

CHAPTER 3

VALUATION OF THE FLOW OF GOODS AND SERVICES FROM FORESTS IN INDIA

3.1 Introduction

The objective of this study is to assess the contribution of the forestry sector to GDP in India. Extension of the concept of capital to include natural capital and its contribution to the economic activity in a country make this imperative. From Chapter 1, we know that the SNA 1993, which now forms the basis of the Indian system of national income accounts sets up production and asset boundaries which make this possible. Chapter 2 documents the studies in other countries that have tried to do this. We find that the consensus at the international level is that:

"Complete accounting of forest related economic benefits may turn out to be impossible in any single country. Making the adjustments every year might turn out to be impossible too.---

----- A pragmatic recommendation is to orient the accounting effort towards those values of forests that are of obvious economic significance now and are likely to remain so in the future and to prepare adjusted national accounts as a special product every few years"

(Vincent, 1999).

In India, we have a long way to go to enable this to be done. As is clear from the last section of Chapter 2, the forestry sector production estimates are based on a number of ad hoc assumptions with regard to its production structure. However, the positive aspect is the proliferation of studies on the valuation of goods and services in the forestry sector in India and the existence of long series of data on some aspects of forests stocks and flows. Using these two starting points and framing our methodology within the SNA 1993 guidelines, we shall, in the next three chapters, attempt the task of

- assessing the contribution of this sector to GDP on an annual basis,
- setting up an asset account from the viewpoint of different dimensions of forest stock (growing stock, species diversity and biomass) and their varying contribution to human well-being.

3.2 Unit of accounting, and the nature of production

The forestry sector can be defined to cover all economic activity due to the existence of land under forest cover. This is estimated to be about 62 million hectares in India even though land under the legal control of the forest department is more than 75 million hectares. Satellite imagery based estimates of forest area and its distribution are available since the late eighties¹. The consensus in this regard is that area under forest cover has remained more or less constant since then, even though its distribution by size class of density may have undergone changes. In this chapter, however, our concern shall be with the value of the major flows of goods and services obtained from this forest-covered area and accruing as output to people in India or abroad. The following aspects of this production activity are of relevance here:

- parts of the output such as timber production may have varying gestation periods depending on the species involved. The output in any one period is a kind of weighted average of outputs with different gestation periods as well as prices (both due to species variation and consumer preferences).
- Other parts such as non-timber forest products may again have cyclical production (sal seeds, resin etc.)
- Services accruing from the forestry sector (such as eco-tourism and carbon sequestration) may be subject to cross sectional variations in prices
- Some eco-system services may not have a market price at all and may need to be valued in terms of alternative valuation techniques, now being developed in the context of the literature on natural resource valuation

Keeping in mind, the above conceptual and practical problems, we suggest that

- unit of accounting for forest resource be the forestry sector I.e. land under forest cover.

¹ These together with information on different aspects of the forest wealth of India are discussed in Chapter 6 as a part of asset accounting

2. See for instance Hadker et al. (1995) for the Borivilli Park in Mumbai, Chopra (2001) for the Keoladeo park in Delhi, Manoharan (1996) for the Periyar Tiger Reserve in South India and Rana (2000) for a sacred lake in Sikkim. Some of these studies are listed in Manoharan (2000) and in MOEF (1999).

- To the extent that this land is leased out, such as to private contractors for logging, these awardees become co-units of management.
- where-ever property rights to forest based products or services exist,(such as to food products or to grazing or game) the right-holders are co-managers.
- When services are used by non-managers such as tourists or the general residents of a nation or the world (as with tourism and carbon-sequestration services) the annual flows of these services be a part of the output of the forestry sector.

In the treatment of production of the forestry sector, different components are viewed as forming parts of a joint production process, with common costs of production. With this structure in mind that this chapter reviews and improves CSO methodology and/or sets up new methodology for valuing the gross annual flows of production of goods and services from the forestry sector to GDP. All aspects of costs corresponding to them are studied in Chapter 4.

Further, it is recommended that forest satellite accounts be set up once in five years. Wherever precise information on annual (gross and net) flows is not available, these are estimated so as to represent average and expected values of these flows as derived from available data and the use of appropriate econometric tools. These yield representative values that use information from a number of studies conducted in different forest. These shall provide a beginning to the process of using available studies, data and techniques to extend the scope of income accounting to include resource accounting in the interests of appropriate policy making. In the next sections, we take up, one at a time, the methodology and estimates with respect to the more significant flows that can be accounted for with the present state of knowledge.

3.3 Values of Annual Extraction of Timber and Fuel-wood

Timber and fuel-wood are the two major forest products, which the CSO includes in its estimates of contribution of the forestry sector to GDP. Adequate coverage of extraction is expected but does not always exist. With reference to fuel-wood, this has been extensively commented on and this has resulted in substitution of the consumption approach for the production approach in estimation

Data on extraction is reported in Forestry Statistics and is implicit in the CSO's estimates as well. It consists of data on extraction of timber, rounded wood and poles. Forestry statistics data is however incomplete as extraction is not reported from some states. The coverage is also not uniform across states. These aspects need improvement. However, timber extraction, after 1990 shows a downward trend for the country as a whole as is evident from Table 3.1. The reported extraction from different states has gone down from 4.039 million cubic metres to 2.101 million cubic metres. Note however, that for 1997-98, important timber extraction states such as the north-eastern ones are not reporting any production. Even after the ban on green felling above a certain altitude, these states must have had some timber extraction.

The above is a very significant lacuna. To get over this, we shall recommend using a trend instead of the actual for value of timber extraction. Another important issue in this context is the question of whether current levels of extraction are sustainable. The FSI (1995) gives a figure of 0.5 cubic metres per hectare as sustainable extraction from forests managed for timber. However, area managed for timber is a part of Forest Working Plans and constitutes a part of planted as well as mature forests, depending on the plan. This area varies as between different parts of the country and also from year to year for the same Working Plan. At the All-India level, our estimates of plantations of different species more than ten years of age cover about 9 million hectares and should be able to yield about 4.5 million cubic metres of timber of different species. This is in the neighbourhood of extraction reported for years in which most Indian states provide data.

However, such a macro-level approach needs to be supplemented by a regional picture of extraction and species wise rotation periods. In all situations where over extraction is expected, the capital stock is being eaten into and present use has a future cost. This cost can be estimated by using the principle of "user cost". This study does not attempt such an exercise in the absence of detailed and accurate regional level data on different aspects.

Table 3.1 Extraction of Timber in the Indian States.

