USE OF GEOSPATIAL DATABASE IN SUSTAINABLE FOREST MANAGEMENT

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KEY WORDS : Geospatial database, Sustainable Forest Management, Working plan, Treatment types, Suitability classes, East Melghat Forest Division

ABSTRACT:

The multiplicity of forest products and their uses, and the conflicts it may cause among the stakeholders and various interests makes forestry planning in India to be considerably complex. The particular features of forestry, namely: its long gestation period and investment horizon (often not matching with the social time preference); the difficulty to distinguish between forest capital and incremental growth (often leading to over-exploitation and capital consumption); and the high level of externalities further add to its complexity. Environmental balance is the prime objective of the management of the forests simultaneously harvesting the increment on sustainable basis to meet the demands of the local people and the society. The conventional method of making inputs for management or working plans in India using ground survey is tedious process and time consuming. The treatment map, for example, which prepared based on ocular estimation results in rather inaccurate and inconsistent treatment types and more than this each division has hundreds of coupes due for working each year hence the above task is assigned to many persons with varying degrees of experience and knowledge. All the treatments are supposed to be carried out according to these treatment maps. Hence the weakness of the present practice is self-evident. The present study analysed the feasibility of using remote sensing and GIS in generation of inputs for forest working plan preparation and the further use of these geospatial database in sustainable forest management. It has been demonstrated that the generation of forest type map; treatment map; stock map; updation of compartment boundary, segregation of working circles, felling series and coupes and site suitability assessment for silvicultural practices and soil & moisture conservation works can be achieved quickly with much more accuracy; consistency and cost-effectiveness by using remotely sensed data in GIS environment. Due to its capability to provide timely, synoptic and repetitive coverage over large areas across various spatial scales, frequent and periodical monitoring and evaluation of the forest resources would be possible for proper maintenance and management. Integration of spatial and non-spatial layers in GIS would help the managers for identifying suitable areas for site-specific treatment, identifying the potentials & limitations of different compartments, making innumerable queries to find answers to their day-to-day management questions.

INTRODUCTION

Indian forests are managed through the working plans and management plans, which are revised once in every ten years. The forest working plans conventionally are prepared for each forest division with 5-10% sampling intensity for ground inventory involving one to two years of time frame. The conventional method of making inputs for working plan using ground survey is tedious process and time consuming. The treatment map is prepared based on ocular estimation. This process results in rather inaccurate and inconsistent treatment maps. Each division has hundreds of coupes due for working each year hence the above task is assigned to many persons with varying degrees of experience and knowledge. All the treatments are supposed to be carried out according to these treatment maps. The other major problem with manual systems is the volume of data. It is very difficult to synthesize and comprehend such large volumes through manual systems. Information is generally collected from various sources and at various times, which not only overloads the system but makes it very unreliable and inconsistent too. Managers for land-based systems have to invariably deal with multitude of maps. These maps are available on different scales and at times even in different projection systems, which makes it very difficult to manipulate geographical information. Hence the weakness of the present practice is self-evident. Working plan officer too has to base his calculations on rough estimations, as he does not have very accurate and consistent stock maps and treatment types to work with. Moreover the input for him is rather fixed and it is almost impossible for him to generate many alternate strategies before picking the best ones.

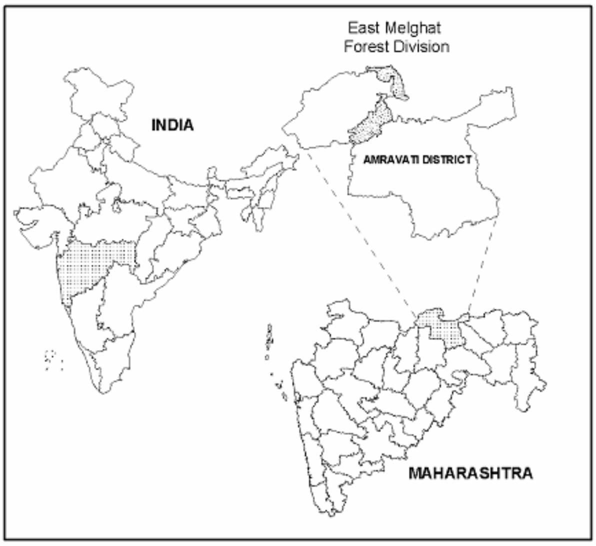

Fig. 1 Location of the study area

To overcome these difficulties, the data from various sources needs to be systematically organized into the database by following proper data structure and coding standards. Requirement of database is usually different for different type of forest activities within a single organization. For extracting meaning, information from spatial and non-spatial database the package should be robust enough to cater to all needs**.** A standard GIS package will have to be used for data input, editing, querying, analysis, modeling etc. Another important source of data, which is of great value for forestry sector is space based, remote Sensing. Remote Sensing plays a very vital role in the collection of spatial information of forests and related parameters. The information derived through further processing helps in importing the same to geographic information system for further query and other value–added information retrieval. Integration of remote sensing data with GIS related decision support systems could make the job of land managers very easy.

