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QUANTIFICATION OF FOREST GROWING STOCK USING REMOTE SENSING DATA FOR PLANNING AND MANAGEMENT: A CASE STUDY OF TIKAULI FOREST IN CHITAWAN DISTRICT, NEPAL

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ABSTRACT

Planners and decision-makers in Nepal are increasingly facing the challenge of responding to forest issues at local, national and regional level. Therefore, Quantification of forest growing stock is necessary for better management and planning because forest of Nepal can be seen as a source of timber and non-timber products. It is also a source of income, fulfills the necessities for rural population, functions as the basis for important generators of industrial economic activities, and works as the basis of environmental protection and watershed management for millions of people. The Nepalese forest managers like the respective forest departments, and national institutes like the Institute of Forestry have, therefore, a serious responsibility to manage these forests for the maximum benefit of present citizens of Nepal and future generation. In recent years, satellite remote sensing has emerged as one of the powerful technology for generation of spatial information, due to number of inherent characters that the satellite data had possessed, such as repetitive, synoptic view, availability of data in inaccessible areas, and digital nature of data. Remote sensing coupled with GIS and GPS has completely revolutionized the forest natural resources quantification and mapping for sound planning and management of forest resources. In the present study, the LANDSAT TM digital data of January 1998 has been digitally interpreted and forest has been classified into different forest types on the basis of density classes. Stratified random sampling method has been used for determination of number of sampling plots for collection of ground inventory data. Area estimation on the basis of digitally classified image of different forest and non-forest cover types has been carried out. With the help of GIS different layers were digitized and maps were produced. Using local volume table derived from general volume table, the volumes per hectare of individual forest cover types for the whole forest area were estimated. Similarly the growing stock per hectare in different blocks slopes, aspects, elevations were estimated

INTRODUCTION

Among the natural resources, forests are one of the most valuable renewable natural resources, because of its economic, environmental, aesthetic and recreational values and renewable nature. In order to meet the ever-increasing fundamental needs of timber, fuel wood and non-timber forest products, the forests are reported to be illicitly cut, overexploited and damaged, by the people. As a result of these factors, forests are facing the consequences in the form of soil erosion, landslide, flood, drought and change in climatic conditions. Now most of the countries including developed countries do realize the importance of forest. To check the further deterioration of these forests and improve their conditions, planned utilization of available resources particularly renewable, i.e. forest with respect to their quality, quantity, distribution, location and accessibility, etc. is quite essential. So as to keep the balance between the exploitation and regeneration processes and to ensure the preservation of environment and its quality through timely, accurately, and scientific survey which is in fact time consuming, more expensive, in certain area very difficult and impossible by conventional methods. A scientific survey of natural resources, essential for forests is prerequisite for planning and development for well being and development of a society (Sharma, 1986).

Certain important qualitative and quantitative parameters of forest inventory such as tree diameter, merchantable height of trees etc., which are important for volume calculation, cannot be measured from satellite imagery. However, the crown density can be estimated from satellite imagery in density classes. The tree height is closely related to volume where as the DBH is correlated with crown diameter to the volume measured on the ground by regression analysis for different forest tree species, It is noted that satellite imageries obtained by remote sensing can only complement, improve and reduce field work rather than replace it (Chaturvedi and Khanna, 1982). It is essential to carryout field reconnaissance visit prior to actual forest survey work. Remote sensing data has to be used as field check afterwards.

In forestry, growing stock estimation is an important parameter required for forest management and planning purposes. General information about stock available per unit area, is the key information desired for forest inventory (Singh and Roy, 1990). To evaluate, monitor and harvest the available natural resources efficiently and judiciously, and for the scientific management of the forest for future planning forest inventory data and various information at national, regional and local levels are required. This gives insight for the availability of wood biomass, volume and forest resource as a whole. The present study has been carried out for the quantification (assessment) of growing stock using remote sensing data for management and planning in the Tikauli forest of Chitwan district, Nepal.

