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USE OF VOLUME/ ALLOMETRIC EQUATIONS IN NATIONAL BIOMASS ESTIMATION

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ABSTRACT

The role of volume/allometric equations in precise estimation of National Forest Biomass/Carbon is immense. In the United Nations Framework Convention on Climate Change, the potential benefits for non-annex-I parties will be based on results that must be measured, reported and verified. Therefore, precise volume/allometric equations will play an important role in verifying the volume and carbon stock estimates for the country. The data collected during National Forest Inventory (NFI) is used for estimation of carbon stock in country's forest using species wise volume/allometric equations developed by FSI. FSI has developed around 750 volume equations for 190 species spread throughout India, Bhutan and parts of Nepal. In addition, FSI also developed more than 600 allometric biomass equations for different species in different physiographic zones of the country through a special study. FSI continuously develop local volume equations using the data collected during NFI and used them for estimation of volume. In addition, volume equation can be used for estimation of quantity of wood contain in trees, prediction in future yield and estimation of increment.

Key words : Volume, Allometric equation, Biomass estimation, Carbon stocks.

Introduction

Growing stock (volume of wood) constitutes the most important parameter of the forest resources. Growing stock is an indicator of forest productivity (GoI, ISFR, 2005). Historically forest have been managed to produce wood (timber) as a major product. Forest inventories primarily aimed at assessing the growing stock and the traditional working plan prescription focused on sustained yield of timber from forests. Growing stock information has gained further importance in the present scenario because of the role forests play in climate change and global carbon cycle. Growing stock provides biomass of forest eco-system and carbon pool. Thus periodic assessment of growing stock both inside and outside forest through inventories has become the need of the hour. The precise estimates of growing stock largely depend upon the availability of accurate volume/allometric equations.

Forest Survey of India has been generating information on growing stock of forests since its inception in 1965 when it was known as the Pre-Investment Survey of Forest Resources (PISFR). The immediate objective of PISFR was to estimate availability of wood from forests rich catchment areas for establishing wood based industries. The inventory was continued in different parts of the country till 1981, the year when PISFR was renamed as Forest Survey of India (FSI). Different sampling designs were followed in different parts of the country during PISFR. Even after the creation of FSI, inventory of forest in the country was one of the main activities following a uniform sampling design. Three - fourth part of the county's forests had already been inventoried till 2001 with some areas inventoried twice. Since the inventory was carried out in different parts of the country in different time periods, it was not possible earlier to have national level estimates of growing stock of the country which was imperative for strategic planning of the forestry sector. Therefore, in 2002, FSI revised its methodology so as to have national level estimates of growing stock for both inside and outside the forest areas at an interval of two years. FSI has been publishing information on national level estimates of growing stock both inside as well as outside forest areas in its biennial reports since 2003.

National Forest Inventory (NFI)

FSI started NFI in 2002 for generating national level estimates of growing stock both inside and outside the forest area at an interval of two years. The sampling design adopted for national forest inventory is two 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, East ghats, West coast and East coast.

Sample of 10 per cent districts (approximately 60 districts in the country) distributed over all the

FSI has developed around 750 volume equations for 190 species spread throughout India, Bhutan and parts of Nepal.

physiographic zones in proportion to their size are selected randomly for detailed inventory of forests. In the second stage selected districts are divided into grids based on latitude and longitudes which form 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 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 intersections 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 North East and South West 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 the trail. For dead wood two plots of 5x5 m are laid out at NE and SW corner. The data is collected in various pre-designed field forms.

The data collected in the field is entered into the computer with the help of data entry module developed by FSI. The data entry is carried out by zonal offices of FSI. The entered data is checked and cleaned before processing. The data processing is carried out by in-house developed data processing software. The final output of forest inventory is growing stock at national and state level, species and diameter class wise estimated stems and their volume. This form the basis for calculation of biomass and finally carbon stock in the forest.

Volume equations

The annual increase in growing stock (interest on the capital) is harvestable and, more often than not, guides the quantity prescribed for harvesting. For the management purposes, the forester is often concerned with determining the volume of a large number of trees falling within certain dimension viz. Diameter and height classes. This is where the volume tables come into picture, as they help in determining the volume of the trees. Volume tables are based on diameter and / or, height and /or form of the trees. A volume table may, therefore, be defined as a statement giving in tabular form the average volume of trees by girth, diameter, height or form classes. Volume tables are constructed from volume equations.

