ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 9, Issue, 08, pp.56073-56082, August, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

FOREST CANOPY DENSITY MAPPING FOR NATURAL RESOURCE MANAGEMENT OF JANGALMAHAL AREA, INDIA, USING GEOSPATIAL TECHNOLOGY

Jatisankar Bandyopadhyay, *Ismail Mondal, Kunal Kanti Maiti, Antara Biswas, Nirupam Acharyya, Subrata Sarkar, Anurupa Paul and Panchanan Das

Department of Remote Sensing & GIS, Vidyasagar University, Midnapore-721102, West Bengal, India

ARTICLE INFO

Article History:
Received 06th May, 2017
Received in revised form
25th June, 2017
Accepted 16th July, 2017
Published online 31st August, 2017

Key words:

NDVI,
LAI,
SAVI,
PVI,
Canopy Density,
RS & GIS.

ABSTRACT

Forest cover is an important crucial role to a variety of scientific and land resource management applications. Many of these applications not only need information on forest categories, but also the information on tree canopy density should be considered. Due to the advancement in Remote sensing technology and availability of many sources of imagery and various digital classification techniques, forest canopy cover assessment has been readily accessible. The need of understanding the capability and limitations of various types of imagery and classification methods is essential. The management, development, and conservation of an area require vast knowledge of forest resources, its distribution and utilization pattern by its flora and fauna. But because of various reasons such as the development of population, increasingly changing forest to the other unsuitable applications such as agriculture, providing energy and fuel, millions of hectares from this natural resource are destroyed every year and the remaining surface change quantitatively and qualitatively. The rate of forest density should be investigated for the better management of forests. An overview of several remote sensing techniques has been used to assess the forest canopy cover. We have generated the FCD model by using Landsat 8 OLI image in an old growth forest of Paschim Medinipur sub- division of India.

Citation: Jatisankar Bandyopadhyay, Ismail Mondal, Kunal Kanti Maiti, Antara Biswas *et al.*, 2017. "Forest canopy density mapping for natural resource management of Jangalmahal area, India, using geospatial technology", *International Journal of Current Research*, 9, (08), 56073-56082.

INTRODUCTION

Remote sensing is a technology which gathers information about objects without being in physical contact with them while using different wavelength regions of electromagnetic spectrum (Kushwaha *et al.*, 2005) for mapping of forest resource management. The forest mapping are reliable and up-to-date information on the state of deforestation and forest degradation is critical in understanding whether forests in tropical regions are being managed sustainably (Myat *et al.*, 2012, Hayes and Cohen 2006, Kumar et. al. 2007, Mon *et al.*, 2010). Numerous image classification algorithms have been developed that enable quantitative and qualitative assessment of forest vegetation from data obtained by remote sensing (Lambin 1999, Defries *et al.*, 2000, Mayaux *et al.*, 2005, Laurance 2007, Lu and Weng 2007). Forest attributes such as forest density, species composition, basal area, volume, biomass, leaf area index, canopy density and canopy cover can be identified using remotely sensed data (Boyd *et al.*,1999, Defries *et al.*, 2000, Puhr and Donoghue 2000, Franklin *et al.*, 2003, Phua and Saito 2003, Koy *et al.*, 2005, Lefsky *et al.*, 2005, Foody and Cutler 2006, Hall *et al.*, 2006, Sivanpillai *et al.*, 2006, Kumar *et al.*, 2007, Prasad *et al.*, 2009, Htun *et al.*, 2011). Two such attributes, forest canopy density (FCD) and forest canopy cover (FCC), are closely related to strem density and the growth and health of the trees (Rikimaru 1996, Rikimaru and Miyatake 1997, Jennings *et al.*, 1999, Gill *et al.*, 2000, Joshi *et al.*, 2006, Paletto and Tosi 2009, Prasad *et al.*, 2009). Thus, estimates of FCC and FCD have been adopted for monitoring and assessing deforestation and forest degradation (Food and Agriculture Organization (FAO) 2000, 2005, Chandrashekhar *et al.*, 2005, Joshi *et al.*, 2006, Panta *et al.*, 2008, Mon *et al.*, 2010). The presence of forest in Jangalmahal sub-divisional area are relevant at several levels. Socially and economically speaking, forests are traditional resources for local communities as a source for fuel wood and construction wood. In addition, it is used for commercialization of the non-timber product in some local market. Moreover, they represent pasture for domestic grazers. Ecologically, forest is essential for some villagers to earn money by selling fuel wood also the plant leaf. Furthermore, vegetation is one of the most important components of the eco-system. The knowledge about the variation in vegetation species and community distribution pattern.

***Corresponding author: Ismail Mondal,**
Department of Remote Sensing & GIS, Vidyasagar University, Midnapore-721102, West Bengal, India.

Alternations in vegetation phonological cycle and modification in plant physiology and morphology provide valuable insight into climate, geologic and physiographic characteristic of an area (Jones, *et al*., 1998). Scientist has devoted a significant amount of effort to develop sensors and visual and digital image processing algorithms to highlight and extract important vegetation bio-physical information from remotely sensed data (Huete 1999 and J. Qi, *et al*., 1984). During 1985-86 the pilot project was reviewed, evaluated and analyzed. It appeared that the entire project area had become restocked with nearly 700 ha of beautiful Sal coppice forests and 300 ha of plantation crop. In fact, this pilot project proved to be a success. The formula of involvement of indigenous people in forest protection and management was translated in another area including West Midnapore Division since mid-eights very successfully. Govt. gave recognition to these systems of management of forests (popularly termed as joint forest management) by issuing a Govt. Order during 1989 and amendments during 1990 and 1991. Presently this division is having nearly 480 Forest Protection Committees from 1st April, 2006 the west Midnapore Division has been recognized and rename as Jhargram Forest Division.

