

Assessment of Growing Stock, Biomass and Carbon in India's Forests

Background:

This study which started in 2001, has been a part of the project NATCOM sponsored by the Ministry of Environment & Forests, Government of India. NATCOM is India's Initial National Communication to UNFCCC (United Nations Framework on Climate Change Convention) under its Article 12 wherein participating nations were to provide estimate of GHG emissions in respect of their countries. FSI was identified as a secondary Institute for providing information on volume, biomass and carbon of India's forests in collaboration with Forest Research Institute (FRI), Dehradun for the years 1994 and 1984. The report was submitted to MoEF in 2002.

Methodology

Growing stock for the entire country (major forest strata-wise) was assessed using information available from the vegetation maps, thematic maps and the ground forest inventory done by the FSI. For this purpose all the states and Union Territories (UT), were divided into grids of 2.5' x 2.5' (lat. x long.). From approximately 170,000 such grids, data were collected in respect of parameters related to growing stock. This exercise yielded information on the extent of forest cover, composition (21 species strata), density (3 classes) and inventory data on growing stock. The following information for each grid was collected:

a) Density

The land use category occupying more than 50% area of the grid was taken into account e.g. if more than 50% area is forested, the grid was marked as forested otherwise 'non-forested'. Then in each forested grid only one major density class was taken as the density class for the entire grid. This information was collected from satellite data used in 1989, 1995 and 1997 assessments. For each grid any one of the following three density classes were obtained from the satellite data:

Crown density

1. Very dense forest	70% and above
2. Dense forest	40 to 70%
3. Open forest	10 to 40%

Areas, which were having less than 10% forest density, were treated as scrub. Grids falling under non-forest and scrub were not used further. Any grid, which spread over more than one state, was included in the state in which its maximum area fell.

b) Forest composition

The major forest type/strata in each grid were marked using information from the following resources.

- i) Thematic maps prepared by the FSI on 1:50,000 scale using aerial photographs were used for marking the major species composition of each grid.
- ii) For the areas for which thematic maps were not available in FSI, the information on species composition was collected from the stock maps of the State Forest Department, irrespective of the year and scale of preparation of stock map.
- iii) For the areas for which neither thematic maps nor the stock maps of state forest departments were available, the information was collected from the inventory field forms.
- iv) In case of areas for which none of the above sources of information was available on species composition, the information, of adjoining area was taken into consideration.

In all, twenty-one forest strata for major species compositions were identified⁵. These include fir, spruce, blue-pine, deodar, chir pine, mixed conifers, hardwood mixed with conifers, upland hardwoods, teak, sal, bamboo, Dipterocarpus, khasi pine, khair, salai, alpine pasture, western ghat evergreen, western ghat semi-evergreen, western ghat deciduous and miscellaneous.

c) Forest inventory data

The data of forest inventory surveys done by the FSI in various states was used for determination of growing stock. Forest inventory design was based on the methodology developed by the FSI⁶.

For estimation of the growing stock of any state, the number of grids for each combination of density and each forest stratum was calculated. The volume per ha for a particular combination of density and forest stratum was generated by processing data of forest inventory surveys carried out in various states/UTs by the FSI. Three wood volume factors were calculated for each stratum and density class for each map sheet for each state. Wherever the inventory data were not available for a grid, wood volume factors were borrowed from nearby areas considering the agro-ecological zones (i.e., area falling under the same agro-ecological zone was taken into consideration). Trees with less than 10 cm diameter and branches less than 5 cm in diameter were not taken into account. The growing stock was first estimated for each map sheet and then summing up all the data in the map sheets for each state, the total growing stock of each state was arrived at.

Biomass and Soil Carbon estimation: Based on the above information on forest cover and growing stock, the Forest Research Institute, Dehradun estimated above ground biomass and carbon for the period 1984 and 1994. The methodology used by the FRI is given in brief as follows:

The volume or growing stock estimated, by the above method, for various strata was multiplied with the specific gravity (Rajput et al., 1996; Limaye & Sen, 1956) of the dominant tree species, of that strata, to get the biomass, of that particular strata i.e.,

$$\text{Biomass (ton)} = \text{Volume (000, cm}^3\text{)} \times \text{Specific Gravity}$$

Carbon Estimation:

Carbon estimation was done by ash methods under this study.

Results

The total forest cover of the country as estimated in 1989, 1995 and 1997 assessments (SFR,1989, SFR,1995 and SFR,2001) and growing stock as assessed based on these estimates are given in Table16. These estimates are for forests having more than 10% crown density.

Table16: Forest cover and growing stock in India's forests

Assessment Year	Forest Cover (km ²)	% Forest Cover	Growing stock (million m ³)	Volume /ha Forest cover In m ³
1989	638,777	19.43	4328.5	67.8
1995	639,600	19.46	4740.9	74.1
1997	633,359	19.27	4340.0	68.5

Biomass and carbon contents were estimated only for the 1989 and 1997 assessments by the FRI. A comparison of growing stock, biomass and carbon of forests in India is given in Table 17. Results of this table indicate that biomass and carbon in India's forests has shown a marginal increase in the period between 1989 and 1997 assessments.