Trees with similar diameter and height even for the same species do not necessarily have the same volume. This is due to the variation in the form of the trees caused by natural forces or the pattern of utilisation. A single volume table that would apply to all conditions and species is therefore not possible. There are different types of volume equations as described below:

i) *Local volume equation:* The local volume equations have limited application for a forest or small locality and are based only on diameter at breast height (dbh). The basic assumption involved in preparation of local volume equations is that the trees of same dbh have same height and form. It may be true as all the three variables; dbh, height and form are the products of the site quality, age and other conditions affecting the growth. A volume equation of this type applied to the sites with similar ecological conditions and productivity values gives true result.

ii) *Regional volume equation:* It is normally based on two variables such as dbh and height and covers a wide range of distributions of the species in a particular region.

iii) *General or standard volume equation:* It is more broad based and covers the full distribution of the species over a large area.

As far as the accuracy is concerned, the first two are accurate as the standard volume equation. Regional volume equation is a standard volume equation with limited application .A local volume equation can be easily prepared from a standard or regional volume equation by finding out the dbh/height relationship of the species for the locality. FSI continuously develops local volume equations from the general volume equation by using the data collected during NFI.

Volume equations for different species found in different part of the country were developed by FSI. For preparation of volume equations of a tree species, efforts were made to cover a good range of available diameter. Generally thirty or more trees were measured for this purpose. The trees for the measurement were selected randomly. Volume equations are selected on the basis of

R^2 (coefficient of determination), adjusted R^2, Standard error of model, Analysis of Variance, testing of regression coefficients, analysis of residuals etc.

Forest survey of India has developed a total number of 753 volume equations for 198 species spread throughout India, Bhutan and parts of Nepal (Govt. of India 1996). The detailed general description for 198 species has been given in the book on Volume Equation in India, Nepal and Bhutan. The 'n'(total number of sample trees on which regression equations were based)and 'R^2' (Co–efficient of determination) values have been given for 592 volume equations. The states and Union Territories covered through these studies are Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, and Gujarat , Goa , Haryana, Himachal Pradesh, Jammu & Kahmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra Manipur, Meghalaya, Mizoram, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura , Uttar Pradesh, West Bengal and Andaman & Nicobar Islands.

These volume equations are based on a large volume of data collected during the field inventory work and have been developed during the last 30 years. These volume equations are useful to determine the volume of trees and crops, growing stock, increment etc. These parameters/ information are in turn useful not only for the judicious management of forests but also become important source of information for national level planning.

Allometric equation for 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 (Govt. of India 2012, Carbon Stock Report). 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 was done by developing 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 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.

To collect data for this purpose separate format 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. diameter is reached. All such material from window is felled i.e. woody branches up to 5 cm meter, 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.

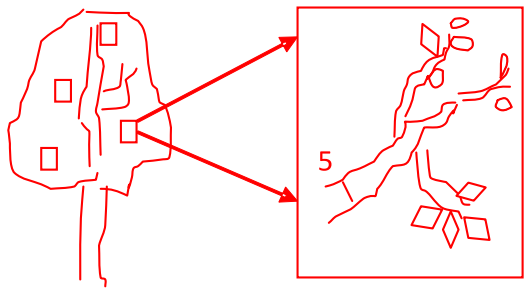


Fig.1

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.

Similarly biomass equations for other species were developed which are given in Annexure-II of FSI report Carbon Stock in India's Forests (2012).