Background of the study

Jangalmahal is a sub-divisional municipality in the Paschim Medinipur district in the Indian state of West Bengal. Beyond the genetic planes of West Bengal, India, Jangalmahal offers the most exotic beauties of undulating topography in hill ranges of Belpahari, Kankrajhor is the North to the serene beauties of meandering Subarnarekha River in the South. Jhargram is the paradise of nature loves with beautiful forests of Sal, Mahul, Wild Elephants, Deer, and Birds. For scientific management of forests vested in Government under Estate Acquisition Act, 1953, Jhargram forest under the administrative setup as Jhargram division style as Midnapore division was divided into two division viz. West Midnapore Division (renamed as Jhargram division) with headquarters at Jhargram and east Medinipur Division with headquarters at Midnapore. The West Midnapore Division came into existence on 29.01.1954. The Jhargram sub-division is mostly a dry area with rain-fed farming and now faced climate change problems. Jangalmahal has a much higher proportion of the Tribal population and chronic poverty condition despite a multitude of on-going poverty reduction measure. A dry area with some parts forested is one of the most deprived and maximum rural population dependent on rain-fed farming, the district has one of the lowest average rate of Rs.38/- per day. With one of the highest member of Scheduled Caste and Schedules Tribes families below the poverty land. There are three categories of poor-the destitute (live in mud house no assets, self-forest produce, beg and borrow) The very poor(live in mud house, engaged in wage labor and have some land to grow food for 6-9 month, some are also beneficiaries of huts constructed under the Indira Awaas Yojna.). In such area many households are engaged in selling forest products such as Sal leaves, Wild fruit, fuel wood, mushroom, wild potato, and other items are locally available. Their local forest is mostly under the Joint Forest Management Programmed overseen by their Local Forest Protection Committee. Forest-related livelihood are especially crucial for the women-headed households and elderly women as compared to other group-one primary reason being that seasonal migration or naval is generally undertaken in selected seasons for a few days. In April-May-June, after migration, some families use their earning to repair huts, the pay of their old debts and few are able to get their daughters married with cash earned.

MATERIALS AND METHODS

Study Area

The area lies between 22° 49' and 22° 23' North Latitude and 87° 30' and 87° 00' East Longitudes and bounded on the north and west by Rup Narayan Forest Division and river Kangshabati, on the East by Medinipur-Keshpur-Road .The sub-division cover the Civil Blocks viz. Binpur-I, II, Salboni, Jhargram, Jamboni, Gopiballavpur-I and Gopiballavpur-II, Garbeta- II, Sankrail, Mednipur, Nayagram (Fig.1).

Geology

The parent rock is a mixture of metamorphic rock of sedimentary origin and igneous rock both basic and acidic. Lateritic, the characteristic formation of the district occupies a large tract. The thickness of the lateritic varies from place to place but is not known to exceed 15mt. in this area. The sandy loam and loamy soil of reddish or reddish brown colour covers the upper layer of almost the whole area (Fig. 2).

Data and methodology

The Landsat 8 OLI data are collected to the selected study area were produced from USGS, the United States. The imagery was visually interpreted to delineate geomorphologic units and land use/land cover with the help of standard characteristic image interpretation elements like tone, texture, shape, size, pattern, and association. All the data are pre-processed and projected to the Universal Transverse Mercator (UTM) projection system. The objective of the present study are follows to show the canopy cover measurement using remote sensing technology and implementation of spectral indices and Multi-Criteria Decision Making analysis instead of traditional method of vegetation study. To identify the land use-land cover classification of this area and importance of the digital remote sensing techniques as an advance mapping system.

Utility of Spectral Indices in Vegetation Study

Vegetation monitoring is usually accomplished by simple regression modeling approach using remote sensing data and by computing Vegetation indices should (Rouse, J.W., 1974) the maximize sensitivity to plant biophysical parameters, preferably with a linear response in order that sensitivity is available for a wide range of vegetation conditions and to facilitate validation of the index. The normalize external effects such as sun angle and the atmosphere for consistent spatial and temporal comparisons and internal effects such as canopy background variations, including topography (slope and aspect), soil variations and differences in sensed or woody vegetation (no photosynthetic canopy components). Be coupled to some specific measurable biophysical parameter such as biomass, LAI as part of the validation effort and quality control.

