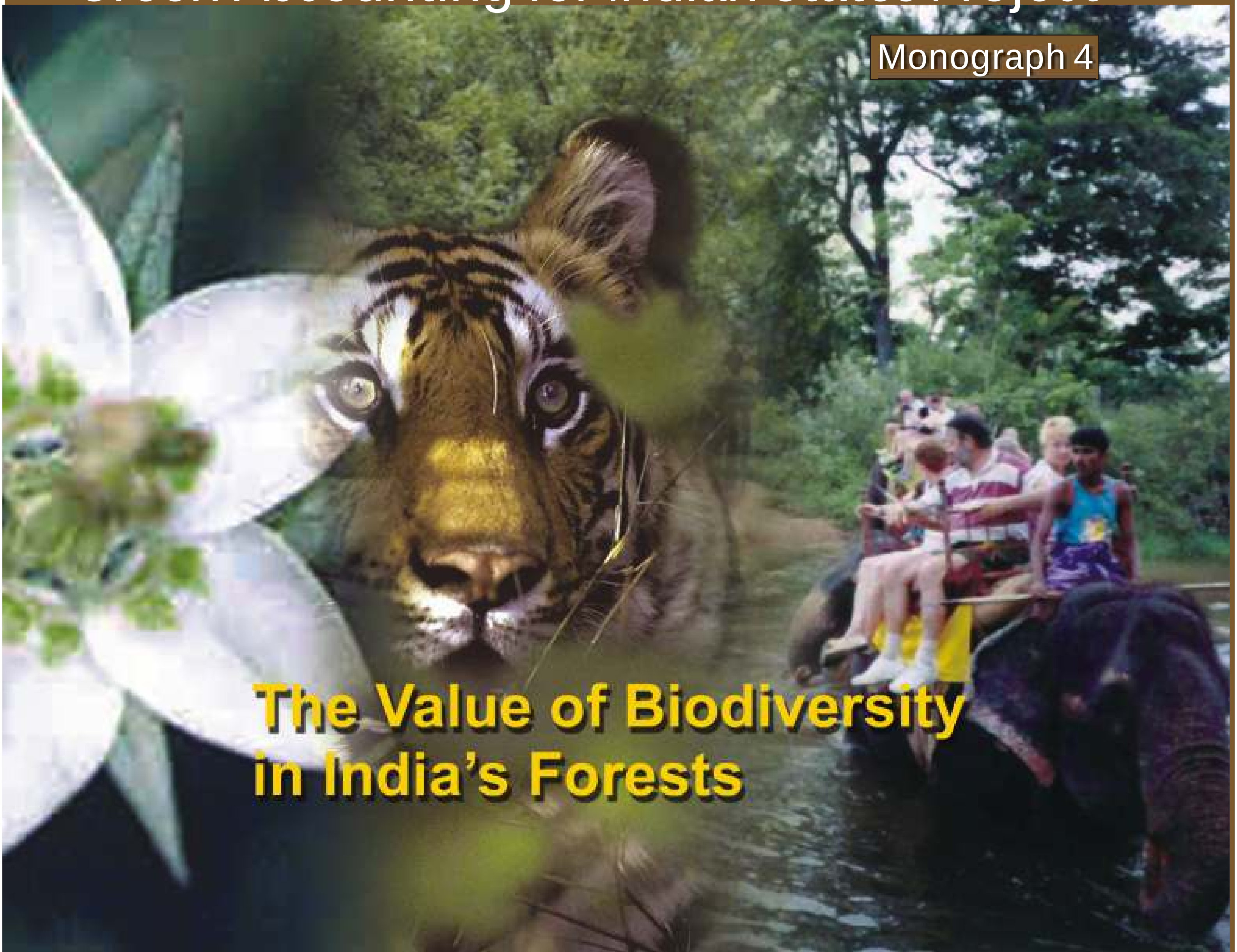
Green Accounting for Indian States Project

Monograph 4



The Value of Biodiversity in India's Forests

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Contents

List of acronyms

AIDS	acquired immune deficiency syndrome
BSI	Botanical Survey of India
CVM	contingent valuation method
ESDP	Environmental adjusted state domestic product
FRLHT	Foundation for Revitalizations of Local Health Traditions
GAISP	Green Accounting for Indian States and Union Territories Project
GDP	gross domestic product
GNP	Gross national product
GSDP	gross state domestic product
IRRI	International Rice Research Institute
ISM	Indian System of Medicine
IUCN	The World Conservation Union
ITCM	Individual travel cost method
km	kilometre
MoEF	Ministry of Environment and Forests
NGO	non-governmental organization
NSDP	net state domestic product
OECD	Organisation for Economic Cooperation and Development
R&D	research and development
TCM	travel cost method
WCMC	World Conservation Monitoring Centre
ZTCM	Zonal travel cost method

The value of biodiversity in India's forests

Background

In common with most developing nations, India faces many trade-offs in its attempt to reduce poverty and improve the living standard of its people. There is a need for an empirical basis on which to base policy decisions on trade-offs among the many competing priorities of a developing nation, including inter-generational claims—for example, trade-offs between the needs of present and future generations. Available indices of development, including the current system of national accounts 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, extent of education, and quality and extent of India's environmental resources. All these aspects have a significant impact on the well-being of India's citizens generally, and most of them are critical to poverty alleviation, providing income-generation opportunities and livelihood security for the poor. GDP accounts and their state-level equivalents, GSDP (gross state domestic product) accounts, are, therefore, inadequate for properly evaluating the trade-offs encountered by India's policy-makers.

GAISP (Green Accounting for Indian States and Union Territories Project) was launched in July 2004, largely in recognition of the fact that although 'GDP growth percentages' are substantially misleading as yardsticks of growth, development, wealth, or well-being, they continue to be used extensively and even uniquely by planners, policy-makers, business houses, and the media. GAISP proposes to build a framework of adjusted national accounts that represents genuine net additions to the national wealth. These are sometimes referred to in literature as 'Green Accounts'. Such a system of environmentally-adjusted national income accounts will not only reflect in economic terms the depletion of natural resources and the health costs of pollution, but 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 compared to GDP (national income) growth percentages and GSDP (state income) growth measures. They will also encourage the emergence of sustainable development as a focus of economic policy at the state level.

GAISP aims to develop 'top-down' economic models for state-wise annual estimates of adjusted GSDP for all major Indian states and union territories. A top-down or macroeconomic approach is adapted to the 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 is 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 faced by the nation. Policy-makers and the public will be able to engage in a much better informed debate on the sustainability of economic growth, both at the national level as well as through interstate comparisons.

The first phase of GAISP consists of the following eight monographs, each of which will evaluate 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 (published in February 2005)

2 Estimating the value of agricultural cropland and pastureland in India (published in December 2005)

3 The value of India's sub-soil assets

4 The value of biodiversity in India's forests (current monograph)

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 India's forests: soil conservation, water augmentation, and flood prevention (published in July 2006)

8 Estimating the value of freshwater resources in India

All adjustments calculated in the above eight GAISP monographs apply to the same set of GSDP accounts (for example, for the year ended March 2003) and they are all additive. The website of GAISP (http\\:www.gistindia.org) will carry a record of the cumulative state-wise adjustments to these GSDP accounts. To a first-order approximation, these adjustments may be added/subtracted as indicated in the GSDP growth percentages for the year 2002/03.

The final report of GAISP will consolidate the work done on these eight and will provide commentary as well as analysis on the policy implications of our results.

The value of biodiversity in India's forests

Introduction

In this paper, we attempt to value the biodiversity functions of India's natural ecosystems and suggest a method to adjust national (GDP) and state income (GSDP) accounts. 'Biodiversity' is a very valuable and yet very poorly understood natural resource, which is depleting rapidly as a result of human activities. The term 'biodiversity', a contraction of the term 'biological diversity' was first coined by Walter Rosen in the 1986 Forum on Biodiversity (Wilson 1988) and is a brief description of the great variety of life that exists on the earth (Wilson 1988). However, biodiversity entails more than just the accumulation of species. The United Nations Convention on Biological Diversity defines biodiversity as '. . . the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems' (UNEP 1992).

The most significant anthropogenic threats to biodiversity are habitat loss due to forest conversion, degradation of habitat due to pollution or pesticides, grazing leading to reduction in plant biomass, fragmentation of habitat, logging, introduction of exotic species from other regions or continents, and climate change. The primary reason for the failure to conserve biodiversity is that its value is not well understood. For example, the decision to convert one hectare of forest rich in biodiversity for purposes such as agriculture or construction is usually based only on the immediate visible benefits with scant attention paid to the many non-measurable ecological services provided by these ecosystems. Thus, if biodiversity is not measured, there is no way to arrive at rational decisions relating to competing land uses that may affect the preservation of species.

The editorial in *Resource and Energy Economics* by Heal (2004) explains how biodiversity matters to society. For example, biodiversity can substantially contribute to the productivity of agricultural systems through the development of newer breeds of plants and animals. During the Green Revolution in the 1960s and the 1970s, it was shown that genetic diversity in the plant population could significantly increase the productivity of agriculture. This is because diversity helps natural ecosystems to make the most favourable adjustments to conditions that vary over time or space (Tilman and Karieva 1997). Further, a lack of diversity can have a detrimental effect on natural systems. For example, it can lead to an increased susceptibility to disease and hence to a greater risk of diseases spreading rapidly through a population. Genetic diversity within a crop plant or animal species helps in developing strains that are resistant to particular diseases or that act as an effective substitute for those lost to disease.

Biodiversity can also be regarded as an 'insurance' for society and ecosystems as illustrated through examples in Heal (2004). In the 1970s, a new disease carried by the brown plant virus threatened the Asian rice species with the potential to destroy a large fraction of the crop. The development of a form of rice resistant to this virus was, therefore, of crucial importance. The IRRI (International Rice Research Institute) in the Philippines located a variety of wild rice that was not used commercially but was resistant to the virus. The resistant gene was successfully transferred to commercial rice varieties, thereby yielding commercial rice resistant to the threatening disease. The importance of this non-commercial variety of rice can be understood from the fact that, without it, the most important food crop in the world would have been seriously damaged. Moreover, as noted by Myers (1997) the variety of wild rice, which was resistant to the virus, was found only in one location. A hydroelectric dam flooded this valley shortly after IRRI found and collected this critically important rice variety. This clearly illustrates how easily valuable species may be destroyed before their true worth is understood and highlights the role of biodiversity as a form of insurance for crops and farm animals against the diseases and epidemics that may affect these food sources.

Biodiversity is also a form of insurance against human disease, being a bank of knowledge wherein potential cures can be found for diseases such as Cancer or AIDS (acquired immune deficiency syndrome). When a species becomes extinct, we run the risk of losing a unique chemical that could be the basis of a cure for cancer or other life-threatening diseases. For example, the drug used to fight malaria is extracted from the bark of the Cinchona tree, and it may not have been discovered if this species had been extinct. The critical point is that we cannot a priori know the loss society incurs due to the extinction of a particular species.

Finally, biodiversity in itself is necessary for the proper functioning of ecosystems on which human beings are so dependent. Even the removal of a single type of organism or changes in one species can cause an imbalance with far-reaching consequences. These important species are termed as 'keystone species'. For example, the presence of elephants is considered to be a good indicator of ecological health as they contribute to many interlinked habitat systems. They pull up trees, trample down bushes, create salt licks, and dig water holes, all processes on which other animals depend. Wherever elephants live, they provide a good habitat for associated species such as the sambar, spotted deer, barking deer, and so on. The survival of these species is, in turn, essential for the survival of tigers or leopards. In addition, baboons and birds feed on the undigested seeds and nuts in elephant droppings, and dung beetles reproduce in these deposits. This nutrient-rich manure also replenishes the depleted soil. Elephants are a vehicle for seed dispersal, and some seeds do not germinate unless they have passed through an elephant's digestive system. Thus, the extinction of elephants would lead to profound changes in the ecosystem.

Small changes in ecosystems and biodiversity have knock-on effects as shown by the extinction of the red panda due to the loss of bamboo forest. Similarly, the fall in vulture population has reportedly exacerbated the spread of diseases like rabies; with no vultures to feed on the diseased animal remains, wild dogs and other scavengers move in, spreading the disease. Just as the removal of a species leads to a profound transformation of the system, the introduction of a new species (called exotic species) also has its own effect. For example, the introduction of *Prosopsis juliflora* to cater to rural fuelwood needs in India has reportedly displaced many endemic species. Both the loss of species and their introduction may reduce resilience of ecosystem and its capacity to adjust to the ever-increasing rates of environmental change (Heal 2004).

These examples illustrate that loss/changes in even apparently unimportant species can have tremendous consequences due to the complex patterns of the interdependence of species. Biodiversity is declining at an alarming rate despite the fact that its loss can destabilize the natural environment and reduce both the possible sources of food and the sources of potentially useful pharmaceuticals, in addition to diminishing the aesthetic value of nature. One possible reason for this decline (as mentioned earlier) is that we do not know *how much* we are losing. This suggests that there is a need for a range of appropriate indicators (as a single indicator alone could not represent all biodiversity) with which to measure biodiversity. Moreover, biodiversity should be treated as an asset and its loss should be adequately represented in the national accounts. The current system of national accounts includes only the returns provided by biodiversity but does not account for the losses that occur when valuable ecosystems are lost for uses such as agriculture and non-forest purposes. Only the expenditures incurred in clearing or improving ecosystems are recorded under the heading 'gross capital formation'.

Against this backdrop, the main objectives of this study are as follows.

1 Identify appropriate indicators to assess the state of biodiversity in different states in India based on the available data from secondary sources.
2 Estimate the value of biodiversity in Indian forest ecosystems.
3 Estimate the value of the depletion of biodiversity due to forest losses in different Indian states.

The rest of the paper is structured as follows. We first discuss the biodiversity profile in India, followed by various biodiversity indicators. In the following sections, we discuss the ways to estimate the value of biodiversity in India, discuss the results of our estimates, and conclude with policy implications.

Biodiversity profile in India

India occupies 2.4% of the world's area and is host to 7% of the global biodiversity, accounting for 8% of the world's mammals, 13% birds, 6% reptiles, 4% amphibians, 12% fish, and 6% flowering plants. It is one of the 12 mega-diversity hot spots of the world, the other countries being Bolivia, Brazil, China, Colombia, Ecuador, Indonesia, Mexico, Peru, South Africa, USA, and Venezuela. In addition, India also has many endemic plants and vertebrate species. Among plants, species endemism is estimated at 33% (BSI 1983). Endemism among mammals and birds is relatively low. Areas rich in endemism are north-east India, the Western Ghats, and the north-western and eastern Himalayas. A small pocket of local endemism also occurs in the Eastern Ghats. The Gangetic plains are generally poor in endemics, while the Andaman and Nicobar Islands contribute at least 220 species to the endemic flora of India (BSI 1983). However, India is losing biodiversity at a rapid rate. Around 39 species of mammals, 72 species of birds, and 1336 species of plants are considered vulnerable and endangered, as these species have not been sighted during the last 6–10 decades (see Appendix I for the IUCN [The World Conservation Union] categories). Among the higher plants, about 20 species are categorized as 'possibly extinct' and about 3120 species are categorized as endangered under different threat categories (Table 1). The major factors threatening species and genetic diversity are habitat destruction, overexploitation, poisoning by pollutants, introduction of exotic species, and the imbalances in community structure, epidemics, floods, droughts, and cyclones.

Among the 34 biodiversity hot spots in the world, two are in India—the Eastern Himalayas and the Western Ghats (Appendix II). They are home to at least 150 000 endemic plants species, covering 50% of the world's total area. These regions used to cover nearly 15.7% of the earth's land surface. However, they are vanishing at a high rate with 86% of their habitat already destroyed. Apart from these two biodiversity-rich regions, the north-eastern part of India is endowed with a rich flora and has four micro-endemic centres, of which are 24 in India (Appendix III and IV). More than 5000 plant species have been reported from this region, of which 52% species known in India are from Arunachal Pradesh (Figure 1).

