Methodology used by FSI in Carbon Stock Accounting

Chapter 3

As stated in earlier chapters, for the purpose of Second National Communication (SNC), the FSI conducted a study 'Greenhouse Gas Inventory in Forest Land Remaining Forest Land & Land Converted into Forest Land for the period 1994 to 2004 under LULUCF'. To conduct this exercise, land use matrices were developed for the period 1994 to 2004 for forest land remaining forest land and land converted into forest land. The changes in carbon stock and hence CO_2 emission and sequestration were measured for the five carbon pools.

The calculation of GHG inventories require information on extent of area (in case of LULUCF) of an emission/removal category termed as 'Activity data' and emission or removal of GHG per unit of area (removal of CO_2 per ha of added forest area) termed as 'Emission factors' as per the 'Good Practices Guidance' (GPG) developed by Intergovernmental Panel on Climate Change (IPCC). The methodology used by FSI for activity data and emission factors has been described in the following paragraphs.

3.1 Methodology for Estimating Activity Data

Three different methodologies are advocated in GPG and are being used by different countries to assess the extent of area (activity data) under 'Forest land remaining forest' and 'Non-forest land converted to forest'. These methodologies are: Wall-to-wall mapping using remote sensing data, Mapping of sampled areas using remote sensing data and Using field survey methods. For the SNC, it was decided to use remotely sensed (RS) data and adhere to the guidelines of GPG with respect to RS data. A hybrid approach combining automated digital classification techniques with visual interpretation was used. This technique is generally used as it is simple, robust and cost effective. For the purpose of this exercise, data pertaining to year 1994 had to be brought to compatible format vis-à-vis 2004 with regard to the scale and the technique of interpretation.

3.1.1 Forest Cover Mapping

Though the forest cover data of the country is available with FSI on a two years interval since 1984, there has been significant change in the interpretational techniques and its scale particularly since 2001. Prior to 2001, the interpretation of satellite data was manual/ visual and scale of interpretation was 1: 250,000 giving the minimum mappable area as 25 ha. Since 2001, it became fully digital thus making the interpretation more objective on a scale of 1: 50,000, giving a minimum mapping unit (MMU) as 1 ha. Therefore, the data of 2004 was not directly comparable with that of 1994.

Thus, to make information comparable, one major step in the refinement of the methodology was to use Landsat TM data of 1994, freely available in digital form and interpret it digitally on a 1:50,000 scale. For areas where Landsat TM (resolution 30 m) was not available, LISS-III of IRS 1B (resolution 36.25 m) was used. Further, instead of 2 forest density classes (dense and open) categorised earlier, the interpretation was carried out more precisely in three density classes (very dense- more than 70% density; moderately dense- between 40% to 70%; and open - between 10% to 40%) to make it fully comparable with 2004 data. This resulted in redoing of 1994 national forest cover assessment with the advance technology and as per present standards. The forest cover assessment figures of 1994 were duly normalised before finalization.

The forest cover assessment based on interpretation of 2004 satellite data (satellite IRS P6, sensor LISS III, resolution: 23.5m) had already been done as part of the FSI's mandated activity and has appeared in the 'State of Forest Report 2005'.

3.1.2 Forest Type Mapping

Forest type wise extent of forest cover is useful information which provides a basis for characterizing forests in terms of floristic composition and ecological value. Recently, FSI has done mapping of forest types of India, according to Champion & Seth classification (1968) on 1:50,000 scale down up to 200 types described in the classification. In the first ever such attempt at the national level, extensive study in GIS framework using the relevant layers like, soil, rainfall, temperature along with the remote sensing data, details from the working plans, thematic maps of FSI, inventory information etc was carried out. The exercise involved extensive and widespread ground truthing covering every part of the country. The district wise forest type maps of the entire country have been prepared. Using the forest type maps, distribution of forest cover in different forest types has been determined for the country. Regrouping type groups, fourteen forest type group classes and one plantation group were considered for SNC.