(Cu m)

States	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
Andhra Pradesh	51639	45085	41633	32821	49931	22339	42228	44923
Arunachal Pradesh	212786.5	372496.9	345052				31005.44	
Assam		21120	45545.1	68328.54	47058.93			
Bihar	169545	112553	162505	147735	147735	147229	66000	41178
Delhi								
Goa	135.178	383.338	306.809	292.658	519.026	193.197	458	764.11
Gujrat	25125	53000	24250	37375	42500	3600	32800	37500
Haryana	61234	58697	55773	81082	53308	53006	47795	45706
Himachal Pradesh	312281	356379	390992	371246	449673	425784	451141	460683
Jammu & Kashmir	154000	48000	37000	116000	34050	112880	63100	69274.2
Karnataka	148188	220687	220978	169335	89207	60192	86015	79166
Kerala	39000	42000	51554		123501.2	61429.54	51971.92	19000
Madhya Pradesh	685114	732035	569176	513338	609245	517000		674558
Maharastra	99954	104434	90176	90006	64555	85534	78450	88880
Manipur	25511	13373	13540	8817	12874.77	22366.3		
Meghalaya	2243	1606	1085	4041	483125.6	461748	2131.51	945.25
Mizoram	303404	79193	69789	62172	21800	128400	10486.34	24945
Nagaland	806603	687610			60467.29	62467.2	304546	24945
Orissa	186000	106000						52787.6
Punjab	53681	65554	54724	76738	59431	79144	55711	103245
Rajastan					931	1330	1719.69	2090.12
Sikkim							45.8	15
Tamil Nadu	716	37863	1259	2840	7492	5385		
Tripura	52967	21473			5856	1506		512.8
Uttar Pradesh	486050	520974	410330	469962	337196	403203	185737	330089
West Bengal	88252	94754	117164	84489	84903	8855	86363	88728
A&N Island	80581	85713	102143	101861	100653	97279	92465	
Chandigarh		43.39						
D&N Haveli			132.062	304.481	213.244			
Lakshadweep								
Pondicherry								
India	4039985	3870427	2800257	2431309	2877726	2760870	1611724	2101055

Source: Forestry Statistics of India: (1987-94, 1995, 1996, 2000), ICFRE.

The second component determining value of timber is prices. In the main, forests are worked on for timber by Forest Corporations and sometimes by private contractors. The proportion of the two varies from state to state. Prices derived from data in the Forestry Statistics are a combination of auction prices from government corporations and market prices. A series of this is presented in Table 3.2 for different states in India. This database gives us a ten-year series, which shows a rising trend as illustrated in Figure 3.1

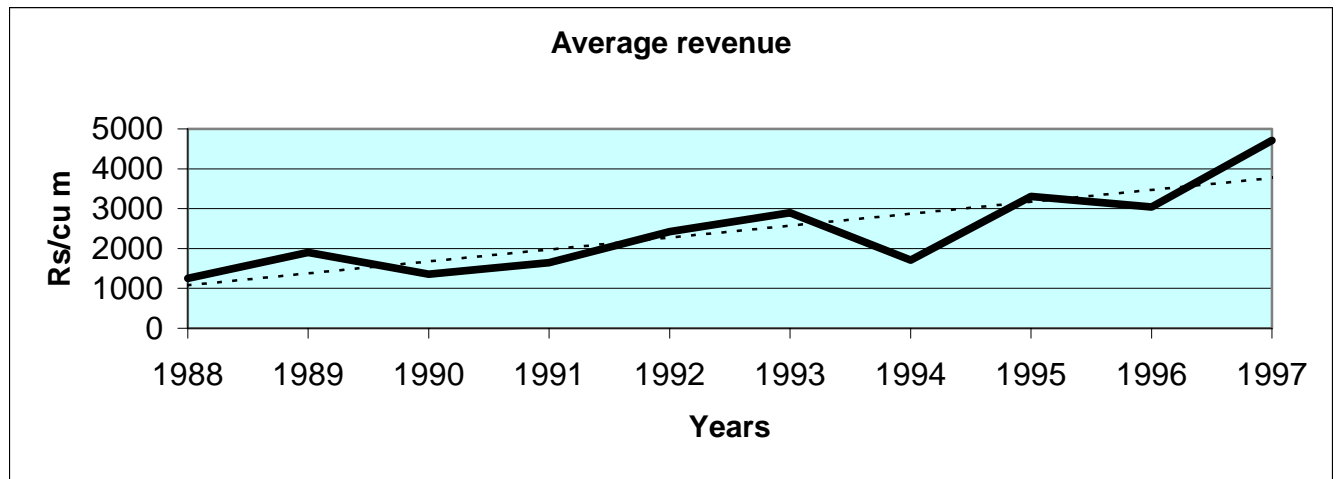
Table 3.2 Average Revenue obtained from timber extraction by the States of India

(Rs per Cu m)

States	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
Andhra Pradesh	3825.345	4818.299	5695.602	6845.343		9189.982	4080.302	4587.539
Arunachal Pradesh	776.9526	458.6052	539.5013				5715.481	
Assam			2511.532	2124.866				
Bihar	1.887405	4.975434					1450	2718.393
Delhi								
Goa	466.0522	2376.493	1525.379	1113.928	1822.64	3773.351	4707.424	2718.195
Gujrat	3929.592	4899.604	3838.268	4876.736		63674.72	36.58537	41.30667
Haryana	883.7901	1024.686	1226.292	1271.343	2290.74	1435.932	1791.338	2206.866
Himachal Pradesh	325.348	486.2801	319.1881	1476.11		823.2249	695.962	650.2476
Jammu & Kashmir	912.5584	3381.938	7170.649	170.0345	568.516	224.0078	278.3201	7550.841
Karnataka	2632.285	1876.604	1944.026	3440.919	6963.57	9913.278	7391.734	8583.23
Kerala	7596.333	11026.45	13179.64			22612.67	26164.82	65239.74
Madhya Pradesh	3251.722	3777.005	5074.704	6472.539	5571.97	7229.787		6886.732
Maharashtra	5943.734	4763.774	4345.946	5327.423		6776.393	8463.99	8771.377
Manipur	227.8625	725.1926	845.3471	1183.282	388.123	608.9519		
Meghalaya	905.9296	1410.959	2061.751	2042.069	8.69960		2124.785	2272.415
Mizoram	4.943903	24.85068	48.9762	29.917	147.018	24.47819	581.9952	6366.967
Nagaland	57.80043	57.80021				351.3679	42.50589	423.7723
Orissa	894.2634	1328.915						1870.572
Punjab	585.3095	612.0908	1041.39	1251.727	936.3632	1935.914	938.4861	1964.444
Rajastan						1353.383	1503.759	1503.741
Sikkim							4366.812	6666.667
Tamil Nadu	17645.25	319.1242	7868.149			10342.25		
Tripura	494.9686	1412.006			1588.969	2390.438		4869.345
Uttar Pradesh	1090.82	1008.889	1600.814	1530.66		1460.783	3435.169	1691.329
West Bengal	1997.462	2237.784	2013.246	3280.545	4550.84	38344.44	4302.884	3001.826
A&N Island	1564.637	1981.345	1945.557	2510.588	2888.419	2848.076	3030.401	
Chandigarh		1152.339						
D&N Haveli			3574.079	5809.886	8581.719			
Lakshadweep								
Pondicherry								
Average for India	1356.706	1645.615	2425.418	2895.101	1707.812	3304.37	3042.313	4708.486

Source: Forestry Statistics of India: (1987-94, 1995, 1996, 2000), ICFRE.

Figure 3.1 Trend in the average revenue from Timber extraction from 1987 to 1997.



Source: Data source for the above figure is same as that of Table 3.1.

The broader line is the average revenue series and the dotted line is the linear trend line fitted to the series.

