ANALYSIS OF LAND USE, DIVERSITY, BIOMASS, C AND NUTRIENT STORAGE OF A DRY TROPICAL FOREST ECOSYSTEM OF INDIA USING SATELLITE REMOTE SENSING AND GIS TECHNIQUES

T. Thakur [1] and S.L. Swamy [2]

[1]Mission Biofuels India Pvt. Ltd, Bhopal, Madhya Pradesh, India
[2]Department of Forestry, I.G. Agricultural University, Raipur, Chhattisgarh, India

Abstract

Tropical forests are recognised as rich, diverse and highly productive ecosystems of the world. More than half of the global annual NPP occurs in the tropics. In India, the tropical forests covers about 75%. The present study was carried out to characterize the land use, vegetation structure, diversity, biomass production, C and nutrient storage of a dry tropical forest ecosystem in Barnawpara Sanctuary, Raipur district of Chhattisgarh through satellite remote sensing techniques and GIS. Results revealed that density of different forest types varied from 324 to 733 trees ha-1, basal area from 8.13 to 28.87 m2 ha-1 and number of species from 9 to 26. Similarly, the diversity ranged from 1.36 to 2.98, concentration of dominance from 0.07 to 0.49, species richness from 3.88 to 6.86 and beta diversity from 1.29 to 2.21. Sal mixed forest type recorded highest basal area and diversity was highest in Dense mixed forest, while Teak forest recorded maximum density. It was poor in Degraded mixed forests. Results revealed that the highest biomass was found in Dense mixed forest (321464.28 Mg), while net production was highest in Teak forests. Both were lowest in Degraded mixed forests (42996.08 Mg) in different forest types. The total storage of nutrients in vegetation (OS+US+GS) varied from 105.1 to 560.69 kg ha-1 in N, 4.09 kg ha-1 to 49.59 kg ha-1 in P, 24.59 kg ha-1 to 255.58 kg ha-1for K and 7310 to 4836 kg ha-1 for C in different forest types. They were highest in Dense mixed forest and lowest in Degraded mixed forest.

The study also showed that NDVI and carbon storage was strongly correlated to Shannon Index and species richness thus it indicates that the diversity of forest type play a vital role in carbon accumulation. The study also developed reliable regression model for the estimation of LAI, biomass, NPP, C & N storage in dry tropical forests by using NDVI and different vegetation indices, which can be derived from fine resolution satellite data.

Both quantitative and qualitative information derived in the study helped in evolving key strategies for maintaining existing C pools and also improving the C sequestration in different forest types. The study explores the scope and potential of dry tropical forests of Chhattisgarh for improving C sequestration and mitigating the global warming and climatic change.

Key words: Diversity, Biomass, Carbon & Nutrients, RS & GIS techniques.

1. INTRODUCTION

Tropical forests are one among the rich and complex terrestrial ecosystems store approximately 50% of the worlds living terrestrial carbon and also harbor variety of life forms. They are important both ecologically and economically, and have direct bearing on regulating the biosphere climate and also meeting the diverse needs of biomass. However, during last few decades increased anthropogenic perturbations, over grazing and alarming rates of land transformation caused severe environmental degradation and affected the biogeochemical cycle, biological diversity, productivity and consequently altered the global ecology (King *et al*., 1997). The quantitative as well as qualitative information on land use pattern and vegetation status are necessary for formulating useful policies for timber harvesting, conserving biodiversity, carbon sequestration, combating environmental hazards and sustainable management of the resources. The data on biomass and forest productivity are scarce in many important tropical forests.

2. MATERIALS AND METHODS

The study was conducted in macro watershed representing typical dry tropical forest ecosystem of Chhattisgarh. IRS ID LISS III cloud free digital data of path 103 and row 57, December 2002 was procured from NRSA Data center Hyderabad, India. The digital analysis of data was performed on ERDAS Imagine (Version 8.6) Image analysis software in personnel computer and the ancillary data collected from SOI topomaps was analyzed in ARC-GIS (Version 8.2) in PC environment.

Stratified random sampling approach was followed for conducting phyto-sociological survey and assessing biomass, carbon and nitrogen storages. Ground sampling was done by randomly laying 20 m X 20 m quadrates. Sample plots wee demarcated and measured for DBH & height. Phyto-sociology and diversity analysis carried to characterize structure and composition of different plant communities. The data were analyzed for density, abundance, relative basal area and diversity.