RESULTS AND DISCUSSION

Normalized Differences Vegetation Index

The Normalized Difference Vegetation Index (NDVI) was introduced by (Kauth, *et al*., 1976) in order to produce a

Table 1. The pairwise comparison method for assigned weight of vegetation indices

PAIRWISE COMPARISON METHOD									
	SAVI	PVI	NDVI	GVI				Character	Rank
SAVI	1	2	6	8				Equally important	1
PVI	0.25	1	5	6				Equal to strong	2
NDVI	0.16667	0.2	1	5				Moderate	3
GVI	0.125	0.1667	0.2	1				Moderate to strong	4
SUM	1.54167	3.3667	12.2	20				Strong	5
								Strong to very strong	6
	SAVI	PVI	NDVI	GVI	Weight	Final Weight		Very strong	7
SAVI	0.64865	0.5941	0.4918	0.4	2.134511	0.533627833		Very to extremely strong	8
PVI	0.16216	0.297	0.40984	0.3	1.169028	0.292256983		Extremely strong	9
NDVI	0.10811	0.0594	0.08197	0.25	0.499481	0.124870315			
GVI	0.08108	0.0495	0.01639	0.05	0.196979	0.049244869			
SUM	1	1	1	1		1			
	SAVI	PVI	NDVI	GVI	Sum	Average	Lamda	CL	CR
SAVI	0.53628	0.5845	0.74922	0.394	2.263975	4.242610312	4.21234	0.070779862	0.07864
NDVI	0.13341	0.2923	0.62435	0.2955	1.345485	4.603772739			
PVI	0.08894	0.0585	0.12487	0.2462	0.518484	4.152180004			
SAVI	0.0667	0.0487	0.02497	0.0492	0.189632	3.850795291			
Sum						16.84935835			

Table 2. Forest canopy mapping the value are collect from different five fixed point on different indices

CLASS	SL NO	LATTITUDE	LONGITUDE	GVI	NDVI	SAVI	PVI
VERY LOW	VL-1	23°38′00.26″N	86°59′59.84″E	50	0.063	0.554	24
	VL-2	22°24′42.68″N	87°10′10.04″E	59	0.017	0.093	34
	VL-3	22°20′53.05″N	87°03′39.09″E	54	0.006	0.091	48
	VL-4	22°24′05.74″N	86°32′21.23″E	31	0.056	-0.073	44
	VL-5	22°34′54.43″N	86°48′2.05″E	78	0.041	0.01	33
AVERAGE				54.4	-0.0366	0.135	36.6
LOW	L-1	22°36′18.59″N	86°53′03.25″E	56	0.117	0.086	39
	L-2	22°19′16.72″N	87°00′12.51″E	33	0.159	-0.053	14
	L-3	22°21′49.16″N	87°16′41.46″E	39	0.043	0.069	23
	L-4	21°58′19.06″N	87°12′59.53″E	61	0.005	-0.357	33
	L-5	21°55′25.78″N	87°03′29.65″E	65	-0.034	0.13	16
AVERAGE				50.8	-0.058	-0.025	25
MODERATE	M-1	22°37′33.80″N	86°50′12.28″E	58	0.152	0.222	31
	M-2	22°40′32.89″N	87°05′00.72″E	55	0.224	0.333	34
	M-3	22°33′32.32″N	87°06′23.08″E	56	0.191	0.298	34
	M-4	22°22′55.11″N	87°00′50.67″E	60	0.167	0.163	32
	M-5	22°15′36.90″N	87°00′45.09″E	63	0.125	0.228	32
AVERAGE				58.4	0.1718	0.2488	32.6
HIGH	H-1	22°23′32.73″N	87°51′39.68″E	67	0.267	0.28	43
	H-2	22°25′59.39″N	87°56′7.75″E	60	0.006	0.028	37
	H-3	22°20′36.99″N	86°56′2.01″E	66	0.261	0.373	41
	H-4	22°14′15.78″N	87°05′46.63″E	65	0.057	0.089	35
	H-5	22°13′09.85″N	86°55′28.60″E	60	0.204	0.02	38
AVERAGE				63.6	0.159	0.158	38.8
VERY HIGH	VH-1	22°42′31.72″N	86°37′59.11″E	61	0.283	0.413	38
	VH-2	22°38′43.01″N	86°59′18.02″E	85	0.438	0.633	73
	VH-3	22°34′26.22″N	87°01′50.60″E	96	0.433	0.56	69
	VH-4	22°26′01.28″N	87°08′25.78″E	47	0.432	0.449	40
	VH-5	22°25′34.93″N	87°00′48.57″E	67	0.326	0.747	54
AVERAGE				71.2	0.3824	0.5604	54.8

spectral vegetation index (VI) that separates green vegetation from its background soil brightness using Landsat 8 OLI digital data. It is expressed as the difference between the near infrared and red bands normalized by the sum of those bands. The expression of NDVI Index is written as follows: (NIR-RED)/ (NIR+RED) it is the most commonly used NDVI as it retains the ability to minimize topographic effects while producing a linear measurement scale. In addition, division by zero errors is significantly reduced. Furthermore, the measurement scale has the desirable property of ranging from -1 to 1, with 0 representing the approximate value of no vegetation, and negative values non-vegetated surfaces. The present study of Jangalmahal area indicate NDVI value between 0 to -0.05 low, 0 to -0.1 very low, 0 to 0.15 moderate, 0 to 0.17 high and 0 to 0.035 very high (Fig. 3; 4).