The equation for the above trend line is given by: -

$$\text{AVERAGE REVENUE} = 1306.74775 + 379.7085357 * (@\text{TREND} (1988))$$

We also have independent estimates of market prices for different species of timber collected from the Timber and Bamboo trade bulletins for the relevant periods. The average price per cu m of timber species is quite high at Rs 24804 as the species that has been mentioned above are the best of the timber species. Grade II of each timber species and an average dimension with mid-girth, and length specification was chosen to arrive at a single price for that species. Prices differ according to size and species and the variation is often in few thousands rupees per cu m. The average price is also the weighted average of timber prices where the relative abundance of a stratum (here referred to as species) in the total growing stock (sum of all stratum) is used as weights.

Table 3.3 Prices of selected timber species in the available forest stratum in different States of India, June 1999.

(Rs per cu m)

States	Most prominent timber species from the available forest Stratum.	Average Price
Andhra Pradesh	Teak	38000
Arunachal Pradesh	Teak	10190
Assam	Sal	17500
Bihar	Sal	25760
Gujrat	Teak	35805
Haryana	Sal	24700
Himachal Pradesh	Deodar, Chir-pine	22356
Jammu & Kashmir	Deodar, Chir-pine	13673
Karnataka	Teak	20000
Kerala	Teak	35073
Madhya Pradesh	Teak, Sal	20854
Maharastra	Teak, Sal	35710
Manipur	Sal, Deodar	24557
Meghalaya	Teak Sal	18820
Orissa	Teal, Sal	18681
Rajastan	Teak	30160
Sikkim	Sal	17500
Tamil Nadu	Teak	50145
Tripura	Teak, Sal	26286
Uttar Pradesh	Teak, Sal, Deodar, Chir-pine	19695
West Bengal	Teak, Sal	25696
Average for India	Teak, Sal, Deodar, Chir-pine	24804

Source: Timber and Bamboo trade bulletin June 1999, ICFRE.

Variations in the species-specific prices and also by quality of timber are very high. The above table gives an average all India price for the better timbers. A large part of the total timber extraction may however be from the miscellaneous forest stratum, which constitutes a large part of total forest stock in India. Table 3.3 which puts together market prices of 7 important timber species in South zone of Himachal Pradesh for the years 1994-95 provides an approximation to the range of variation from about Rs. 1091 per cubic metre for eucalyptus to Rs. 11780 per cubic

metre for deodar. The average figure which is a weighted average for the region is Rs 5541 per cubic metre.

Table 3.4 Prices of important timber species in South Zone of Himachal Pradesh.
(Rs per cu m)

Species	1994-95	1995-96
Deodar	9502	11780
Kail	5442	6839
Fir	3699	4466
Chil	3238	3481
Shisham	3901	2846
Sal	5192	3272
Sain	2821	2702
Kokat	1134	1202
Eucalytus	1091	1087
Simbol		1307
Neeja		2060
Popular	1124	1523
Sirse		1523
Mulberry		1523
Kikar		1523
Goldmore		1523
Mango		1523
Average		5541

Source: Chopra Kadekodi (1997).

Notes: The period of reference is April to March.

A comparison of the three data sources is revealing. Prices implicit in the Forestry Statistics data seem to be close to the weighted average for seventeen species. Timber and bamboo Trade Bulletin gives high ranges since this source refers to the superior qualities of timber. A comparison of prices in different data sources is made in Table 3.5. On balance, prices implicit in the Forestry Statistics are closer to market prices than the other series

Table 3.5 Comparing Timber prices across sources.

(Rs per Cu m)			
Sources	Timber and Bamboo Trade Bulletin (1999)	Chopra Kadekodi (1997)	Forestry Statistics of India. (2000)
Method	Average price of two major species in Himachal	Average price of 17 major species in Himachal Pradesh in 1995-96.	Obtained by taking means of the average revenue for different states in the year 1995-96.
Prices	22356	5541	3304 for India

Notes: The prices of course do not refer to the same grade of timber species and neither do the year of assessment match, so comparison might not be justified, still this table will give an idea of how much the average revenue vary from the average price of selected species. This table further shows that the average revenue for India in any year is lying with the prices suggested in the micro studies. The average revenue column is the most generalized timber prices followed by Chopra and Kadekodi's studies that mention around 17 species, while the Timber and Bamboo trade bulletin is based on at least one and at most four elite timber species like Sal, Teak, Deodar and Chir-pine.

To get over these problems with respect to extraction and price data, we recommend that trend estimates of value of Industrial wood extraction obtained from a longer-term trend obtained from ten year data series be used for the proposed forest sector satellite accounts. This value obtained from the relevant series with a time trend come to Rs. 2441.750 for Industrial wood in 1997.²

In the case of fuelwood, illegal extraction which was unaccounted, led to gross under estimation of extraction. This has been adjusted for by the CSO by assuming that actual extraction is 10 times the reported extraction. This assumption has been verified by reference to independent NSSO estimates of fuelwood consumption in the country. We have therefore not attempted to make any adjustments to the fuel-wood estimates. However, in line with methodology for other sectors and to make the estimates appropriate for satellite accounting once in five years, we use a trend value obtained from CSO estimates. This figure comes to Rs. 14, 272 crores for the country as a whole. Trend estimates for industrial wood and fuel wood values for a few years in the nineties are given below.

Table 3.6 Trend Estimates for Value of annual flows of Industrial wood and Fuelwood.
(in Rs. Crores)

Year	Industrial wood Actual	Industrial Wood Trend Values	Fuel-wood Actual	Fuel-wood Trend Values
1993	1928	1912.464	9312	8847.393
1994	2227	2044.786	10428	10203.79
1995	2126	2177.107	11056	11560.18
1996	2210	2309.429	12198	12916.57
1997	2160	2441.750	14211	14272.96

² The extraction series implicit in CSO data was used to avoid the underestimation of extraction reported in the Forestry Statistics data.

1998	2636	2574.071	16017	15629.36
1999	2879	2706.393	17194	16985.75

Notes: Industrial Wood refers to Joint output of Timber, Poles, Railway Sleepers and Pulp and Matchwood.

3.4 Value of the Annual flow of Non-timber Forest Products

Non-timber forest products, (referred to in the system of national income accounts as minor forest products) are sources of livelihood and food security for a large number of rural communities living in and around forests. Additionally, some of them are also important industrial raw materials (resin, tans and dyes). In recent years, there is a proliferation of studies aimed at estimating their contribution to income, consumption and employment.

Typically, the kind of NTFPs obtained from forests of a particular kind depends on the species found. Variations in these are approximated by the forest "stratums" defined by FSI to be distinguished in accordance with the dominant species. Studies conducted in different parts of India are identified as located in different stratums and the value of NTFP per hectare. Table 3.6 presents values of NTFP per hectare in different strata.

Table 3.7 Value of NTFP extraction per hectare for different forest Strata.

(Rs per hectare)

Forest Stratum	Value of NTFP per hectares
Fir	7509
Spruce	7509
Fir-spruce	7509
Blue-pine	7509
Deodar	7509
Chir-pine	7509
Mixed conifers	7509
Hardwood mixed	7509
Upland hardwoods	1500
Teak	2000
Sal	2000
Bamboo	3050
Dipterocarpus	3050
Khasi pine	3050
Khair	1166
Salai	1166
Alpine Pastures	1372
Miscellaneous	822
Western Ghat ever	1400

Western Ghat semi	1400
Western Ghat	1400

Sources: collection of micro studies (see references).

Notes: the Value of NTFP per hectares of forestland in certain forested areas in India were obtained from some micro studies. The area to which these Values referred to was then identified with the available forest stratum in that area. The above table gives us those values.

