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Original Research Paper

Assessment of Tree Volume and Growing Stock in Kharagpur Forest Range of Bhimbandh Wildlife Sanctuary in Bihar - An Integrated Geospatial Approach~

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Key Words:
Forest cover type Forest stratum
Crown density
Tree volume
Growing stock

ABSTRACT

Planners and policy makers need information about availability of wood from important tree species growing inside and outside forest areas. In recent years, satellite remote sensing has emerged as one of the powerful technologies for generation of spatial information due to repetitive, synoptic view, availability of data in inaccessible areas, and digital nature of data. In the present study, IRS LISS-III satellite data of November 2006 has been digitally interpreted and forests have been classified into different forest types on the basis of density classes. With the help of GIS, different layers have been digitized and maps were produced. Using general volume equations and specific gravity of different species from FSI publications, the volume per hectare and growing stock per hectare of individual forest cover types for the whole forest area were estimated. The study revealed that pure Sal forest has maximum volume content followed by bamboo-mixed forests, Sal-mixed and miscellaneous forests. This is probably first attempt for detailed survey of remote and inhospitable areas of Kharagpur forest range of Bhimbandh Wildlife Sanctuary in Bihar, which has accessed detailed ground truth collection for tree volume mapping and growing stock estimation.

INTRODUCTION

According to FAO, forest is a land with a tree canopy cover of more than 10 percent and area of more than 0.5 ha.~In India, however, legal connotation of forest is employed as an area of land recorded as forest in revenue records or proclaimed to be forest under a forest law or Act is described as forest. Assessment and monitoring of forest cover is important mandate of forest department. According to the Forest Resource Assessment 2000, world forests cover 3.9 billion ha and spread on about 30 percent of land. The net change in forest area was 9.4 million ha per year (rate of deforestation is 14.6 million ha and expansion 5.2 million ha). World total standing volume was 386 billion m^3, global total above ground wood biomass was 422 billion tones and in forests per ha biomass was 109 tones (FAO 2000a-d).~

The conventional methods of forest inventory are cumbersome, time consuming, and accuracy of the information is often disputable. Remote sensing provides an effective solution to this problem. Forests are one of the most important renewable natural resources because of their economic, environmental, aesthetic and recreational value. Forests are no more seen merely as storehouse of timber but as important ecosystems for biodiversity conservation and environmental amelioration. Hence, periodic assessment of the forests for their spatial extent and the distribution has become an essential requirement for all nations of the world.~

The stratification of forests gives estimates of volume at a low cost with limited ground sampling and thus reducing the fieldwork. However, certain qualitative and quantitative parameters of forest inventory such as tree diameter, merchantable height of tree, etc. are important for volume calculation, which cannot be measured from satellite image. However, forest cover type and tree canopy density classes can be made from satellite image. Thus, satellite images obtained by remote sensing can complement and improve the quality of estimates as well as reduce volume of work. Remote sensing technology with a limited ground truth/ground based studies can make it possible to carry out detailed forest inventories and monitoring of natural vegetation cover (Maslekar 1983).~

Remote sensing has become a valuable source of information over past three decades for forest mapping and monitoring activities. New developments in the remote sensing technology have indicated that, if these methods are judiciously combined with ground based studies, it is possible to carry out detailed forest inventories and monitoring of natural vegetation cover (Tucker et al. 1985). The information content available in multispectral data has become a necessity for integrated resource inventory in modern forestry practices (Roy et al. 1985, 1991, Kushwaha 1990, Benchalli & Prajapati 1998). Remote sensing-based two and three phase inventories have been found to be cost and time effective (Koehl & Kushwaha 1994).~

Timber volume, total growing stock and biomass content are the key information required for the forest planning and management (Tomar 1974, Strahler 1978, Peterson et al. 1986, Chaturvedi & Shah 1992). Satellite remote sensing data are being increasingly used in forest inventory. These are extremely useful in the correct delineation of strata depending upon species, density and in development of sampling designs. Remote sensing data facilitates in the stratification of forests within the limits of resolving capacity of the sensor system which in turn reduces the sampling error and allows the growing stock and biomass content assessment with fewer samples.~