3.1.3 Stratification of Activity Data

Stratification is required for any heterogeneous population to gain precision of estimates by dividing it into relatively homogeneous sub-population based on some stratification variable. Since, in this case, carbon stored in the vegetation is principal variable which definitely depends upon canopy density and forest type; these two has been considered as stratification variables. Canopy density wise spatial information is available from the 'forest cover mapping'. This was supplemented with the forest type wise information generated under the national forest type mapping project carried out by FSI. This gave three canopy density classes and fifteen type group classes, thus resulting forty-five classes in all.

For example, forest of Uttarakhand state of India is stratified using these two stratification variables as shown in Fig. 3.1.

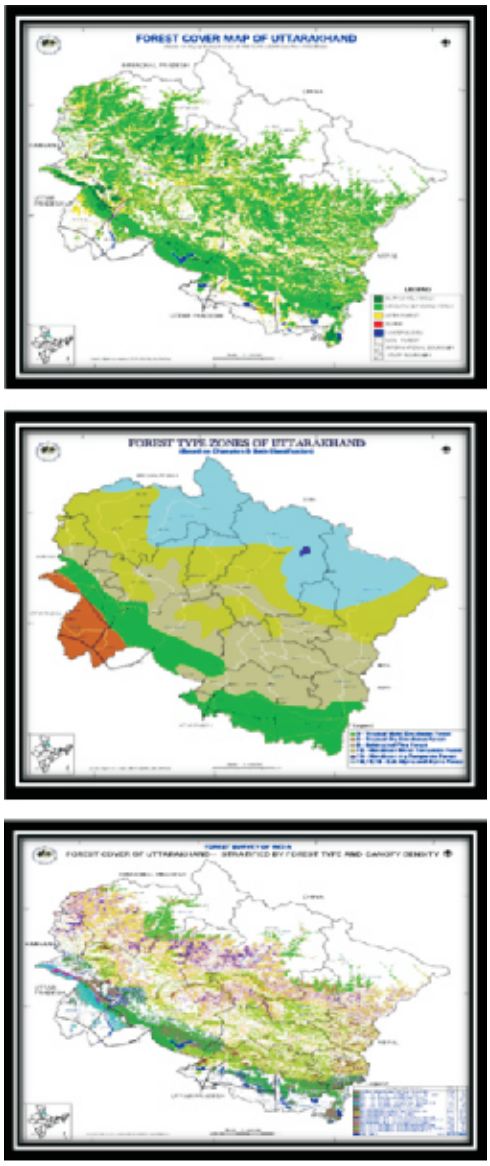


Figure: 3.1 Illustration of Statification

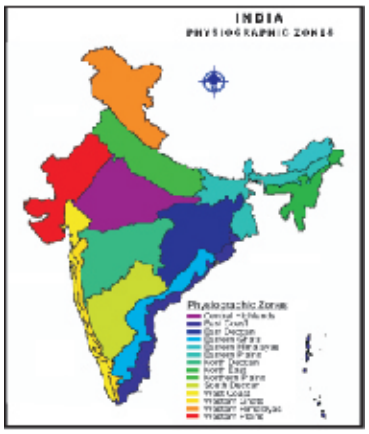
On the 1994 forest cover maps the forest type information of 2004 was projected as the best approximation in the absence of any information about the geographic distribution of forest types of India in 1994. This approximation draws strength from the fact that forest type of an area does not change within a span of 20-30 years.

Using this classification, area statistics (activity data) were generated through GIS technique for the two categories: forest land remaining forest land in 1994 and 2004; non-forest land in 1994 becoming forest land in 2004.