India also contains globally important populations of some of the Asia's rarest animals, such as the Bengal fox, Asiatic cheetah, marbled cat,

Table 1

Biodiversity status of the species in India and the world

Group	*Number of species in India*	*Number of species in the world*	*% of world's species*	*Endangered*	*Vulnerable*	*Rare*	*Indeterm-inate*	*Insufficiently known*	*Total*
Mammals	350	4 629	7.60	13	20	2	5	13	53
Birds	1 224	9 702	12.60	6	20	25	13	5	69
Reptiles	408	6 550	6.20	6	6	4	5	2	23
Amphibia	197	4 522	4.40	0	0	0	3	0	3
Fish	2 546	21 730	11.70	0	0	2	0	0	2
Flowering plants	15 000	250 000	6.00	1	3	12	2	4	22
Total	19 725	297 133	6.64	26	49	45	28	24	172

Source <www.unep-wcmc.org>

Note See Appendix I for definition of various IUCN categories

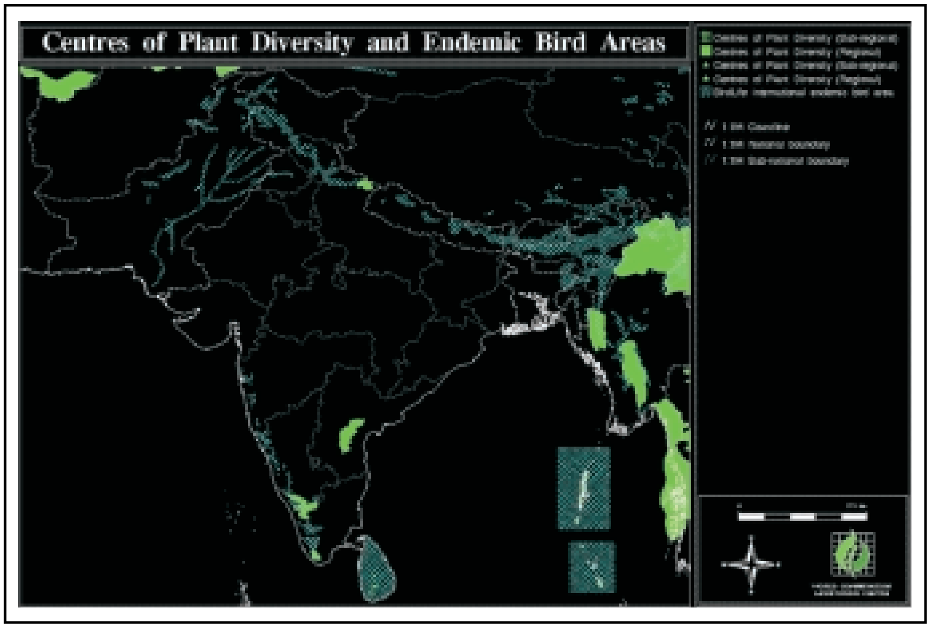

Figure 1

Centres of plant diversity and endemic bird areas

Source <www.unep-wcmc.org>

Asiatic lion, Indian elephant, Asiatic wild ass, Indian rhinoceros, markhor, gaur, and the wild Asiatic water buffalo. To protect the wildlife, India had set up 90 national parks, 502 wildlife sanctuaries, and 35 zoological gardens (Table 2). The table shows that about 20% of the official recorded forest area (not the area under actual tree cover) in India has been accorded a protected area status, with Gujarat having the highest percentage of area under the protected area status, while Nagaland and Lakshadweep occupy the lowest ranks in terms of the protected areas.

Besides the rich flora and fauna that India possesses, it also has one of the world's richest medicinal plant heritages. According to Schippmann, Leaman, and Cunningham (2002), about one-fifth of all the plants found in India are used for medicinal purpose. The world average stands at 12.5% while India has 20% plant species of medicinal value in use (Table 3). However, according to another study by Shiva (1996), India has about 44% of flora, which are used medicinally. Both the studies indicate that India ranks first in per cent flora that contains active medicinal ingredients. According to an all India ethno-botanical survey carried out by MoEF (Ministry of Environment and Forests), over 8000 species of plants are being used by the people of India, with 90%– 95% of these coming from forests. However, of the 8000 species which are used, only 1800 species are systematically documented in the codified ISM (Indian System of Medicine) while the rest of the species are undocumented and their details are transmitted orally through traditional knowledge (EXIM 2003). Of the documented species, only 880 medicinal plant species are involved in the all India trade, with 48 medicinal plant species exported to foreign countries and about 42 medicinal plants being imported. These 880 species are spread across 151 families, with nearly 80%

Table 2

Area under national parks and wildlife sanctuaries

	National parks		*Sanctuary*		*Total*			
State / Union Territory	*Number*	*Area* (km²)	*Number*	*Area* (km²)	*Number*	*Area* (km²)	*Forest area* (km²)	*% of protected areas to forest*
Andaman and Nicobar Islands	9	1 153.90	96	466.20	105	1 620.20	7 171	22.60
Andhra Pradesh	4	373.20	21	13 096.20	25	13 469.50	63 814	21.10
Arunachal Pradesh	2	2 468.20	11	7 606.40	13	10 074.60	51 540	19.50
Assam	5	1 977.80	16	888.20	21	2 866.00	27 018	10.60
Bihar	1	335.60	11	2 993.20	12	3 328.80	6 078	54.80
Chandigarh	0	0	2	26.00	2	26.00	32	81.30
Chhattisgarh	3	2 929.50	11	3 419.50	13	6 349.00	59 285	10.70
Dadra and Nagar Haveli	0	0	2	92.00	1	92.00	203	45.30
Daman and Diu	0	0	10	2.20	1	2.20	1	218.00
Delhi	0	0	1	17.80	1	17.80	85	20.90
Goa	1	107.00	1	648.00	7	755.00	1 224	61.70
Gujarat	4	479.70	1	16 602.60	26	17 082.30	18 999	89.90
Haryana	2	47.00	6	287.30	11	334.30	1 551	21.60
Himachal Pradesh	2	1 429.40	22	5 665.90	34	7 095.30	37 033	19.20
Jammu & Kashmir	4	3 810.10	9	10 163.70	20	13 973.70	20 230	69.10
Jharkhand	1	231.70	32	1 868.30	11	2 100.00	23 605	8.90
Karnataka	5	2 472.20	16	4 231.40	26	6 703.60	33 724	19.90
Kerala	3	536.50	10	1 788.20	15	2 324.70	11 221	20.70
Lakshadweep	0	0	21	0.01	1	0.01	23	0.04
Madhya Pradesh	9	3 656.40	12	7 199.50	34	10 855.90	95 221	11.40
Maharashtra	5	955.90	1	14 729.60	41	15 685.60	61 939	25.30
Manipur	1	40.00	25	706.50	6	746.50	17 418	4.30
Meghalaya	2	267.50	36	34.20	5	301.70	9 496	3.20
Mizoram	2	200.00	5	775.00	7	975.00	15 935	6.10
Nagaland	1	202.70	3	20.40	4	222.40	8 629	2.60
Orissa	2	990.70	18	7 961.90	20	8 952.60	58 135	15.40
Punjab	0	0	10	316.70	10	316.70	3 059	10.40
Rajasthan	4	3 859.40	24	5 301.80	28	9 161.20	32 494	28.20
Sikkim	1	1 784.00	6	265.10	7	2 049.10	5 765	35.50
Tamil Nadu	5	307.84	20	2 997.60	25	3 305.40	22 871	14.50
Tripura	0	0	4	603.10	4	603.10	6 293	9.60
Uttar Pradesh	1	490.10	23	5 185.90	24	5 676.00	16 826	33.70
Uttaranchal	6	4 083.30	6	2 868.00	12	6 951.30	34 662	20.10
West Bengal	5	1 693.30	15	1 223.50	20	2 916.70	11 879	24.60
All India	90	36 882.00	502	120 052.00	592	156 934.00	768 436	20.40

Source MoEF (2003)

belonging to high-class quality. Ayurveda accounts for more than 80% of the traded medicinal plants with 710 plants beings used in this sector. Only 49 species are used in the modern systems of medicine.

The analysis of the distribution of the origin of species across major biogeographic zones reveals that about 18% of the species are exclusively confined to the Himalayan and the trans-Himalayan zones, 4% belong exclusively to the Western Ghats, and about 77% of the species belong to other biogeographic zones. Figure 2 gives a rough approximation of the distribution of medicinal plants in India. About 61% of the traded species are from the wild, with no known plantations or cultivation. Only 10% of

Table 3

Number of plants used medicinally worldwide

Country	*Plants species*	*Medicinal plant species*	*Percentage*
China	26 092	4 941	18.90
India	15 000	3 000	20.00
Indonesia	22 500	1000	4.40
Malaysia	15 500	1 200	7.70
Nepal	6 973	700	10.00
Pakistan	4 950	300	6.10
The Philippines	8 931	850	9.50
Sri Lanka	3 314	550	16.60
Thailand	11 625	1 800	15.50
USA	21 641	2 564	11.80
Vietnam	10 500	1 800	17.10
Average	13 366	1 700	12.70
World	422 000	52 885	12.53

Source Schippmann, Leaman, and Cunningham (2002)

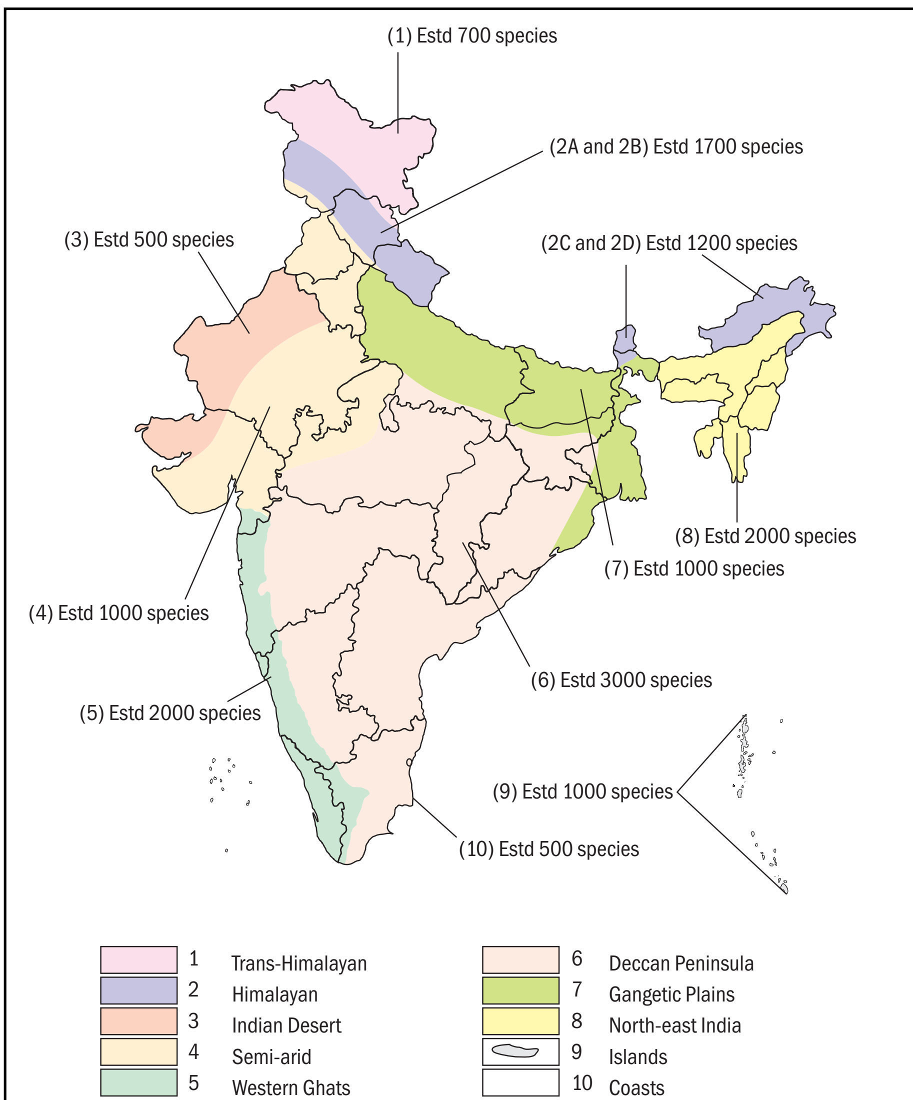

Figure 2

Medicinal plants species in different biogeographic zones of India

Source Ved *et al.* (2001)

these species are cultivated. The consequence of this skewed pattern of sourcing medicinal plants is that about 100 medicinal plants are under the IUCN Red List category. Fourteen species are identified as threatened globally as they are endemic to India. The causes of overextraction include open access to medicinal plants in the wild, the low price paid to gatherers of medicinal plants, and the lack of sufficient data on wild plant populations, marketing, and trading. The biodiversity loss is not only a threat to the ecology of the planet but also a more immediate threat to the livelihood security of rural communities. The following sections of this paper focus on examining the implications of this loss to the economy.

Indicators of biodiversity

Unlike forests, which can be measured in terms of area or volume of growing stock, it is difficult to find a single indicator that can provide a good measure of biodiversity. This is because biodiversity represents not only a number of different components of the stock of natural capital but also thousands of ecological processes that are crucial to the proper functioning of the environment. Measuring biodiversity is complicated because while measuring an asset base, there is not only the need to consider the stock of biodiversity but also the composition of the asset base and its variability. We are still in the process of understanding this complex ecology, which cannot be described in terms of an easily recognizable output that can be valued by human beings.

Biological diversity can be measured in terms of different strata—genetic, population/species, and community/ecosystem. These represent three fundamental levels of biological organization: genes, species, and ecosystems, where genes are found within species and species exist within ecosystems (Pearce and Moran 1994). Genetic diversity means the variation in the genetic information that is found in the genes of living organisms. The number of genes varies according to the complexity of the organism. In addition to the degree of variability in the number of genes within a population of a given species, there is also genetic variability between different populations of a given species. Greater diversity means that the evolutionary process has a broader base from which to work, leading to a more resilient system.

Genetic diversity can be measured in terms of (1) allelic frequencies, (2) phenotypic traits, and (3) DNA (deoxyribonucleic acid) sequencing (Nunes and van den Bergh 2001). The same gene can exist in different frequencies or variants called alleles. Using alleles as a unit, the probability that two alleles sampled at random are different is commonly used as a measure of genetic diversity (called average expected heterozygosity), which can be measured using different indices. The more the alleles, the greater the genetic diversity. The second measure, phenotypic diversity measures whether individuals share the same characteristics, and is based on an individual's phenotypic traits. This indicator focuses mainly on the variance of certain features and, in general, involves readily measurable morphological and physiological characteristics of the individual.

However, individual genetic information is often difficult to assess and comparisons are difficult when individuals or populations are measured in terms of different qualitative traits. To overcome this difficulty, scientists now use DNA sequence variation to measure genetic variety. The DNA sequence information is obtained using a polymerase chain reaction. This means that only a small amount of material, ultimately one single cell, is required to obtain the DNA sequence data. The higher the proportion of shared DNA sequences between species, the lower the overall genetic diversity (Nunes and van den Berg 2001).

The simplest measure of species diversity is the number of species in the area under consideration. However, due to the inherent difficulty in defining the term species, counting the species is difficult unless the area under consideration is small. In practice, species diversity is often based on a sample area. The central measures of species diversity are α, β, and γ diversity (proposed by Whittaker 1960, 1972). α diversity measures the local diversity within each site or the average of the local measures across all the sites. β diversity measures the change in species composition from one site to another. Fewer the species that various sites have in common, the higher the β diversity. γ diversity gives the 'total' diversity measured over the entire set of sites being considered. This can be estimated directly, or calculated from the α and β diversities. In addition to using the number of species as a measure of diversity, the variability of species in a given area is also important. This is commonly quantified in terms of the species richness and the relative abundance of each species. Several diversity indices like the Simpson's diversity index and the Shannon–Weiner diversity index are available to compare one area with another. In Simpson's diversity index,[1] as the total number of species increases, the diversity of the index becomes higher. However, if one species becomes very abundant and other species become rare, the diversity index will be lowered even though the total number of species stays the same. The Shannon–Weiner index[2] belongs to a subset of indices that maintain that diversity can be measured much like the information contained in a code or message (hence the name 'information index'). The rationale is that if we know a letter in a message, we can know the uncertainty of the next letter in a coded message (that is, the next species to be found in a community). The uncertainty is measured as H', the Shannon index. A message coded bbbbbb has low uncertainty (H' = 0). Indicators based on species richness and abundance look very crude but have been used to compare patterns of diversity at the global, regional, and local scales. For example, extinction rates are calculated either in absolute terms as a rate of loss or as an estimate of a ratio of species lost in relation to the amounts of transformed habitat.

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[1] Simpson's diversity index is given by $D = [N(N-1)] / [\Sigma n(n-1)]$, where D is diversity, N is the relative abundance of each species (species richness), and n is the total number of species in that area.

[2] The Shannon–Weiner index is given by $H = \Sigma(P_i)(\log P_i)$, where $P_i = n_i / N_i = 1$ to n; N_i is number of individuals in a species, and P_i is the proportion of individuals found in the ith species.

The third organizational structure is the ecosystem, which is a distinct assemblage of plants and animals. Ecosystem diversity is used to describe the number of different habitats or biomes. The measurement of biodiversity at the organizational level of ecosystem diversity encompasses a multi-complexity of relationships that play a crucial role in defining the overall distribution and abundance of species. At the ecosystem level, many different units of diversity are involved, ranging from the pattern of the habitat to the age structure of the population. Hence, it is not clear where to draw the boundaries delineating the units of biodiversity. Given such unambiguous boundaries, there are different measurement approaches. These include biogeographical realms or provinces based on the distribution of species, and eco-regions or eco-zones based on physical attributes such as soils and climate (UNEP 1995). Appendix V provides a list of the various biogeographic zones in India, along with some typical medicinal plants found in them.

In this paper, our focus is on species-level indicators and we have used the number of species (species richness) as a measure. Though we could have used other indices, we could not obtain the information on different kinds of species for all the states in India. Though some estimates exist, they are site-specific. Table 4 gives the number of species (flora and fauna) in the different states in India along with the number of flora of conservation importance.