In forestry, growing stock content estimation is an important parameter required for forest management and planning purposes. In earlier days, such information was collected by only ground methods. At present, satellite data are being increasingly used in forest inventory. It is extremely useful in the application of remote sensing techniques as it helps in the correct delineation of strata depending on species, density, volume etc. and distribution of sampling units in them. The stratification of forests gives the estimate of volume and biomass content in the shortest possible time. In order that the sampling may raise the most accurate estimate of the population. ~

The sampling design depends on certain factors, some of the important ones are: (i) objective of inventory; (ii) description of forest vegetation type; (iii) time and funds available; (iv) availability of personnel and survey equipments; (v) availability of satellite data and topographic maps; (vi) availability of automatic data processing equipment, and (vii) the results of the previous survey carried out in the area.

In fact, the main aim of preparation of forest inventory is the estimation of volume of trees and growing stock content. This is possible only when the forest is classified by the species/type, so that the tree volume and growing stock can be estimated precisely.~

STUDY AREA

Kharagpur forest range of Bhimbandh Wildlife Sanctuary is situated in the Kharagpur hills, southwestern part of Bihar. Its spatial distribution is approximately from 24°55’ to 25°45’N latitude and from 86°15’ to 86°33’E longitude. The sanctuary attained its legal status in 1976 vide Forest & Environment Department notification No. S.O. 965 dated 27th May 1976 and spreads over an area of

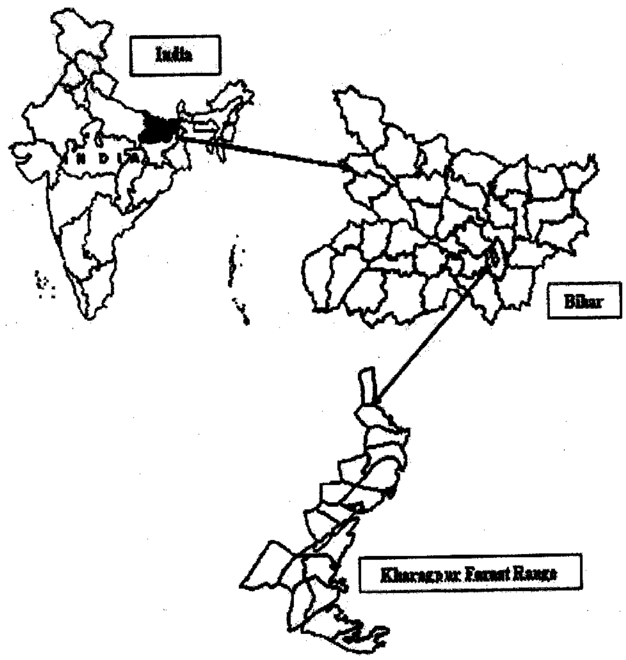

Fig. 1: Location of the study area.

178.49 sq. km (Fig. 1).~

The hill range consists of a number of steep ridges rising from the low ground on all sides with scraped faces of massive quartzite in places. They are of irregular formations and do not run in any uniform direction. Generally speaking the range is a bold and striking mass of rocks covered for most part with good to degraded forests. There are several peaks rising to a height of about 450 meters and the highest point is Maruk (488 m above MSL), a table top hill covered with forest and crowned with a deep layer of laterite.~

It has monsoon sub-tropical climate ranging from sub-dry to sub-humid conditions. There are three distinct seasons in this zone viz., summer, monsoon and winter. The average annual rainfall of the zone is 1078.7 mm. The rainfall distribution has a marked seasonal character. The rainfall under this zone is mainly influenced by the south-west monsoon. Soil is grey to dark grey in colour, medium to heavy in texture, slightly to moderately alkaline in reaction, cracks during summer becomes shallow with onset of monsoon, with clay content nearly 40% to 50% throughout the profile.