The objective of the present work is to study the feasibility of generating inputs for working plan revision through remote sensing and GIS by achieving the following targets like updating of compartment boundaries with the latest geo-referenced village map and satellite imagery; revision of stock maps; generation of spatial data for infrastructure, terrain and multithematic resource data; preparation of treatment types for coupe treatment map and integration of spatial & non-spatial layers in GIS for identifying suitable areas for site specific treatment, identifying the potentials & limitations of different compartments and making queries.

STUDY AREA

East Melghat Forest Division is nestled in the Northeast of the Amravati District of Maharashtra State and is coming under Amravati Circle (Fig.1). It is lying between the geographical coordinate 21^0 13'14" to 21^0 46' 6" North latitude and 77^0 10'39" to 77^0 36' 00" East longitude. The total area of East Melghat Forest Division as per official notification is of 56087.60 ha. Melghat is literally a meeting place of ghats as the name implies. The tract is very hilly and consists of succession of hills and valleys with very constant and abrupt variations in the altitude, aspect and gradient. Even within the limits of a compartment whose average area is slightly more than 2 sq. km, all the variation is visible. In some compartments, the difference in the elevation is as much as 600 m and hardly any compartment in which the difference is less than 150 m. Due to rapid variation in the altitude and aspect, the climate in Melghat is very varying. The annual precipitation is 770 mm although the total annual rain fall in the Melghat is good; it is not well distributed over the period of the year. The temperature, like the rainfall, varied considerably with the altitude. The plateau and higher hills enjoy almost equitable and pleasant climate throughout the year while valleys become very cold during winter then the temperature falls below 7 degree C in December–January. The forest of Melghat are entirely dry deciduous and belong to the formation 'Dry tropical forest' of the Champion and Seth's 'Revised survey of the forest type of India.' and fall under the sub group 5-A southern tropical dry deciduous forests (Champion and Seth, 1968).

MATERIALS AND METHODS

The steps involved in the generation of working plan inputs essentially are as follows: (1) Generation of grid base and map grid for the study area (2) Rectification of satellite and ancillary data (3) Generation of multithematic spatial resource data viz. forest type, crown density and soil (4) Spatial data creation for characterizing terrain, viz slope, drainage etc (5) Spatial data for infrastructure, viz. village locations, administrative boundaries, road network (6) Proximity analysis for drainage buffer, different types of fire lines (7) Preparation of treatment types based on the weightage prescribed (8) Zonation of forest division into different working circles based on the preponderance and continuity of treatment types (9) Integration of spatial and non-spatial data for identifying suitable areas for site specific treatment, identifying the potentials & limitations of different compartments and making queries.

Treat. Areas	Type	Characteristics & Minimum patch size
Protection areas	A1 A2 A3	Area having > 25 degree slope 20 m. wide strip on both sides of stream Area susceptible to excessive erosion (Mini.patch size- any size)
Open Forests	B	Open forests, density < 0.4 (2 ha)
Pole crop & old plantation	C	Pole crop of the identified valuable species, suitable for retention of the future crop, having density 0.4 or more and old Teak plantation (1 ha).
Well stocked	D	Areas having density 0.4 and over (2 ha).

Table 1 Criteria for Treatment types

Forest Administrative Boundary maps and other ancillary maps, provided at 1:50,000; and 2":1 Mile scale has been rectified using the mapgrid prepared for the study area. The database for working plan has organized by incorporating inputs from various sources by following proper data structure and coding standards. Requirement of database is usually different for different type of forest activities within a single organization. The IRS P6 LISS III data of 23rd December 2004 has been used for the present study for generating various thematic layers. Geometric and radiometric correction of satellite data was done following the standard methods. Supervised maximum likelihood technique was adopted for classifying the forest type (Jenson, 1996). Out of the five forest types present in the study area, only four types could able to separate out through supervised maximum likelihood technique with 90% accuracy. Crown density classification of the forest has been done by running Normalized Difference Vegetation Index (NDVI) of satellite data. Classification of the forest density was done as very dense forest (> 70% crown density), Dense forest (40% to 70%), open forest (10% to 40% density), and forest blanks (< 10%). Treatment types have been generated based on the criteria given in the table 1. The suitability map has been generated by integrating spatial & non-spatial layers in GIS and assigning weightage for each class (Table 3).