Further, $VNTFP_i$ is defined as the weighted average of the $NTFP_j$, which is the average value of NTFP in Rs per hectare of different forest stratum (j) available in any state. In this manner, the variable VNTFP is generated at the state level from studies referring to certain regions with forest strata specific to them. Table 3.7 gives these values for major states.

Table 3.8 State wise Value of NTFP per hectare of forestland.

(Rs per hectare)

States	Value of NTFP per hectare of Forest Land
Andhra Pradesh	906.2
Arunachal Pradesh	1110.5
Assam	944.7
Bihar	1699.8
Goa	1121.3
Gujrat	1488.6
Haryana	1397
Himachal Pradesh	6753.6
Jammu & Kashmir	7364.8
Karnataka	914.1
Kerala	833.9
Madhya Pradesh	1268.6
Maharastra	1361.5
Manipur	953.8
Meghalaya	1290.5
Mizoram	904.7
Nagaland	857.1
Orissa	1547.9
Punjab	2704.6
Rajastan	916.1
Sikkim	1711.4
Tamil Nadu	827.3
Tripura	1065.8
Uttar Pradesh	3724.4
West Bengal	2486.9
A&N Island	1327.5

Dadra & Nagar Havelli	2276.2
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Source: same as table 3.5.

Notes: The Value of NTFP for each State was evaluated by taking a weighted average of the Value of NTFP per hectare for each stratum available in that state, the weights being the ratio of a particular stratum over the total growing stock in that state.

However, in order to arrive at a value of NTFP extraction per hectare which could appropriately claim to represent an underlying trend in extraction, we postulate that it depends on the availability /supply of forest biomass in a certain state and the opportunity cost of labour which represents the alternative opportunities for gainful employment. This is approximated by the agricultural wage rate in the state. Demand pressures are allowed for in the model by including population per hectare of forest area as an explanatory variable. The model is run for all 196 districts with forest cover. Finally, complete data was available for 172 districts with some data being approximated by state level estimates.

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Average value of NTFP per hectare for India is estimated to be Rs. 1671.54

Table 3.9 Model for evaluating Value per hectare of NTFP.

Variables	Source of Data
<i>Dependent Variable</i>	
Value of NTFP per hectares (Value)	Collection of micro studies : see references
<i>Independent variables</i>	“Extent Composition, density of growing stock and annual increment of India forests.” Forest Survey of India report (1995),
Biomass per hectares (Biomassperhec)	Rabindra Nath, B S Somashekar and Madhav Gadgil (October 1992)
Agricultural wages (Agrwag)	Agricultural wages in India 1994-95, Ministry of agriculture.
Population per hectares of forest land (popperhec)	State of Forest Report (1999) Forest Survey of India.

Table 3.10 OLS regression results: -

Dependent Variable: VALUE				
Method: Least Squares				
Sample: 1 196				
Included observations: 172				
Excluded observations: 24				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
CONSTANT	-356.0894	305.8670	-1.164197	0.2460
AGRWAG	3.484855	7.899923	0.441125	0.6597
BIOPERHEC	16.33936	1.386055	11.78839	0.0000
POPPERHEC	31.75380	29.56538	1.074020	0.2844
R-squared	0.474873	Mean dependent variable	1653.263	
Adjusted R-squared	0.465495	S.D. dependent variable	1433.896	
S.E. of regression	1048.319	Akaike info criterion	16.77074	
Sum squared resid	1.85E+08	Schwarz criterion	16.84394	
Log likelihood	-1438.284	F-statistic	50.64082	
Durbin-Watson stat	0.211064	Prob (F-statistic)	0.000000	

Results are given in Table 3.9. We find that the Coefficient for Bioperhec is significant at even at 1 % level of error and its value is positive with a magnitude of 16.33936, which can be interpreted as the partial derivative of a unit change in the biomass per hectare to the Value of NTFP collected.

The Coefficient for popperhec is positive with a magnitude of 31.75380. The positive sign is an indicator of a demand factor, which says that the population pressure on a hectare of available

forestland forces for a higher per hectare NTFP extraction. However the coefficient is not statistically significant as evident from the high probability value of the T statistics of the coefficient.

Agricultural wages are not significant in determining the level of NTFP extraction per hectare. This may be due to the fact that agricultural wages for the districts where the forest cover is large enough are simply not available and we had to rely on the agrwag of neighbouring districts.

From this model we can estimate the all India average value of NTFP in Rs to be **Rs 1671.54** per hectare. This is the estimate that shall be used to approximate value of NTFP per hectare.

Studies on NTFP collections from different parts of the country emphasise the large variation in collection per hectare in different forest tracts. This implies that for a country level estimate of NTFP collection, we need to know the area to which property rights exist. No estimates exist at the national level for the area from which NTFPs are collected. It can safely be assumed that the lower limit estimate for such lands lying within forest areas is given by the forest based common property estimates, one recent estimate of which is of 25.16 million hectares out of a total forest area of 62 million hectares. This yields a figure of Rs. 4188.85 crores as the estimate of gross value of NTFPs harvested on average in India

3.5 Value of the Flow of Eco-tourism services per hectare

Eco-tourism services accrue from protected areas, otherwise classified as national parks and wild life sanctuaries. These services have a market and tourists are willing to pay a price for availing of them. A large number of studies in recent years have estimated the value of these ecotourism services using alternative valuation methods.³

Using a method similar to that in the case of NTFPs, we arrive at a generalized value of the eco-tourism services as perceived by the tourists. Using a cross-section regression for eco-tourism services, their value per hectare of Eco-Tourism of a State is regressed upon Net State Domestic Product per Capita (to stand for capacity to pay of tourists, road length per Square Km to represent accessibility of parks and sanctuaries and total protected area of that state to stand for availability of sites in the state.

Average value of eco-tourism in India per hectare of Protected land is estimated to be Rs 7443.39.

The Model for obtaining per hectare value of Eco-Tourism along with the sources for each of the variables used for the model are mentioned in table 3.10.

Table 3.11 List of variables used in the Model for Eco-Tourism and the source of these.

Variable	Source
<i>Dependent Variable</i>	
Value of Eco-tourism per hectare (VALUE) Unit Rs per Hectare	A collection of micro level studies was used to collect information on the value per hectare of Eco-tourism. See references.
<i>Independent Variables</i>	
Road length per unit of geographic area (ROADPERGA) Unit (Km) ⁻¹	<i>Selected socio-economic indicators of India, 1998.</i> Indian Infrastructural Report, 2001. Statistical Abstracts of India, 1999.
Net State Domestic Product per capita (NDPPERCAP) Unit: Rs Crore.	Hand Book of Statistics on Indian Economic 2000. Statistical Abstracts of India, 1999.
Protected area (PROTECTED) Unit: Square kilometers.	Forestry statistics of India 2000

Notes: Protected Area includes Wildlife sanctuaries and National Parks.

Value per hectare of Eco-Tourism of a State is regressed upon Net State Domestic Product per Capita, Road length per Square Km and Total Protected area of that state. This exercise was carried out with 26 observations (25 states and 1 UT).

From the fitted model we obtain the average value per hectare of eco-tourism in India as Rs **7443.39** per hectare of Protected land.