The forests of this tract are mostly of deciduous nature except in moist valleys and by the site of streams of the Kharagpur hills where moist sal forms almost a pure crop varying from pole to middle aged tree. The forests of the area can be broadly classified into the following types as per classification laid down in “A Revised Survey of Forests Types of India” by Champion & Seth (1968). 1. Moist deciduous low-level sal [3c/C2e (ii)]; 2. Tropical deciduous sal (5B/C1c); 3. Northern dry mixed deciduous with bamboo (5B/C2); 4. *Boswellia* (5B/E2); 5. *Aegle* Forest (5B/E8); 6. Scrub forests (5B/E8); 7. *Euphorbia* forest (5B/Ds3). There are also plantations of *Eucalyptus* and *Acacia*. Here, Sal is the main species mixed with its main associates such as *Terminalia*, *Bamboo* and other underwood and ground flora.

MATERIALS AND METHODS

Primary data consisted of digital data of IRS-1C, LISS-III sensor (Path/Row-105/54) of November 2005 with spatial resolution 23.5m for B2(g), B3(R) and B4(IR) and 60 m (SWIR) for B5 band with band width regions in B2 (0.52-0.59µm), B3 (0.62-0.69 µm), B4 (0.77-0.86 µm) and B5 (1.55-1.70 µm).

Ancillary data consisted of Toposheet No. 72 k/8, 72 k/12 (Source: Survey of India) of scale

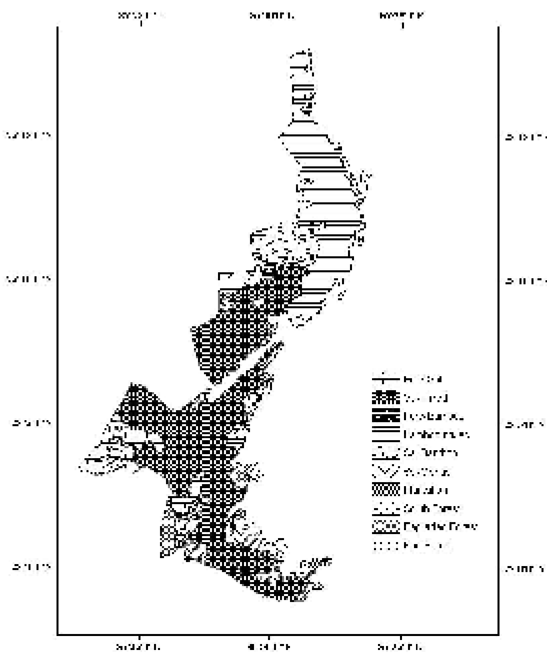

Fig. 2: Cover type map of Kharagpur forest range.

1:50,000, forest compartment map of Munger district, Management plan of Munger Forest Division, FRI publications on general volume equations, and FRI publications on specific gravity.

For image analysis, ERDAS Imagine software, and for data integration and data analysis Arc/Info GIS software were used. Garmin (model-72) 12 Channel Global Positioning System was used to record ground truth locations. Instruments used for collecting ground inventory data were Silva ranger compass, Blume Leiss hypsometer, diameter tapes and nylon rope.~

Preprocessing of satellite data: Radiometric and geometric distortions in satellite data were corrected following standard methods. Geometric distortions were removed by georeferencing the image-to-map registration using Survey of India sheets on 1:50,000 scale. The registration of image was performed using the nearest neighborhood resampling algorithm with second order polynomial. Scenes were geometrically corrected after selection of proper ground control points with a root-mean-square (RMS) error of less than half pixel.~

Sampling design: The precision of sample estimate of population depends not only upon the size of sample, but also on the variability in the population is very high, sampling variance can be reduced by dividing the population into the number of homogeneous groups and then selecting random sampling from these groups of population independently (Chako 1980). The homogeneous groups in which the population is divided are called strata and the procedure of sample selection is called stratified random sampling. The use of stratification is only possible only when the complete frame for all the strata and sizes are available. Effectiveness of stratification can be investigated by the analysis of variance. The variance of total population is made up of the variance within individual strata and of variance within the strata.~

