.000	589.40	2397365	383.869	246750	1573	671.607	1644.876
1983	9.020	61.030	3.290	1285.85	2393722	332.327	153095	2378	873.429	2491.606
1984	10.710	54.550	5.190	906.09	1763603	181.308	141314	1661	818.164	1905.562
1985	8.380	59.590	4.650	1425.37	2449878	583.855	43008	1804	2050.043	4059.268
1986	8.810	55.500	4.580	1231.58	2049277	534.410	60450	1200	1982.535	3748.525
1987	8.890	48.340	4.940	1154.64	2919380	464.490	128638	1835	950.590	2569.720
1988	16.290	59.550	10.150	2510.90	2276533	741.600	150996	4252	1377.800	4630.300
1989	8.060	34.150	3.010	956.74	782340	148.820	75176	1718	1298.770	2405.330
1990	9.303	40.259	3.179	695.61	1019930	213.733	134154	1855	455.266	1708.920

Continued

Appendix XI *Continued*

			Damage to crops		*Damage to houses*					
Year	*Area affected* (million ha)	*Population affected* (millions)	*Area* (million ha)	*Value* (crore rupees)	*Numbers*	*Value* (crore rupees)	*Cattle lost* (numbers)	*Human lives lost* (numbers)	*Damage to public utilities* (crore rupees)	*Total damages to crops, houses and public utilities* (crore rupees)
1991	6.357	33.889	2.698	579.015	1134410	180.421	41090	1187	728.893	1488.329
1992	2.645	19.256	1.748	1027.578	687419	306.284	78669	1533	2010.670	3344.532
1993	11.439	30.409	3.206	1308.627	1926049	528.324	211193	2864	1445.534	3282.485
1994	4.805	27.548	3.963	888.622	914664	165.206	52315	2078	740.762	1794.59
1995	5.245	35.932	3.245	1714.787	2001898	1307.894	624	1814	679.627	3702.308
1996	8.049	44.729	3.827	1124.491	726799	176.589	73208	1803	861.393	3005.743
1997	4.569	29.663	2.258	692.743	505128	152.504	27754	1402	1985.934	2831.181
1998	9.133	68.718	5.872	2372.541	1118920	302.036	105828	2758	3171.403	5845.98
1999	3.978	25.659	1.762	1663.213	696311	174.456	8852	576	268.689	2107.858
2000	5.166	39.153	2.927	446.677	2349763	301.681	39144	2335	911.780	1660.138
2001	3.008	22.444	1.911	446.734	492164	357.740	25025	811	1820.338	2624.812
2002	2.866	22.411	1.266	547.127	445698	455.169	3647	640	486.490	1488.786
Total	368.403	1648.350	173.762	29848.260	59309428	9454.093	4577732	78000	28311.780	68804.199
Average	7.382	32.967	3.475	596.965	1186190	189.102	91555	1560	566.236	1376.084
Maximum	17.500	70.450	10.150	2510.900	3507542	1307.894	618248	11316	3171.403	5845.980
Year	1978	1978	1988	1988	1978	1988	1979	1977	1998	1998

Sources Aggarwal *et al*. (2004), Bhan *et al*. (2004), and CSE (1991)

Appendix XII

Economic value of livestock and human life (statistical)

Year	*Loss of human lives* (numbers)	*Statistical value of human life at 2002 price* (millions)	*Loss of cattle lives* (numbers)	*Value of livestock loss at 2002 price* (million rupees)	*Total of statistical value of human life and value of livestock loss (at 2002 price,* million rupees	*Value deflated by wholesale price index*
1970	1076	420.96	19198	191.98	612.94	49.99
1971	994	388.88	12866	128.66	517.54	44.57
9172	544	212.83	58231	582.31	795.14	75.35
1973	1349	527.77	261016	2610.16	3137.93	357.52
1974	387	151.41	16846	168.46	319.87	45.63
1975	686	268.38	17345	173.45	441.83	62.34
1976	1373	537.16	80062	800.62	1337.78	192.68
1977	11316	4427.14	556326	5563.26	9990.40	1513.88
1978	3396	1328.61	239174	2391.74	3720.35	563.76
1979	3637	1422.90	618248	6182.48	7605.38	1349.72
1980	1913	748.42	59173	591.73	1340.15	281.23
1981	1376	538.33	82248	822.48	1360.81	312.20
1982	1573	615.40	246750	2467.50	3082.90	741.94
1983	2378	930.34	153095	1530.95	2461.29	636.95
1984	1661	649.83	141314	1413.14	2062.97	571.73
1985	1804	705.78	43008	430.08	1135.86	326.78
1986	1200	469.47	60450	604.50	1073.97	326.96
1987	1835	717.90	128638	1286.38	2004.28	659.85
1988	4252	1663.50	150996	1509.96	3173.46	1122.67
1989	1718	672.13	75176	751.76	1423.89	541.29
1990	1855	725.73	134154	1341.54	2067.27	866.50
1991	1187	464.39	41090	410.90	875.29	417.28
1992	1533	599.75	78669	786.69	1386.44	727.45
1993	2864	1120.48	211193	2111.93	3232.41	1837.64
1994	2078	812.97	52315	523.15	1336.12	854.54
1995	1814	709.69	624	6.24	715.93	494.92
1996	1803	705.39	73208	732.08	1437.47	1042.75
1997	1402	548.50	27754	277.54	826.04	623.64
1998	2758	1079.01	105828	1058.28	2137.29	1709.59
1999	576	225.35	8852	88.52	313.87	259.27
2000	2335	913.52	39144	391.44	1304.96	1155.10
2001	811	317.29	25025	250.25	567.54	520.43
2002	640	250.39	3647	36.47	286.86	272.18