The Output of OLS regression on NTFP value per hectare is given in Table 3.11

Table 3.12 OLS Regression Output.

Dependent Variable: VALUE				
Method: Least Squares				
Sample: 1 26				
Included observations: 26				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	860.1617	3276.999	0.262485	0.7954
ROADPERGA	1880.854	2353.459	0.799187	0.4327
NDPPERHEAD	199792.7	905787.0	0.220574	0.8275
PROTECTED	0.817971	0.280954	2.911402	0.0081
R-squared	0.278913	Mean dependent variable		7443.385
Adjusted R-squared	0.180583	S.D. dependent variable		8850.470
S.E. of regression	8011.593	Akaike info criterion		20.95581
Sum squared resid	1.41E+09	Schwarz criterion		21.14936
Log likelihood	-268.4255	F-statistic		2.836495
Durbin-Watson stat	1.403810	Prob (F-statistic)		0.061543

3.6 Estimation of Carbon Sequestration Flow and Its Methodology

There are several methodologies for estimation of carbon sequestration of forest. Most of these methodologies try to estimate the stock of forest sequestration of Carbon. Either they compare with-project carbon sequestration with without- project scenario of carbon sequestration. Alternatively, some methodologies try to capture the carbon sequestered in natural as well as plantation forest. Fearnside and Malheiros (1996) show biomass levels of 52.8 t/ha in 5-year-old stands of Brazilian secondary forest and levels of 196.6 t/ha in 25-year-old stands. Anderson (1996) estimate long-term carbon storage capacity at 140 t/ha in mature primary forests, 55 t/ha in partially intervened forests and 10 t/ha in pastureland. These studies clearly establish the role of forest ecosystem in storing the carbon and consequently stabilizing the atmosphere temperature.

In accounting and valuation of the carbon sink services of forest ecosystem, one should be aware of the differences in technical nomenclature of carbon storage, carbon parking and carbon sequestration. Carbon storage means the capacity of a forest to maintain a certain amount of biomass per hectare. Retention of biomass also means that the carbon in a forest is not being released into the atmosphere. Thus the value of carbon storage services lie in avoiding potential

future CO₂ emissions forever. Carbon parking refers to the situation when under some agreement and at certain price, land use changes are postponed for some stipulated time in such a way that emission of carbon is avoided. Based on some incentive, deforestation and land use change are forestalled, avoiding the carbon emission into the atmosphere. Carbon sequestration refers to removal of carbon (CO₂) currently in the atmosphere. It is also mitigation of past CO₂.

Carbon sequestration by forests is a function of biomass growth rates. While methodology exists for physical accounting of carbon sequestration of forest ecosystems, valuation remains a problem area because it has to be the avoided marginal social damage cost of emission through the sequestration of forest and this is very difficult to estimate due to its global nature, although several attempts have been made in the past (Frankhauser and Tol, 1995)

In estimation of carbon sequestration some studies view this function as stock variable where net accumulation in carbon stocks of cultivated forest is calculated to make the necessary adjustment in the Net Domestic Product (NDP) (Hassan, 2000).

Hassan (2000) uses dynamic method to estimate C storage in industrial plantation in South Africa. His model can be summarised in the following form

$$S_t = \sum C_{tj}A_{r-t}C_gA_r$$

Where

S_t =net difference in C stored in year t in Mg C

C =C density per ha of plantations of age t and type j

A_{r-tj} =area of type j planted in year $r-t$

C_g =C density per ha of the preceding land use

A_r =area of previous vegetation type at time r (time of conversion)

For calculation of C for each age and forest types, following conversion factor are used by Hassan,

$$C = V_s D_w F_c / F_s$$

Where,

C is the Carbon biomass density in Mg C/Ha

V_s is the stem wood volume in cubic m/ha

D_w is the density of wood in Mg/cubic meter

F_c is fraction of oven-dry mass that is carbon

F_s is fraction of whole tree biomass per ha in stem wood

While many others consider the carbon sequestration function of forest as flow variable and estimate the flow of carbon prevented from entering into the eco-space due to the forest and vegetation on annual basis. Ramirez (2000) follows the biomass accumulation model to estimate the annual growth of biomass for the forest of Costa Rica. His estimate borrows from Brown et al (1989) equation, which is as follows,

$$Y = 13.675 - 6.1181D + 0.8391D^2 + e$$

Where dataset consists of 50 observations

Y is the total biomass of dry weight in kg

D is the tree's diameter at breast height

e is the error term

The coefficient of multiple determination (R^2) for this eq. comes as 0.90. The biomass accumulation on each of the experimental plots at year-of-measurement t, which correspond to a given forest age in that plot and site, is estimated by adding up the biomass predictions for all individual trees on the plot at year t and transformed into per ha basis using the plot's area. The resulting dataset consists of 50 biomass observations from forests of 1 to 44 years of age. This dataset is used to estimate a non-linear model based on an adaptation of the forest volume growth function proposed by Richards (1959) which is widely used due to its flexible nature. In fact it can accommodate a wide variety of growth rates following non-linear, curvilinear and s-shaped patterns and always ends on a plateau. The model is

$$Y(t) = a_s (1 - \exp^{-bt})^c + e; s = 1, 2, 3, \dots, n$$

where

Y (t) is biomass accumulation as a function of forest age (t), a_s estimates the maximum biomass accumulation capacity in each forest site s, b is the growth rate and determines the amount of time that it takes for the function to reach its maximum

(a_s), does not have a particular biological interpretation.

Second model of carbon flow needs disaggregated and experimental data while the first one by Hassan depends upon relatively less demanding database.

Another methodology, which is dynamic in nature, directly estimates the stock of carbon sequestered in the forest.

The net carbon stock (tons per ha) per period is calculated as:

$$C_{st} = 0.45 (B_t + \sum 0.9^{\pi+1} P_{t-\pi} + \sum 0.9^{\pi+1} L_{t-\pi} - G_t - W_t) \quad **$$

Where: C_{st} is the net carbon storage in year t ,

B_t is biomass stock at the end of period t ,

P_t represents poles harvested,

G_t represents gross removal,

and W_t is the amount of firewood used in period relative to the base case, keeping account of the changes in living biomass as well as the accumulation (and depreciation) of the woodlands products. Thus poles and commercial timber harvested in previous periods is included in the carbon stock until it has fully depreciated. Fire is included in the model and removes biomass according to a randomly generated fire probability. Thus, the carbon stocks calculated are actually a form of expected carbon stocks that will vary if the fire regime changes.

Around 45 % of biomass is comprised of carbon. Thus, Gross carbon stored in vegetation (tons per ha.) will be the stock of biomass in the woodland multiplied by 0.45 plus carbon storage in removals. However, the length of the time period for which carbon is removed from the atmosphere depends on the rates of mortality of trees and the different decay (emission) rates of the various categories of woodland products. Biomass decay and the release of carbon as CO_2 in each end-use category are assumed to occur at a constant rate until the end of the lifetime of the product. Poles are assumed to decay at a rate of 10% per year, and the same rate is assumed for products from commercial timber and natural mortality in the woodland stand. Grass is assumed to decay in 1 year, releasing all the carbon in it, and firewood and vegetation burned during fires is also assumed to decay 100% (although there could be significant amounts of carbon stored in charcoal representing a very stable store for carbon).