3.2 Methodology for Estimating Emission Factors

To measure exchange of GHGs between forest eco-system and the atmosphere which is eventually the change in carbon stocks over time, FSI has used Stock-Difference method (inventory based approach or periodic accounting) for estimating various emissions factors as recommended by GPG. The various emission factors are not separately available for the year 1994 and 2004. However, the same have been estimated partly by using the NFI data collected during 2002-2008 and partly by conducting a special study between 2008-10. The same factors have been used for both the year viz 1994 and 2004. The methodologies followed in deriving these factors are given below:

3.2.1 Above Ground Biomass (AGB) of Trees having DBH ≥ 10 cm and Bamboo



Under the national forest inventory (NFI) programme, FSI has been conducting forest inventory since 2002. The sampling design adopted for national forest inventory is two in stages. In the first stage the country is divided into homogeneous strata, based on physiography, climate and vegetation, called as physiographic zones and the civil districts form the sampling unit. There are 14 physiographic zones; Western Himalayas, Eastern Himalayas, North-East, Northern Plains, Eastern Plains, Western Plains, Central Highlands, North Deccan, East Deccan, South Deccan, Western Ghats, Eastern Ghats, West Coast and East Coast.

A sample of 10 percent districts (approx. 60 districts in the country) distributed over all the physiographic zones in proportion to their size are selected randomly for detailed inventory of forest. In the second stage selected districts are divided into grids of latitude and longitudes which form

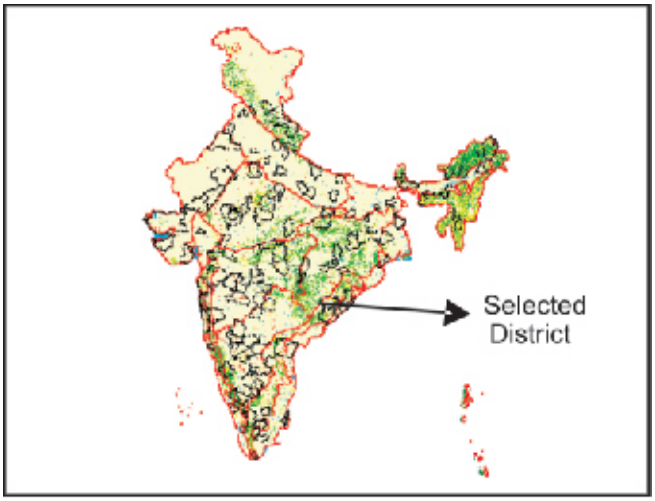


Figure 3.2: Selected districts of a cycle

the second stage sampling unit.

For forest inventory in selected districts, plots are systematically laid out in forest area which is indicated on topographic sheets by double dotted line, printed as RF, PF, thick jungle, thick forest etc, shown in green wash and any other area reported as forest area (generally un-classed forest) by the

Figure 3.3: Scanned Toposheet of 1:50,000 scale

local Divisional Forest Officer.

For each selected district, Survey of India (SOI) toposheets of 1:50,000 scale (size 15'×15' i.e 15 minutes latitudes and 15 minutes longitudes) is divided into 36 grids of 2½'×2½' which is further divided into sub-grids of 1¼'×1¼' forming the basic sampling frame. Two of these sub-grids are then randomly selected to lay out the sample plots. Other forested sub-grids in the districts are selected systematically taking first two sub-grids as random start. The intersection of diagonals of such sub-grids are marked as the centre of the plot at which a square sample plot of 0.1 ha area is laid out to record the measurements. Within sample plot, sub plots of 1m x 1m are laid out at NE and SW corner for collecting data on soil, forest humus. The data on herbs and shrubs including regeneration are collected from four square plots of 1m x 1m and 3m x 3m respectively. These plots are laid out at a distance of 30 meters from the centre of 0.1 ha sample plot in all four directions along diagonals in non-hilly area and along trails in hilly areas. In case of hilly areas, the plot are taken randomly 3-10 meters away either side of