Source Report on Currency and Finance, RBI.

Appendix XIII

Following assumptions and methods have been adopted in the study.

1 Three ecological services of forest ecosystems, namely, prevention of soil erosion, augmentation of groundwater, and reduction of flood damage have been considered in this monograph.

2 For estimation of soil loss, observations from experimental plots from south-west and north-east India have been considered.

3 For economic valuation of soil loss, replacement–cost approach has been adopted, as productivity–loss approach is not on firm footing due to uncertainty of yield–loss relationship in the literature. Further, N (nitrogen), P (phosphorus), K (potassium), and organic matter have been accounted. Functions such as moisture retention and sustenance to fauna etc., have been left out on account of unavailability of reliable data.

4 Groundwater recharge by the forest ecosystems has been considered in a static framework, and influences of adjoining watersheds have been ignored.

5 Based on scientific evidence and findings from the peer-reviewed literature, incidence of flood is supposed to be reduced by the presence of dense forest by one-third only.

6 While estimating the flood damage, the statistical value of life has been computed, following the cost of capital approach. Deflating the current price figure by the wholesale price index has normalized damage to physical assets.

7 All functions have been linked with the dense forest while other types of forests also perform the same functions. Hence, the estimate is a conservative one.

8 Annualized value of the prevented damage (benefits) by forests has been computed at 4% rate of discount adopted throughout all the monographs.

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Green Accounting for India's States and Union Territories Project

In common with most developing nations, India faces many trade-offs in its attempt to improve the living standards of its people. The trade-offs emerge in various arenas, and several mechanisms for decision-making (including political institutions) have been developed to help choose between competing alternatives. Unfortunately, most of these decision mechanisms do not take into account intergenerational choices, i.e. trade-offs between the needs of the present and the future generations. In our view, it is urgently necessary to develop a mechanism to do this because many of the choices we make today could severely affect the welfare of our children tomorrow.

Therefore, we propose to build a framework of national accounts that presents genuine net additions to national wealth. This system of environmentally-adjusted national income accounts will not only account for the depletion of natural resources and the costs of pollution but also reward additions to the stock of human capital.

The Green Accounting for Indian States and Union Territories Project (GAISP) aims to set up economic models for preparing annual estimates of 'genuine savings', i.e. true 'value addition', at both state and national levels. The publication of the results will enable policy-makers and the public to engage in a debate on the sustainability of growth as well as make cross-state comparisons. It is hoped that a policy consequence of the project is gradual increases in budgetary allocations for improvements in education, public health, and environmental conservation, all of which are key elements needed to secure India's long-term future.

Monograph 7

This study is part of a larger exercise to build an empirically based framework that would allow and enable policy judgments regarding the accumulation and depletion of natural and human capital. Earlier monographs have covered some of the economic benefits of forests, such as carbon storage, timber production, non-timber forest products, and the many values of biodiversity including eco-tourism. This monograph attempts to value three crucially important ecological functions of our shrinking forest ecosystems: prevention of soil erosion, augmentation of groundwater by improving recharging capacity, and reduction in flood damage through rainwater absorption. The results suggest that shrinking forest cover, especially in mountainous states, comes at a significant cost to the national economy. The authors recognize the limitations placed by a paucity of data and the problems of methodology. It is noted, however, that these estimates of the economic value of these ecological services are conservative, and should be treated as a lower bound.

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