3.7 Carbon Sequestration in Indian Forests

In recent years, a few attempts have been made to estimate the Carbon Sequestration of Indian Forest. Ravindranath and Someshekhar and Gadgil (1992) have estimated the flow of Carbon in Indian Forest. By depending on the forest and land use data for 1986, they come out with around 9.5×10^6 t of net carbon storage (net of release). In another improved estimation the same authors (1996) come out with the figure of more than 10^6 of arbon for the year, 1986. Their estimation is based on COPATH model developed by Makundi et al (1996). Lal and Sigh (1998) estimate the

Carbon pool for the Indian Forest around 2.02×10^6 t of Carbon for 1995. Lal and Singh estimate the biomass on the basis of growing stock of Forest Stratum provided by the Forest Survey of India (FSI, 1995). This volume of biomass is converted to Forest carbon by applying appropriate conversion factor. G.S. Haripriaya (2000) estimates the carbon in Indian Forest as 128×10^6 tonnes. Haripriaya's annual carbon budget is based on the disturbance matrix of land use change and for relevant conversion factor she depends upon several other studies including Ravindranath (1996) and Kurz et al (1992).

These three studies albeit attempt to quantify the contribution of Indian Forest, give different results. Methodology remains more or less the same where volume of biomass is converted into tonnes of carbon; they land up measuring the stock variable (except Haripriaya). Lal and Singh ignores the Soil carbon while data on land use in case of Ravindranath et al is not up to the mark. Following table provides a comparative sketch of these three studies on estimation of Carbon Sequestration of Indian Forest-

Table 3.13 Studies on Carbon sequestration in Indian forests:

Studies	Ravindranath et al (1996)	Haripriaya (2000)	Singh & Lal (1998)
Carbon sequestered in Million tons	9.58	128	2
Ref. Year	1986	1993-94	1995
Stock/flow	Flow	Stock	Stock
Methodology	Conversion of Biomass	Disturbance Matrix	Conversion of biomass
Soil Carbon	Included	Included	Included
Nature of Use of Timber	Short-run	Short-run as well as long run	Not accounted
Remarks	1	2	3

1. Estimates gross and net carbon sequestered in the forest. Short term and long-term uses of harvested wood and other biomass are assumed to stay for 3 years. Carbon emission is estimated at 2.7 million tons in the reference year hence the net carbon sequestration becomes 6.9 million tons.

2. 90% of harvested wood is assumed to stay in use for short period as only 10 % are for long duration. Estimate of biomass is based on Ravindranath's calculation. It is gross sequestration in Indian forest.

3. Does not include wood in use for different purposes staying beyond the current year.

Haripriya's study is based on land use disturbance matrix and many of its coefficients of carbon contents are based on studies done by Kurz et al for entirely different kind of forest ecosystem and it cannot be readily transferred to Indian forest.

3.10 Computation of carbon sequestration in Indian Forest.

For our computation of carbon sequestration we are adopting the expression: - **

$$C_{st} = 0.45 \left(B_t + \sum_{\pi=0}^{t-1} 0.9^{\pi+1} P_{t-\pi} + \sum_{\pi=0}^{t-1} 0.9^{\pi+1} L_{t-\pi} - G_t - W_t \right)$$

Where:

C_{st} = Stock of Carbon in year t.

B_t = Biomass

P_t = Poles or rounded wood.

L_t = Timber

G_t = Grass removal

W_t = Fire wood

• = initial year of reference.

0.45 = conversion factor for Biomass and other components into their carbon contents.

3.10.1 Data Base for relevant parameters

Biomass (B_t)

A point estimate for Growing Stock and the Annual increment rate was obtained from Forest survey of India report on Growing stock (1995). Using a standard ratio of 100:69 between biomass and growing stock the Biomass figures were obtained. However a compound growth/decline rate had to be used to get the point estimates of Biomass from the figure reported in 1995.

Poles (P_t)

Poles refer to extracted amounts of poles (or round wood) for the different years and for the last year i.e. in 1997 extraction data is not considered and the reported Biomass in that year is all-inclusive.

Timber (L_t)

Timber similarly refers to the extracted timber for different years and for the year 1997 timber extraction figures are not included because the Biomass is all-inclusive.

Firewood (W_t)

Firewood refers to the accounted removal of Firewood in each year and it is assumed that the whole of it is burnt up in the year of collection itself; thereby releasing the whole of the carbon store in it in to the atmosphere.

Grass (G_t)

Grass removal is also the accounted removal of grass from forest area in each year that is either consumed or dried up in the year of collection itself. So the release of carbon is again 100% in this case.

The detailed source of database has been given in the appendix (Appendix 3.2)

This expression directly yields the stock of carbon in the forest. By deriving the differences over two consecutive years, the flow of sequestered carbon is obtained. For the calculation of annualised carbon flows three years of rotation were chosen viz 15, 20 and 25 and for each rotation age data for 20 years were collected. That is how we reached from 1953 to 1997. Two decay rates for Carbon from the extracted timber were 10 and 5 % and the entire exercise was repeated for the two rates. I am leaving out the details here because that forms a part of the methodology. For firewood of course the decay factor was taken to be 100% and that is why we had used the firewood data for only a single year assuming that the firewood extracted the previous was totally burnt up thereby releasing the entire carbon stored in it. The same holds for charcoal wood. So the decay factors mentioned here refers to the Timber and Poles extractions only.

The value of π actually referred to the number of years for which harvested wood remains in use. If we considered a 25 years period then π was 25. Alternatively, 20 years and 15 years time have been considered for simulation purpose. And as said earlier for each rotation period a set of 20 observations (which are the differences of stock for the consecutive years making it as a flow variable) were taken in order to reach at an average flow of carbon for a particular rotation period and for a particular decay rate. In this way we get 6 trends of flows of carbon and a simple average of the flows under each rotation period for two different rates were taken. That is how we

reached at 3 flow estimates (i.e. average flow specific to a particular rotation period and from the two rates of decay). Then on a grand average for the three flows was taken to arrive at a single flow of carbon estimate out of three rotation periods and out of two decay rates. The carbon flows is assumed to be zero on the net from the natural forests and so the annualised flow of carbon from India forests can be attributed to the plantation area cumulated from 1980 and up to 1997. This figure was around 10.85669 million hectares and this was used as a denominator to evaluate the annual flow of carbon per hectares from the Indian Forests.

In Table 3.14 the stocks of carbon in different years has been provided. Table 3.15 gives the flow of carbon in those years and finally table 3.16 comprises of the trend values of carbon flows. These values are the smoothed values of the carbon flows that have been generated by regressing the carbon flows against a constant and a trend.

The fitted the trend equation: -

$$\text{Carbon flow} = \text{a constant (c)} + \text{@trend (1995)}$$

For which a significant positive trend in carbon flows over the years could be obtained.

Table 3.14 Stocks of carbon in 000' tons.