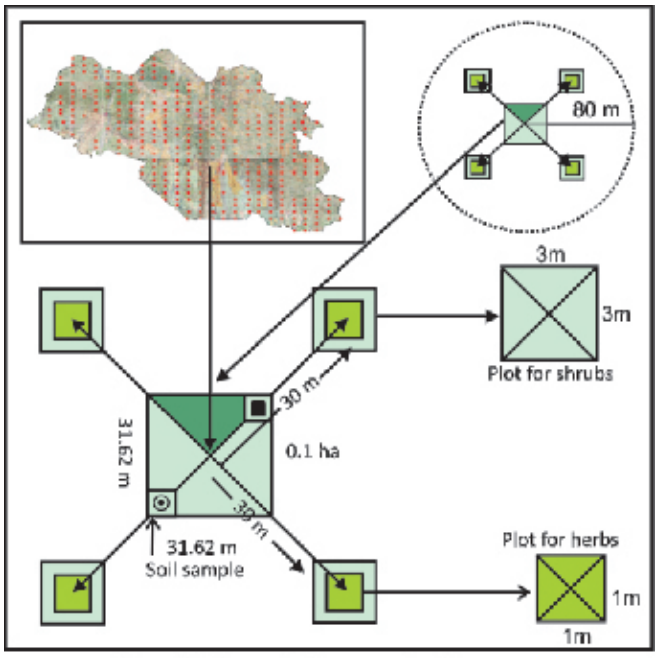


Figure 3.4: Layout of the sample plot

the trail.

At each sample plot all trees of diameter 10 cm and above were measured. The woody volume of trees for each sample plot was calculated using volume equations developed by FSI for various species (given in Annexure-I). The volume equation provides above ground woody volume i.e. above ground volume, which includes volume of main stem measured upto 10 cm diameter and volume of all branches having diameter 5 cm or more. As per the design, data from about 21,000 sample plots (size 0.1 ha) had been collected between years 2002-2008. Data of specific gravity and percentage carbon content of most of the tree species have been obtained from different published literature. For few species, percentage carbon content was ascertained by experimentation and for remaining an average of all other species was used. Standard formulae were used to calculate biomass and carbon content of each tree.

The estimates of bamboo biomass and carbon stocked in this resource are also calculated from NFI data. For estimating volume of the bark, the double bark thickness of trees measured during forest inventory and volume equation of trees have been used. Using species-wise, dbh and bark thickness, bark volume equations were developed and were adjusted for 'bark void factor' which were utilized to estimate bark volume. With the help of the specific gravity of bark, the volume was converted into biomass. Using carbon content percent of wood, carbon stored in bark was estimated and included in the above ground biomass.

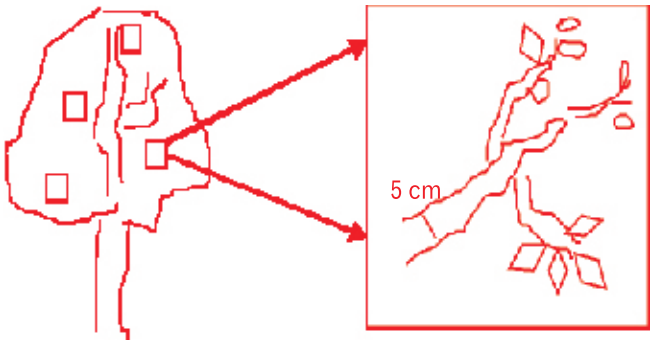
3.2.2 Above Ground Biomass of Branches, Foliage of Trees having DBH ≥ 10 cm

The trees measured under national forest inventory (NFI) give the volume of main stem measured upto 10 cm diameter and volume of all branches having diameter 5 cm or more. It does not give the volume of main stem less than 10 cm in diameter, small branches, foliage, fruits and twigs. Since these components also stock carbon

in them, their contribution in carbon stock should be accounted. This can be done by developoing biomass equations taking dbh as independent variable and biomass of these components as dependent variable. Once these equations are developed, biomass of each enumerated tree can be estimated for small wood and foliage.