In the present study, stratified random sampling was carried out. The number of sampling units was calculated by the following formula.

$$N = \frac{t2\ (CV\ \%)^2}{E^2 \sim}$$

Where, n = Number of samples required for allowable error (E %)

t = value of t-static at 95% level of significance: 1.96

CV = Coefficient of variation ± 33.5

Assuming the E% equal to 10% the required number of sample unit comes out to be 30. These sample plots were allotted to different strata of homogeneous vegetation according to stratified random sampling method. Random tables were used to select 30 sample points, and these points were transferred on the toposheet to get correct location on the ground for the growing stock estimation.~

In compliance with the earlier mentioned objectives, a suitable remote sensing GIS based methodology was adopted which has been elucidated below. The entire work was carried in the following steps.

- Pre-field work
- Reconnaissance survey, ground truth and field data collection
- Post-field work

Pre-field work: The location of sample points on toposheet (1:50000) was considered necessary for preparing the movement plan during the field work.
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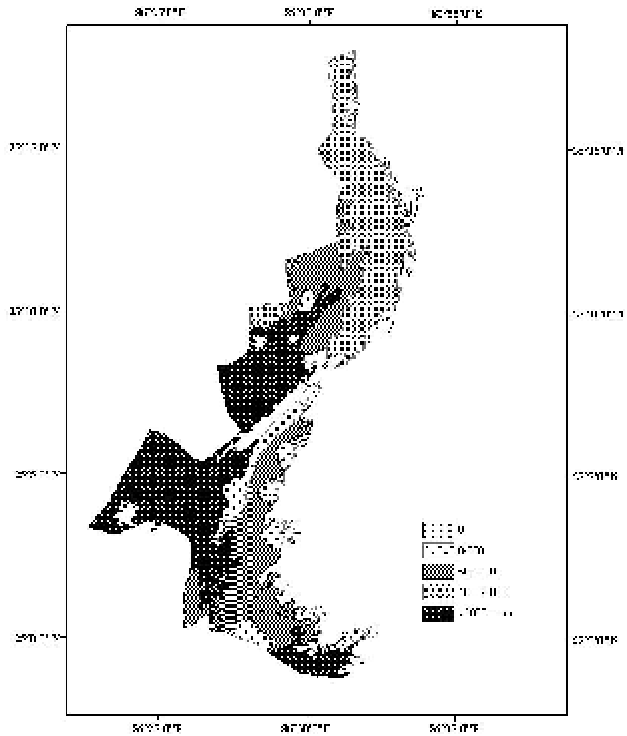

Fig. 3: Tree volume map of Kharagpur forest range.

~Permanent features like roads, highways, stream junctions were utilized as most points to serve as references for the exact location of the sample points on ground. All these permanent features and sample plots were transferred on the toposheet for correct location on the ground. Correction or changes were made using information available on FCC.~

Ground truth and field data collection: A date-wise systematic movement plan showing location of sample plots on the toposheet was drawn up in advance. Wherever, distinctness in the forest types and species composition was seen, relevant photographs were taken for suitable illustration of the study area. With the help of toposheet, the sample plots were laid out in the field. The size of sample plots was kept 0.1 hectare divided into four equal quadrants. Diameter measurements at breast height above 30 cm diameter of each tree species were made. Similarly, height of each tree in the sample plots were also measured. These measurements were promptly recorded in the individual formats for each of the sample plots. At the time of visits to the sample plots, constant visual observations were made to recognize and relate vegetation type with their tonal variation on satellite im-

Table 1: Area under different forest categories.

Forest	Area (ha)	Forest Area in (%)
Pure Sal	1132.93	6.35
Sal-mixed	9044.84	50.70
Sal-mahua	315.29	1.77
Sal-bamboo	1150.07	6.45
Pure-bamboo	123.77	0.69
Bamboo-mixed	4268.81	23.93
Plantation	61.76	0.35
Scrub forest	380.05	2.13
Degraded forest	689.99	3.87
Non-forest	674.15	3.78
Total	17841.66	100.00

Table 2: Forest canopy density classes with area in %.