RESULTS

For the delineation of working circles, felling series and coupes, the first requirement is the generation of treatment types. Each compartment for the purpose of annual coupe operations and site-specific silvicultural treatment has to be divided in to be various treatment types on the basis of the criteria, given in table1. Preparation of treatment types will be depending upon requirements of environmental stability, protection of topography, biodiversity conservation, characteristics of growing stock in the forest and forest produce utilization. Areas having 25 degree slope and more than a quarter hectare in extent have been classified as protection area A1-type (Table 2). Protection area A2 type is coming under twenty-meter strip on either side of the drainage line or around water bodies. Protection area A3 type has been taken from the severe to very severe erosion category of soil erosion coverage. The entire forest coming under protection areas A1, A2 and A3 will be protected from harvesting. Area coming under open forest in the integrated cover excluding the protection areas with a minimum area of 2 hectare in extent is considered for open forest – B type.

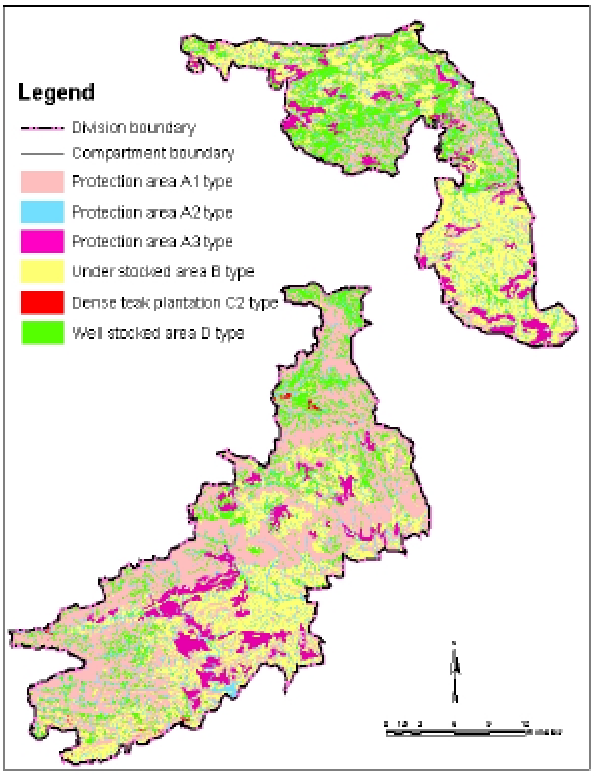

Fig. 2. Treatment types generated for the study area

Treat. Types	Jarida	Ghatang	Chikaldara	Anajangaon
A1	4335.56	7531.68	7240.23	7485.31
A2	2035.43	848.84	801.28	1248.13
A3	1379.85	124.89	502.81	110.95
B	3401.31	539.42	1129.78	2704.62
C	10.55	86.12	0.00	91.37
D	6525.12	3364.87	1434.82	1919.19

Table 2. Area of treatment types in ranges (in ha)

Pole crop and old plantation (C1-type) areas would include groups of naturally grown poles having 15-45 cm. gbh, suitable for retention as future crop. This area and old plantations come under this type. This area could not be delineated directly from satellite imagery. For generating this areas, well-stocked areas prepared from satellite image and plantations digitized from the old working plan map has been used with the ground truth information. The minimum extent prescribed for the C-type is 1 hectare. Scheduled cleaning and thinning operations are expected in these areas.

Well-stocked areas, with a minimum area of two hector in extent, have been taken from > 40% crown density by excluding the protected areas and dense teak plantation. Infestation of *teak defoliator* (*Hyblaea puera*) and leaf *skeletoniser* (*Eutectona machaeralis*) on teak encumbered the generation of density map for the study area. After the onset of southwest monsoon the infestation of *teak defoliator* and *skeletoniser* on teak forest leads to defoliation of the leaves. This would adversely affect the generation of density map. This problem has been tackled by making a mask for the infested area.