STUDY AREA

The study area falls in the buffer zone of Royal Chitwan National Park and national forest of Chitwan district. It is located in the central Terai (low land) region of Nepal covering an area of 7,540.20 hectare and it extends between $27^0 43' 00''$ N- $27^0 33' 30''$ N Latitude to $84^0 23' 30''$ E- $84^0 29' 00''$ E Longitude. The forest has numerous swampy areas, which is full of water during rainy season and some lakes inside the forest. Sal (*Shorea robusta*) is the main timber dominated species spread over the forest. It has subtropical climate with a mean annual rainfall of 1512mm and equable temperature (17-31^0c). The altitudes of the highest and lowest points are 67m and 368m above mean sea level respectively. The soil texture varies from sandy loam to loam and loamy rubble. Geologically, the study area comprises of sedimentary soft rocks containing sand, shale and pebble beds etc. Topographically, the study area can be divided into Mahabharat hills, Chure hills and the valley bottom locally called Doon valley. The physiography shows its feature as the broken drainage system of the Siwalik to the alluvial terraces formed by numerous stream systems flowing into the Rapti and Rew rivers. The forest type comprises Bhabar and Terai Sal Forest and Doon Sal forests. The vegetation is more or less uniform throughout the study area comprising valuable timber species of Sal (*Shorea robusta*). The other important tree species found in the area are Asna (*Terminalia tomentosa*), Harro (*Terminalia chebula*), Barro (*Terminalia bellirica*), Jamun (*Syzygium cumini*), Botdhairo (*Lagerstroemia parviflora*), Dabdabe (*Lannea coromandelica*), Tatari, etc (Jackson, 1994).

DATA AND SYSTEM USED

Primary data

- **Satellite data:** The LANDSAT TM (FCC), with 2,3&4 band combination, January 1998, on 1: 25,000 scale with 30*30 m ground resolution and 185*185m terrain coverage.
- **Field data:** Data on various forest types, species composition, phenology, crown density, DBH, tree height, field level observations, and measurements.

Secondary data (Ancillary data)

- Topo sheet number 2784 06B and 2784 06D (Source: Department of Survey, Nepal)
- The forest management plan of Chitwan district (Source: Chitwan District Forest office)

Instruments, hardware and software

The instruments used in the study for collecting ground data were Sunto Clinometer, Silva Ranger Compass, diameter and linear measuring tapes, diameter calliper, nylon rope, cloth flags, wooden pegs.

System used

Pentium1 PC-686 with 32 MB RAM and 3.2 GB hard Disk, MS Excel
Arc View Image Analysis and Arc View Spatial analyst (Version 3.1 and 1.0)
Cartalinx the spatial data builder GIS (version1.0)

Sampling Design

The precision of sample estimate of population mean depends not only upon the size of sample, but also on the variability in the population, where 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 (Husch Bertan, 1972). The use of stratification is only possible 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 between the strata.

In the present study, stratified random sampling was carried out. The coefficient of variation for the volume per hectare was obtained from management plan of the Bharatpur forest division of Chitwan district (1998). The number of sampling units was calculated by the following formula.

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

Where n= Number of samples required for allowable error (E%)
t = value of t-statics at 95% level of significance: 1.96

CV= co-efficient of variance ± 33.5

Assuming the E% equal to 10% the required number of sampling unit comes out to be 45. These sample plots were allotted to different strata of homogeneous vegetation according to stratified random sampling method. Random table was used to select 45 sample points, and these points were transferred on the toposheet to get correct location on the ground for the growing stock estimation.

METHODOLOGY

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: 25000) was considered necessary for preparing the movement plan during the fieldwork. Permanent features like roads, highway, stream junctions, lakes, canals bridges, firelines, elephant riding tracks were utilized as most important points to serve as the references for the exact location of sample plots on the 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 the location of sample plots on 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 10cm diameter of each tree species were done. Similarly heights 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 image. In addition to that some other information like status of forest, types of forest, species occurring in each storey, topography, rocks and soil, ground flora, leaflitter etc were also observed and recorded. Later on this knowledge has been utilized giving training sets for the digital supervised classification of the forests. It has been observed in the field that certain patches of forest show variation from the actual interpreted data with respect to their density. These changes were noted and corrections were made on interpreted maps.

Post field-work

On the basis of fieldwork, ground truth and available data and knowledge, the finalization of mapping, work was done and further analysis was carried out.

DATA ANALYSIS AND PRESENTATION OF RESULTS

Use of Cartalinx GIS for intensive mapping

With the help of Cartalinx GIS (version 1.0), different layers such as location map, block map, contour map, roads and highway maps, lakes, canals and steam maps have been separately digitized. The digitized contour map was used to generate DEM through contour interpolation model. DEM was used to generate slope and aspect map. Finally area estimation has been undertaken for the following maps.

Interpretation of Remote Sensing Data

By using basic field knowledge of the forest on the ground the discrimination of various forests cover types and land use has been digitally classified. In this manner, it is possible to discriminate and complete the digital interpretation of all the forest cover types in the study area. Sal forest has been discriminated in into three density classes (>70%, 40-70%& <40%). Some other classes include Sal Mixed, open forest /grass land, marshy grassland, lakes/water bodies (Table-1) Finally, a classified forest cover type map of the study area has been prepared. On the basis of digitally interpreted map, under each forest cover type, the area calculation has been done by multiplying the total number of pixel (one pixel size is 30*30m) with the different number of land use (Table-2).