Biomass was estimated from DBH & height measurements of trees recorded in sample plots by employing species-specific regression equations. For biomass estimation of shrub components, regression equations was developed by harvesting few sample shrub species commonly present in different forest communities. Herbaceous biomass was estimated by harvesting from three randomly distributed plots of 50 x 50 cm size from each sampling quadrate. Sample were dried at 80^0C to constant weight and weighed. Finally, the sum of biomass for trees (by components), herbs & roots yielded the total biomass for the replicate. All these biomass values will be extrapolated on ha^{-1} basis. Total stand biomass were computed by adding the individual biomass of tree, shrub and herbaceous components. DBH and height of trees and shrubs was measured for three successive years (2003, 2004 and 2005). The average biomass production of individual components (trees & shrubs) were calculated as $\{(B_3 – B_2) + (B_2 – B_1)/2\}$.

The component wise samples viz., foliage, bole, branches and roots were collected and analyzed for total carbon and N, P and K. Nitrogen and carbon pools in vegetation were quantified by multiplying the biomass of each component with their respective N and C concentration of that component. Total vegetation C and N was obtained by adding tree, shrub and herbaceous component.

3. RESULTS AND DISCUSSION

3.1 LAND COVER AND VEGETATION MAPPING

In the present study, different classification techniques were used to classify the satellite data for delineating different land cover and vegetation types. Among them, the maximum likelihood supervised classification was most suitable for precisely classifying different land cover classes. The classification of accuracy for different classes ranged from 71.23 to 100%. The overall accuracy of classification is 73.77 presented in Figure 1. Several workers analysed land use and vegetation using satellite remote sensing in different environments through adopting various classification algorithms (Saxena *et al.,* 1992; Sudhakar *et al.,* 1994; Krishana *et al.,* 2001).

3.2 STRUCTURE AND DIVERSITY OF TROPICAL FORESTS

The study showed that Shannon index values in different forest types ranged from 1.36 to 2.98 for tree and 0.84 to 3.05 for shrub. Concentration of dominance ranged from 0.07 to 0.49 in tree and 0.07 to 0.62 for shrubs. Species richness ranged from 3.88 to 6.86 in trees and 0.19 to 3.49 for shrubs are presented in Table 1. The diversity parameters of these forests are comparable with the diversity indices reported in different tropical forests (Singh and Singh, 1991; Pande, 2002; Singh *et al*., 2005; and Pandey, 2005; Thakur & Swamy, 2009). The present study indicated a positive correlation between mean NDVI and Shannon index of diversity for different vegetation types of study area (Figure- 2).

3.3 BIOMASS, CARBON & NUTRIENT STORAGE IN VEGETATION

Tropical forests are assuming great importance in the context of carbon cycle and its impact on climate change processes. In the present study, the biomass was estimated through conjunctive use of ground and satellite data. Total biomass varied from 20.25 Mg ha^{-1} to 103.43 Mg ha^{-1} in different forest types of the study area. These values were well within the range and comparable to those estimated in other dry tropical forests (Murphy and Lugo, 1986; Singh and Singh, 1991; Zheng *et al*., 2004). Results of this study also showed that among the different forest types, Dense mixed forest type showed highest biomass (103.43 Mg ha^{-1}) compared to Teak forest and Sal mixed forests (Table 2).

In India, only few attempts were made in this direction to quantify biomass, carbon storage and flux rates in tropical ecosystems (Jha 1990; Singh and Singh, 1991; Ravan, 1994; Roy *et al*., 1993). In present study use of satellite data was quite promising in understanding the N, P, K and C distribution. Among several vegetation indices tested, NDVI is strongly correlated with C and N densities in the forests. This might be due to NDVI is a greenness index, strongly correlated with biomass, both C and N pools directly depend on the amount of biomass. These findings are more or less similar to the findings of Swamy *et al.,* 2004.

In the present study, the concentration of nutrients (N, P and K) in vegetation followed the order: foliage> branch> root> stem> fine root and the total N, P, K and C storage of vegetation (trees + shrubs +herbs) varied from 105.1 kg ha^{-1} to 560.69 kg ha^{-1}, 4.09 kg ha^{-1} to 49.59 kg ha^{-1}, 24.59 kg ha^{-1} to 255.58 kg ha^{-1} and 7310 kg ha^{-1} to 4836 kg ha^{-1} respectively, in different forest types are presented in Table 3 & 4. N, P, K and C storage were highest in Dense mixed forest followed by Teak forest and lowest in Degraded mixed forest. The greatest amount of nutrients resided in branch and bole components, although the bole and branch had the lowest and the foliage had the highest nutrient concentrations. The standing state of nutrients (N, P and K) in the present study is lower than in humid tropical forests.

4. CONCLUSION

The study shows that dry tropical forests of Chhattisgarh are quite immature and not in standing state and have strong potential for carbon sequestration. Both quantitative and qualitative information derived in the study helped in evolving key strategies for maintaining existing C pools and also improving the C sequestration in different forest types. The study explores the scope and potential of dry tropical forests of Chhattisgarh for improving C sequestration and mitigating the global warming and climatic change.