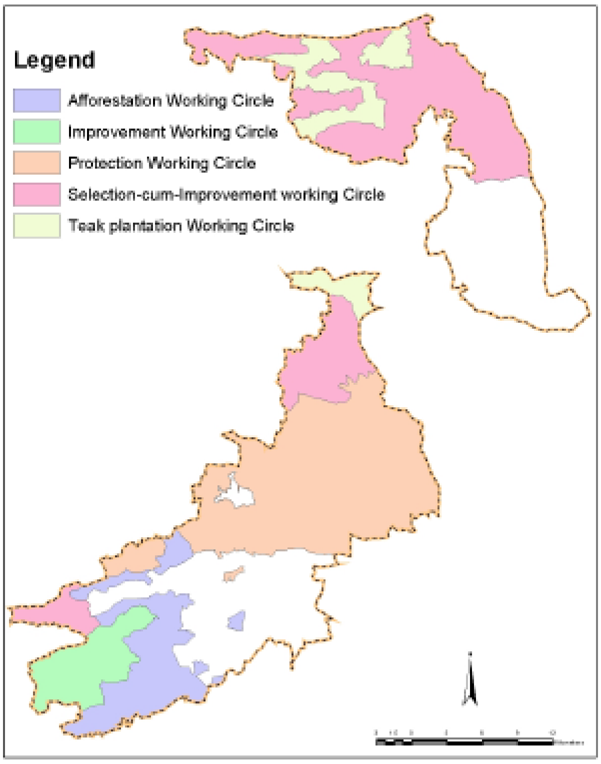

Fig. 3. Working Circles demarkated for the present working plan

A total of five working circles have been demarcated for site-specific treatment of the division (Fig.3). For the purpose of formation of working circles, and felling series compartments have been using as units for distribution based on the preponderance of suitability to a specific working circle. Area susceptible to high erosion and the catchments of high water bodies are included in protection working circle (protection areas A1, A2 and A3). The compartments that are dominated by the above-mentioned class and in continuation with similar other compartments had been demarcated for this type. Like wise, areas having sparse tree, open areas without tree growth and isolated small forest patches are included in the afforestation-working circle. In such areas the focus will be upon tending of existing rootstock supplemented by seeding, plantation wherever necessary. Compartment having matured crop with the little generation but potentially capable of producing good teak plantation are included with in teak working circle. The area of well-stocked teak forest has been derived from the forest type and stock map coverages. Within this area ground truth information has been collected related to regeneration status for classifying this type further to teak working circle. Teak plantation working circle is coming nearly 5340.35 ha of area in this division. Compartment having sufficient dense tree cover and all age classes with mature trees fit for harvesting with adequate regeneration are allotted to the selection-cum improvement working circle. This working circle is expected to produce timber. This area has been demarcated from the density coverage with limited ground truth information. Total area coming in this working circle is 19444.24 ha area. Compartment having preponderance of pole crop, dense tree covers without enough mature tree area is designated as the improvement-working circle. These compartments are expected to produce poles, small timber and firewood. Improvement working circle occupy minimum area out of the five working circles in this division, i.e. 4654.96 ha.

No	Jarida	Ghatang	Chikaldara	Anajangaon
1	79.34	6.68	6.48	0.13
2	499.61	41.28	23.14	0.97
3	172.31	205.56	604.31	355.33
4	325.72	141.20	273.73	1168.67
5	1017.73	140.07	343.58	500.21
6	2926.49	292.74	931.25	2634.25
7	7167.02	3398.22	1886.83	2498.69
8	5511.92	8277.29	7040.82	6408.75

Table 3. Area (in ha) of suitability classes in ranges

1. Cement / massionary dam - A2 Protection areas having below 2^0 slope.
2. Percolation tanks - Areas having below 2^0 slope associated with forest blanks.
3. Plantation - Areas having less than 10% crown density with very deep soil depth excluding protection areas A1, A2 and A3.
4. Afforestation / Reforestation - Areas having less than 10% crown density with deep to moderately deep soil depth excluding protection areas A1, A2 and A3.
5. Non-Timber forest produce - Forest blanks associated with shallow to very shallow soil cover.
6. Enrichment planting / gap filling - Areas of 10–40% crown density excluding protection areas A1, A2 and A3.
7. Tending and selection felling - Areas having more than 70% crown density excluding protection areas A1, A2 and A3.
8. Protection areas - Areas coming under protection areas A1, A2 and A3