Physical indicators may not, however, be very useful, as they do not give a clear indication of the possible impact of losing one crucial species and the resultant reduction in biodiversity. Weitzman (1992, 1995) has argued that if biodiversity indicators are to be truly useful for policy purposes, at some point, they must be translated into a value of the diversity function. This implies attaching economic value to biodiversity to make it commensurable with other benefits and costs, so that society is able to determine how diversity ought to be preserved at the expense of sacrificing other choices. However, some researchers are extremely critical of placing a value on biodiversity. Gowdy (1997) for instance argues, 'devising a single measure, monetary/otherwise, of the value of biodiversity is impossible' as one cannot substitute for biodiversity, and hence, standard ways of measuring its values are not available. Since a functioning ecosystem is essential to the very possibility of human lives, its services cannot be traded for other goods. Similarly, Mainwaring (2001) states that the substitution of ecosystem services is beyond human capacity with examples of non-substitutable services being: 'the formation and retention of soils and the maintenance of soil fertility via the nitrogen cycle and the activity of micro-organisms and the breakdown and recycling of organic matter by micro-organisms', and so on.

Loomis and White (1996) point out, 'with regard to the utility of biodiversity, gains are obtained in several ways'. For instance, these gains may be obtained from observing a certain species for its beauty or its uniqueness, their use values, or the probable genetic information provided to the pharmaceutical industry for developing new products, and

Table 4

Number of species in different states and union territories in India

State / Union Territory	*Total flowering plants (BSI)*	*Medicinal plants (FRLHT)*	*Species of conservation importance (WCMC)—flora*	*Fauna (mammals and birds)*
Andhra Pradesh	2586	483	46	300
Arunachal Pradesh	4500	878	128	700
Assam	3017	1206	86	1020
Bihar and Jharkhand	2650	700	7	209
Goa, Daman and Diu	1547	10	8	95
Gujarat	2106	700	35	338
Haryana	1227	600	1	49
Himachal Pradesh	2885	667	74	1559
Jammu and Kashmir	4252	250	140	371
Karnataka	3849	1956	92	760
Kerala	4500	1864	280	578
Madhya Pradesh and Chhattisgarh	2317	2262	16	272
Maharashtra	2513	1200	94	291
Manipur	2376	430	43	500
Meghalaya	3000	876	164	560
Mizoram	2141	230	10	241
Nagaland	2431	972	46	84
Orissa	2630	1000	113	559
Punjab	1843	291	3	485
Rajasthan	1911	50	58	480
Sikkim	4500	483	163	594
Tamil Nadu	5640	1793	441	450
Tripura	1546	628	3	240
Uttar Pradesh and Uttaranchal	4250	1303	202	731
West Bengal	3580	850	40	837
Andaman and Nicobar Islands	2500	1000	172	301

BSI – Botanical Survey of India; FRLHT – Foundation for Revitalization of Local Health Traditions; WCMC – World Conservation Monitoring Centre

Source Compiled from different sources

so on. Sometimes we derive satisfaction by simply knowing that a particular species exists. Finally, we may also wish to pass on this rich asset to future generations. Hence, it is possible to value biodiversity as it is implicit in our utility function. In the next two sections, we attempt to value the flora and fauna of India's forests.

Recreational value of fauna in Indian forests

An important contribution of biodiversity to economic development in recent years has been 'nature tourism'. This can be seen from the fact that in the last few years, India has experienced a large increase in international tourism, to which a key contributor is India's system of national parks and the biodiversity present in these parks. In 2002, for instance, there was a 14.6% increase in international tourist arrivals along with a 22.4% growth in foreign exchange.[3] As forests provide tourism benefits, the best way to approximate the value of protected areas is through

[3] <www.tourismindia.com>

exploring their potential value as a source of nature recreation (also called ecotourism). Nature tourism can be defined as 'going to relatively undisturbed or uncontaminated areas with the specific objective of studying, admiring, and enjoying the scenery and its wild plants and animals as well as existing cultural manifestation' (Wunder 2000).

Most of the studies used the TCM (travel cost method) and CVM (contingent valuation method) to assess the value of ecotourism. The TCM is an indirect valuation method where the visitor's travel costs to a recreational area are used as a proxy for the price of the recreational activity together with participation rates and visitor's attributes to estimate the recreational value of the site. The travel cost demand function can be described as V = f (TC, X), where V is the number of visits to the park, TC is the travel cost, and X represents other socio-economic variables like income and education, affecting the choice of visits to the park. Based on this, a demand curve similar to Figure 3 can be derived. The TCM is mainly used to get the 'use' values.

There are two variants of the TCM. One is ZTCM (zonal travel cost method) and the second is ITCM (individual travel cost method). In ZTCM, the unit of analysis is a zone, where the visitation rate is calculated for each zone and is estimated as the ratio of the number of visitors from a zone to the total population of the zone. ITCM uses an individual as a unit. TCM has some limitations: (1) use for international visitors is complicated by the difficulty in determining the quantity of environmental goods demanded; (2) multiple-purpose visits occur when an individual travels to a region for several reasons such as visiting a park, seeing family members, and touring archeological sites, and so on. Assigning the entire expenditure to a particular site could be arbitrary and unjustifiable; (3) Randall (1994) points out that the travel costs are inherently

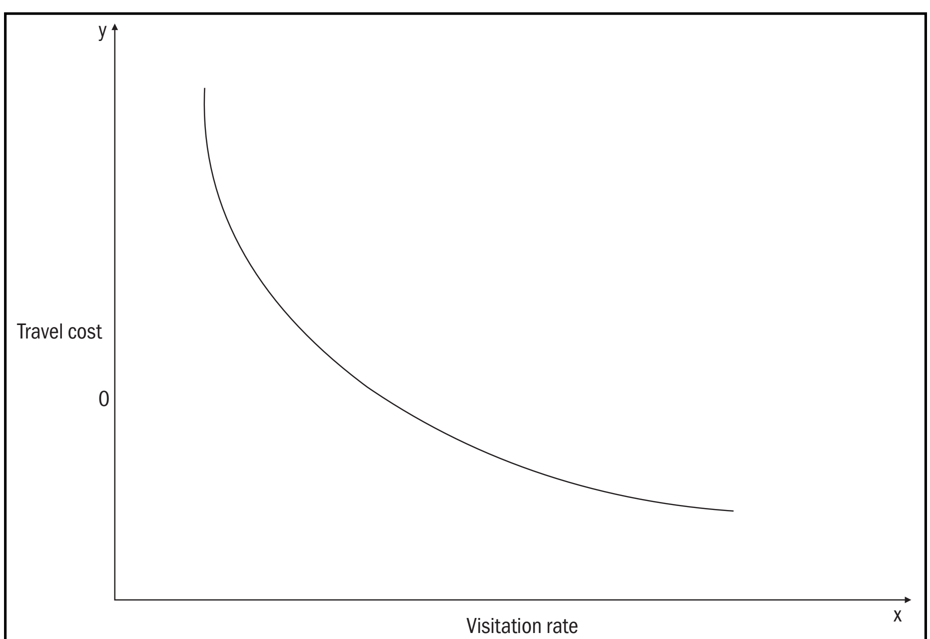

Figure 3

Demand function for the travel cost method subjective but are treated as ordinal as long as the costs increase with the distance travelled; and (4) apart from the aforementioned drawbacks, the treatment of opportunity cost for the time spent on travelling is very difficult.

The second approach adapted in the literature is the use of CVM. CVM attempts to value non-market goods by asking people directly for their WTP (willingness to pay) to obtain specified improvements or to avoid decrements by using a social scientific survey technique. It uses a questionnaire survey to create a hypothetical market or referendum and then allows the respondent to use it to state or reveal his or her WTP for recreation, option, existence, and bequest values (Mitchell and Carson 1989). CVM remains the subject of heated debate within the non-market valuation literature due to the hypothetical nature of the market and its susceptibility to biases (Freeman 1993; Mitchell and Carson 1989). One of the most important potential biases of CVM is scenario mis-specification, especially on the amenity to be valued. This is a serious bias in estimating non-use values. CVM has four primary ways of eliciting value. They are direct questioning, bidding game, payment card, and referendum choice. The payment vehicle defines the structure or mechanism through which the monetary payment will be transferred. Even non-use values can be obtained using CVM.

However, using the TCM and the CVM is very data intensive, time consuming, and very expensive. As our objective is to get estimates for all Indian states, a primary survey is not possible. Hence, in this study, we use the benefit transfer method, which refers to using existing information and knowledge to new contexts. In this study, we adapt and use information from already existing studies in India on ecotourism to different protected parks in India. To apply the benefit transfer technique, we can use either the value transfer or the function transfer approach. Value transfer involves the transfer of a single (point) benefit estimate or mean or median values for several benefit estimates from the study site(s). Function transfers encompass the transfer of benefit or demand function from a study site, or meta-regression analysis derived from several study sites. The site-specific characteristics are substituted in the function to obtain the estimates for the site of interest.

To obtain the consumer surplus estimates for all the states, we used the benefit function transfer approach, as this is more sound than using value transfers. Rather than just transferring the demand curve obtained, we used a meta-regression analysis. We compiled consumer surplus from different studies and regressed it on the specific site variables. Consumer surplus is referred to as the net WTP or WTP in excess of the cost of the good. When the changes in recreation supply or days are small and localized, consumer surplus is equivalent to a virtual market price for a recreation activity (Rosenthal and Brown 1985).

Table 5 gives a summary of the studies that estimated the recreational value of national parks in India. All these studies estimated the consumer

Table 5

Summary of ecotourism studies

Name of the national park	*Method used*	*Consumer surplus*	*Area of the park* (km^2)	*Specially known for*	*Mammals*	*Birds*	*Flora*	*Distance to international airport* (km)	*Total tourists*	*Source*
Bharatpur	Travel cost	Rs 427 for Indian tourists and Rs 432 for foreign tourists)	29.00	Birds	28	359	377	190	125 122	Chopra, Chauhan, Sharma, *et al.* (1997)
Borivli	Contingent valuation	Rs 248 million per year (for 10 million people in Mumbai)	103.09	Leopards	40	251	1000	18	12 000 000	Hadker, Sharma, David (1997)
Bandhavgarh	Travel cost	Rs 17197.71 per hectare annually for Indian tourists and Rs 107 850 per hectare annually for foreigners	448.00	Tigers	22	250	100	237	6 060 997	Amalendhu (2005)
Periyar	Travel cost and contingent valuation	For Indian tourists, Rs 13.5 million according to travel cost method and Rs 84.5 million per annum according to contingent valuation for foreigners and Indian visitors	777.00	Tigers	49	246	5000	190	196 255	Manoharan (1996)
Arunachal	Travel cost	Rs 6.96 million (Rs 991.51 / Indian tourist and Rs 1232.48 / foreign tourist)	83 743.00	Tigers, Red Panda	200	500	4500	216	2 318	Mitra (2000)
Sikkim	Travel cost	Rs 104.63 per person	7 096.00	Birds	144	600	4000	124	159 000	Bhattacharya (2003)
Sundarbans	Household production, function, and travel cost	Rs 624 per person	10 000.00	Tigers	45	270	330	112	90 000	Haque (2003)
Pench	Contingent valuation and travel cost	Rs 550 per person	257.26	Tigers	33	164	32	93	104 437	Kulkarni and Vaidya (2002)

km – kilometres

Source Author's compilation from various sources surplus for different parks. Some studies estimated the consumer surplus per hectare and some others per person per annum. We brought these into a single unit of consumer surplus per person per hectare.

In general, we estimated the following functional form.

$CS = \alpha + \beta_1 \times X_1 + \beta_2 \times X_2 + \beta_3 \times X_3 + \varepsilon$
(using the estimates from these eight studies)

where,

X_1 is the area of the park,
X_2 is the species richness (indicated by flora and fauna),
X_3 is dummy for bird or mammals, and
X_4 is dummy for method used (whether TCM or CVM).

Instead of using area as one of the explanatory variables, we considered consumer surplus per hectare per tourist as the dependent variable. We used the density of fauna and dummy for method as explanatory variables. We preferred using faunal density per hectare as one of the explanatory variables instead of biodiversity (defined as a sum of flora and fauna), as fauna and flora are highly correlated with correlation coefficient of 0.80. Moreover, though visitors mainly visit the park to view a tiger or lion, placing a value on the species indirectly means placing a value on the ecosystem as a whole.

Using the following relation we obtained the consumer surplus for different states for domestic tourists:

$$PCS = -0.063 + 47.85 \times pfauna - 0.69 \times dcvm + e \qquad (1)$$

Similarly, for foreign tourists we used the following relation

$$PCS = -0.39 + 300.1 \times pfauna - 4.36 \times dcvm + e \qquad (2)$$

The results of this estimation are given in Table 6. We then estimated the consumer surplus for different states based on Equations (1) and (2). Keeping all other variables at their mean values, we used the actual number of fauna (mammals and birds) per hectare (from Table 1) in different states to obtain the consumer surplus per tourist per hectare for domestic and foreign tourists visiting the state.[4] Column (III) in Table 7 gives the estimates of consumer surplus per tourist per hectare in different states.

[4] The total number of fauna in each state is divided with the area under protected parks to obtain the fauna per hectare. The implied value per hectare is obtained by multiplying the per hectare fauna with its coefficient i.e. 47.85 in case of domestic tourists and 300.1 in case of foreign tourists.

Table 6

Results of the regression equations

Equation 1: PCS_domestic = $\alpha + \beta_1 \times$ Pfauna + $\beta_2 \times$ dummy_method + ε — R-square = 0.97

PCS_domestic – consumer surplus per hectare for domestic tourist — F (2,6) = 126.8; Number of observation = 9

Explanatory variables	Definition of variable	Coefficient	t-ratio
Pfauna	Number of fauna per hectare multiplied by the number of parks in the state	47.850	15.60
Dummy_method	Dummy for method = 1 if CVM	–0.690	–2.31
Constant		–0.063	–0.40

Equation 2: PCS_foreign = $\alpha + \beta_1 \times$ Pfauna + $\beta_2 \times$ dummy_method + ε — R-square = 0.96

PCS – consumer surplus per hectare per person — F (2,6) = 77.11; Number of observation = 9

Explanatory variables	Definition of variable	Coefficient	t-ratio
Pfauna	Number of fauna per hectare multiplied by the number of parks in the state	300.09	15.60
Dummy_method	Dummy for method = 1 if CVM	–4.36	–2.31
Constant		–0.39	–0.40

Equation 3: ldomestic = $\alpha + \beta_1 \times$ leco + $\beta_2 \times$ Dummy_connectivity + $\beta_3 \times$ lattractions + ε — R-square = 0.62

PCS – consumer surplus per hectare per person — F (3,22) = 12.24; Number of observations = 26

Explanatory variables	Definition of variable	Coefficient	t-ratio
Larea	Logarithm of the area under protected parks	0.466	1.78
Dummy_connectivity	Dummy for connectivity of the place = 1, if the place is not well-connected	–3.211	–4.49
Lattractions	Total number of tourist attractions in the state	0.354	0.68
Cons		8.567	2.63

Equation 4: lforeign = $\alpha + \beta_1 \times$ leco + $\beta_2 \times$ business + $\beta_3 \times$ dummy_popular + $\beta_4 \times$ dummy_connectivity + ε — R-square = 0.75

Lforeign—logarithm of the number of foreign tourists — F (4, 21) = 15.64; Number of observations = 26

Explanatory variables	Definition of variable	Coefficient	t-ratio
Leco	Logarithm of number of protected areas	0.743	1.86
Business	Business centre	1.675	2.03
Dummy_connectivity	Dummy for connectivity of the place = 1, if the place is not well-connected	–2.664	–3.48
Dummy_Popular	Dummy for popular places = 1, if the place is popular, otherwise 0	1.450	1.91
Cons		8.603	6.69

Source Authors' estimates

The per hectare consumer surplus has to be multiplied with the total number of tourists visiting the park and the area of the park to get the total consumer surplus. However, we could get the data on the number of tourists visiting the national parks in India for only two states, and therefore for very few national parks. Nevertheless, we had the statistics on the number of foreign and domestic tourists visiting different states. Table 7 (column IV) gives the average number of tourists in the different states during the years 1998–2003 (average of 1998–2003). Even if we could obtain information on the number of tourists visiting national parks, we have to take care of the 'multiple destination' problem as tourists visited different places for recreational, religious or business purposes. From this, we have to estimate the share of consumer surplus attributable only to national parks. We, therefore, attempted to fit a regression between the number of tourists in a particular state and the variables influencing tourism on the basis of the following functional relationship using ordinary least squares

$$Y = \alpha + \beta_1 \times d_1 + \beta_2 \times d_2 + \beta_3 \times d_3 + \beta_4 \times d_4 + \beta_5 \times d_5 + \varepsilon$$

where Y is the number of tourists, d_1 is the dummy for religious places, d_2 for national parks, d_3 for beaches, d_4 for the number of tourist attractions, and d_5 is a connectivity dummy (places like the northeast and the Andamans are very attractive but less visited due to less connectivity).