Greenness Vegetation Index

Green Vegetation Index is the second of the four new bands that extracted from raw Landsat 8 OLI images. The GVI provides Global coefficients that are used to weight the original OLI digital counts to generate the newly transformed bands. The expression of the green vegetation index band, GVI, is written as follows for OLI data: GVI = [(-0.2848 OLI1) + (-0.2435 OLI2) + (-0.5436 OLI3) + (0.7243 OLI4) + (0.0840 OLI5) + (-0.1800 OLI7)]. Using Landsat OLI imagery it represents the Greenness of the study area. According to the Tasseled Cap Transformation Technique Greenness conveys information concerning abundance and vigor of living vegetation. The negative weights of the GVI on the visible bands tend to minimize the effects of the

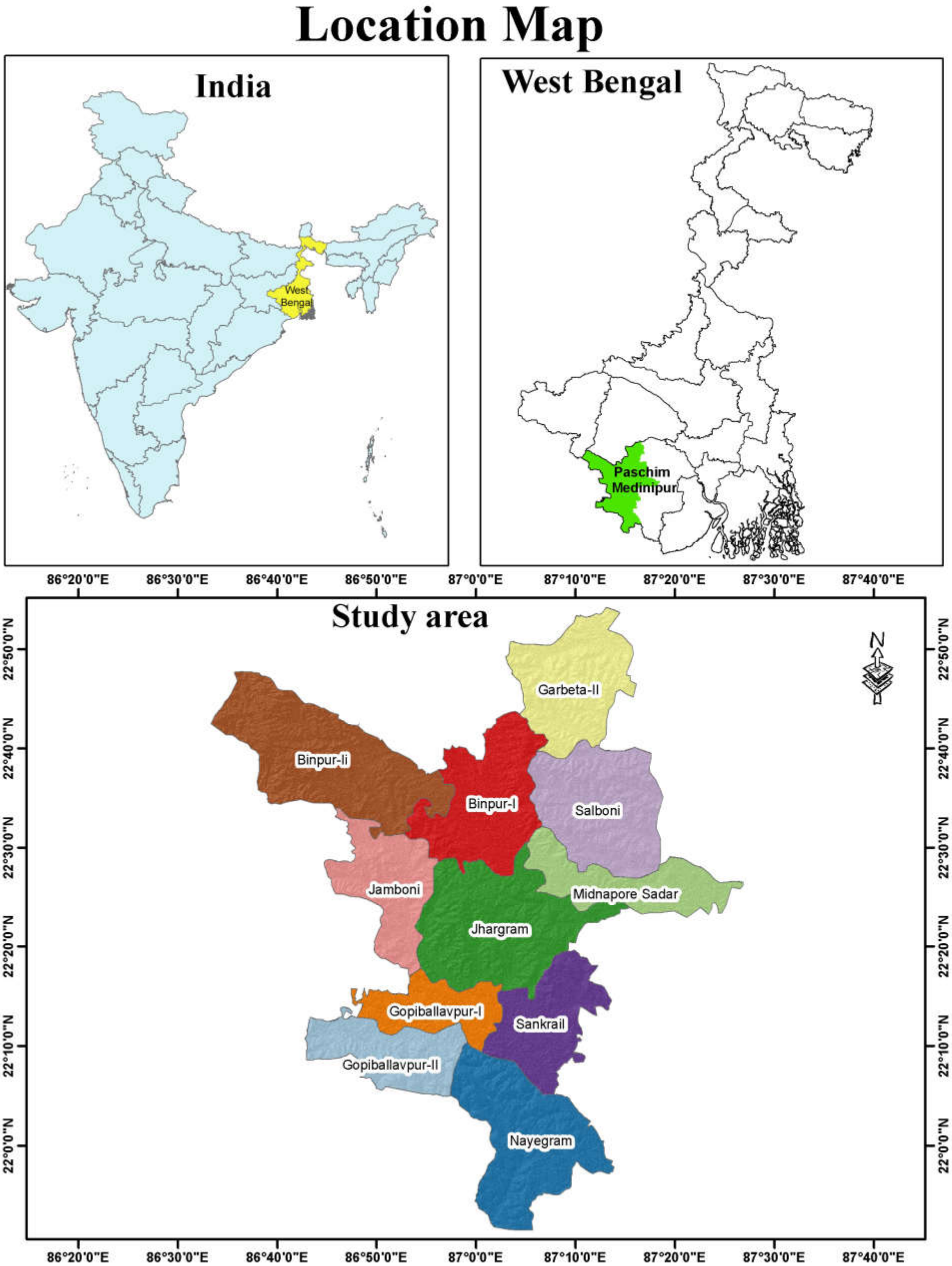

Fig. 1. Location Map of the Study area

background soil, while its positive weights on the near infrared bands emphasize the green vegetation signal. In (Fig. 5) it is seen that the greenness value of lower ranges represent the low vagueness, where the value represent (0 to .59), moderate range represent moderate vagueness (0 to .65) and higher range represents higher vagueness (<.70).

Perpendicular Vegetation Index

It is the distance based vegetation index designed to eliminate the effect of background soil wetness and only to detect the features of vegetation cover (Richardson, *et al*., 1977).