Table17: Growing stock, biomass and carbon in India's Forests

Assessment Year	1989	1997
Growing Stock (million m ³)	4328.5	4340.0
Biomass (Million ton)	2398.5	2395.4
Carbon (Million ton)	1085.2	1083.8

State/UT wise information on growing stock, biomass and carbon in forests for 1989 and 1997 assessments is given in Table 18 and Table 19.

Table 18: State wise forest cover, growing stock, biomass and carbon for 1989

State/UT	Forest Cover (Km ⁻²)	Growing Stock (000, m ³)	Biomass (000, tons)	Carbon (000, tons)
Andhra Pradesh	47290	293924.13	219010.98	98433.53
Arunachal Pradesh	69002	538173.70	184145.78	83386.96
Assam	24832	304245.15	168264.15	75757.31
Bihar	26668	122845.51	81530.34	37182.39
Goa, Daman & Due	1255	8551.57	6046.55	2720.95
Gujrat	11921	48295.33	29538.10	13137.57
Haryana	513	378.66	254.19	114.76
Himachal Pradesh	12480	199161.07	86386.20	39671.46
Jammu & Kashmir	20449	461792.37	179648.81	82635.73
Karnataka	32104	239312.42	146907.03	66054.84
Kerala	10292	89239.65	47801.75	21466.62
Madhya Pradesh	135541	708491.05	447667.36	202057.94
Maharashtra	44044	209605.90	126821.51	56489.43
Manipur	17685	80214.93	43415.68	19588.16
Meghalaya	15645	104531.12	67897.26	30477.01
Mizoram	18170	62638.67	34144.86	15331.92
Nagaland	14399	104769.75	57026.41	25665.85
Orissa	47227	248479.88	175575.19	80136.82
Punjab	1338	702.97	466.91	210.78
Rajasthan	12884	11977.88	7317.90	3304.16
Sikkim	3041	38347.81	18895.47	8524.96
Tamilnadu	16992	67520.81	43010.75	19353.78
Uttar Pradesh	33627	295840.84	169264.50	77498.27
West Bengal	8015	59411.51	40162.51	18204.90
Tripura	5535	14883.66	8236.33	3698.52
Dadar and Nagar Haveli	206	1393.92	913.99	410.14
A&N Islands	7622	13719.60	8108.47	3648.81
Total	638775	4328449.86	2398458.98	1085163.57

Note: Figures given in Table 3 correspond to 1989 assessment (SFR '1989) and data correspond to period from 1983 to 1985

Table19: State-wise forest cover, Growing Stock, Biomass and Carbon for 1994

State/UT	Forest cover (Km ⁻²)	Growing Stock (000, m ³)	Biomass (000, tons)	Carbon (000, tons)
Andhra Pradesh	43290	267477.55	199009.01	89434.15
Arunachal Pradesh	68602	527494.13	180673.44	81820.37
Assam	23824	299329.57	165652.81	74580.80
Bihar	26524	107356.63	71805.32	32765.22
Goa, Daman & Diu	1250	8969.56	6375.36	2868.91

Gujrat	12578	71938.23	44735.27	19924.12
Haryana	604	689.72	464.85	210.20
HP	12521	247483.99	106442.18	48909.11
J & K	20440	465185.73	180931.27	83225.78
Karnataka	32403	240865.41	147861.54	66484.14
Kerala	10334	89532.17	47959.28	21537.31
MP	131195	696440.96	439853.33	198427.67
Maharashtra	46143	207016.36	125582.63	55954.62
Manipur	17418	81473.92	44046.03	19868.31
Meghalaya	15657	112631.18	73216.88	32857.56
Mizoram	18775	65585.68	35765.64	16058.45
Nagaland	14221	95045.32	51701.86	23272.92
Orissa	46941	242737.85	171486.83	78264.95
Punjab	1387	934.80	648.40	291.83
Rajasthan	13353	12853.49	7863.78	3550.03
Sikkim	3129	39535.59	19481.35	8789.05
Tamilnadu	17064	65690.44	41844.81	18829.17
UP	33994	300518.10	172032.75	78773.06
West Bengal	8349	62661.05	42339.55	19200.71
Tripura	5546	15458.79	8564.13	3846.41
Dadar and Nagar Haveli	204	1418.34	937.02	420.73
A & N Islands	7613	13703.40	8098.13	3644.16
Total	633357	4340027.96	2395373.45	1083809.74

Note: Figures given in Table 4 correspond to 1997 assessment (SFR '1997) and data correspond to period from 1993-1995

Above results are based on forest cover as assessed by visual interpretation of satellite data on 1:250,000 scale. Due to cartographic limitations, it was not possible to delineate forest cover bearing areas less than 25 ha in extent. There is considerable forest cover in such isolated patches. Moreover, linear features like roadside, canal side, rail side plantations, village woodlots, trees on farmlands are not reflected in satellite data based assessments.