Years	25 years period		20 years period		15 years period	
	Decay rates		Decay Rates		Decay Rates	
	10%	5%	10%	5%	10%	5%
1978	1823188	1836383	1822426	1833909	1820628	1829464
1979	1857681	1871328	1856850	1868639	1854999	1864065
1980	1891616	1905653	1890734	1902806	1888798	1898023
1981	1926490	1940877	1925572	1937913	1923436	1932652
1982	1963027	1977841	1962060	1974700	1959731	1968954
1983	2000215	2015419	1999153	2011980	1996653	2005830
1984	2038067	2053619	2036974	2050080	2034302	2043487
1985	2076621	2092553	2075477	2088851	2072661	2081873
1986	2115891	2132236	2114630	2128164	2111765	2121053
1987	2160365	2177146	2158990	2172701	2156101	2165514
1988	2201207	2218327	2199731	2213569	2196876	2206463
1989	2240300	2257688	2238722	2252587	2235887	2245529
1990	2279855	2297356	2278192	2291956	2275264	2284701
1991	2320394	2337798	2318702	2332295	2315877	2325263
1992	2362042	2379257	2360336	2373696	2357586	2366836
1993	2404300	2421172	2402614	2415673	2399948	2409005
1994	2447130	2463598	2445456	2458137	2442897	2451725
1995	2490985	2506982	2489256	2501368	2486849	2495370
1996	2455914	2471406	2454246	2465965	2459559	2451653
1997	2495746	2510686	2494122	2505378	2491348	2498555

Table 3.15 Annual flows of Carbon in 000' tons.

Years	25 years period		20 years period		15 years period	
	10% decay	5% decay	10% decay	5% decay	10% decay	5% decay
1979	34493.05	34945.4	34423.37	34729.96	34371.22	34601.38
1980	33934.6	34324.55	33884.59	34167.32	33799.09	33957.15
1981	34873.83	35223.68	34838.14	35106.99	34638.59	34628.93
1982	36537.58	36964.13	36487.88	36786.11	36294.96	36302.55
1983	37188.17	37578.22	37092.9	37280.05	36921.29	36875.72
1984	37851.31	38200.07	37820.51	38100.58	37649.49	37657.43
1985	38554.04	38933.74	38503.55	38771.11	38358.6	38385.44
1986	39270.17	39682.72	39152.33	39312.8	39103.8	39179.82
1987	44474.24	44910.83	44360.32	44536.66	44336.67	44461.25
1988	40842.18	41180.88	40740.84	40868.01	40774.43	40948.86
1989	39092.39	39360.92	38991.4	39018.02	39011.6	39066.23
1990	39555.02	39667.97	39469.42	39369.55	39377.06	39171.86
1991	40539.06	40441.76	40510.4	40338.86	40612.13	40562.21
1992	41648.03	41459.11	41634.07	41400.75	41709.98	41572.92
1993	42258.1	41914.75	42277.93	41977.31	42361.21	42169.01
1994	42829.78	42426.04	42841.71	42463.35	42949.65	42720.3
1995	43854.99	43384.25	43800.62	43231.29	43951.41	43644.79
1996	-35070.7	-35576.1	-35010.8	-35403.3	-27290.2	-43717.1
1997	39831.56	39280.25	39876.38	39413.47	31789.31	46901.82

Table 3.16 Trend values of annualized carbon flows in 000' tons.

	25 years period	20 years period	15 years period
--	-----------------	-----------------	-----------------

	10% decay	5% decay	10% decay	5% decay	10%decay	5%decay
1979	34807.97	35426.35	34729.83	35174.65	34541.85	34706.20
1980	35367.24	35928.93	35291.77	35685.60	35122.81	35264.29
1981	35926.52	36431.52	35853.70	36196.56	35703.76	35822.38
1982	36485.79	36934.10	36415.63	36707.51	36284.71	36380.47
1983	37045.06	37436.68	36977.56	37218.46	36865.67	36938.57
1984	37604.33	37939.26	37539.50	37729.42	37446.62	37496.66
1985	38163.60	38441.84	38101.43	38240.37	38027.57	38054.75
1986	38722.88	38944.42	38663.36	38751.33	38608.53	38612.84
1987	39282.15	39447.00	39225.29	39262.28	39189.48	39170.93
1988	39841.42	39949.58	39787.23	39773.23	39770.43	39729.03
1989	40400.69	40452.16	40349.16	40284.19	40351.39	40287.12
1990	40959.97	40954.74	40911.09	40795.14	40932.34	40845.21
1991	41519.24	41457.32	41473.02	41306.09	41513.30	41403.30
1992	42078.51	41959.91	42034.96	41817.05	42094.25	41961.39
1993	42637.78	42462.49	42596.89	42328.00	42675.20	42519.48
1994	43197.05	42965.07	43158.82	42838.95	43256.16	43077.58
1995	43756.33	43467.65	43720.75	43349.91	43837.11	43635.67

It may be noted that the difference in the annualized flows of carbon sequestration is mainly due to the change in the biomass and only a mere 2% contribution comes from the carbon stored in the extracted tracts of timber and poles. This high sensitivity of carbon flows to the biomass necessitates availability of proper data on biomass.

Table 3.17 Average value of Flow of Carbon sequestration (in Million tons)

Time Period	Rates of decay		Average of flows at the two rates for each rotation period.
	10%	5%	
25 years	37.3643	37.46129	37.4128
20 years	37.31642	37.30383	37.3101
15 years	37.26224	37.17171	37.2170
Grand Average flow of Carbon			37.3133

From this table it evidently appears that the total carbon emission in Indian Forest lies in the range of 37.17 million to 37.46 million tons. However looking at the ailing natural forests in India, until the very recent years in which the area under forest has registered some positive change, the positive carbon flows from Indian forests seems to be very interesting. The status of plantation forests in India provides a possible explanation of the positive flows that come out of our study. The following table gives the details of plantation forest in India.

Table 3.18: Plantation Forests in India

Cumulative planted area (000' Hectares)	Up to 1980	Up to 1985	Up to 1990	Up to 1995	Up to 2000

	3898	6612	10300	14506	18487
Increment in plantation area (000' Hectares)	Between 1980 and 1985	Between 1985 and 1990	Between 1990 and 1995	Between 1995 and 2000	
	2714	3689	4206	3981	
Percentage Growth	69.6	55.8	40.8	27.4	

It can be identified from the percentage growth figures that forest plantation in India have continuously been increasing. Plantation area as a percentage of total forest covered land in India is more than 28% in the year 2000 and there have been uninterrupted additions to plantation area through the last two decade. This is a clear indicator of the fact that plantations in India are a potential source of carbon flows and also other tangible benefits of the forest. Out of the 18.48 million hectares of plantation forest at least 10.85 million hectares of the plantations are in the age group of 10 and above in the year 2000. This mix of young and middle-aged plantation forests keeps the rate of growth in these tracts much higher than that in the natural forests. Thus even though natural forests may be zero net contributors in the positive carbon flows that void is more than offset by the growing plantations in India.

3.11 Price of Carbon

Price of Carbon is generally based on the cost of marginal social damage inflicted by global warming. Global warming causes severe damage to different sectors of economy. When the mean concentration of CO₂ increases in the atmosphere; world's dry land, coastal resources, species and crucial ecosystem, forestry, agriculture, fisheries and innumerable other resources get affected. The mechanism of damage is perceptible but lots of uncertainty is involved. There are various sources of damage associated with the rise in temperature due to CO₂ and these estimates suggest that the damage could be in the range of 1-2% of world's GNP. Frankhauser, (1995). In one of the earlier estimates done by Nordhous (1991) basically for US but extended for the world came out 1 per cent of GNP. This was confirmed by the Cline (1992) who came out with the similar figure for the US. On the other hand Titus (1992) estimate the total damage associate with rise of temperature (4⁰C) as 2.5 per cent of the GNP of US. In all these estimates many of the damages have not been incorporated owing to unavailability of relevant data or methodological problems

or both. However in order to arrive at the cost associated with addition unit (1t) of carbon estimation of actual marginal social or shadow price of costs of greenhouse gas emission will be helpful.