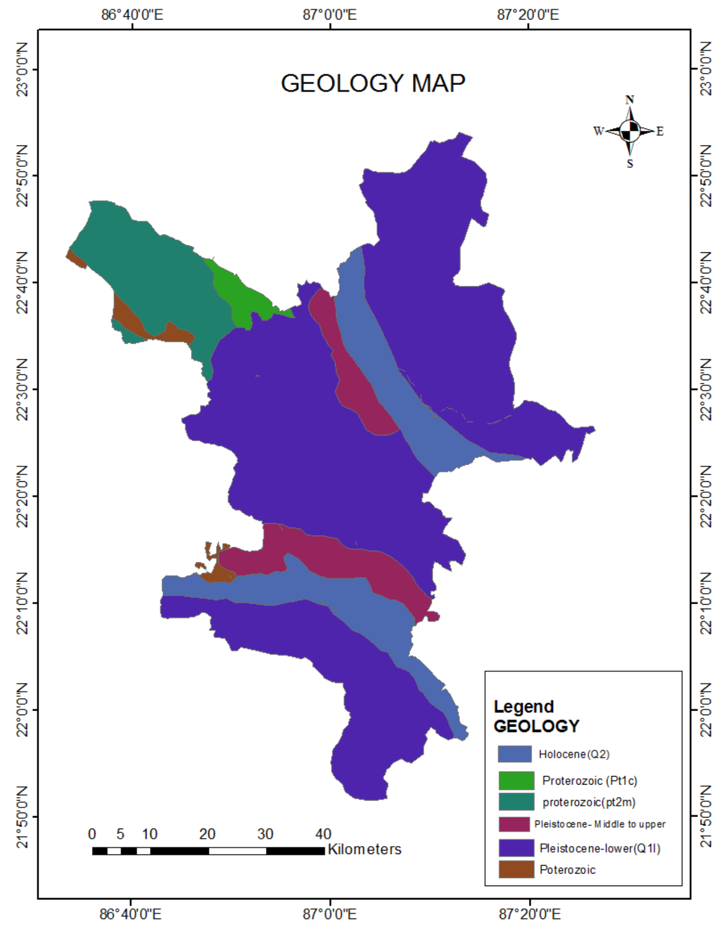

Fig. 2. Geology Map

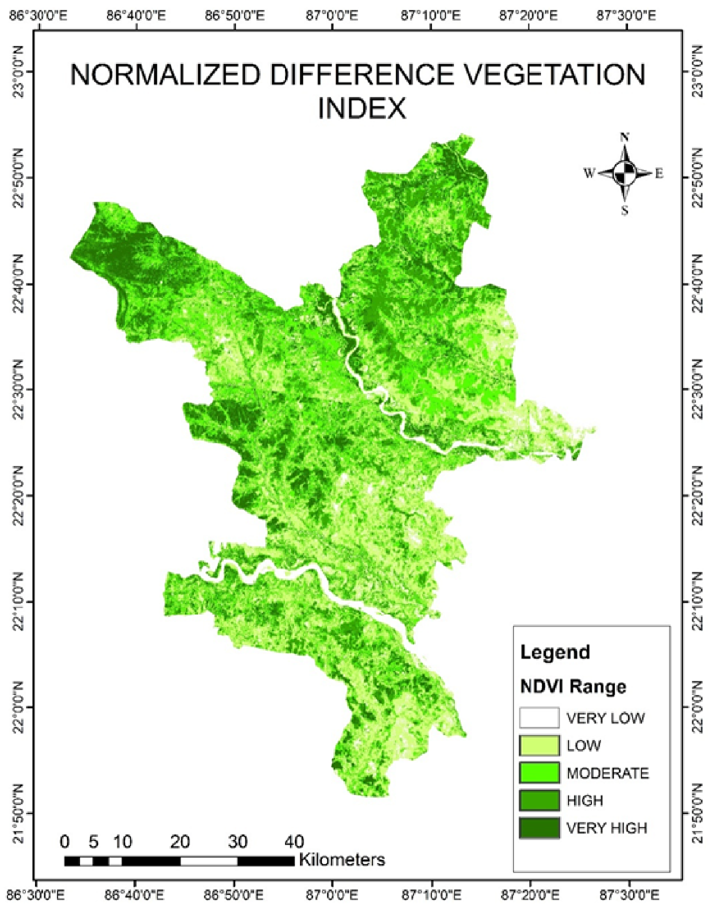

Fig. 3. NDVI Map

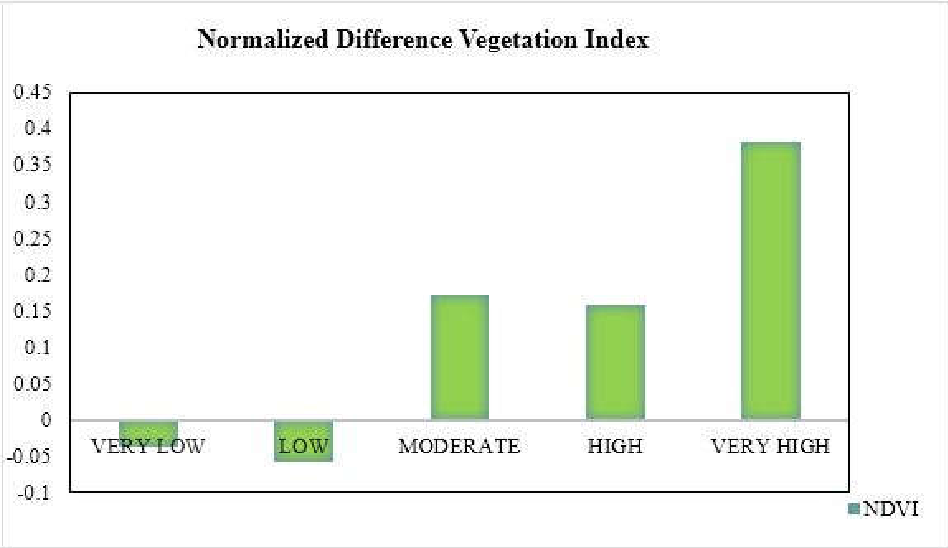

Fig. 4. NDVI Value

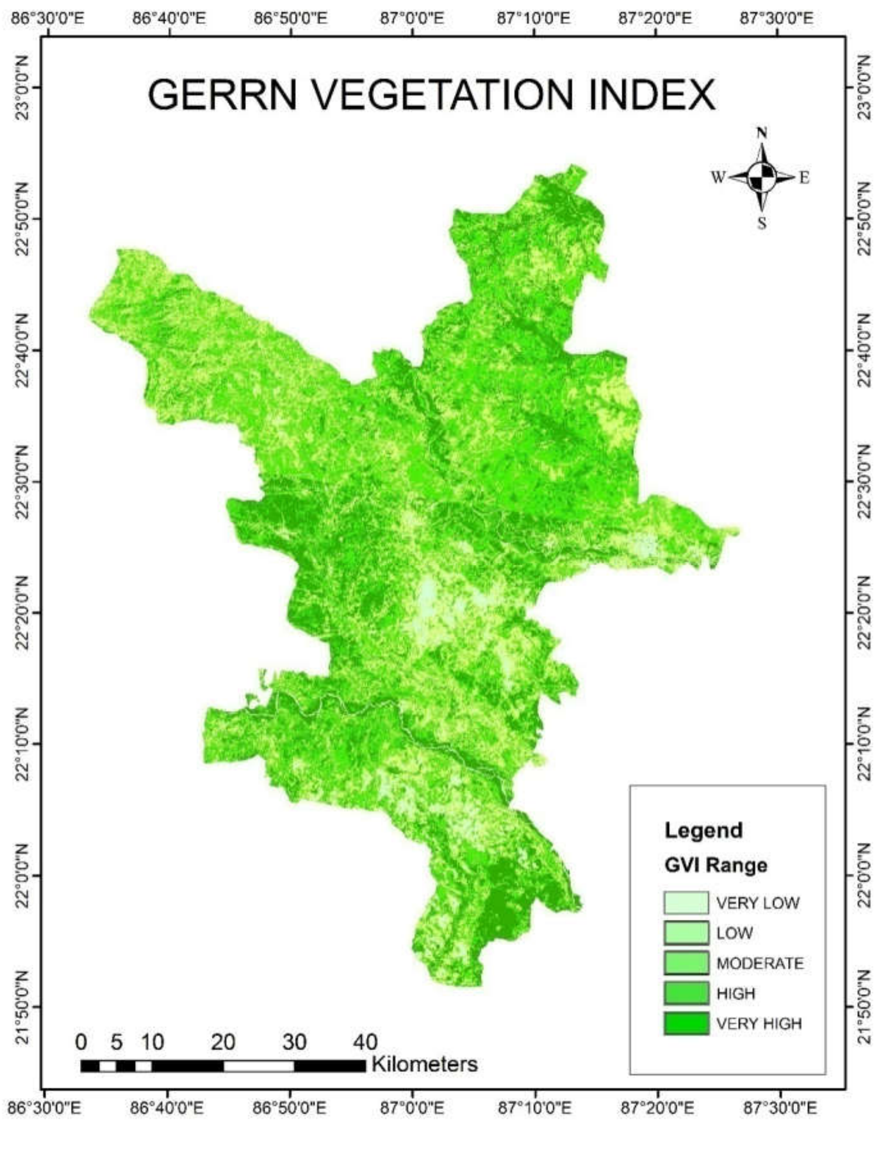

Fig. 5. GVI Map

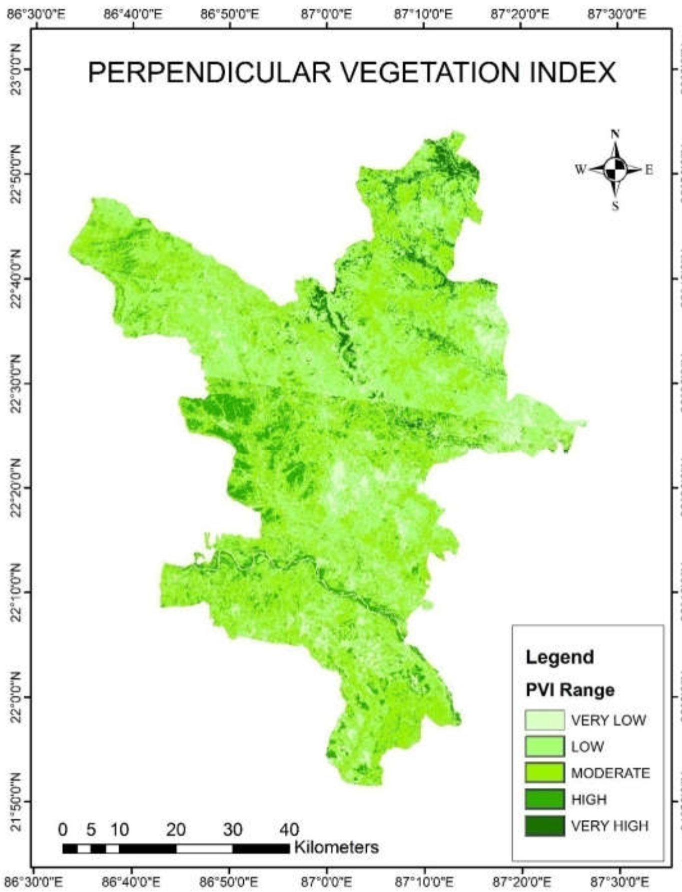

Fig. 6. PVI Map

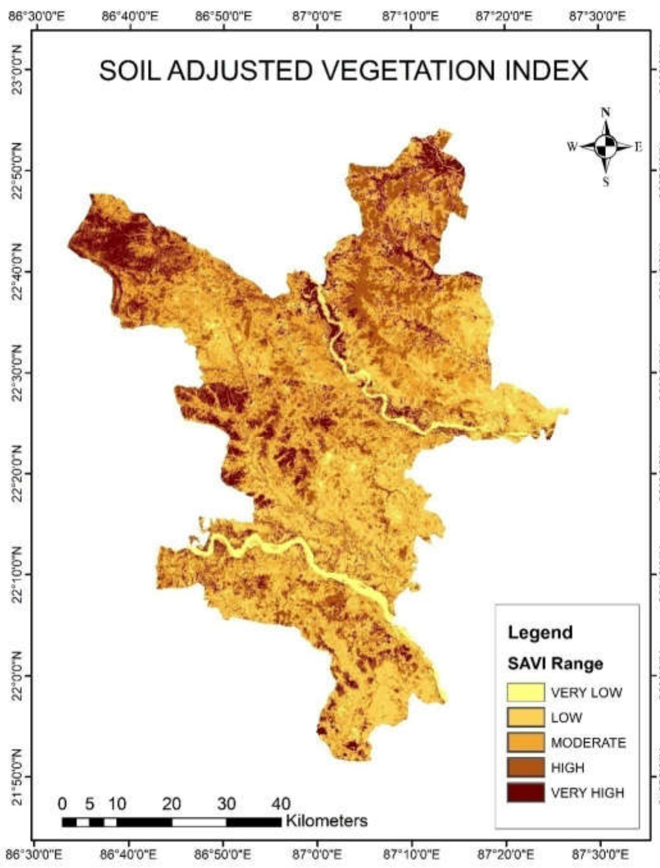

Fig. 7. SAVI Map

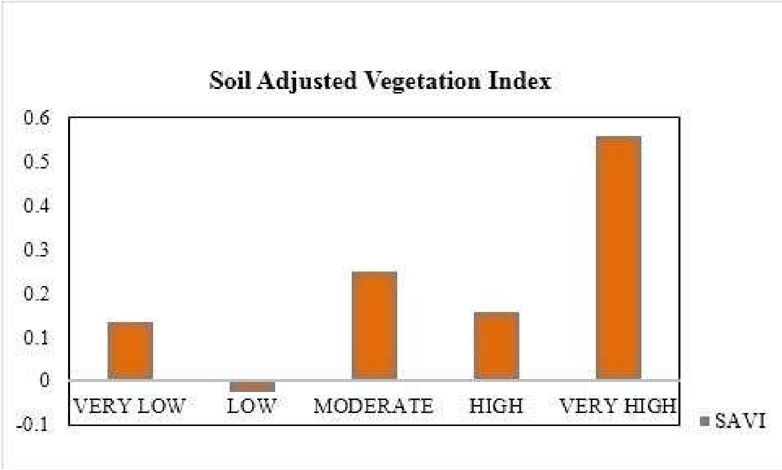

Fig. 8. SAVI Value

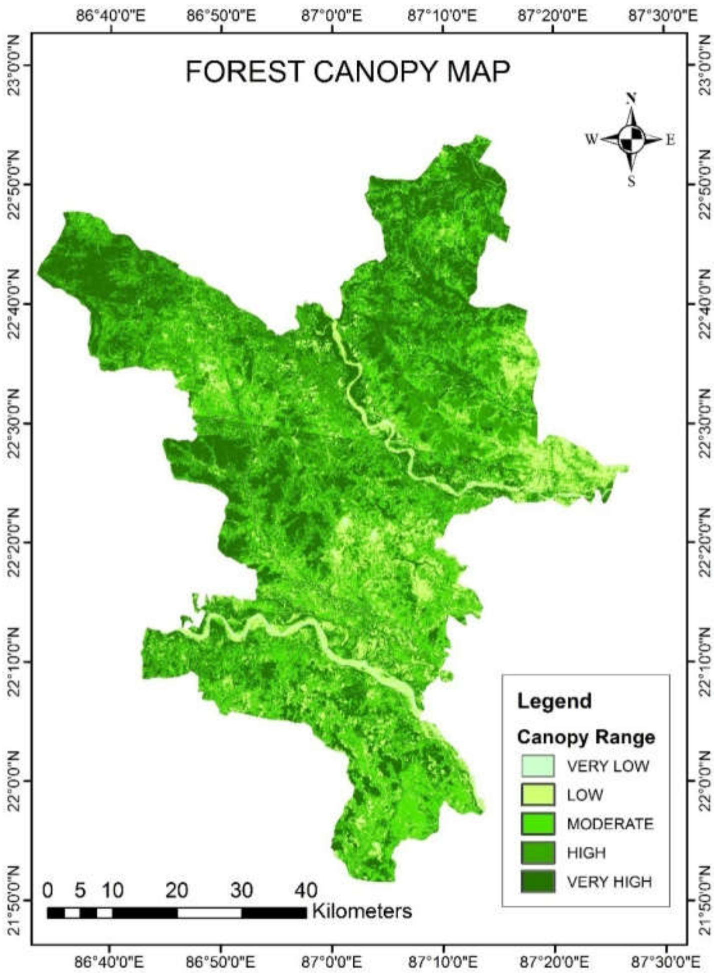

Fig. 9. Forest Canopy Density Map

The Perpendicular Vegetation Index (PVI) suggested by Richardson and (Huete, *et al*., 1988) is the parent index from which this entire group is derived. The PVI uses the perpendicular distance from each pixel coordinate to the soil line. These indices are eliminated the effect to the background soil wetness and only detect the feature of vegetation cover. In this index, the soil line concept is a linear regression of NIR against the RED band for the pixel of bare soil. The expression of the perpendicular vegetation Index is written as follows: (b NIR-RED) +a/$\sqrt{}$b^2+1. In (Fig. 6) it is seen that the PVI value ranges between 0 to -58. This whole range is classified here as the presence of wet soil and low, partial and full vegetation canopy cover of the study area.

Soil Adjusted Vegetation Index