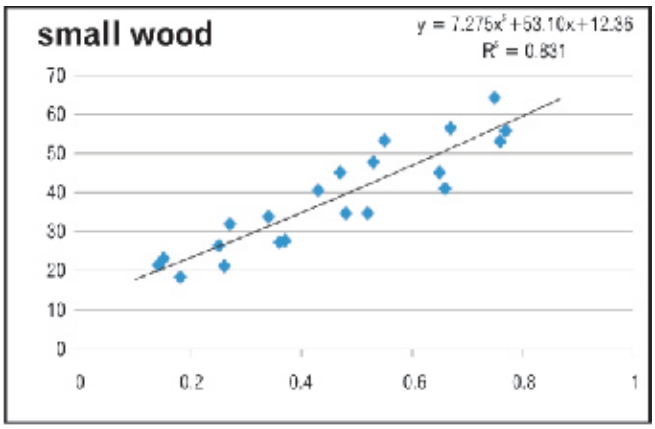
To develop biomass equations of small wood and foliage for each such species other than palm like trees, FSI undertook a special study during 2002-08. The classical approach of developing biomass equation demands for destructive sampling involving felling of trees. In addition, the process is very tedious and therefore a new method which required lopping off, at the most few branches of few trees, was developed. With the analysis of NFI data collected during 2002-08, 20 important species were identified in each physiographic zone and thereafter dbh range was ascertained for each of the species. DBH of most of the species were ranging from 10 cm to 90 cm. Therefore, it was decided to make dbh classes of 10 cm interval starting from 10-20, 20-30,……,80-90 and 90 cm and above.

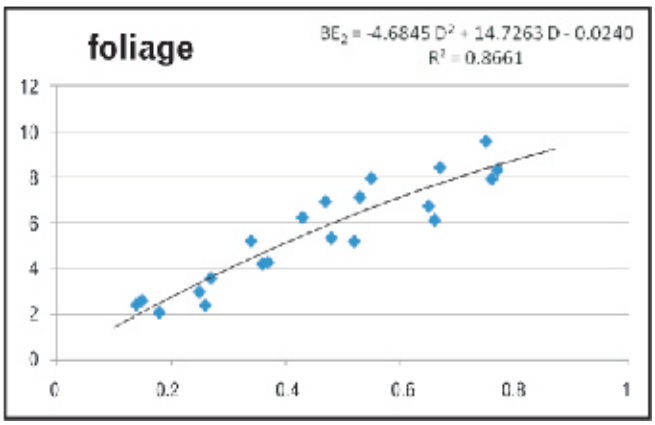
To collect data for this purpose, separate formats were devised. In each of the diameter class, three normal trees are selected. The normality is defined with respect to that forest. The tree chosen for data collection represent the general condition of that species in that forest. Its DBH, height, crown length, crown width in two direction and shape of the crown is recorded. In addition, canopy blank in that tree is also recorded.



For the purpose of biomass calculation, one normal tree of each diameter class of each species is selected. In the selected tree, one square meter window in all the four directions is opened in the crown until woody branches of 5 cm. dia is reached. All such material from window is felled i.e. woody branches up to 5 cm dia, twigs, leaves, fruits and flowers. Biomass of all these parameters is separately recorded in the prescribed formats. For palm like species two leaves are felled from each tree in each diameter class and their weight and total number of leaves in those trees is counted and recorded for biomass calculation.

Taking the dry biomass of small wood/foliage as dependent variable and dbh as independent variable, biomass equations were developed for each species. For example, equations developed for Dalbergia sissoo giving weight in kilograms