Table 1. Forest cover as per the digital interpretation of Landsat TM data

Particular	Symbol	Forest cover type	Area (in hectare)

Sal forest cover type	1	Sal dense (>70%)	965.07
	2	Sal medium (40-70%)	844.92
	3	Sal low (10-40%)	3234.78
Other forest cover type	4	Sal mixed	491.04
	5	Open forest/Grassland	623.43
	6	Marshy Grassland	457.38
	7	Lakes/Water bodies	175.5

Table 2. Area estimation of the landuse map as per the digital interpretation

Particulars	As per toposheet		As per digital interpretation	
Total area	7540.2 h		7540.2 ha	
Forest area (recorded)	6568.32	87.11	6159.22 ha	81.68 %
Non forest area	971.88	12.89		18.32 %

It is found that the actual forest cover area is 81.68 % in the study area.

Classifications of Landsat TM digital data by using DIP.

By using Arc view image analysis (version 3.1), the relevant portion of the study area was extracted by masking from the Landsat TM data produced in a CCT (bands 2,3 4). A FCC was made by applying 2,3, 4 band combination. A detailed interpretation key was developed for effective discrimination of the forest. With the help of Arc view Image analyst, training sets on the FCC were given for the supervised classification. Guassian maximum likelihood method was used for the purpose of this study. Error matrix generated through the statistical analysis of the classified output show that the over all accuracy level obtained by the supervised classification is 88%.

RESULTS

Using local volume table, the total volumes of the sample plots were calculated by adding the volume of individual tree of the sample plots. In this way the total and per hectare growing stocks for each of the forest cover types (Table-3) and also for each of the forest cover types in different blocks of the study area (Tble-4) have been computed by multiplying the volume/hectare and the estimated area obtained from the digital classification of Landsat TM data. Similarly sample plot wise volume/ha under different slope classes (Table-5), aspect classes (Table-6), elevation classes (Table-7) and forest type wise density and volume stocking (Table-8) have been calculated respectively. The total growing stock in the study area is estimated to be 2194635.8 cubic meters and average growing stock/ha of the whole forest area comes out to be 352 cubic meter/ha. The average growing stock/ha in Sal dense forest is much higher (588.7 m^3) and the average growing stock/ha in case of Sal medium forest (390.09m^3) and Sal low forest (318.34m^3) is nearly equal. The average GS in Sal mixed forest (180.30m^3) is lowest than all other types of forest where as the average GS in case of open forest/grass land (286.48m^3) is higher than Sal mixed forest. Volume/unit area is higher than the volume estimate carried out by the forest research division of the department of forest but the standard error of this study is quite reasonable.

Table 3. Forest cover type-wise total & per hectare growing stock

S.N.	Particulars	Total Area in hectare	Total growing stock (m^3)	Per hectare growing stock (m3)
1	Sal Dense (>70% CC)	965.07	568146.40	588.71
2	Sal Medium (40-70% CC)	844.92	329594.80	390.09
3	Sal Low (20-40% CC)	3234.78	1029759.90	318.34
4	Sal Mixed	491.04	88534.50	180.30
5	Open Forest/Grassland	623.43	178600.20	286.48
6	Marshy grassland	457.38		
7	Lakes/Water bodies	175.5		
	Total Classified Area	6792.12		
	Unclassified Area	748.08		
	Total	7540.2	2194635.80	291.06

Table 4. Block-wise Estimation of Growing Stock (m^3) from each forest types

S.N.		Blocks	Total

		Block I	Block II	Block III	Block IV	Block V	Growing stock
1	Sal Dense (>70% CC)	56427.85	12451.22	119425.7	199855.3	179986.3	568146.4
2	Sal Medium (40-70% CC)	49186.45	32053.7	77729.33	102410.3	68215.04	329594.8
3	Sal Low (20-40% CC)	218317.6	185598.6	248171.5	180069	197603.2	1029759.9
4	Sal Mixed	7042.518	1233.252	15269.61	31042.25	33946.88	88534.5
5	Open Forest/Grassland	43186.86	48549.77	18306.07	12504.85	56052.68	178600.2
	Total Growing stock	374161.3	279886.5	478902.2	525881.7	535804.1	2194635.8