These equations were estimated separately for domestic and foreign tourists. The variables which were collinear and insignificant were dropped. Finally, we estimated the following equation.

$$\text{ldomestic} = \alpha + \beta_1 \times \text{leco} + \beta_2 \times \text{number of attractions} + \beta_3 \times \text{connectivity dummy} + \varepsilon \quad (3)$$

ldomestic stands for the logarithm of the domestic tourists; and leco is the logarithm of the area under protected areas. We have not considered pilgrimage centres separately because they are correlated with the area under protected parks and also the number of ecotourism centres.[5] Instead, we used the total number of attractions in the state (including monuments, pilgrim centres, beaches etc.) as one of the explanatory variables.

Similarly, we calculated separate estimates for foreign tourists. As per the tourism statistics, around 95% of foreigners visiting India do so for recreational purposes. As foreigners visit India mainly to watch wild animals, visit beaches, or on business, we included these three activities as the explanatory variables. We also introduced a dummy for popular destinations like Goa (known for its beaches), Kerala (for health tourism), Himachal and Uttaranchal (for skiing and natural beauty), UP (for the Taj Mahal), Rajasthan (its fortresses and vibrant culture), and so on. We also included a 'connectivity' dummy to reflect accessibility due to neighbouring airports, and so on.

[5] Most of the famous pilgrim centres in India are located in forest areas.

Table 7

Net consumer surplus estimates from ecotourism in different states (2001/02)

State/Union Territory	*Area (I) Protected areas* (km^2)	*Average number of tourists visiting the state during 1998–2002 (II)*		*Consumer surplus/ hectare/tourist from the estimates (in Rupees) (from Equations (1) and (2) (III)*		*Share of consumer surplus attributable to tourists visiting national parks (from Equations (3) and (4) (IV)*		*Consumer surplus per hectare for tourists visiting the national park* (in rupees) *(V)*	
		Domestic	*Foreign*	*Domestic*	*Foreign*	*Domestic*	*Foreign*	*Domestic*	*Foreign*
Andhra Pradesh	13 469.5	50 381 464.0	479 318	0.006	0.035	0.0010	0.0100	644.7	184.9
Arunachal Pradesh	10 074.6	2 213.7	123	0.033	0.209	0.0290	0.3000	27.9	105.4
Assam	2 866.0	864 960.9	6 610	0.170	1.068	0.0290	0.3000	4297.0	2228.4
Bihar and Jharkhand	5 428.7	7 280 293.6	60 820	0.018	0.116	0.0010	0.0100	168.9	95.3
Goa, Daman, and Diu	755.0	1 401 142.0	314 357	0.060	0.378	0.0010	0.0100	614.7	6031.5
Gujarat	17 082.3	6 418 108.1	37 534	0.009	0.059	0.0010	0.0100	124.5	47.5
Haryana	334.3	1 946 456.0	84 981	0.070	0.441	0.0010	0.0100	149.3	216.7
Himachal Pradesh	7 095.3	4 664 125.9	167 902	0.105	0.659	0.0020	0.0100	888.9	799.2
Jammu and Kashmir	13 973.7	5 049 529.1	24 330	0.013	0.080	0.0020	0.0100	1434.3	346.2
Karnataka	6 703.6	13 090 140.0	249 908	0.054	0.340	0.0020	0.0100	1089.9	490.6
Kerala	2 324.7	5 145 159.4	294 621	0.119	0.746	0.0020	0.0100	939.7	1591.4
Madhya Pradesh and Chhattisgarh	17 204.8	6 200 319.7	92 278	0.008	0.047	0.0220	0.3000	1038.6	1378.1
Maharashtra	15 685.6	2 022 591.4	986 544	0.009	0.056	0.0020	0.0100	30.5	593.7
Manipur	746.5	91 488.0	257	0.320	2.010	0.0420	0.3000	1237.0	163.8
Meghalaya	301.7	200 206.3	6 304	0.888	5.570	0.0540	0.3000	509.3	591.6
Mizoram	975.0	28 958.3	279	0.118	0.742	0.0490	0.3000	1167.5	459.0
Nagaland	222.4	14 614.9	743	0.723	4.534	0.0350	0.3000	93.0	267.4
Orissa	8 952.6	3 053 011.4	25 020	0.030	0.187	0.0020	0.0100	165.3	33.9
Punjab	316.7	474 951.3	4 589	0.073	0.460	0.0020	0.0100	631.3	122.1
Rajasthan	9 161.2	7 906 555.1	628 560	0.025	0.157	0.0020	0.0100	304.2	713.9
Sikkim	2 049.1	152 889.4	11 966	0.139	0.870	0.0400	0.3000	847.0	3298.4
Tamil Nadu	3 305.4	26 769 788.0	901 504	0.065	0.409	0.0020	0.0100	742.2	562.1
Tripura	603.1	245 543.6	3 196	0.190	1.194	0.0540	0.3000	439.1	211.0
Uttar Pradesh and Uttaranchal	12 627.3	63 028 873.0	825 000	0.028	0.174	0.0110	0.0100	6609.7	346.6
West Bengal	2 916.7	469 187.7	705 457	0.137	0.861	0.0020	0.0100	45.5	3025.9
Andaman and Nicobar Islands	1 620.2	152 093.9	4 142	0.089	0.558	0.0370	0.3000	494.8	724.9
All India	156 796.0	2 07 054 665.0	5 916 343	0.040	0.240	0.0001	0.0002	1113.4	240.6

Source Author's estimates

$$\text{lforeign} = \alpha + \beta_1 \times \text{leco} + + \beta_2 \times \text{business} + \beta_3 \times \text{dummy\_popular} + \beta_4 \times \text{dummy\_connectivity} + \varepsilon \quad (4)$$

By estimating Equations (3) and (4), first, we tried to assess the proportion contributed by the national parks to tourist activity in the state, and second apportioned the expenditures incurred by tourists to national parks to take care of the multiple destination problem (wherein tourists visit more than one recreational spot and do not go specifically for a single location).

Table 7 (continued)

Net consumer surplus estimates from ecotourism in different states (2001/02)

State/Union Territory	*Total consumer surplus for tourists visiting the national parks* (rupees millions) *(VI)* Domestic	Foreign	*Cost of maintaining the parks* (Rs million) *(VII)*	*Net ecotourism value* (Rs million) *(VIII)*	*Total net present value of ecotourism* (Rs million) *(IX)*	*Net present value of ecotourism per hectare* (Rs) *(X)*
Andhra Pradesh	868.4	33.0	47.6	442.10	95 638.41	37 030.00
Arunachal Pradesh	28.1	55.2	62.0	3.70	798.11	148.00
Assam	1 231.5	294.1	43.1	38.80	8 385.66	5 297.00
Bihar and Jharkhand	91.7	11.8	27.0	185.00	40 015.50	26 397.00
Goa, Daman, and Diu	46.4	181.0	15.6	255.50	55 264.08	10 000.00
Gujarat	212.7	2.8	30.2	251.50	54 396.74	62 720.00
Haryana	5.0	3.5	3.5	4.00	864.57	7 591.00
Himachal Pradesh	630.7	33.8	31.0	1 312.80	283 992.46	272 310.00
Jammu and Kashmir	2 004.2	36.8	5.2	217.50	47 041.52	39 704.00
Karnataka	730.6	69.8	155.0	847.00	183 232.34	70 054.00
Kerala	218.5	165.1	50.8	2 055.10	444 578.13	377 657.00
Madhya Pradesh and Chhattisgarh	1 786.9	1890.4	146.6	200.30	43 328.64	5 267.00
Maharashtra	47.9	68.8	73.3	253.10	54 744.63	17 720.00
Manipur	92.3	46.2	5.4	78.70	17 033.10	29 830.00
Meghalaya	15.4	184.4	15.3	652.80	141 210.99	248 567.00
Mizoram	113.8	114.7	40.8	1.90	421.17	471.00
Nagaland	2.1	89.2	20.4	830.20	179 587.78	333 002.00
Orissa	148.0	8.3	91.8	407.20	88 090.62	31 492.00
Punjab	20.0	3.0	6.9	21.40	4 624.65	29 856.00
Rajasthan	278.7	41.7	41.6	425.20	91 986.16	145 502.00
Sikkim	173.6	150.5	12.4	14.70	3 171.84	13 266.00
Tamil Nadu	245.3	48.3	31.9	1 217.00	263 280.47	210 641.00
Tripura	26.5	37.3	12.8	1 902.70	411 610.00	411 610.00
Uttar Pradesh and Uttaranchal	8 346.3	36.3	105.8	840.80	181 891.95	64 989.00
West Bengal	13.3	161.8	79.0	1 703.30	368 464.55	580 625.00
Andaman and Nicobar Islands	80.2	4.4	5.1	2.83	612.65	929.24
All India	17 457.9	3771.8	1160.1	14 164.94	3 064 266.69	65 193.00

Findings

From Table 6 it can be seen that all the variables are significant. The higher the number of fauna in a park, the higher is the consumer surplus. The relationship between the number of tourists visiting a state and the number of ecotourism centres is positive and significant, indicating that biodiversity does contribute positively and significantly to tourism. Similarly, the lower the connectivity, the lower the number of tourists in that state. The tourist visitation rate is higher in states that are popular. Similarly, if an area is known as a prime business centre it attracts a higher number of foreign tourists. The greater the area of the national parks in a state, the greater the number of domestic tourists. For foreigners, we used the number of protected parks as one of the explanatory variables instead of the area under the national parks. The results show that the number of protected areas in the state and the number of foreign tourists visiting the state are positively and significantly correlated. Using relationships (3) and (4), we estimated the share of consumer surplus attributable to tourists visiting the national parks (given in Table 7 (column IV))[6]. The consumer surplus per hectare per domestic and foreign tourist is given by multiplying the consumer surplus per hectare attributable to tourists visiting the national parks with the number of domestic and foreign tourists. This is given in Column V of Table 7.

The total consumer surplus per tourist per hectare (Column V) is multiplied with the number of domestic and foreign tourists visiting the park (that is Column II) to get the total consumer surplus per hectare (Column VI). However, we used the consumer surplus estimates as a proxy for income. From this income, we need to deduct the amount of expenditure incurred to protect, maintain, and upkeep the national parks and sanctuaries (Column VII) to calculate the net price. To compute the amount of expenditure incurred, we used the amount sanctioned under the following programmes: Biosphere Reserves, Project Tiger, Project Elephant, Eco-development Project, Development of National Parks and Sanctuaries, Central Zoo Authority, and Protection of Wildlife in India, to different states during 2001/02, as an approximation of the costs of providing and maintaining the national parks. The details of the funds released under various schemes from the year 2001/02 are given in Table 8.

The total expenditure incurred under the schemes mentioned above is deducted from the total consumer surplus in different states to get the net benefit from ecotourism. The results are given in Column VIII in Table 7. The net present value of ecotourism is obtained by using a discount rate of 4%. However, here we have not assumed that the number of tourists is constant. We assumed that ecotourism is growing at the rate of 9.2% as per the projections made by the World Tourism Council for different countries. We assumed that ecotourism grows at this rate until 2020 and after that the growth stabilizes at the 2020 level. Based on these assumptions, we estimated the net present value of ecotourism, which is given in Column IX of Table 7.

From Table 7 it can be seen that 15.67 million hectares of forests in India assume protected area status with around 13 095 numbers of fauna (the same variety species may be found in different parks). About 207 million domestic tourists and 5.9 million foreign tourists visited different states in India (average during the period 1998–2002). The consumer surplus/hectare/domestic tourist varies from 0.89 in Meghalaya to 0.005 in case

[6] The number of domestic tourists visiting a particular state = antilog (8.56 + 0.466 × logarithm of actual area under protected parks –3.211 × 1 (if the place is well-connected) + 0.353 × number of attractions in the state).

Table 8

Amount sanctioned under different schemes for protection, maintenance, and upkeep of national parks and wildlife sanctuaries, 2001/02 (rupees in lakhs)

State/Union Territory	*Biosphere Reserve*	*Project Elephant*	*Project Tiger*	*Eco-development Project*	*Development of National Parks and Sanctuaries*	*Central Zoo Authority*	*Protection of Wildlife in India*	*Total expenditure released*
Andhra Pradesh	0	51.4	21.0	69.6	88.6	104.5	140.6	475.7
Arunachal Pradesh	0	84.2	35.0	41.1	160.5	0	299.2	619.9
Assam	0	94.5	46.0	43.8	35.6	0	211.1	430.9
Bihar	0	0	50.0	7.0	4.5	53.1	54.5	169.2
Chhattisgarh	0	0	35.0	24.7	31.1	0	71.9	162.8
Goa	0	0	0	0	78.1	0	78.1	156.3
Gujarat	0	0	0	37.3	127.2	10.0	127.2	301.6
Haryana	0	0	0	0	15.6	3.5	15.6	34.7
Himachal Pradesh	0	0	0	101.3	97.5	0	111.2	310.0
Jammu and Kashmir	0	0	0	0	26.0	0	26.0	52.0
Jharkhand	0	22.7	50.0	5.1	0	0	22.7	100.4
Karnataka	30.0	92.5	146.4	202.7	288.3	140.6	649.7	1550.1
Kerala	0	95.9	50.0	66.9	81.5	0	213.5	507.8
Madhya Pradesh	49.1	0	274.5	136.7	99.4	171.5	571.6	1302.7
Maharashtra	0	0	167.5	37.5	144.2	21.3	362.6	733.1
Manipur	0	0	0	0	26.8	0	26.8	53.6
Meghalaya	7.2	50.0	0	0	27.9	0	68.0	153.1
Mizoram	0	0	10.0	154.4	95.0	0	149.0	408.4
Nagaland	0	66.9	0	28.5	25.7	0	83.1	204.3
Orissa	0	117.0	126.8	46.6	70.3	0	557.4	918.1
Punjab	0	0	0	12.3	26.6	0	29.6	68.5
Rajasthan	0	0	70.0	30.0	73.0	0	243.3	416.3
Sikkim	20.0	0	0	26.2	20.0	27.8	30.5	124.4
Tamil Nadu	17.4	58.7	16.0	6.4	75.2	13.9	131.2	318.8
Tripura	0	0	0	34.0	46.4	0	47.4	127.8
Uttar Pradesh	0	0	50.0	132.8	79.8	31.1	147.2	440.9
Uttaranchal	28.0	140.9	150.0	75.0	38.1	11.5	173.4	616.7
West Bengal	21.8	109.9	80.0	82.7	87.0	0	408.1	789.5
Andaman and Nicobar Islands	0	0	0	0	25.6	0	25.6	51.2
Chandigarh	0	0	0	0	18.4	0	18.4	36.8
Dadra and Nagar Haveli	0	0	0	0	6.0	0	6.0	12.0

Source <www.Indiastat.com>

of Andhra Pradesh, and the consumer surplus/hectare/foreign tourists varies from 5.57 for Meghalaya to 0.035 for Andhra Pradesh. Of these tourists visiting different states, only a few would actually have visited the national parks. So we need to find the share of consumer surplus attributable to domestic and foreign tourists visiting the national parks. From column IX of Table 7, it can be seen that the states Tripura, Kerala, West Bengal, Himachal Pradesh, Tamil Nadu, and Karnataka have very high ecotourism values while the north-eastern states Arunachal Pradesh, Mizoram, and Andaman and Nicobar Islands have very low ecotourism values. North-eastern India has a very high proportion of endemic species and forest cover. Due to the inaccessibility of the forests, their full potential is not tapped. Table 9 gives the implied US dollar value of the

Table 9

Implied US dollar value consumer surplus per domestic and foreign tourists

States	*Implied aggregate US dollar value consumer surplus per foreign tourist*	*Implied aggregate US dollar value consumer surplus per domestic tourist*
Andhra Pradesh	1 118	178
Arunachal Pradesh	5 002	798
Assam	7 288	1162
Bihar and Jharkhand	1 493	238
Goa, Daman, and Diu	679	108
Gujarat	2 415	385
Haryana	351	56
Himachal Pradesh	11 139	1776
Jammu and Kashmir	2 651	423
Karnataka	5 430	866
Kerala	4 130	659
Madhya Pradesh and Chhattisgarh	1 943	310
Maharashtra	2 079	332
Manipur	3 573	570
Meghalaya	4 001	638
Mizoram	1 722	275
Nagaland	2 401	383
Orissa	3 994	637
Punjab	347	55
Rajasthan	3 430	547
Sikkim	4 244	677
Tamil Nadu	3 215	513
Tripura	1 715	273
Uttar Pradesh and Uttaranchal	5 223	833
West Bengal	5 980	954
Andaman and Nicobar Islands	2 151	343
All India	3 638	558

consumer surplus for domestic and foreign tourists. These figures give an approximate value of consumer's WTP to visit different ecotourism areas in different states.

Value of genetic diversity in Indian forests

One of the most important services that biodiversity provides to the economy is in the form of the genetic material. Modern pharmaceutical research has relied heavily upon plant-based genetic material to develop lifesaving commercial drugs that are marketed nationally and internationally. About 119 pure chemical substances taken from 90 species of higher plants are used internationally in medicines. In the developed world, some 25% of all medicinal drugs are based on plants or their derivatives, however, this number is three times higher in developing countries (Principe 1991 [to be included in references]). As per the WCMC (1992), 80% of the developing country inhabitants rely one way or other on traditional medicines. The plant-based drugs already exist in the market, but losing any one species may be a risky proposition because that species may potentially contain a new and useful chemical. Given the uncertainty how then do we estimate the value of genetic material in forests? Several approaches have been used in the literature to address this issue (Table 10).