In almost every study, the social cost of global warming has been based on an intertemporal optimisation model. The focus remains on estimation of socially optimal level of CO₂ emission explained in terms of pollution tax necessary to maintain the emission at optimal level. Optimal level of CO₂ emission is based on two approaches.

- (i) The Cost-benefit approach and
- (ii) The Carbon budget approach

(i) The Cost benefit approach

Under the cost- benefit approach, the optimality of emission is elicited where marginal benefit equates the marginal cost of emission. In another words, optimal level of CO₂ emission is determined by the point where the incremental costs of additional CO₂ abatement equalizes the additional benefit of avoided damage of emission at each point in time. This is obtained by penalizing emission through appropriate taxes equal to the marginal global damage it inflicts on the society. Thus the shadow price of emission is equal to the actual social costs. Generally it is assumed that the emission will be predictable even in future and it will follow the optimal emission trajectory path of devised model. However discrepancies are bound to be there and so will be an error in marginal cost of social damage of emission. But in any case that may not be significant.

(ii) The Carbon budget approach

Based on precautionary consideration and other political and ethical concerns, an exgenously determined CO₂ concentration limit is imposed under carbon budget approach. Under this method the shadow value of emission will reflect the costs of the additionally imposed constraint and then it will have no connection with the actual CO₂ damage happening. Under this approach modeling is not needed but doubt is expressed against the subjective limit of emission. It has been found that carbon budget approach always gives higher estimate than the cost-benefit approach. One study for example (Anderson and Williams, 1990) proposes a carbon tax starting at \$ 120/tc by

2010. Higher tax of this study adopts a very strict constraint and expects to introduce an economical carbon-free energy source by 2010.

Following above two approaches various studies have come out with prices of per unit of carbon which have been debated and subsequently accepted by different bodies of the world. Nordhus's study (1991) provides a figure of \$ 7.3/tc. By adopting a simpler version of dynamic optimisation model, Nordhaus calculates the social costs of CO₂ emission. Variation in rate of discount in his model yields range of value as 0.3-65.9/tc Nordhus's estimation has been criticized on several criteria and many alternate estimations have emerged.

In Nordhaus's study the assumption of resources steady state, which implies a constant level of CO₂ overtime, is always questionable. In this context, the prediction made by IPCC is noteworthy where value of carbon is given in slab, which increases decade wise. The assumption of linearity is another objectionable assumption. Climate processes are non-linear and thereby the cost of CO₂ emission will depend upon future consideration - a variant of time. Another study done Ayres and Walter (1991) gives a value of 30-35 U.S dollars per tc. This study, which is based on Nordhaus's model, assumes same price for land across the region of the world, which is, unrealistic. Nordhaus (1992, 1993) again came out with improvised result based on DICE (Dynamic Integrated Climate Economy), which is an optimal growth model in Ramsey framework. The model has been extended to incorporate a climate change module along with a damaged sector, which feeds climate changes back to the economy. Under this revised estimation the value comes to be as 5.3 per tc in 1995 and rises to 6.8 per tc in 2005. Cline (1992) expresses concern about of parameter done by Nordhaus and attributes this to the under-estimation of real cost. Cline provides a value, which has a wide range of 5.8 to 124 per tc carbon. Other studies like, Peck and Teisbery (1992), Maddison (1993) and Frank Hauser (1995) provide estimation of cost of CO₂ emission, which are higher than that of the earlier studies. Following table provides the details:

Table 3.19 Estimates of CO₂ emission (\$/tons)

Study	Type	1991-2000	2001-10	2011-20	2021-30
Nordhaus (1991)	MC		7.3 (03. - 65.9)		
Ayres and Walter	MC		30-35		

(1991)					
Nordhaus (1993)	CBA	5.3	6.8	8.6	10.0
Cline (1992,93)	CBA	5.8-124	7.6-154	9.8-186	11.8 -221
Peck and Teisberg (1992)	CBA	10-12	12-14	14-18	18-22
Maddison (1993)	CBA/MC	5.9-6.1	8.1-8.4	11.1-11.5	14.7-15.2
Frankhauser (1995)	CBA/MC	20.3	22.8	25.3	27.8

Table3.20 Price of Carbon (\$/t) for the period 1991-2000.

Source	Price	Mean price	Overall Price Range
Nordhaus (1993)	5.3	5.3	5.3 to 20.3
Cline (1992,93)	5.8-12.4	9.1	
Peck and Teisberg (1992)	10-12	11.0	
Maddison (1993)	5.9-6.1	6.0	
Frankhauser (1995)	20.3	20.3	

Peck, Teisberg and Maddison base their estimation on Carbon Emission Trajectory Assessment (CETA) model. This model is similar to DICE but it is more detailed on the economy side but incorporating a carefully modeled energy sector. In both the studies a 3% of utility discount rate has been applied.

This value of per tonne of carbon emission is the basis for price of a unit of CO₂, the world community is willing to pay. A unit of CO₂ stored in terms of carbon is the amount saved by its unit price. Of course, this price is based on supplied-side mechanism. But the Kyoto Protocol and the subsequent confirmation by different countries (India is one of them) has accepted this price. By being a part of this convention, the world community has indicated that the demand side is matching minimum the supply side at this price.

3.12 Value of Flow of Carbon Sequestration in Indian Forests

Table 3.21 Annual Carbon flows in million tons.

Annual Carbon Flow (in Million Tonnes) (1)	Mean Price (\$/tons) (2)	Total Value (\$ Million) (1×2)
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37.3133	5.3	197.76049
	9.1	339.55103
	11.0	410.4463
	6.0	223.8798
	20.3	757.4599
	Range of Values (in \$ million): 197.76049 to 757.4599	
Mean total value: \$ 477.61 million		

Table 3.22 Value of Flow of Carbon Sequestration in Indian Forest

Annual Range of Carbon Flow (in Million Tonnes) 37.1717 to 37.4613					
1997's Exchange rate (Rs/\$) 37.16					
Mean Price (\$/tons)	Mean price RS/tons	Range of Value (\$ Million)		Range of Value Rs Million	
5.3	196.948	197.01	198.5449	7320.89197	7377.928
6	222.96	223.03	224.7678	8287.80223	8352.371
9.1	408.76	338.262	340.8978	12569.8334	12667.76
11	338.156	408.889	412.0743	15194.3041	15312.68
20.3	754.348	754.586	760.4644	28040.3976	28258.86

Table 3.23 Value of flow of Carbon sequestration in Indian Forest

Lower limit	Upper limit
Rs.7320.89197 Million	Rs.28258.86 Million

Range of Values (in Rs million): 7320.89197 to 28258.86, Mean total value: Rs. 17789.87435 Million and the Per hectare Value for the same is: Minimum (Rs. 674.73) and Maximum (Rs. 2604.50).

This was obtained after dividing the total value by the total area under plantation since 1980 and up to 1997.

Mean price in Rs./tons has been calculated by multiplying exchange rate of 1997 by mean price \$/ton.