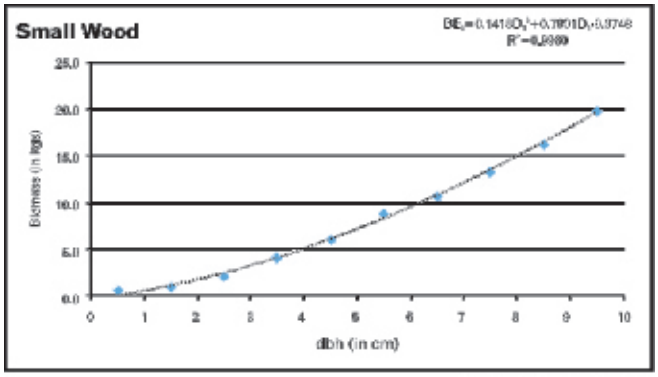


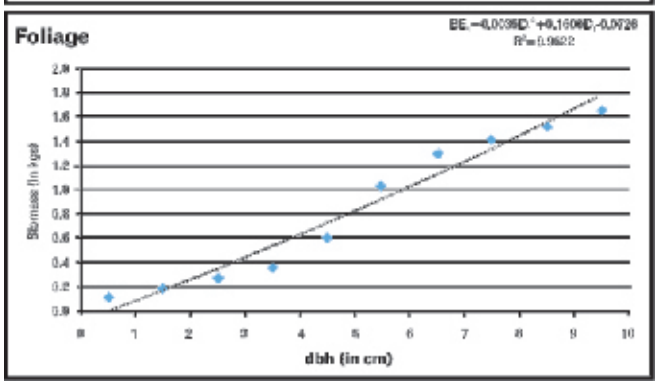


and dbh in meters is given as follows:
Similary biomass equations for other species were developed which are given in Annexure-II. Using the plot level data of NFI, species wise carbon content, the total biomass and carbon content at plot level was calculated.

3.2.3 Above Ground Biomass of Trees having DBH < 10 cm

During the NFI, all trees having diameter 10 cm and above are taken into account. The trees less than 10 cm in dia are not measured. Since from carbon accounting view, these trees are to be measured, a special study was conducted by FSI to develop biomass equations for such trees. For this purpose, as described above, 20 important tree species were identified for each of 14 strata on the basis of NFI data collected between 2002-08. For each of such species, 3 trees of diameters 1-9 cm (at 1.37 m. height) were felled. From the felled trees, separate biomass was calculated and recorded for wood, twigs and leaves in the prescribed format. Taking the dry biomass of wood/foliage as dependent variable and dbh as independent variable, biomass equations were developed for each species. For example equations developed for Dalbergia sissoo giving weight in kilograms and dbh in cms is given as follows:





Similary biomass equations have been developed for other species which are given in Annexure-II. Using the plot level regeneration data from NFI i.e. recruits, un-established, established and all trees having dbh between 5 to 10 cm, biomass and carbon content at plot level is calculated.

3.2.4 Above Ground Biomass of Shrubs, Herbs, Climbers and Biomass of Dead Organic Matter (DOM: Dead Wood and Litter)

For this purpose, the data of forest inventory conducted during 2002-08 was analysed to ascertain the optimum number of plots required for each combination of forest type and forest density. It revealed that about 15 clusters of 2 sample plots for each combination, would suffice for estimating the biomass/carbon factors for these components if 30% permissible error is considered. This survey was conducted in the districts on randomly selected points which were already inventoried during 2002-2008 and for which forest type and density were known.

For the desired combinations of forest type and forest density, the exact geographical locations (latitude and longitude) of the optimum number of randomly selected sample plots were visited. Using this information, centre of sample point, three concentric plots of size 5mx5m, 3mx3m and 1mx1m were laid out at a distance of 30m away from the centre of sample point in North and South direction. In 5mx5m plot, all dead wood above 5 cm diameter were collected, weighed and recorded. In 3mx3m plot, all woody litter i.e. all branches below 5 cm diameter were collected, weighed and recorded. All shrubs & climbers in 3mx3m plots were uprooted, weighed and recorded in the prescribed format. In 1m x 1m plot, all herbs were uprooted, weighed and recorded. Dry biomass was converted to carbon stock. Thus on the basis of data collected, carbon factors were developed for each forest type and

density.

3.2.5 Organic Matter in Soil and Forest Floor

During forest inventory, the data on forest floor (non-woody litter and humus) and soil carbon is also collected from each sample plot. For collecting data on humus and soil carbon, two sub-plots of size 1mx1m are laid out within the main plot. The forest floor from both the plots was first swept and material so collected was weighed and a portion of same was kept for carbon analysis. Further, at the center of these two sub-plots, a pit of 30cmx30cmx30cm was dug and a composite sample of soil of 200gm was kept for organic carbon analysis. Samples of soil and humus were got analysed from the standard soil labs using Walkley-Black method and were used for the calculation.

3.2.6 Below Ground Biomass

This is the most difficult pool to measure and generally not measured in forest inventory. It is being included using a relationship (usually a root-to-shoot ratio) to aboveground biomass which have been established by various researchers. GPG also provide default ratios for six major global forest types. FSI has selectively used these defaults to arrive at the carbon number.