REFERENCES

Jha, C. S., Goparaju, L., Tripathi, A., Gharai, B., Raghubanshi, A. S. and Singh, J. S. 2005. Forest frgmentation and its impact on species diversity: An analysis using remote sensing and GIS, *Bio. and Cons.,* 14 (6): 1335-1344.

King, A.W., Wilfred, M., Post, M. and Wullschleger, S.D. 1997. The potential response of terrestrial Carbon storage to changes in climate and atomospheric CO_2. *Climatic Change,* 35: 199-227.

Murphy, P.G. and Lugo, A.E. 1986a. Structure and biomass of a subtropical dry forest in Puerto Rico. *Biotropica,* 18:89-96.

Ravan, S.A. 1994. Ecological analysis of vegetation from satellite remote sensing at Madhav National Park Sivapuri (M.P.). Ph.D. Thesis, HNB Garhwal University, Srinagar, India.

Roy, P.S., Singh, S. and Porwal, Mc. 1993. Characterization of ecological parameters in tropical forest community – a remote sensing approach. *Journal of Indian Society of Remote Sensing,* 21(3): 127-148.

Saxena, K.G., Tiwari, A.K., Porwal, M.C. and Menon, A.R.R. 1992. Vegetation maps, mapping needs and scope of digital processing of Landsat Thematic Mapper data in tropical region of South-West India. *International Journal of Remote Sensing,* 13(11):2017-2037.

Singh, L. and Singh, J.S. 1991. Species structure, dry matter dynamics and carbon flux of a dry tropical forest in India. *Annals of Botany,* 68: 263-273.

Sudhakar, S., Das, R.K., Chakraborty, D., Bardhan Roy, B.K., Raha, A.K. and Shukla, P. 1994. Stratification approach for forest cover type and landuse mapping using IRS-1A LISS-II data – A case study. *Journal of the Indian Society of Remote Sensing,* 22(1): 21-29.

Swamy, S.L. and Puri, S. 2002. Growth, biomass, carbon storage and nutrient distribution in *Gmelina arborea* Roxb. Stands on red lateritic soils in central India. *Bioresource Technology*.

Zheng, D., Rademacher, J., Chen, J., Crow, T., Bresee, M., Moine, J. L. and Ryu, S. R. 2004. Estimating aboveground biomass using landsat 7 ETM + data across a managed landscape in northern Wisconsin, USA. *R. S. Env.,* 93 (3): 402-411.

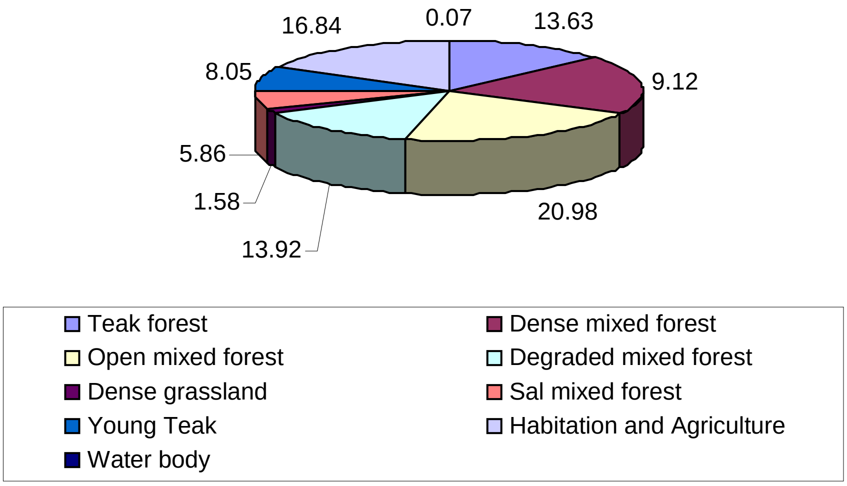

Fig. 1: Spatial extent of vegetation types (%)