Table 5. Forest type wise Growing Stock (m^3) under different slope classes

S.N.		Slope classes (in degree)					Total Growing Stock
		0-5	5-10	10-15	15-30	>30	
1	Sal Dense (>70% CC)	564225.6	2808.1	847.7	264.9	0	568146.4
2	Sal Medium (40-70% CC)	323942.4	3686.4	1158.6	667.1	140.4	329594.8
3	Sal Low (20-40% CC)	1016380.0	9397.4	2320.7	1518.5	143.3	1029759.9
4	Sal Mixed	87171.4	973.6	194.7	146.0	48.7	88534.5
5	Open Forest/Grassland	178342.4	206.3	51.6	0	0	178600.2
	Total Growing Stock	2170061.9	17071.8	4573.3	2596.5	332.4	2194635.8

Table 6. Forest type wise Growing Stock (m^3) under different aspect classes

S.N.		Aspect classes									Total
		Flat land	North	North-East	East	South-East	South	South-West	West	North-West	
1	Sal Dense (>70% CC)	159	25538.2	29459	53354.8	118683.9	133943.3	104007.4	71475.3	31525.4	568146.4
2	Sal Medium (40-70% CC)	0	15693.3	16430.6	38618.9	69127.8	91877.9	51819.6	31878.2	14148.6	329594.8
3	Sal Low (20-40% CC)	343.8	55954.6	59765.2	149040.4	233187.2	239862.8	139786.3	102139.4	49680.1	1029759.9
4	Sal Mixed	16.2	3878.3	5533.4	8146.0	12851.8	21371.0	18450.1	13403.5	4884.3	88534.5
5	Open Forest/ Grassland	180.5	8224.8	11757.1	30682.0	44940.1	47080.1	16269.2	11550.9	7915.4	178600.2
	Total Area	699.5	109289.3	122945.3	279842.1	478790.9	534135.1	330332.5	230447.2	108153.9	2194635.8

DISCUSSION

Information on quantification of growing stock is very important for scientific management of forest. In the past, this information was entirely obtained on the ground by taking a full stock of each and every tree of different diameter classes above 10cm diameter. Collection of ground data is not only time taking and expensive, but it is difficult in inaccessible areas. In most of the cases, systematic sampling method was used to collect the ground data. But this method has inherent drawbacks, because certain forest cover types are over sampled or under sampled. Some times, the sample plots may fall in the inaccessible areas. Therefore, this method may not give accurate results; where as stratified random sampling method has advantages over the stratified systematic sampling. The present study deals with combined usage of satellite remote sensing data and ground survey inventory.

CONCLUSION

This study enables to understand the potential and limitation of remote sensing and GIS in forest inventory and quantification of growing stock. It has observed that the technique of remote sensing and GIS obviously has its limitations. However, remote sensing and GIS has great potential and it was possible to stratify the forest in different types and density classes. After having stratified the forest, it was possible to take the stratified random sampling, which resulted in accurate growing stock estimation with less sampling intensity, time and cost. Digital image analysis and supervised classification of the remote sensing data resulted in area wise forest cover types map of the study area. Using GIS creation of slope, aspect, elevation maps and estimation of area is possible. Creation of database that is of primary requirement for the inventory and growing stock estimation is possible. 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 quantification of growing stock for management planning of the department of forest.

Table 7. Forest type wise Growing Stock (m^3) under different elevation classes

S.N.		Elevation classes (in meter)					Total
		167.848-192.339m	192.339-216.83m	216.83-241.32m	241.32-265.811m	265.811-290.301m	
1	Sal Dense (>70% CC)	438335.8	81648.2	46784.8	1218.6	159.0	568146.4
2	Sal Medium (40-70% CC)	207313.3	80397.5	39286.0	2457.6	140.4	329594.8
3	Sal Low (20-40% CC)	481100.9	418585.3	124916.6	4698.7	458.4	1029759.9
4	Sal Mixed	71236.5	10693.6	5322.5	1006.1	275.9	88534.5
5	Open Forest/Grassland	79850.6	84233.7	14180.8	335.2	0	178600.2
	Total Area	1277837.1	675558.3	230490.6	9716.2	1033.7	2194635.8

*** CC represents crown closure in each forest cover type**

Table 8. Forest type wise density and volume stocking

Forest type	*Density/ha*	*Volume (m^3)*
Sal dense forest	234	588.71
Sal medium forest	172	390.09
Sal low forest	126	318.34
Sal mixed forest	120	180.30
Open forest/Grass land	105	286.48
Average	152	352.78

The plot volumes were statistically analysed. The results are given as follows:

Plot wise volume results	
Mean	38.6
Standard error	2.10
Standard Deviation	14.09
Sample Variance	198.69
Confidence Level (95%)	4.23

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