3.3 Synthesizing Data for National Carbon Estimation

GIS techniques were used to intersect forest type map (2004) and forest cover map (1994 and 2004) resulting in two maps having 45 strata (forest type and canopy density intersections) one corresponding to each year. The resulting map of 1994 was overlaid on map of 2004 to estimate the forest type canopy density wise area of forest land remaining forest and non-forest land converted to forest land. The extent of area of these strata were ascertained using GIS techniques. The geographical location of each sample plot of NFI was duly recorded with GPS during field visits. These locations helped in creating a GIS compatible point layer of the forest inventory plots. This NFI point layer map was overlaid on the above map having 45 forest type - canopy density strata. The NFI points falling in each stratum were identified. For each stratum, the plot wise information on all the parameters of each carbon pool, were aggregated to have generalized factor for that stratum. Biomass and carbon factors were specifically developed for each stratum like, shrubs, herbs, climbers, dead wood and woody litter. Multiplying activity data with these factors, different parameter wise total carbon for all the 45 strata were arrived at. This information was arranged into five carbon pools. Adding pool wise carbon contents, national carbon estimates were arrived at for the year 1994 and 2004. The difference between pool wise carbon estimates gave the net removal of carbon.

3.4 Methodology to Estimate Carbon in Finished Wood Products

The carbon stored in the harvested wood products was estimated from the study "Production and Consumption of wood" conducted by FSI in 75 districts in the country during 2008-09. Stratified random sampling was employed for the survey. The country was stratified into 23 strata formed on the basis of large states or group of states/UTs. The districts were first stage sampling units. It was presumed that production and consumption of wood in the district is related with the per capita forest cover. Accordingly, per capita forest cover of districts was utilized to ascertain optimum number of districts (sample size) required for the study, which in this case, comes out to be 62. To get proper representation of the said 23 strata, districts within strata were arranged in two groups, one containing districts having per capita forest cover more than or equal to the average per capita forest cover of the state (strata) and other containing districts having per capita forest cover less than the average per capita forest cover of the state. It was decided to choose at least three first stage sampling units (districts) from large states (strata). In this process the ascertained sample size of 62 districts has increased to 75 which were chosen randomly. In each selected district, data on production and consumption of wood was

collected.

3.4.1 Carbon in Finished Wood Products in Commercial Units

The optimum number of registered industrial units (sample size) to be surveyed was based upon the results of the study on "Saw milling Survey" conducted by FSI during 1978-79. It was presumed that the average production of industrial units would remain, by and large, same and so is its variation. The sample size from this study was ascertained as 2300 for whole of the country. This sample size is equally distributed in all the selected 75 districts ie, 30 industrial units from each district. In a district industrial units are categorized in four groups on the basis of products it makes. 30 sampling units are proportionately allocated to different groups. In addition to data on production, inputs like quantity of wood in usage in construction and furniture and fixtures etc. were also recorded. Wood based industrial units which are not registered with the agency from which the list of WBI is obtained and the small establishments (Match, Packing case, Furniture, Sports goods, Wood carving, Basket making, Kattha, Mining, Brick kilns, Lime kilns, Oil & jiggery mills, Potteries & utensil making, Body building of various vehicles including boats, tool handles making, tent house, Dhaba, Pole & balli suppliers etc.) consuming wood as input for manufacturing products or as a source of energy was covered separately while surveying households.

3.4.2 Carbon in Finished Wood Products in Households and Small Establishment

The sample size for estimating wood consumption in households and small establishments had been determined on the basis of "Wood Consumption study of Haryana" conducted by FSI during 1995. Using the results of this survey, it is ascertained that 100 villages and 50 UFS blocks are to be surveyed from each state/group of states/UTs for collection of consumption data on small timber, pole, bamboo and fuel wood in households and small establishments in rural and urban areas.100 villages and 50 UFS blocks were equally distributed among all the selected district of the state. All villages of district were arranged in descending order of population. If n villages are to be selected then this list of villages were to be grouped into n/2 groups and 2 villages were randomly selected from each such group. In the selected villages/UFS blocks, the households were categorized in three groups based on their economic status. Thereafter 12 household from each village and UFS block were selected proportionally and randomly from each stratum. Villages were second stage sampling units for rural area and households were the third stage sampling units. UFS blocks were second stage sampling units and households were the third stage sampling units for urban sector. All the wood based and fuel wood based small establishments falling in the selected villages/UFS blocks were surveyed. In each selected households, apart from other

The total estimated carbon stored in harvested wood products is 257 million tonnes.