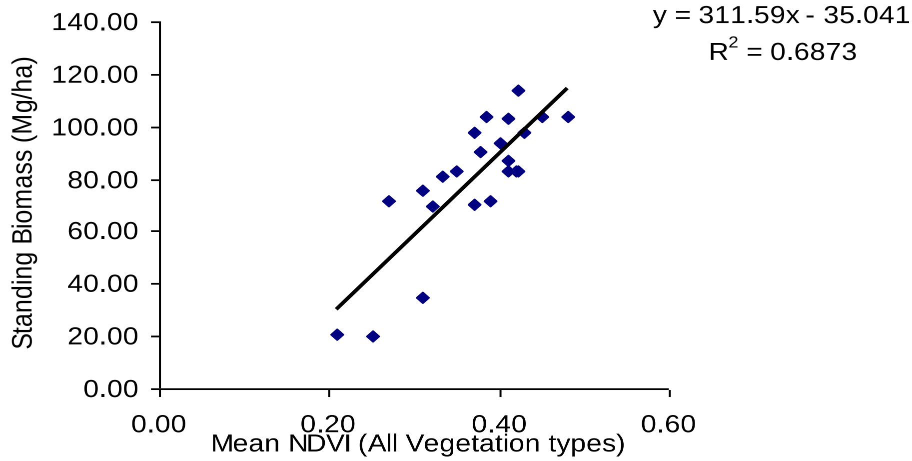

Fig. 2: Relationship between NDVI and Biomass in dry tropical forest (Pooled data)

Table 1: Diversity parameters for Trees, Shrubs and Herbaceous layer of different forest types

Forest type	Shannon Index	Simpson Index	Species Richness	Equitability	Beta diversity
Overstorey					
Teak Forest	1.36	0.49	3.88	0.51	2.21
Sal Mixed Forest	2.14	0.26	6.55	0.68	1.35
Open Mixed Forest	2.55	0.14	6.37	0.84	1.47
Dense Mixed Forest	2.98	0.06	6.86	0.94	1.29
Degraded Mixed Forest	1.42	0.07	6.20	0.54	2.21
Understorey					

6.26.20

Table 2: Standing biomass of different components of over storey, under storey and ground storey in dry tropical forest (Mg/ha)

Overstorey components						
Forest type	**Stem**	**Branch**	**Foliage**	**Root**	**Fine root**	**Total**
Teak forest	61.84	8.09	4.70	7.23	1.13	82.99
Sal mixed	40.05	15.12	7.80	2.74	1.01	66.72
Dense mixed	59.00	21.31	10.67	3.32	0.97	95.27
Open mixed	39.05	15.17	7.62	2.22	1.31	66.68
Degraded mixed	7.86	3.24	2.10	0.71	0.79	14.70
CD at 5%	**3.65**	**2.10**	**1.09**	**0.07**	**0.34**	**10.32**
Understorey						
Forest type						
Teak forest	1.23	-	0.38	0.24	-	1.85
Sal mixed	2.18	-	0.29	0.19	-	2.66
Dense mixed	1.62	-	0.42	0.32	-	2.36
Open mixed	1.72	-	0.35	0.17	-	2.24
Degraded mixed	1.38	-	0.19	0.10	-	1.67
CD at 5%	**1.02**		**0.08**	**0.07**		**1.04**
Groundstorey						
Forest type	**Shoot**			**Root**		
Teak forest	0.22	-	-	0.11	-	0.33
Sal mixed	0.47	-	-	0.16	-	0.63
Dense mixed	0.51	-	-	0.14	-	0.65
Open mixed	0.47	-	-	0.18	-	0.65
Degraded mixed	0.21	-	-	0.07	-	0.28
CD at 5%	**0.09**			**0.04**		**0.11**

Table 3: Total N and C content of trees, shrub and herb layers (Kg/ha)

Forest type	**Tree**		**Shrub**		**Herb**		**GT**	
	N	**C**	**N**	**C**	**N**	**C**	**N**	**C**
Teak forest	360.38	36890	23.46	2880	1.87	115	385.71	39885
Sal mixed	425.09	29480	36.64	3760	4.2	195	465.93	33435
Dense mixed	533.96	45340	23.34	2890	3.39	140	560.69	48370
Open mixed	390.17	29600	39.21	4990	4.25	223	433.63	34813
Degraded mixed	89.47	5620	14.16	1650	1.47	73	105.1	7343
CD at 5%	31.47	3.74	10.36	1.44	0.79	0.032	38.15	5.212

Table 4: Total P & K content of trees, shrub and herb layers (Kg/ha)

Forest type	**Tree**		**Shrub**		**Herb**		**GT**	
	P	**K**	**P**	**K**	**P**	**K**	**P**	**K**
Teak forest	27.56	174.78	2.29	15.63	0.09	0.93	29.94	191.34
Sal mixed	23.37	143.36	2.09	18.54	0.04	1.66	25.50	163.56
Dense mixed	47.42	235.38	2.11	18.09	0.06	2.11	49.59	255.58
Open mixed	24.05	124.61	2.36	18.22	0.04	1.31	26.45	144.14
Degraded mixed	3.54	19.89	0.52	4.44	0.03	0.26	4.09	24.59
CD at 5%	3.20	3.52	0.07	0.07	0.01	0.01	4.23	5.02