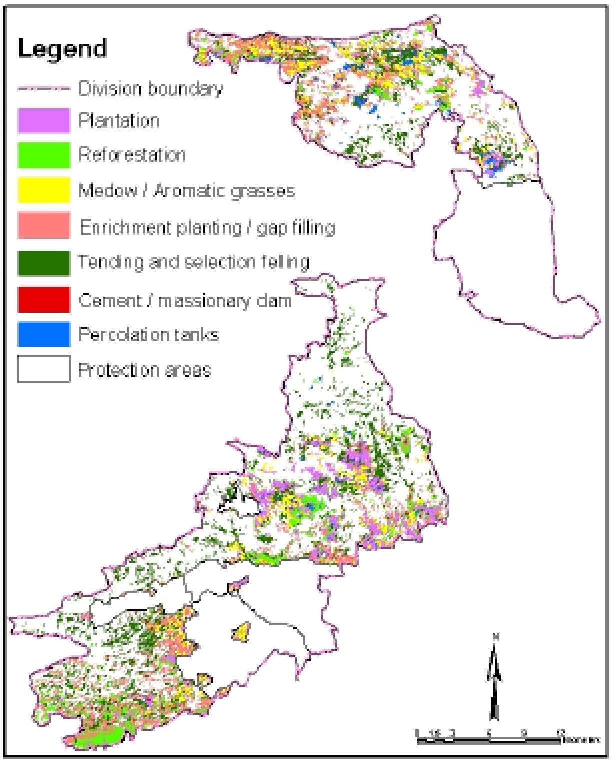

Fig. 4. Suitability classes generated for the study area

A suitability map (Fig.4) for management operations area also prepared based on the criteria given in the legend of table 3. Apart from these, the integrated data can be used for generation, analysis and estimation of grazing closure and fire closure areas for a particular year; area suitability analysis for continuous contour trenches (CCTs), lying fire lines etc.

DISCUSSION

The entire operational procedure for generating inputs to working plans through remote sensing based inventory sampling and analysis could be automated in a GIS. The plot wise estimates of volume, basal area and frequency according to type/cover stratum it belongs to, could be integrated and estimated in a bottom-up manner from a stratum, compartment, beat, round, range and thereby to the divisional level with appropriate extrapolation procedures. Essentially, GIS reduces cumbersome aspects of area estimation under different hierarchical level and enhances the fidelity of the data while preserving accuracy and case in computation. Besides this, the quantitative details along with their respective spatial outputs could be useful in visualization and offer various management options like site conditions, slope maps, forest composition, density classes, increment classes, plantations, soil types, geology of the area, volumetric information, forest cover, causes of damages, regeneration status, minor forests products, climate, physiography, forest produce and assessment for local needs, stock/enumeration etc.

A good query, processing and analysis system would be able to efficiently perform once the above are systematically followed in creating a comprehensive database. Integrated layers of administrative boundaries, slope, drainage, forest type, density, soil, site quality and spatial data for infrastructure would assist the managers for identifying areas for site specific treatment. The above mentioned integration of management information system (MIS) and GIS is not only a powerful planning tool for the working plan officer but these digital databases are very potent decision support and monitoring tools for the implementing managers in the real time mode also. In the GIS environment they can make innumerable queries to find answers to their day-to-day management questions.

Utilization of RS & GIS inputs for working plan preparation can further enhanced by measurement of tree height and stand volume through remote sensing. However, tree height and stand volume could not be estimated directly from optical remote sensing data owing to poor correlation between tree height and reflectance values. The analysis of radar data acquired at different frequency showed that sensitivity and correlation of radar backscatter with tree height and volume. Research work is going on in this direction for standardizing methodology for height and stand volume mensuration for tropical forests of India.

CONCLUSION

The present study analysed the feasibility of using remote sensing and GIS in working plan preparation. It has been demonstrated that remote sensing and GIS have potential to provide comprehensive information on various facets of forest working plan inputs like, generation of stock map & forest type map, preparation of treatment types for coupe operations and site specific treatment and zonation of working circles, felling series and coupes. The spatial information derived at compartment level has been helped in preparing forest working plan in terms of timeliness, cost-effectiveness and accuracy. The integration of MIS and GIS is not only a powerful planning tool for the Working Plan Officer but these digital databases are very potent decision support and monitoring tools for the implementing managers in the real time mode also. In the GIS environment they can make innumerable queries to find answers to their day-to-day management questions.

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