Items	Household	Commercial Units		Total
		Own Account Establishments	Other Establishments	
Volume of wood (m cu m)	652.99	50.25	155.64	858.88
Biomass (m tons)	424.44	32.66	101.17	558.27
Carbon (m tons)	195.24	15.02	46.54	256.80

information, consumption of wood in all the wood articles in use, were recorded. In small establishments, in addition to data on production, inputs such as quantity of wood used in construction and furniture and fixtures were also recorded.

From this data, volume of wood in finished products in industrial units, small establishment and household sectors were estimated. Since, it was difficult to know the timber species; a common specific gravity was used to convert volume data to biomass data and similarly common carbon content percentage was assumed to convert biomass into total carbon stored in finished wood products.

3.5 Quality Assurance & Quality Control Plan

The quality assurance is the process which surveying/assessing institution put in place for assuring the quality of product prior to implementation of work, viz, defining objective (s) & all the terms and concepts, designing of work plan, preparation of working manuals, capacity building of concerned officials, testing of all developed procedures before finalisation, preparation of regression equations & indices using validation, use of suitable factors (carbon content, wood density etc) etc. The carbon stock estimation carried out by FSI uses four products viz. Forest cover maps, Forest type maps, NFI data sets and results of biomass study. All these products have been generated following the strict quality assurance processes specifically developed for each of the programme.

The quality control is the process which surveying/assessing institution put in place for controlling the errors which may arise during the implementation of work, viz. data acquisition, data recording, coding, data entry, data processing, interpretation of results etc. For each of the programme and for each of the error mentioned above, separate quality control processes are evolved and put in place for quality product.

Following above measures, the different products used for estimation of carbon estimates are of high reliability. The forests cover classification has an accuracy of 92%; the forest type classification which is used for carbon stock estimation has an accuracy of 88%; and the standard error percentage of the estimate of growing stock at national level arising from NFI is about 2%. The standard error percentage of the estimates of carbon contents of dead wood, woody litters, shrubs, climbers, herbs and grasses at national level arising from special biomass study is high, about 30% as was envisaged. Thought, the contribution of dead wood and woody litter and shrubs, climbers and herbs and grasses is 3% and 1% respectively of total forest carbon, the estimates of these pools is important as they have distinct regional variation. This margin of error will be reduced considerable in future as they have been made a part of regular NFI since 2010.

3.6 Constraints

All attempts are made to report the carbon stock as precise as possible. However there are some constraints in the study, the activity data i.e. forest cover classification used in the study pertains to 1994 and 2004, the results of these two years are not same due to difference in technology and methodology. Therefore, the forest cover classification 1994 was re-done using advance technology and methodology used for assessment of 2004 to make it comparable with 2004 data. Since the classification for 1994 data was carried out in 2008, it was not possible to carry out any ground truthing. Similarly the emission factors which are based on field inventory data collected during 2002-2010, has been applied both for 1994 and 2004. The biomass equations used in the estimation of Carbon Stock have been developed by FSI through a special study. These biomass equations have been envisaged to be developed for 20 major species found in each physiographic zone. However in some of the physiographic zones, equations could not be developed for few

species due to inadequate data. The species wise specific gravity and carbon content percentage is also not available for all the species. The below ground biomass has been estimated using root-to-shoot ratio as per the guidelines of IPCC in absence of any field data. While collecting the soil sample, the area of rocks and percentage of gravel in soil sample is being estimated occularly. For estimation of carbon stock at state level, small area estimation technique has been used where data is not adequate. FSI is continuously working to overcome these stated limitations and it is