For plant-based drugs already in the market, three approaches have been used to obtain the value of genetic material contained within them. The first approach looks at the values arising from traded plant material on the assumption that the market value represents the true WTP. The second approach uses the market value of plant-based drugs. The third approach estimates the value of plant-based drugs in terms of their life-saving properties.

However, these studies are for genetic material, which has already been discovered and mostly undervalued due to market imperfections. If we want to know whether the conservation of a species is worthwhile, we need to know the value of undiscovered genetic material. Several approaches have been used for this. One approach has been to simply look at the investment already committed by companies for the exclusive right to bioprospect. The best known example for such a transaction occurred in 1991 when Merck and Co., the world's largest pharmaceutical company, paid Costa Rica about 1 million dollars for the private rights to examine 2000 samples of the gene pool. This is in addition to promising to pay royalties associated with new commercial products. More recently, Glaxo-Welcome, the world's second-largest pharmaceutical company, signed an agreement with a Brazilian company for the right to screen 30 000 samples of compounds from plants, fungus, and bacteria. The value of the transaction was 3.2 million dollars in 1999 (Nunes and van den Bergh 2001).

A second approach has been to estimate the future expected returns to pharmaceutical companies if a new drug is discovered. The potential contribution of the unknown species to the new drug can be interpreted as the value of preserving a plant species. Such an approach has been used by Aylward (1993). He assumed that a genetic prospector is able to examine a wild area that contains over 10 000 different plant species to find one potential pharmaceutical product. Assuming a success rate of 1 in 10 000, on an average, one new drug source will be found by the end of one year. The net return on the new drug is calculated as the gross revenue net of costs associated with prospecting and development. The value of the plant species is estimated as the species success rate multiplied by the net return to biotic samples adjusted for the number of samples per species that are screened. If two samples from each species are screened, then the success rate for biotic samples (as opposed to species) is 1 in 20 000. Finally, the average net return per biotic sample is estimated.

All these procedures are likely to yield very low values for pharmaceuticals due to market imperfections. This is a major problem in developing countries like India where medicinal plants are collected at a very

Table 10

Estimates of the medicinal value of plants (2001 dollar value)

Study (to be included in references)	*Value*	*Comment*
Farnsworth and Soejarto (1985)	325 million dollars per plant-based drug, USA.	Value of prescriptions for plant-based drugs divided by 40 drugs based on plants. Average value.
Farnsworth and Soejarto, (1985)	2.6 million dollars per year per single untested plant species, USA.	Forty successful plants out of 5000 tested entails one success per 125 tested plants. Total value of plant-based drugs (298 million dollars) divided by 125 gives value of untested species. Average value.
Principe (1991)	0.5 million dollars per year per untested plant species, OECD.	Based on Farnsworth and Soejarto (1985), but with modified probability of success in deriving a drug from a plant test. OECD total value of 600 million dollars (1980 dollar value) × 1 in 2000 probability of success = 300 000 dollars per untested drug = 510 000 dollars per untested drug 1998 prices. Average value.
McAllister (1991)	10 355 dollars per untested tree species, Canada, per annum.	Three in 100 Canadian trees estimated to have marketable medicinal properties. Value of untested species = Annual global value of a drug = 250 000 dollars × 0.03 = 7500 dollars in 1990 prices. Average value (low value due to low assumed value of successful drug).
Principe (1991)	31 million dollars per untested species, OECD, per annum.	37.5 billion dollars annual value per successful species, divided by 1 in 2000 probability of success = 18.8 billion dollars per untested species, or 28.4 billion dollars in 1998 prices. Value based on value of statistical life saved of 8 million dollars (1984 prices).
Ruitenbeek (1989)	207 dollars per untested species per annum.	Assumed 10 research discoveries in Cameroonian rainforest each with patent value of 7500 dollars per annum. Divided by 500 species = 150 dollars or 190 dollars in 1998 prices. Note use of patent values as measure of value.
Pearce and Puroshothaman (1995)	810 to 1.45 million dollars per untested species, OECD, per annum.	Uses Principe and Farnsworth data. Lower value is private value and upper is social value based on VOSL of 7 million dollars.
Reid *et al.* (1993)	4–5014 dollars per untested species per annum, hypothetical deal (annualized at 5% over 20 years).	Royalty of 3% assumed, 1 in 10 000 success rate.
Artuso (1997)	Present value of 944 dollars per sample extract in terms of private WTP; 10 790 dollars per extract in social terms.	Detailed analysis of cash flows associated with sampling 25 000 extracts. Average value.
Mendelsohn and Balick (1995)	Net revenue to drug companies = 3.0 to 4.5 billion dollars from rights of access to all tropical forests. About 1 dollar per hectare.	Average value based on likely discoveries and their market value.
Simpson et al. (1994, 1996)	'Private' WTP of 0.02 to 2.5 dollars per hectare of 'hot spot' land.	
Simpson and Craft (1996)	'Social' WTP of 31.6 to 3148 dollars per hectare of 'hot spot' land.	
Rausser and Small (1998a)	'Private' WTP of 0 to 10,000 dollars per hectare of 'hot spot' land.	

OECD – Organization for Economic Cooperation and Development; VOSL – value of statistical life; WTP – willingness to pay

Source SCBD (2001)

minimal charge. The first method will undervalue genetic material and even the second approach will not represent the value properly because in India, almost 8000 plants are used in traditional medicines whereas only 88 species are traded in the market. There are many Ayurvedic practitioners who prefer processing medicine on their own and the value generated is not recorded anywhere. Even households use traditional plant based medicines. For example, most of the rural households in India use neem for cleaning their teeth and also as a pesticide. Similarly, turmeric, *tulsi*, pepper, and honey are used to cure minor health problems. All these values are unrecorded. The third approach (valuation in terms of the life-saving properties of the plant) may lead to overestimates and also suffers from other controversies regarding estimating the statistical value of life. The remaining two approaches are also likely to give very low values and will not reflect the social value of pharmaceuticals.

Due to the limitations in the existing studies, some recent studies focused on estimating the value of marginal species. In the pharmaceutical context, the relevant economic value is the contribution that one more species makes to the development of new pharmaceutical products (termed as marginal value). The marginal value is the incremental contribution of a species to the probability of making a commercial discovery.

The study by Simpson, Sedjo, and Reid (1994, 1996) falls in this category. The researchers argue that the marginal value of a species is more appropriate than the average values given by earlier researchers because they can take account of redundancy (substitutability) among natural components. The fundamental equation used by Simpson, Sedjo, and Reid (1994, 1996) to estimate the maximum WTP by a pharmaceutical company is

$$\text{Max WTP} = (\lambda/r)[(R - c)/(n + 1)]e^{-R/R-K} \quad (5)$$

Where

λ = expected number of potential products to be identified = 10.52

n = number of species that could be sampled = 2500

c = cost of determining whether a species will yield a successful product = 3600 dollars

r = discount rate = 0.1

e = natural logarithm = 2.718

K = expected R&D (research and development) cost per new product successfully produced = 300 million dollars

R = revenues from new product net of costs of new product sales but gross of R&D costs = 450 million dollars.

Substituting these estimates into the equation gives a maximum WTP of 9410 dollars for the marginal species. The value obtained is sensitive to the number of species chosen. For a lower number of species, the values are high, while the value approaches zero for a greater number of species. This value of marginal species, though interesting, offers little help in undertaking policy analysis unless it is translated in terms of value per hectare. This is because large tracts of land are converted from forests to non-forests and hence we need to find the biodiversity value per hectare if we are to take decisions on whether to conserve or convert this land. Rausser and Small (1998a) convert the value for marginal species to WTP per hectare for the so-called 'biodiversity hot spots' as follows.

- First, the species–area relationship was estimated using the formula $n = \alpha A^Z$, where n is the number of species, A is area, α is a constant reflecting the species richness potential of the area, and Z is a constant equal to 0.25.
- Second, the economic value V of the land area A is given by V [n (A)].
- Third, the value of a change in land area A is given by $\partial V/\partial A = (\partial V/\partial n) \cdot (\partial n/\partial A)$. The expression $\partial V/\partial n$ is the marginal value of the species, that is, 9410 dollars.
- Fourth, $\partial n/\partial A = Z\alpha A^{Z-1} = Zn/A = ZD$, where D is the density of species.
- Hence, the value of marginal land is given by value of marginal species × 0.25 × density of species.

However, using this approach, the marginal values were found to be extremely low (about 20 dollars per hectare). Rausser and Small supported the low values by arguing that (a) as biodiversity is abundant in these hot spots, the marginal value of extra species is lower, (b) there is redundancy, that is, once a discovery is made, finding a plant with the same chemical (or compound) has no value. Simpson and Craft (1996) argued that it is possible that these values represent only private values on the part of pharmaceutical companies hoping to use plant species as input into their production process. As biodiversity is a public good, it is possible that the social incentives for conservation may be quite high.

Simpson and Craft (1996) used the same approach as Simpson, Sedjo and Reid (1994, 1996) used but assumed that the species are differentiated (unlike the latter who assumed perfect substitutability between the two products) and estimated the social surplus (defined as the sum of profits and consumer surplus) as

$$V(n) = E(\pi)\,[(5 - 12\tau)/12n] \qquad (6)$$

where V (n) is the value of marginal species, E (.) is the expected present value, π is industry profits, τ is the ratio of R&D expenditures to total profits, and n is the number of species on which experimentation might take place. Assuming the following values, E (π) = 4 trillion dollars, $\tau = 0.375$, n = 10 million, the social surplus is estimated as 33 000 dollars. To analyse the impact of loss of a certain number of species, they used the following formula:

$$\int_{75000}^{10000} V(n)dn$$

They illustrated the effect of losing 25% of the species, and found the net present value of the social loss to be quite small (111 billion dollars), about 0.01% of the world's GNP (gross national product).

Rausser and Small (2000) pointed out that Simpson, Sedjo, and Reid (1996) obtained low marginal values for species because their assumptions were unrealistic. For instance, they assumed sampling without replacement from a large set of research leads and also assumed that each draw incurs some fixed costs. Two features of the process are key. The first is uncertainty; it is unknown prior to testing whether the given lead is good or bad. The second essential feature concerns the potential for redundancy among the leads. A lead that enables an innovation may not do so uniquely. They modified the Simpson, Sedjo, and Reid (1996) model in which the leads are differentiated by their expected quality and then tested sequentially. The insight they provide is that efficient search techniques will make the number of potential leads (actual species tested) smaller, thereby reducing R&D costs. In particular, with scientific data describing the nature of leads, it is possible to order them in such a way as to examine high-hit probabilities first and low-hit probabilities last. Testing is then done sequentially. If a particular test is successful, the company obtains a return and once a discovery is made, testing stops for the particular project. This implies that testing will be done first on the most promising leads and may never be done on leads for which the ratio of expected costs to returns is less than the probability of success.

The Rausser and Small model can be summarized as follows. A set of N leads is partitioned into K classes of varying quality. For n = 1, …, N, let k (n) denote the index of the class containing lead n. Let e_k be a measure of the quality of leads in the kth class, for k = 1… K. Hit rates are proportional to the lead quality: $p_n = \bar{p}e_{k(n)}$, where $\bar{p}$ is a constant. Given the financial parameters c and R and under the assumption of an optimal programme of search, the contribution v_n of the nth lead is given as follows in Equation 7.

$$v_n = \left\{ \left(\frac{a_n}{a - p_n}(p_n - p_n)R + \left[\sum_{i=n+1}^{N-1} \frac{a_i}{a - p_n}(p - p_i) \right] c \right) \right\} + a_n(p_n R - c) \quad (7)$$

The net present bioprospecting value of the nth lead is then given by

$$\sum_{t=0}^{\infty} \lambda(1+r)^{-t} v_n = \lambda v_n / r \tag{8}$$

The last term in Equation (7) is the scarcity rent of a lead. This is in fact the value of a marginal lead since it is the expected amount that would contribute to the value of a project if all leads were substituted for one another, ex ante. As long as the number of leads is finite and we expect that random screening is profitable, the scarcity rent will be positive. The first term in the brackets is the information rent. The first component of this term represents the increase in expected benefit associated with a higher probability of obtaining a hit before exhausting all leads. The second component in square brackets represents the drop in the expected costs of search that will no longer be needed if a hit is made earlier. Thus, information rent will depend upon a particular lead's success probability compared to the success probabilities of other leads. To estimate this model, we need information on the annual turnover of pharmaceutical companies that use plant-based raw materials, and also on their R&D costs, administrative and managerial costs, the probability of a hit, the number of species in each state, the endemic species and the species of medicinal importance, the number of leads, new drug approvals each year, and the discount rate.

Rausser and Small illustrated the model for the same hot spots considered by the earlier studies and used the same assumptions as Simpson, Sedjo, and Reid (1996). A single lead corresponds to land parcels of a uniform area (1000 hectares), where an investigator can collect biological samples. The quality of a parcel as a potential source of new drugs is defined as the density of endemic higher plant species in that ecosystem, measured as the average number of species per hectare. Other parameters in the drug discovery process are based on those developed by Simpson, Sedjo, and Reid (1994). The probability that the test of a site in ecosystem k will yield a discovery is taken to be $p = 1.2 \times 10^{-5}$. The probability that a project will terminate unsuccessfully, exhausting the available leads without yielding a discovery, is $\coprod_{k=1}^{18} (1 - \bar{p} e_k)^{N_k}$. Here, N_k denotes the number of sites in the ecosystem. Achieving a realistic yield of 10 new natural source drugs per year, therefore, requires that the project be launched at a rate of $\lambda = 26$ per year. Each successful discovery generates a return of R = 4500 million dollars. In the baseline case, costs are set at c = 485 dollars per test. The bioprospecting values for the Western Ghats and the eastern Himalayas in India using this method are 2026 dollars and 332 dollars, respectively. This they term as the WTP by the pharmaceutical companies per hectare (incremental value per hectare). The values associated with them on the highest quality sites are of the order of 9000 dollars per hectare. In this framework, the incremental value of a given lead, say the nth lead, can be thought of as the maximum amount that a firm would be willing to pay at the start of a search project for a call option on the nth lead.

Bioprospecting value of Indian forests

In this paper, we used the method suggested by Rausser and Small (2000) to estimate the bioprospecting value of Indian forests.[7] As the difference between the Rausser and Small approach and Simpson's method boils down to a difference in the choice of parameter values, we did a sensitivity analysis to see how the bioprospecting values change as we change the parameter values. The important information needed to estimate the model is the annual sales turnover of pharmaceutical firms using plant-based raw materials along with their operating expenditures and R&D costs. Though, in India, the highest volume of medicinal plants is consumed by the manufacturing sector, we do not have sufficient reliable data on the extent of their current consumption of specific raw materials. The overall turnover (domestic) of the manufacturing sector comprising around 8000 units is known to be about 42 billion rupees per annum. The total export turnover of the country for finished herbal products was estimated to be about 2.39 billion rupees per annum, whereas it was about 6.34 billion rupees with respect to the export of crude drugs and plant extracts. Based on the current commercial consumption levels (3.84 billion rupees) and the export level (4.63 billion rupees of only crude drugs), it is estimated that the commercialization of medicinal plant cultivation was to the tune of 8.47 billion rupees (in 2001/02) in India (EXIM 2001).

Global exports of medicinal plants and parts (primarily used in pharmacy, perfume, and insecticides) in fresh, dried, or powdered forms was of the order of 759 million dollars in 2001. This excludes India's exports estimated to be worth 100 million dollars. The major exporters were China, followed by India, USA, Germany and Korea. India is expected to be the second major exporter, accounting for over 10% of the global exports. Global imports of the medicinal plants and parts were estimated to be to the tune of 1 billion dollars in 2001. Medicinal plant exports from India in 2001/02 were worth 133.28 million dollars. The export of the top 10 medicinal plant products accounted for over 85% of the total exports. India exports mainly crude drugs and extracts, which account for nearly 70% of the total medicinal plant product exports. The remaining 30% are exported as finished products. Assuming that the industry witnesses a growth of 15% per annum, by the end of 2006/07, the export level of finished medicines would be worth 259 million dollars and crude drugs and extracts would be of the order of 111 million dollars (EXIM 2000).

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[7] We do not argue that the Rausser and Small approach is universally accepted and is better than Simpson's method of random search. The disparity between these researchers boils down to differences in assumptions about parameter values rather than the search process (Costello and Ward 2003).

To obtain the gross revenue, administrative costs, and the R&D expenditures of firms, we identified a list of 70 firms, which use plant-based raw materials and are listed on the stock market. We collected financial information relevant to these firms using their annual reports. The required details are given in Table 11. However, we could not get R&D expenditures for all the firms, but we could get the R&D expenditures for the top 10 firms. We used these R&D expenditures and extrapolated for other firms as well. In India, an average firm spends about 4.2% of its gross income on R&D.