Allometric equation for 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

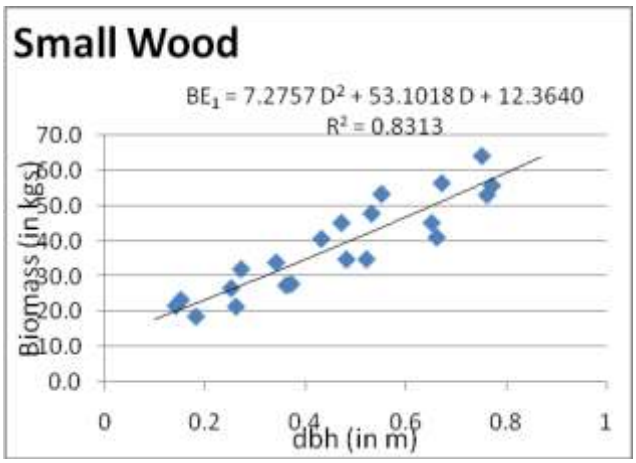


Fig. 2

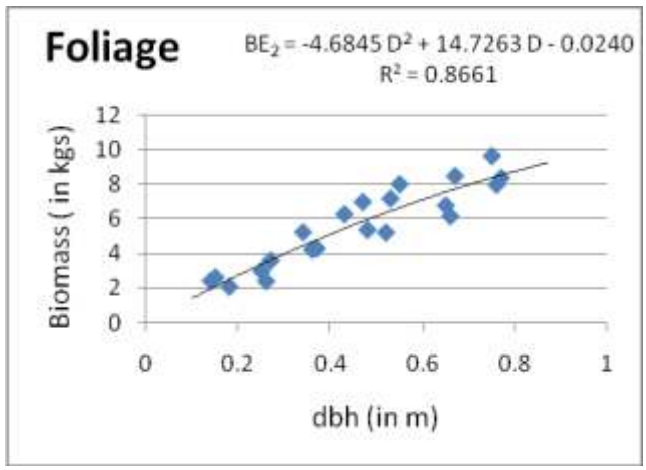
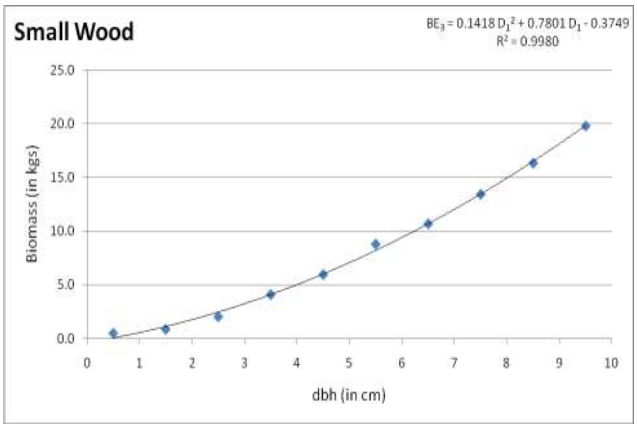


Fig. 3



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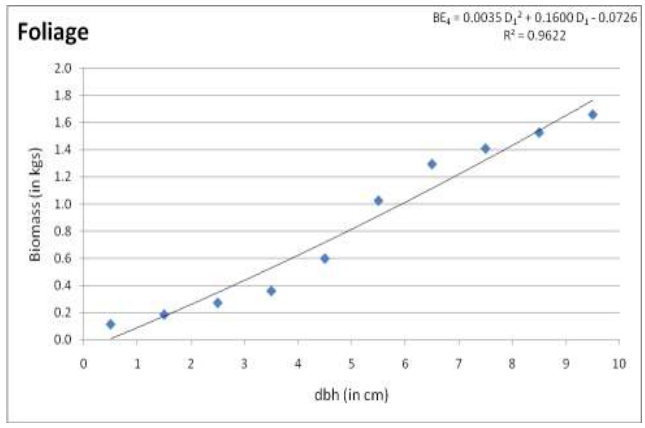

Fig. 5

diameter 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, 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 in Fig. 2 & 3.

Similarly biomass equations have been developed for other species which are given in Annexure-II of FSI report Carbon stock in India's Forests (2012).

National Biomass and Carbon Stock Estimation

The data collected during NFI is used for estimation of Carbon Stock in the Country's Forest using volume equations and allometric equations developed by FSI. The final output obtained from forest inventory is number of stems and their volume for different species accordingly to different diameter classes at the national level. The volume is converted into biomass using specific gravity of different species obtained from various research papers published by ICFRE, FRI etc. To convert the biomass data into carbon, carbon content percentage in different species was estimated from FSI. The biomass estimates are multiplied by carbon content percentage to obtain the carbon stock in different species. Similarly for Above Ground Biomass of branches, foliage of trees having dbh 10 cm and of trees having dbh < 10 cm are estimated using biomass equations developed by FSI. To obtain the carbon stock in different species, biomass estimates are multiplied by carbon content percentage.

As per the India State of Forest Report (2013), the total carbon stock in forest is estimated to be 6941 million tones (Govt. of India ISFR 2013). There is an increase of 278 million tonnes in the carbon stock of country as compared to the last assessment of the year 2004. The estimates of carbon stock as per ISFR (2013) which corresponds to data year of 2011 and the changes in carbon stocks with respect to 2004 as given in ISFR (2011) are presented in the table below:

Table 1: Change in Carbon stock between 2004 and 2011

Pools	Carbon stock in forests in 2004 as given in ISFR 2011 (m. tones)	Carbon stock in forests in 2011 (m. tones)	Net Change in carbon stock (m. tones)	Per cent Increase (Million tonnes)
Above ground	2,101	2,192	91	4.33
Below ground	663	694	31	4.68
Dead wood	25	27	2	8.00
Litter	121	130	9	7.49
Soil	3,753	3,898	145	3.86
Total	6,663	6,941	278	4.17

Conclusion

FSI is estimating biomass/Carbon stock under different pools following a standard methodology as defined by IPCC. These estimates are reported in FSI biennial report ISFR and also being reported to UNFCCC. The use of volume/ allometric equation is immense in precise estimation of carbon stock. In addition, volume equation can be used for estimation of quantity of wood contain in trees, prediction in future yield and estimation in increment.

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