The Soil-Adjusted Vegetation Index (SAVI) was proposed by (J. Ronald Eastman 2003; Maiti, *et al*., 2015). It is intended to minimize the effects of soil background on the vegetation signal by incorporating a constant soil adjustment factor L into the denominator of the NDVI equation. L varies with the reflectance characteristics of the soil (e.g., color and brightness). The L factor chosen depends on the density of the vegetation one wishes to analyses. In cases of very low vegetation, the use of an L factor of 1.0 is suggested, for 0 to -0.1 is very low, 0 to 0.2 moderate and for high densities, 0. 0.06 (Fig. 7; 8) suggests that the best L value to select is where the difference between SAVI values for dark and light soil is minimal. For L = 0, SAVI equals NDVI. For L = 1, SAVI approximates PVI. The expression of SAVI Index is written as follows: (NIR-RED)/ (NIR+RED)*(1+L).Where (L) is the line of soil.

Forest Canopy Density

Forest canopy are categorized on the basic of five types are class value and the given table show the value of various indices with five sub-categorized which used the forest canopy mapping. The value is collected from different five fixed point on different four indices. Now if an intersection operation (Boolean and operator) is followed over the NDVI, GI, PVI, and SAVI. Now it can identify the succession pattern as well as the nature of the canopy coverage. This has been said prior that no clear succession pattern is seen in the Jangalmahal regions. The deep green vegetation coverage is showing that the forest canopy density zone of the Jangalmahal area. The final cumulative map was