The assumptions made to estimate the model are given in Box 1

Box 1

Assumptions made to estimate the bioprospecting value of pharmaceuticals

Number of projects implemented in India in a particular year (λ)	=	26
New annual drug approvals	=	10
Discount rate (r)	=	4%
Probability of hit (p)	=	1.2×10^{-5}

The search is carried out in parcels of 1000 hectares

As mentioned earlier, the results of the model are sensitive to various choices of parameters, the important one being the choice of species on which the search is carried out. Rausser and Small illustrated the model using species that are endemic to an area. However, in this paper, we considered three different scenarios. In the base scenario, we assumed that the search is carried out based on the estimated number of medicinal plants in each state (because the higher the number of potential medicinal plants, the greater the amount of information that the area has for potential leads). So the area with highest number of medicinal plants will be given first priority for identifying the leads and if the same species is found in any other forest, the value of the marginal lead is zero. In Scenario 1 we assumed that the search is based on the estimated number of total species present in forests (as there is a probability that any species can yield a drug). In Scenario 2, we assumed that the search is carried out based on the number of species of conservation importance. These three scenarios would give a low, middle, and high estimate. Moreover, we have considered only the area under dense forests in the model, as we believe that open forests are mostly monoculture plantations with very little species diversity. Table 12 gives the results for different states and also the estimates of dense forest cover as per 2001, the number of medicinal plants, species of conservation importance, number of identified species, the probability of a hit, the information rent, and the maximum WTP per hectare by pharmaceutical companies for the base scenario and the two alternate scenarios for different states. These three estimates give us the lower, middle, and upper bounds. We took the base model for adjusting the NSDP (net state domestic product) (see Table 13). However, we also explored the sensitivity of ESDP (environmental adjusted state domestic product) estimates to the high estimates of bioprospecting (see Table 14).

Table 11

R&D expenditure of firms (crores)

Companies	*Total income*	*Raw materials*	*Total expenditure*	*Adjusted net profit*	*R&D as % of turnover*	*Companies*	*Total income*	*Raw materials*	*Total expenditure*	*Adjusted net profit*	*R&D as % of turnover*
Alembic	565	258.5	484.3	33.9	3.9	Cebon India	15.4	11.7	13.2	1.2	4.7
Aurobindo Pharma	1312	802.1	1073.0	127.2	3.6	Cepham Organics	56.6	43.6	49.8	0.0	4.7
Biocon	673	351.3	463.7	174.2	11.1	Ciba CKD Bio-Mer	47.1	14.5	31.4	–4.8	4.7
Bombay Drugs-Mer	13	6.3	11.6	0.2	5.7	Clinigene Intl.	1.5	0.0	3.8	–2.9	4.7
Cadila Health	1176	460.4	944.1	141.1	7.5	Concord Drugs	1.4	1.1	1.7	–0.2	4.7
Cipla	1938	966.3	1489.8	310.5	3.0	Darshak	8.0	0.0	7.4	0.1	4.7
Dabur Pharma	242	70.1	208.5	19.7	8.5	Dee-Pharma	1.9	0.7	2.8	–15.0	4.7
Dey's Medical	46	15.5	43.3	0.6	1.2	Dr Reddy's Labs	1653.2	504.0	1503.6	63.4	4.7
Divi's Lab	366	174.7	247.6	72.9	2.5	Dr Sabharwal Mfg	6.3	3.0	5.6	0.2	4.7
FDC	305	133.5	220.4	61.3	1.8	Eupharma Labs	3.9	1.9	5.1	–2.2	4.7
Geoffrey Manners	152	121.7	145.2	3.8	0.3	Genomics Biotech	1.7	1.3	1.6	–0.1	4.7
Glenmark Pharma	375	125.2	301.7	42.1	9.7	Gufic BioScience	46.2	26.7	40.0	1.8	4.7
Hind Antibiotic	164	44.8	146.1	-9.0	1.1	Indian Drugs	11.3	3.4	101.0	–216.3	4.7
Indoco Remedies	164	67.4	129.5	21.2	1.1	Invinex Lab	20.7	18.8	20.2	0.2	4.7
Ind-Swift Labs	167	122.6	145.8	7.8	5.5	J B Chem & Pharma	376.0	126.2	295.0	59.2	4.7
Ipca Labs	675	303.0	544.9	79.7	4.2	Jayant Vitamins	55.3	18.9	35.0	13.7	4.7
Jagsonpal Pharma	173	98.3	155.7	7.7	0.4	JK Drugs & Pharma	45.1	32.9	58.4	–20.2	4.7
Lupin Labs (Merge)	508	270.8	423.6	31.4	1.9	Jupiter Bio.	67.5	42.8	40.3	15.2	4.7
Lyka Labs	63	37.0	53.4	-3.6	0.9	KDL Biotech	144.5	111.4	131.6	–3.0	4.7
Matrix Labs	591	275.6	410.7	126.0	3.1	Kopran	169.6	102.8	140.0	–2.0	4.7
Nicholas Piramal	1591	624.5	1300.1	97.8	3.9	Mercury Phytoch.	4.5	2.6	4.7	–0.7	4.7
Ranbaxy Labs	5847	2234.1	4839.4	728.2	4.7	Merind	71.6	21.1	61.9	1.8	4.7
RPG Life Science	126	42.6	107.9	–12.4	2.0	Morepen Labs	572.0	478.1	609.7	–97.0	4.7
Surya Pharma	166	126.5	143.0	6.0	2.7	Sri Krishna Drug	20.1	8.9	14.2	3.3	4.7
Themis Medicare	75	33.5	66.6	2.8	1.6	Supriya Pharma	8.1	3.6	6.6	0.9	4.7
Tonira Pharma	28	14.0	25.2	0.8	3.4	Synbiotics	18.4	10.0	20.4	–2.8	4.7
Torrent Pharma	523	202.4	440.1	52.6	8.9	Syngene Intl.	66.3	0.0	30.6	27.5	4.7
Triochem Product	0	0.2	0.3	0.0	8.9	Vardhaman Labs	0.5	0.2	0.5	–0.1	4.7
Unichem Labs	408	177.7	332.1	44.8	2.2	Welcure Drugs	14.2	7.8	13.3	0.2	4.7
Wintac	13	6.6	11.3	0.2	2.2	Avinash Drugs	0.1	0.0	0.2	–0.3	4.7
Wockhardt	884	339.9	609.3	208.2	7.9	Biddle Sawyer	33.8	11.6	19.9	8.8	4.7

R&D – research and development

Source Authors' compilation from companies' annual reports

Table 12

Marginal willingness to pay by the pharmaceutical companies for bioprospecting

State	Forest area (km^2) (1)	Model 1 Search based on number of medicinal plants: Density of species (2)	Model 1: Probability of a hit (3)	Model 1: Information rent (4)	Net bioprospecting value / hectare (5)	Model 2 Search based on number of species of conservation importance: Density of species (6)	Model 2: Probability of a hit (7)	Model 2: Information rent (8)	Net bioprospecting value / hectare (9)	Model 3 Search based on all species: Density of species (10)	Model 3: Probability of a hit (11)	Model 3: Information rent (12)	Net bioprospecting value/ hectare (13)
Andhra Pradesh	25 827	0.19	2.24E-06	6 954	7 134	0.02	2.14E-07	960.3	991	1.00	1.2E-05	43 547	44 643
Arunachal Pradesh	53 932	0.16	1.95E-06	5 668	5 816	0.02	2.85E-07	1 318.8	1 359	0.83	1E-05	33 448	34 291
Assam	15 830	0.76	9.14E-06	37 469	38 411	0.05	6.52E-07	3 170.6	3 257	1.91	2.29E-05	98 296	100 760
Bihar	15 159	0.46	5.54E-06	21 539	22 084	0.00	5.54E-08	161.8	173	1.75	2.1E-05	88 748	90 974
Goa	1 785	0.06	6.72E-07	0	6.16	0.04	5.38E-07	2 595.0	2 667	8.67	0.000104	508 219	520 932
Gujarat	8 673	0.81	9.69E-06	39 871	40 874	0.04	4.84E-07	2 324.9	2 390	2.43	2.91E-05	129 916	133 171
Haryana	1 139	0.44	5.27E-06	20 329	20 844	0.01	1.05E-07	413.7	431	10.77	0.000129	636 234	652 147
Himachal Pradesh	10 429	0.64	7.67E-06	30 977	31 758	0.07	8.51E-07	4177.1	4 289	2.77	3.32E-05	150 385	154 152
Jammu and Kashmir	11 848	0.21	2.53E-06	8 227	8 439	0.12	1.42E-06	7 034.4	7 217	3.59	4.31E-05	200 191	205 203
Karnataka	26 156	0.75	8.97E-06	36 724	37 648	0.04	4.22E-07	2 011.3	2 069	1.47	1.77E-05	72 008	73 815
Kerala	11 772	1.58	1.9E-05	81 083	83 116	0.24	2.85E-06	14 279.0	14 643	3.82	4.59E-05	214 355	219 721
Madhya Pradesh	82 264	0.27	3.3E-06	11 623	11 919	0.00	2.33E-08	0.0	7	0.28	3.38E-06	0	7
Maharashtra	30 894	0.39	4.66E-06	17 645	18 093	0.03	3.65E-07	1 723.9	1 774	0.81	9.76E-06	32 179	32 991
Manipur	5 710	0.75	9.04E-06	37 002	37 934	0.08	9.04E-07	4 440.4	4 558	4.16	4.99E-05	234 862	240 740
Meghalaya	5 681	1.54	1.85E-05	78 883	80 861	0.29	3.46E-06	17 355.6	17 796	5.28	6.34E-05	302 725	310 300
Mizoram	8 936	0.26	3.09E-06	10 689	10 963	0.01	1.34E-07	559.6	581	2.40	2.88E-05	127 960	131 166
Nagaland	5 393	1.80	2.16E-05	92 705	95 028	0.09	1.02E-06	5 045.0	5 178	4.51	5.41E-05	255 862	262 266
Orissa	27 972	0.36	4.29E-06	16 004	16 410	0.04	4.85E-07	2 327.4	2 393	0.94	1.13E-05	39 853	40 856
Punjab	1 549	0.32	3.87E-06	14 161	14 521	0.02	2.32E-07	1 054.5	1 088	11.90	0.000143	704 714	722 339
Rajasthan	6 322	0.08	9.49E-07	1 224	1 261	0.09	1.1E-06	5 435.3	5 578	3.02	3.63E-05	165 914	170 068
Sikkim	2 391	2.02	2.42E-05	104 264	106 876	0.68	8.18E-06	41 145.7	42 181	18.82	0.000226	1127 018	115 5200
Tamil Nadu	12 499	1.43	1.72E-05	73 178	75 014	0.35	4.23E-06	21 238.2	21 776	4.51	5.41E-05	256 145	262 555
Tripura	3 463	1.81	2.18E-05	93 295	95 633	0.01	1.04E-07	406.6	424	4.46	5.36E-05	253 235	259 573
Uttar Pradesh	27 988	0.47	5.59E-06	21 740	22 290	0.07	8.66E-07	4 250.8	4 364	1.52	1.82E-05	74 850	76 728
West Bengal	6 346	1.34	1.61E-05	68 130	69 840	0.06	7.56E-07	3 697.4	3 797	5.64	6.77E-05	324 590	332 712
Andaman and Nicobar Islands	6 593	1.52	1.82E-05	77 544	79 489	0.26	3.13E-06	15 673.0	16 072	3.79	4.55E-05	212 494	217 813
All India	416 551				22 646				3 456				144 539

Table 13

NSDP and ESDP for different states

States	NSDP (million rupees)	Dense forest (km^2) 2001	Dense forest (km^2) 2003	Change in dense forest cover between two years (km^2)	Net present value of ecotourism per hectare (from column X Table 7) (Rs/ha)	Net present value of bioprospecting per hectare (in rupees) (column 5 Table 12)	Annualized loss in non-use values per hectare per year (in rupees)	Gain/loss in value (in million rupees) per year	Loss as % of NSDP per year	ESDP (Rs millions)	ESDP/NSDP
Andhra Pradesh	1 439 754	25 827	24 379	–1 448	37 030.4000	7 134	–4 195	–7 392.10	–0.5	1 432 362	0.99
Arunachal Pradesh	17 395	53 932	53 511	–421	147.9800	5 816	51 107	50 981.90	293.1	68 377	3.93
Assam	317 208	15 830	13 042	–2 788	5 297.3200	38 411	–170 011	–176 104.30	–55.5	141 104	0.44
Bihar	787 033	15 159	14 708	–451	26 397.1900	22 084	146 002	144 908.80	18.4	931 942	1.18
Goa	67 356	1 785	1 255	–530	10 000.0000	6.16	0	–265.20	–0.4	67 091	1.00
Gujarat	1 144 047	8 673	6 345	–2 328	62 719.6300	40 874	0	–12 058.30	–1.1	1 131 989	0.99
Haryana	579 374	1 139	520	–619	7 590.5700	20 844	0	–880.00	–0.2	578 494	1.00
Himachal Pradesh	142 024	10 429	8 976	–1 453	272 310.3000	31 758	0	–22 090.50	–15.6	119 933	0.84
Jammu & Kashmir	128 052	11 848	10 497	–1 351	39 704.1800	8 439	0	–3 252.10	–2.5	124 800	0.97
Karnataka	1 004 063	26 156	22 461	–3 695	70 053.6600	37 648	–55 508	–75 406.30	–7.5	928 657	0.92
Kerala	696 021	11 772	9 628	–2 144	377 657.3000	83 116	–36 046	–85 441.10	–12.3	610 580	0.88
Madhya Pradesh	974 607	82 264	80 823	–1 441	5 267.0200	11 919	59 581	58 342.80	6.0	1 032 950	1.06
Maharashtra	2 632 253	30 894	28 387	–2 507	17 720.1500	18 093	–18 137	–22 626.00	–0.9	2 609 626	0.99
Manipur	32 048	5 710	6 538	828	29 830.2900	37 934	25 482	28 286.90	88.3	60 335	1.88
Meghalaya	38 423	5 681	6 491	810	248 567.1000	80 861	25 035	38 376.60	99.9	76 799	2.00
Mizoram	16 346	8 936	7 488	–1 448	471.3160	10 963	–23 234	–24 061.60	–147.2	–7 716	–0.47
Nagaland	34 272	5 393	5 707	314	333 001.6000	95 028	13 301	20 021.40	58.4	54 293	1.58
Orissa	387 373	27 972	28 170	198	31 492.4300	16 410	36 084	36 558.00	9.4	423 931	1.09
Punjab	629 678	1 549	743	–806	29 855.7300	14 521	0	–1 788.40	–0.3	627 889	1.00
Rajasthan	768 878	6 322	4 496	–1 826	145 501.7000	1 261	–28 674	–42 073.90	–5.5	726 804	0.95
Sikkim	10 387	2 391	2 362	–29	13 265.7500	106 876	2 028	1 853.80	17.8	12 240	1.18
Tamil Nadu	1 367 809	12 499	12 007	–492	210 641.2000	75 014	2 772	–4 255.30	–0.3	1 363 553	1.00
Tripura	56 603	3 463	5 046	1 583	1 188 593.7000	95 633	40 315	80 463.20	250.8	198 565	3.51
Uttar Pradesh	1 568 625	27 988	24 418	–3 570	64 989.2600	22 290	–111 407	–126 985.80	–8.1	1 441 639	0.92
West Bengal	1 537 807	6 346	6 045	–301	580 624.9000	69 840	45 505	35 715.90	2.3	1 573 523	1.02
Andaman and Nicobar Islands	10 507	6 593	6 284	–309	929.2365	79 489	0	–1 242.46	–11.8	9 265	0.88
Total	16 387 941	416 551	390 327	–26 224	65 192.9000	22 646	0.0	–147 460.00	–0.7	16 272 766	0.99

NSDP – net state domestic product; ESDP – environmental adjusted state domestic product; km – kilometres

Source Authors' computations

Table 14

NSDP and ESDP for different states based on high estimate of bioprospecting values