Density Classes	Area (ha)	Area (%)
More than 70 %	2085.4	11.69
40%-70 %	11968.77	67.08
10%-40 %	1989.14	11.15
Less than 10 %	1133.79	6.35
Non-forest	664.15	3.72
Total	17841.25	100.00

age. In addition to that, some other information like status of forests, types of forests, species occurring in each storey, topography and ground flora were also observed and recorded. It was observed in the field that certain patches of forest show variation from the actual interpretated data with respect to their density. These changes were noted and corrections were made on interpreted maps.~

Post-field work: On the basis of field work, ground truth and available data and knowledge, the finalization of mapping work was done and further analysis was carried out.~

RESULTS AND DISCUSSION

Compilation of field inventory data, creation of database in GIS environ, estimation of tree volume content, estimation of growing stock, and data analysis were carried out. ~

~Thematic maps after scanning were imported to ***ERDAS IMAGINE 8.6***, georeferencing and rectification process were carried out. The rectified maps were consequently opened in Arcmap. Onscreen digitization was done in Arcmap8.3 meanwhile cleaning, editing and building topology were done in Arcmap, followed by assignment of attributes to each layer. All the generated layers after assigning attributes, the proper colour and legends were stored in GIS for further analysis. The entire study was focused to generate forest cover type map, forest crown density map, forest stratum map, tree volume map, and growing stock map. Total growing stock of the whole area was computed by multiplying the estimated average volume/ha for sample plots by the respective areas. ~

Table 3: Quantification of tree volume in Kharagpur forest range.

Forest Cover Type	Avg.Volume m^3/0.1ha	Avg.Volume m^3/1ha
Sal (> 70 %)	651.1002081	6511.002081
Sal 70-40 %	202.6986538	2026.986538
Sal-mixed 70-40 %	210.2183908	2102.183908
Sal-mixed 40%-10 %	81.85904498	818.5904498
Sal-mixed < 10 %	30.56433701	305.6433701
Sal-mahua 40-70 %	86.87200883	868.7200883
Sal-bamboo10-40 %	91.3254719	913.254719
Bamboo-mixed 40-70 %	145.6202019	1456.202019
Pure bamboo > 70 %	275.8802051	2758.802051
Plantation < 10 %	20.20265956	202.0265956

Table 4: Quantification of growing stock in Kharagpur forest range.

Forest Type	Volume m^3/ha	Growing Stock (m^3/ha)
Pure Sal	4268.99431	19374830.67~
Sal-mixed	1355.410469	5120378.64~
Sal-mahua	868.7200883	311241.866~
Sal-bamboo	913.254719	1496073.397~
Pure bamboo	2758.802051	888556.3815~
Bamboo-mixed	1456.202019	20180731.72~
Plantation	202.0265956	24653.78694~

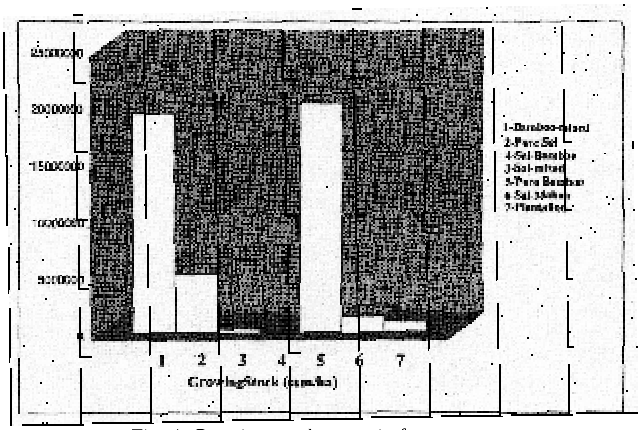

Fig. 4: Growing stock status in forest area.

It was possible to stratify the entire forest into a number of strata viz., sal forest, sal-mixed, sal-mahua, bamboo-mixed, pure bamboo, sal-bamboo, plantation, scrub forest and forest blanks (Fig. 2). The majority of the area was found to be sal-mixed forest (50.70%), followed by bamboo-mixed (23.93%), pure-sal (6.45%), sal-bamboo (6.35%) and sal-mahua forests (1.77%) (Table 1).~

Four forest canopy density classes viz., < 10%, 10-40%, 40-70%, > 70% have been differentiated. Large area (67.08%) fall in 40-70% density class, followed by > 70% density class (11.69%), 10-40% density class (11.15%) and < 10% density class (6.35%) (Table 2).

~Volume per hectare was estimated in each forest type as per density class also viz., sal forest (> 70%-6511.00 m³/ha, 40-70%-2026.98 m³/ha), sal-mixed forest (70-40%-2102.1839 m³/ha, 40-10%-818.5904 m³/ha, < 10%-305.6433 m³/ha), sal-mahua forest (40-70%-868.7201 m³/ha), sal-bamboo forest (10-40%-913.2547 m³/ha), bamboo-mixed forest (40-70%-1456.2020 m³/ha), pure bamboo forest (> 70%-2758.8020 m³/ha), plantation (< 10%-202.0266**)** (Table 3, Fig. 3).~

Total growing stock was estimated by multiplying volume of each species with their respective area, obtained from GIS layers. The growing stock content was maximum in bamboo-mixed (20180731.72 m³/ha), and minimum in plantation (24653.7869 m³/ha). Pure sal growing stock (19374830.67 m³/ha) was more than sal-mixed (5120378.64 m³/ha). Sal-mahua (311241.866 m³/ha) was less than sal-bamboo (1496073.397 m³/ha) and pure bamboo (888556.3815 m³/ha) respectively (Table 4, Figs. 4, 5).

As per analysis on inventory data collected from sample plots, it was found that the volume per hectare correlate with d.b.h. of the trees rather than the number of trees per hectare. In sal and sal-mixed forest, *Buchania lanzer* were dominant. The villagers residing nearby and within the study area, damage the forest by lopping practices and collection of fire wood. Sal regeneration was found to be low.

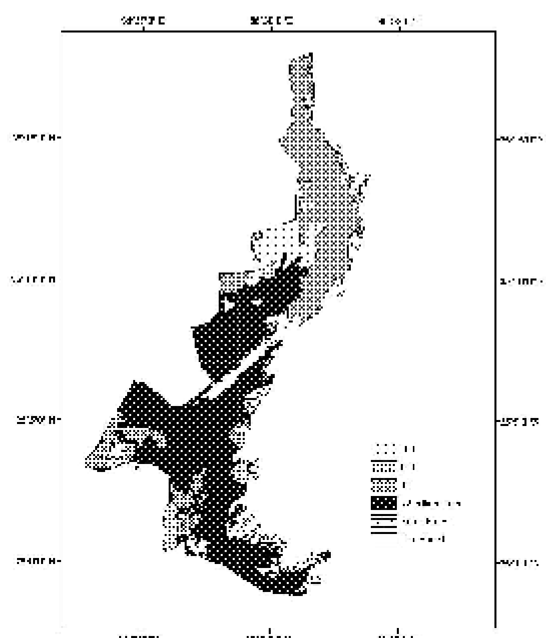

Fig. 5: Growing stock map of Kharagpur forest range.

CONCLUSION

It has been observed that the techniques of remote sensing and GIS obviously have their limitations. However, remote sensing and GIS have great potential, and it was possible to stratify forests in different types and density classes. After having stratified the forest, it was possible to take random sampling, which resulted in accurate assessment of growing stock with less time and cost. Thus, it can be concluded that the application of modern tools and procedures such as remote sensing technology combined with GIS can be a major input for the assessment of growing stock for management planning of the Department of Forests.~

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