States	*NSDP* (million rupees)	*Dense forest* (km²) 2001	(km²) 2003	*Change in dense forest cover between two years* (km²)	*Net present value of ecotourism per hectare (from column X Table 7)*	*Net present value of bioprospecting per hectare* (in rupees) *(column 13 Table 12)*	*Annualized loss/gain in non-use values per hectare per year* (in rupees)	*Gain/loss in value* (in million rupees) *per year*	*Loss as % of NSDP per year*	*ESDP* (Rs millions)	*ESDP/ NSDP*
Andhra Pradesh	10507	6593	6284	–309	3781	44 643	0	–3380	–0.7	1429646	0.99
Arunachal Pradesh	1439754	25827	24379	–1448	143155	34 291	–4195	–10108	289.6	67778	3.90
Assam	17395	53932	53511	–421	68965	100 760	51107	50382	–58.3	132412	0.42
Bihar	317208	15830	13042	–2788	29259	90 974	–170011	–184796	18.2	930388	1.18
Goa	787033	15159	14708	–451	73710	520 932	146002	143355	–20.9	53286	0.79
Gujarat	67356	1785	1255	–530	93385	133 171	0	–14070	–2.0	1121245	0.98
Haryana	1144047	8673	6345	–2328	31844	652 147	0	–22802	–3.5	558955	0.96
Himachal Pradesh	579374	1139	520	–619	25862	154 152	0	–20419	–21.8	111042	0.78
Jammu and Kashmir	142024	10429	8976	–1453	400253	205 203	0	–30982	–12.9	111509	0.87
Karnataka	128052	11848	10497	–1351	343973	73 815	0	–16543	–8.2	921975	0.92
Kerala	1004063	26156	22461	–3695	273333	219 721	–55508	–82088	–14.4	595936	0.86
Madhya Pradesh	696021	11772	9628	–2144	1912380	7	–36046	–100085	6.1	1033808	1.06
Maharashtra	974607	82264	80823	–1441	186544	32 991	59581	59201	–0.9	2607759	0.99
Manipur	2632253	30894	28387	–2507	34901	240 740	–18137	–24494	114.5	68731	2.14
Meghalaya	32048	5710	6538	828	228173	310 300	25482	36683	124.1	86092	2.24
Mizoram	38423	5681	6491	810	848375	131 166	25035	47669	–200.4	–16418	–1.00
Nagaland	16346	8936	7488	–1448	4320	262 266	–23234	–32764	66.1	56919	1.66
Orissa	34272	5393	5707	314	1870271	40 856	13301	22647	9.5	424173	1.09
Punjab	387373	27972	28170	198	98396	722 339	36084	36800	–4.8	599364	0.95
Rajasthan	629678	1549	743	–806	146020	170 068	0	–30313	–7.5	711392	0.93
Sikkim	768878	6322	4496	–1826	100408	115 5200	–28674	–57486	3.2	10720	1.03
Tamil Nadu	10387	2391	2362	–29	15479	262 555	2028	334	–0.6	1358940	0.99
Tripura	1367809	12499	12007	–492	796512	259 573	2772	–8869	273.7	211541	3.74
Uttar Pradesh	56603	3463	5046	1583	410785	76 728	40315	93439	–8.7	1431922	0.91
West Bengal	1568625	27988	24418	–3570	144046	332 712	–111407	–136703	2.1	1569567	1.02
Andaman and Nicobar Islands	1537807	6346	6045	–301	1263277	217 813	45505	31760	–32.2	7128	0.68
Total	16 387 941	416 551	390 327	–26 224	207 448	144 539	0	–8 571 003	–1.7	16 112 941	0.98

NSDP – net state domestic product; ESDP – environmental adjusted state domestic product

Source Authors' computations

Similarly, we estimated the bioprospecting value for different choices of discount rates, species densities, and different probabilities of hit. The results of the sensitivity analysis are given in Figures 4, 5, and 6. It is clear that the bioprospecting value varies depending on the assumption used. If the search is based on all species present in the forests, the WTP per hectare varies from 520 931 rupees in Goa (where the density is very high) to 7 rupees for Madhya Pradesh (where the density of plant species is very low). If the search is based on the estimated number of medicinal plants, the values range from 106 876 rupees (2669 dollars) in case of Sikkim to 6.2 rupees per hectare in case of Goa (Figure 6). Rausser and

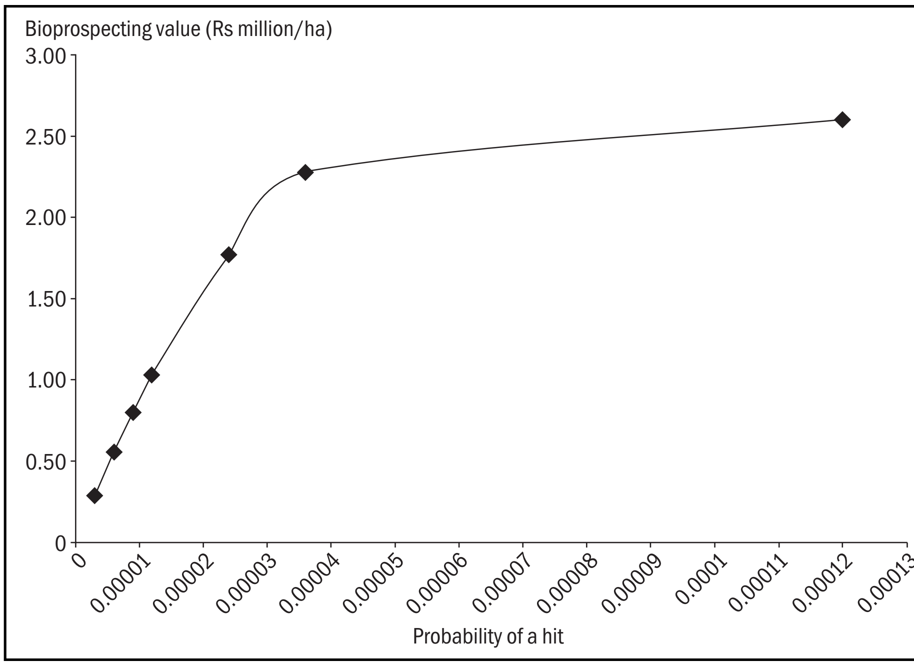

Figure 4

Bioprospecting value for different probabilities of hit

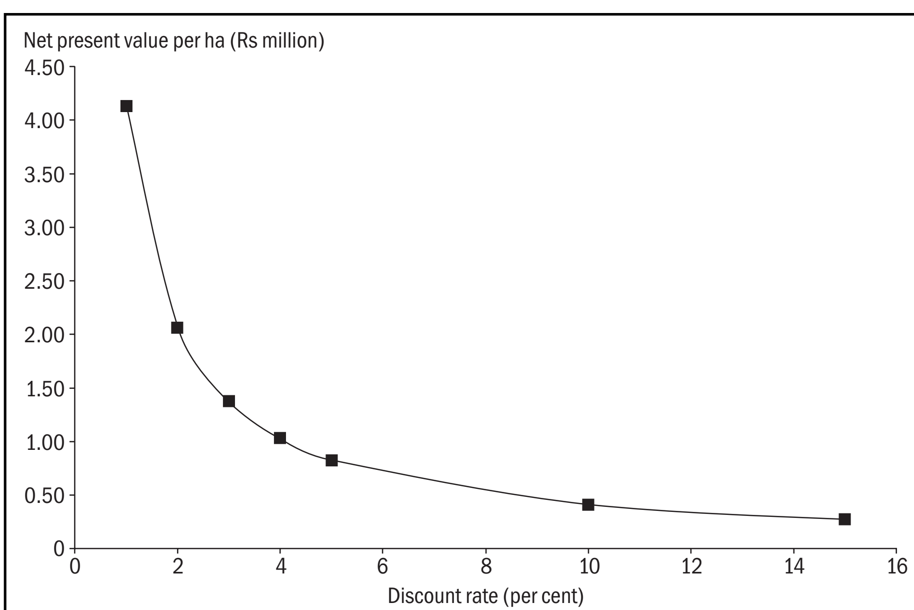

Figure 5

Bioprospecting value for different choices of discount rates

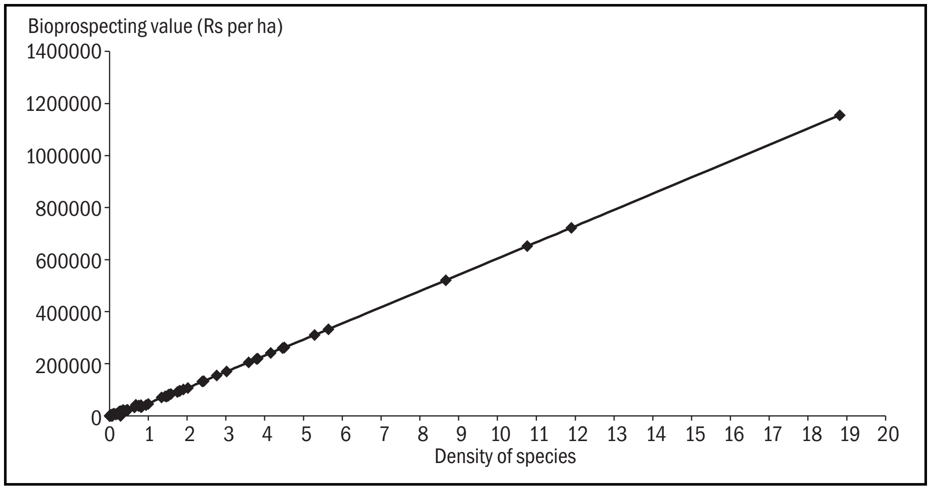

Figure 6

Bioprospecting values for different species density

Small (2000) estimated a value of 2026 dollars for Western Ghats and 332 dollars per hectare for Eastern Himalayas (for a discount rate of 10%).

Non-use values for conservation of biodiversity

In the earlier sections, we discussed the recreational value of fauna (use value) and the option value of biodiversity (for potential pharmaceutical innovation). However, apart from these values, there is a value that the global community would be willing to pay even if they never use the fauna. These values are the non-use values. This can be seen from the fact that over the past one decade, conservation of biodiversity has become an objective of international conventions, national governments, state agencies, NGOs (non-governmental organizations), local communities, school clubs, and individuals. Millions of dollars have been spent in the name of biodiversity and over 150 national governments have signed a treaty committing to biodiversity conservation (UNEP 1992). This is clear from Table 15, which gives an indication of the possible magnitude of WTP for these values by the global community for our national animal under the campaign 'Save the Tiger Fund' (values are also given for other countries where tigers exist). This fund has supported 271 projects in 13 out of the 14 tiger range countries with more than 13.6 million dollars through a partnership between the Exxon Mobil Foundation, the Critical Ecosystem Partnership Fund, and the National Fish and Wildlife Foundation (Table 15). The general public has also played an important role. Nearly 2 million dollars has been contributed by thousands of individuals—from schoolchildren to business professionals.

Several such initiatives are carried out in different countries for different endangered species. This shows the magnitude of the global WTP. Given the fact that people generally give preference to a few charismatic species, that is, species like elephants, tigers, lions, and pandas rather than the vast number of lesser-known species, we focus on WTP to conserve these flagship species due to their association with different habitats (for

Table 15

Country-wise breakdown of 'Save The Tiger Fund' investments

Country	*Investment in dollars*	*Grants (number)*
India	1 635 446	61
Nepal	1 261 327	23
Bhutan	251 277	5
Bangladesh	111 000	3
Cambodia	749 480	15
Lao PDR	125 000	3
Malaysia	503 548	9
Myanmar	248 265	5
Thailand	567 753	14
Vietnam	49 000	2
Sumatra	1 725 740	27
China	567 866	13
Russian Far East	2 961 516	59
Global Support for Tiger Conservation	2 870 667	32
Total	13 627 884	271

Source <http://www.nfwf.org/events/txlegends/fact_sheet_STF.pdf> (page 2)

example, tigers specific to India, the panda to China, and so on). These values need to be captured through a more systematic study. However, in the absence of non-user WTP for conserving endangered and threatened animals in India, we attempt to give a rough indication of the magnitude of these values for flagship species in India from existing estimates for other countries.

Kantolean and Swanson (2003) estimated WTP of people of OECD (Organisation for Economic Cooperation and Development) countries for the Giant Panda. In order to assess the nature of the derived demand, WTP for conservation of the giant panda was decomposed into two components: (1) its quantitative component (WTP for preserving the stock levels of the species) and (2) its qualitative component (WTP for the quality of the environment in which the species resides). For preserving the species in its natural habitat, the study found a mean WTP of 14.86 dollars per person and a median WTP of 10 dollars per person. In another study, Bandara and Tisdell (2004) estimated the WTP to conserve the Asian elephant based on a sample of urban residents in Sri Lanka. IUCN (1996) declared the Asian elephant to be one of the most endangered species of large mammals. Using a dichotomous choice method, the study elucidated the values for WTP to a trust that can conserve elephants. The study found that the mean annual WTP for the conservation of the elephant was 1322 Sri Lankan rupees. This amounted to about 0.933% of their personal income. In yet another paper, Mendonca *et al.* (2003) estimated the value of the three endangered Brazilian species namely the black lion tamarin, golden lion tamarin, and cuica using the upper and lower WTPs for various threatened and endangered species as reported in Loomis and White (1996) but adjusted for Brazilian purchasing power parity. They found that the management value of these three species amounted to about 10 dollars per household.

Unfortunately, we do not have any such studies in India. So in this paper, we try to illustrate the magnitude of non-use values for four flagship species—Asian elephant, Royal Bengal tiger, Asiatic lion, and one-horned rhinoceros. For the elephant, we take the values reported for the Asian elephant in Sri Lanka and we assume that the population WTP for the conservation is the urban population of India above 18 years of age (because of existence of these animals in other countries as well). However, for the Asiatic lion we have assumed that whole population in India above 18 years of age would be willing to pay for the conservation. For the Royal Bengal tiger and the one-horned rhinoceros (flagship species of India), we take the WTP values of the giant panda (which is also a flagship species confined to China) and we assume that the high-income community (above 18 years of age) would be willing to pay for its conservation. Based on these assumptions, the non-use values for these flagship species for different Indian states are given in Table 16.

Incorporation in the national accounts

Our final objective is to incorporate the ecotourism and bioprospecting values of forests into the national accounts. The bioprospecting values, ecotourism values, and the non-use values of the forests are given in Table 13. The difference in the asset values between two different periods gives the value of depletion to be deducted from the national accounts. In this paper, we assumed that only the dense forests have ecotourism, bioprospecting, and non-use values, because open forests are either in a degraded state or are mostly monoculture plantations with no possibility of fauna or new medicinal species.

The ecotourism values per hectare are taken from Table 7 and the average bioprospecting values are taken from Table 12 (search based on the number of medicinal plants) in order to estimate the loss in value due to changes in dense forest cover. We included the non-use values of forests from Table 16. Though this is not very accurate since the studies were not actually done for these species in our country, they do indicate the magnitude of global WTP to conserve globally recognized flagship species such as the tiger and the giant panda. Furthermore, to analyse the loss in non-use values due to changes in dense forest cover, we assumed that global WTP is constant, that is, at the all-India level, the difference in non-use values due to changes in forest cover is zero (because global WTP for tiger, Asiatic lion, elephant, and one-horned rhinoceros has been assumed to be constant). However, the corresponding state values reflect an increase or decrease in non-use values depending on how much dense forest cover the states gain or lose relative to other states. We have included all these three values together in the final table to quantify the loss due to the loss of dense forest cover. We have considered the change in

Table 16

Non-use values for species conservation

State	*Protected areas* (km^2) (1)	*Area under dense forests* (km^2) (2)	*Bengal tiger* (No.) (3)	*Asian elephant* (No.) (4)	*One-horned rhinoceros* (No.) (5)	*Asiatic lion* (No.) (6)	*WTP for species preservation* (million rupees) (7)	*Per hectare value of flagship species* (rupees per annum) (8)	*Present value per hectare* (rupees) (9)
Andhra Pradesh	13469.5	25 827	1	1	0	0	45 196	17 500	437 488
Arunachal Pradesh	10074.6	53 932	1	1	0	0	94 378	17 500	437 488
Assam	2866.0	15 830	1	1	1	0	158 812	100 323	2 508 080
Bihar	5428.7	15 159	1	1	1	0	152 080	100 323	2 508 080
Goa	755	1 785	0	0	0	0	–	–	–
Gujarat	17082.3	8 673	0	0	0	1	103 023	118 786	2 969 645
Haryana	334.3	1 139	0	0	0	0	–	–	–
Himachal Pradesh	7095.3	10 429	0	0	0	0	–	–	–
Jammu and Kashmir	13973.7	11 848	0	0	0	0	–	–	–
Karnataka	6703.6	26 156	1	1	0	0	45 772	17 500	437 488
Kerala	2324.7	11 772	1	1	0	0	20 600	17 500	437 488
Madhya Pradesh	17204.8	82 264	1	1	0	0	143 958	17 500	437 488
Maharashtra	15685.6	30 894	1	0	0	0	44 627	14 445	361 134
Manipur	746.5	5 710	1	1	0	0	9 992	17 500	437 488
Meghalaya	301.7	5 681	1	1	0	0	9 941	17 500	437 488
Mizoram	975	8 936	1	1	0	0	15 638	17 500	437 488
Nagaland	222.4	5 393	1	1	0	0	9 437	17 500	437 488
Orissa	8952.6	27 972	1	1	0	0	48 950	17 500	437 488
Punjab	316.7	1 549	0	0	0	0	–	–	–
Rajasthan	9161.2	6 322	1	0	0	0	9 132	14 445	361 134
Sikkim	2049.1	2 391	1	1	0	0	4 184	17 500	437 488
Tamil Nadu	3305.4	12 499	1	1	0	0	21 873	17 500	437 488
Tripura	603.1	3 463	1	1	0	0	6 060	17 500	437 488
Uttar Pradesh	12627.3	27 988	1	1	1	0	280 785	100 323	2 508 080
West Bengal	2916.7	6 346	1	1	1	0	63 665	100 323	2 508 080
Andaman and Nicobar Island	1620.2	6 593	1	1	0	0	–	–	–
Total	156796	41 6551	19	17	4	1	1 288 104	30 923	773 077

km – kilometre

Source Authors' computations

dense forest cover between the 2001 and 2003 assessments to compute the loss or gain in ecotourism, bioprospecting, and non-use values of forests.

From Table 13 it can be seen that the loss in value is significant— the loss as a percentage of NSDP ranges from 147.2% in the case of Mizoram to a gain of 293.0% in the case of Arunachal Pradesh. The reason for such a huge increase in the value for Arunachal Pradesh is because of the increase in dense forest cover and also partly because the value of forest asset is much higher than the recorded NSDP. The reverse is the case for Mizoram, where we see a huge loss in NSDP as a result of loss in dense forest cover and partly because of low NSDP values. Similarly, the value of biodiversity loss in Kerala as a percentage of NSDP is about 12.3%, which is very high. This is not surprising as the loss in dense forest cover is 2144 km^2 (square kilometres) and Kerala is renowned for being 'God's own country' and so will have high non-use values along with the use values. Therefore, this loss in dense forest cover has a significant impact. Only in the states of Andhra Pradesh, Tamil Nadu, Goa, Haryana, and Maharashtra is the loss of biodiversity as a percentage of NSDP less than or equal to 1%. In Maharashtra, however, although there is a loss of 2507 km^2 of dense forest, this loss is translated into less than 1% of GSDP because of its high value. Similarly, the loss of biodiversity value as a percentage of NSDP in other states are 15.6% in Himachal Pradesh, 2.5% in Jammu and Kashmir, and 0.23% in Punjab. In Manipur, Meghalaya, Nagaland, and Tripura, where there has been an increase in dense forest cover, there has been an increase in asset value of forests ranging from 36% in case of Manipur to 98% in case of Meghalaya. In these states, the ratio of ESDP to NSDP is greater than 1, indicating that the asset value of forests has increased in these states. It should be remembered that these estimates are extremely sensitive to the choice of values of ecotourism, bioprospecting, and non-use values. If any of these values change, the estimates vary. The non-use values in our study may be taken as an upper bound.

There are certain data limitations and hence our estimates should be viewed cautiously. The bioprospecting values are sensitive to the number of species in different states, the number of estimated medicinal plants, the probability of finding a species useful for medicinal purposes, and also the underlying search model (whether the search is carried based on the estimated medicinal plants or the number of species, and so on). We tried to explore how the estimates of NSDP change if underlying search model is changed (that is, how the values change if the search is based on total number of species present). The results are presented in Table 14. It can be seen from Table 14 that the estimates are very different if a high value of bioprospecting is taken. In reality, it is not possible that each species will yield a successful drug. So these values should be only treated as an extreme upper bound. Similarly, the estimates of ecotourism are based on the 'benefits transfer approach'. In reality, we should carry out a primary survey at each of the national parks to get the consumer surplus per hectare per tourist. However, as this is not feasible in a top-down study like ours, we used estimates from existing studies. Further, we did not have the exact number of domestic and foreign tourists visiting the national parks. The figures used in this study are based on estimated values. The value of ecotourism may be higher or lower once we know the exact number of domestic and foreign tourists visiting the national parks. Similarly the non-use values are based on global WTP for some other species. We should, in fact, have taken studies of global WTP for these species. We also made an assumption that the global WTP for a particular species remains constant. The states lose or gain depending on the relative loss or gain in dense forest cover relative to other states.

Despite the limitations imposed by the assumptions in the model and the data, our study does indicate that the biodiversity benefits of forests are very material in the aggregate and significant with respect to national and state GDP. In particular, our study throws light on those states which need a strengthened focus on conservation policy and practice due to their exceptionally high biodiversity potential.

Appendix I

IUCN categories

Extinct

A taxon is EX (extinct) when there is no reasonable doubt that the last individual has died. A taxon is presumed extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range, have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

Extinct in the wild

A taxon is EW (extinct in the wild) when it is known only to survive in cultivation, in captivity, or as a naturalized population (or populations) well outside the past range. A taxon is presumed extinct in the wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range, have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

Critically endangered

A taxon is CR (critically endangered) when the best available evidence indicates that it meets any of the criteria A to E for critically endangered, and it is, therefore, considered to be facing an extremely high risk of extinction in the wild (<http://www.iucnredlist.org/info/categories_criteria2001.html>).

Endangered

A taxon is EN (endangered) when the best available evidence indicates that it meets any of the criteria A to E for endangered (<http://www.iucnredlist.org/info/categories_criteria2001.html>) and it is, therefore, considered to be facing a very high risk of extinction in the wild.

Vulnerable

A taxon is VU (vulnerable) when the best available evidence indicates that it meets any of the criteria A to E for vulnerable (<http://www.iucnredlist.org/info/categories_criteria2001.html>), and it is, therefore, considered to be facing a high risk of extinction in the wild.

Near threatened

A taxon is NT (near threatened) when it has been evaluated against the criteria but does not qualify for critically endangered, endangered, or vulnerable now, but is close to qualifying for or likely to qualify for a threatened category in the near future.

Least concern

A taxon is LC (least concern) when it has been evaluated against the criteria and does not qualify for critically endangered, endangered, vulnerable, or near threatened. Widespread and abundant taxa are included in this category.

Data deficient

A taxon is DD (data deficient) when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution is lacking. Data deficient is, therefore, not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data is available. In many cases, great care should be exercised in choosing between data-deficient and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, the threatened status may well be justified.

Not evaluated

A taxon is NE (not evaluated) when it is has not yet been evaluated against the criteria.

Source <www.iucn.org>

Appendix II

Biodiversity hot spots

Hot spots	*Plant species*	*Endemic plant species*	*Endemics as a % of world total*	*Original extent* (km^2)	*Remaining habitat* (km^2)	*% of habitat remaining*	*Mammals*					*EMT and CEC*
							Occurring	*Endemic*	*Threatened*	*CR*	*EX*	
Atlantic Forest	20 000	8 000	2.7	1 233 875	99 944	8	264	72	38	7	0	26
California Floristic Province	3 488	2 124	0.7	293 804	73 451	25	157	18	11	2	0	7
Cape Floristic Region	9 000	6 210	2.1	78 555	15 711	20	91	4	8	2	1	2
Caribbean Islands	13 000	6 550	2.2	229 549	22 955	10	89	41	18	2	19	20
Caucasus	6 400	1 600	0.5	532 658	143 818	27	131	18	13	1	0	3
Cerrado	10 000	4 400	1.5	2 031 990	438 910	22	195	14	21	0	0	4
Chilean Winter Rainfall - Valdivian Forests	3 892	1 957	0.7	397 142	119 143	30	68	15	12	1	0	6
Coastal Forests of Eastern Africa	4 000	1 750	0.6	291 250	29 125	10	198	11	18	4	0	8
East Melanesian Islands	8 000	3 000	1	99 384	29 815	30	86	39	23	4	3	24
Eastern Afromontane	7 598	2 356	0.8	1 017 806	106 870	10	490	104	74	6	1	53
Guinean Forests of West Africa	9 000	1 800	0.6	620 314	93 047	15	320	67	55	6	0	41
Himalaya	10 000	3 160	1.1	741 706	185 427	25	300	12	44	3	0	6
Horn of Africa	5 000	2 750	0.9	1 659 363	82 968	5	220	20	25	5	1	11
Indo – Burma	13 500	7 000	2.3	2 373 057	118 653	5	433	73	69	12	1	34
Irano – Anatolian	6 000	2 500	0.8	899 773	134 966	15	142	10	16	0	0	3
Japan	5 600	1 950	0.7	373 490	74 698	20	94	46	25	3	3	24
Madagascar and the Indian Ocean Islands	13 000	11 600	3.9	600 461	60 046	10	155	144	52	12	3	63
Madrean Pine - Oak Woodlands	5 300	3 975	1.3	461 265	92 253	20	328	6	25	3	0	2
Maputaland - Pondoland - Albany	8 100	1 900	0.6	274 136	67 163	24	194	4	16	1	0	2
Mediterranean Basin	22 500	11 700	3.9	2 085 292	98 009	5	226	25	34	3	2	12
Mesoamerica	17 000	2 941	1	1 130 019	226 004	20	440	66	48	5	3	33
Mountains of Central Asia	5 500	1 500	0.5	863 362	172 672	20	143	6	17	2	0	3
Mountains of South-west China	12 000	3 500	1.2	262 446	20 996	8	237	5	38	1	0	4
New Caledonia	3 270	2 432	0.8	18 972	5 122	27	9	6	3	0	0	3
New Zealand	2 300	1 865	0.6	270 197	59 443	22	10	3	3	0	2	3
The Philippines	9 253	6 091	2	297 179	20 803	7	167	102	49	7	2	54
Polynesia - Micronesia	5 330	3 074	1	47 239	10 015	21	16	12	9	4	2	12
South-west Australia	5 571	2 948	1	356 717	107 015	30	59	12	10	1	2	7
Succulent Karoo	6 356	2 439	0.8	102 691	29 780	29	75	2	9	2	1	1
Sundaland	25 000	15 000	5	1 501 063	100 571	7	380	172	80	14	2	72
Tropical Andes	30 000	15 000	5	1 542 644	385 661	25	570	75	68	6	0	17
Tumbes - Chocó - Magdalena	11 000	2 750	0.9	274 597	65 903	24	285	11	31	2	2	8
Wallacea	10 000	1 500	0.5	338 494	50 774	15	222	127	50	1	3	45
Western Ghats and Sri Lanka	5 916	3 049	1	189 611	43 611	23	140	18	34	3	0	16

CR – critically endangered; EX – extinct; EMT – Endemic Mammals threatened; CEC – critical and endangered; EBT – Endemic birds threatened; EAT – Endemic amphibians threatened

Source <www.biodiversityhotspots.org>

Biodiversity hot spots

	Birds					EBT and	Amphibians					EAT and	All protected areas	
Hot spots	*Occurring*	*Endemic*	*Threatened*	*CR*	*EX*	*CEC*	*Occurring*	*Endemic*	*Threatened*	*CR*	*EX*	*CEC*	*Area* (km²)	*% of original* extent
Atlantic Forest	934	144	79	15	0	66	456	282	16	4	1	18	50 370	4.1
California Floristic Province	340	8	12	3	2	6	46	25	10	0	0	8	108 715	37
Cape Floristic Region	323	6	8	0	0	0	46	16	11	3	0	9	10 859	13.8
Caribbean Islands	604	163	54	11	13	58	170	170	143	63	0	206	29 605	12.9
Caucasus	378	1	11	1	0	0	17	3	2	1	0	3	42 721	8
Cerrado	607	17	28	6	0	14	186	28	2	2	0	4	111 051	5.5
Chilean Winter Rainfall - Valdivian Forests	226	12	9	1	0	7	41	29	18	6	0	20	50 745	12.8
Coastal Forests of Eastern Africa	633	11	18	0	0	2	88	6	15	0	0	4	50 889	17.5
East Melanesian Islands	360	149	36	3	3	36	42	38	5	0	0	5	5 677	5.7
Eastern Afromontane	1299	106	71	4	0	37	229	68	63	4	0	31	154 132	15.1
Guinean Forests of West Africa	785	75	35	4	0	35	221	85	71	11	0	58	108 104	17.4
Himalaya	977	15	46	4	0	9	105	42	6	0	0	4	112 578	15.2
Horn of Africa	697	24	24	4	0	12	30	6	1	0	0	1	145 322	8.8
Indo – Burma	1 266	64	78	7	0	21	286	154	49	2	0	37	235 758	9.9
Irano - Anatolian	362	0	12	0	0	0	18	2	4	0	0	2	56 193	6.2
Japan	366	13	30	2	4	12	50	44	20	2	0	21	62 025	16.6
Madagascar and the Indian Ocean Islands	310	181	60	12	32	69	230	229	61	9	0	70	18 482	3.1
Madrean Pine - Oak Woodlands	524	22	18	2	1	9	200	50	113	32	0	54	27 361	5.9
Maputaland - Pondoland - Albany	541	0	13	1	0	0	72	11	8	1	0	7	23 051	8.4
Mediterranean Basin	489	25	23	5	1	12	79	27	17	1	1	15	90 242	4.3
Mesoamerica	1113	208	43	4	1	35	555	358	304	95	3	317	142 103	12.6
Mountains of Central Asia	489	0	12	0	0	0	7	4	1	0	0	1	59 563	6.9
Mountains of Southwest China	611	2	26	0	0	2	90	8	30	3	0	5	14 034	5.3
New Caledonia	105	23	10	3	1	10	0	0	0	0	0	0	4 192	22.1
New Zealand	195	86	71	7	20	70	4	4	4	1	0	5	74 260	27.5
Philippines	535	186	61	11	0	67	89	76	48	1	0	49	32 404	10.9
Polynesia - Micronesia	292	163	96	22	40	112	3	3	1	0	0	1	2 436	5.2
Southwest Australia	285	10	5	0	0	3	32	22	3	1	0	4	38 379	10.8
Succulent Karoo	226	1	9	0	0	0	21	1	2	0	0	1	2 567	2.5
Sundaland	769	142	63	9	2	50	244	196	60	4	0	63	179 723	12
Tropical Andes	1724	579	160	15	0	124	981	673	448	115	2	466	246 871	16
Tumbes - Chocó - Magdalena	890	110	52	6	2	26	203	30	43	7	0	9	34 338	12.5
Wallacea	647	262	51	7	0	56	48	33	8	0	0	7	24 387	7.2
Western Ghats and Sri Lanka	458	35	26	2	0	10	178	130	97	21	20	108	26 130	13.8

Appendix III

Micro-endemic centres of plants

1 Andaman Group of Islands
2 Nicobar Group of Islands
3 Agashtyamalai Hills
4 Anamalai and High Ranges
5 Palani Hills
6 Nilgiris–Silent Valley, Wayanadu, Kodagu
7 Shimoga–Kanara
8 Mahabaleshwar–Khandala Ranges
9 Konkan–Raigad
10 Marathwada–Satpura Ranges
11 Thirupati–Cuddappa–Nallamalai Hills
12 Vishakaptnam–Ganjam–Jeypore Hills
13 Southern Deccan (leeward side)
14 Chottanagpur Plateau
15 Kathiawar Kachchh
16 Rajasthan–Aravalli Hills
17 Khasia–Jaintia Hills
18 Patkoi–Manipur–Lushai Hills
19 Assam
20 Arunachal Pradesh Himalayas
21 Sikkim Himalayas
22 Garhwal–Kumaon Himalayas
23 Lahul–Himachal Pradesh Himalayas
24 Kashmir–Ladakh Himalayas

Source Nayar (1996)

Appendix IV

Hot spots of Indian Flora

1 Andaman Group of Islands
2 Nicobar Group of Islands
3 Agastyamalai Hills
4 Annamalai and High Ranges
5 Palani Hills
6 Nilgiris–Silent Valley, Wayanad, Kodagu
7 Shimoga–Kanara
8 Mahabaleshwar–Khandala Ranges
9 Konkan–Raigad
10 Marathwada–Satpura Ranges
11 Tirupati–Cuddappa–Nallamalai Hills
12 Visakhapatnam–Ganjam–Jeypore Hills
13 Southern Deccan (leeward side)
14 Chotanagpur Plateau
15 Kathiawar Kutch
16 Rajasthan–Aravalli Hills
17 Khasia–Jaintia Hills
18 Patkoi–Manipur–Lushai Hills
19 Assam
20 Arunachal Pradesh Himalayas
21 Sikkim Himalayas
22 Garhwal–Kumaon Himalaya
23 Lahul–Himachal Pradesh Himalaya
24 Kashmir–Ladakh Himalaya
25 Nepal
26 Eastern Himalaya plant gene pool
27 Khasi jaintia–Lushai plant gene pool
28 Central Indian plant gene pool
29 Eastern Ghats plant gene pool
30 Southern Western Ghats plant gene pool
31 Northern Western Ghats plant gene pool
32 Western Himalayan plant gene pool
33 Sandstone flora of Dun and Mussorie
34 Myristica swamps of Kerala
35 Sea grasses of Coromandel Coast
36 Mangroves of Sunderbans
37 Mangroves and Coral reefs of Andamans
38 Wetlands flora of Chilka Lake
39 Cold desert flora of Ladakh
40 Lakshadweep coral reefs and algal flora

Source Nayar (1996)

Appendix V

Estimated number of medicinal plants in the biogeographic zones of India

Biogeographic region	*Estimated number of medicinal plants*
Trans Himalayas	700
Himalayan	2500
Desert	500
Semi-arid	1000
Western Ghats	2000
Deccan Peninsula	3000
Gangetic Plain	1000
North-east India	2000
Islands	1000
Coasts	500

Source Ved, Prathima, Morton, *et al.* (2001)

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Green Accounting for Indian 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 4

This study is part of a larger exercise to build an empirical framework that will allow and enable informed policy judgements to be made on key aspects of national wealth (so-called 'externalities' such as the creation or depletion of natural capital and human capital) which are as yet not formally integrated into national accounts and GDP measures. Our other monographs have covered some of the economic benefits of forests, e.g., carbon storage, timber production, non-timber forest products, and ecological services such as flood damage mitigation, prevention of soil erosion, and groundwater recharge. This monograph evaluates the unaccounted economic value of India's bio-diversity, in particular, eco-tourism, bio-prospecting, and the 'willingness to pay' for preserving flagship species in the wild. We find that these values are significant, both as 'per-hectare' accumulations of natural capital as well as negative annual adjustments to GSDP (State) and GDP (National) accounts for those states which have been losing forest cover. The authors recognize the limitations placed by the paucity of data and the need for modelled solutions to address some of these limitations, but it is noted that the values of bio-diversity so derived are conservative, and should be treated as a lower bound.

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