reclassified into five categories of five forest canopy cover types via; 'very low', 'low', 'moderate', 'high', and 'very high'. Pairwise comparison is a kind of divide-and-conquer problem-solving method. It allows one to determine the relative order (ranking) of a group of items. This is often used as part of a process of assigning weights to criteria (Table. 1; 2). In order to weight these criteria, we could simply tackle the problem all at once and, for example, discuss what weights should be assigned to each criterion. This can be very difficult; it can become an insurmountable task in more complex problems where there may be dozens of criteria. An alternative is to divide the problem of assigning weights into two parts: Determine qualitatively which criteria are more important i.e. establish a ranking of the criteria, and assign each criterion a quantitative weight so that the qualitative ranking is satisfied. After studying all the above vegetation index, multi-criteria based weightage analysis has been done to prepared the forest canopy density mapping.

Conclusion and Outlook

The study is aimed at using the different vegetation indices for mapping (namely, NDVI, GVI, PVI, and SAVI) to using Landsat OLI Satellite data. It is possible to evaluate canopy density more accurately but it needs more parameters like DEM, slope, soil type and other values depending upon the environment of the study area. In the relationships between several spectral vegetation indices and plant canopy nature and canopy cover through PVI have been assessed (Mondal, *et al*., 2013). We are using Forest Canopy Density model indicates the growth phenomena of forests by means of qualitative analysis and the accuracy assessment of methodology is checked in the field test for develop the FCD model to useful and monitoring the management with less ground truth survey. So it can be concluded that canopy density is the integrated result of the various parameters and thus can be found more accurate than normal classification scheme.

REFERENCES

Boyd, D.S., Foody, G.M. and Curran, P.J. 1999. The relationship between the biomass of Cameroonian tropical forests and radiation reflected in middle infrared wavelengths (3.0–5.0μm). *International Journal of Remote Sensing*, 20, pp. 1017–1023.

Chandrashekhar, M.B., Saran, S., Raju, P.L.N. and Roy, P.S., 2005. Forest canopy density stratification: How relevant is biophysical spectral response modeling approach? *Geocarto International*, 20, pp. 15–21

Defries, R.S., Hansen, M.C. and Townshend, R.G. 2000. Global continuous fields of vegetation characteristics: a linear mixture model applied to multi-year 8 km AVHRR data. *International Journal of Remote Sensing*, 21, pp. 1389–1414

FAO, 2005. Global Forest Resource Assessment 2005. Food and Agriculture Organization of the United Nations, Rome

Food and Agriculture Organization (FAO), (2000): Global Forest Resource Assessment 2000. Food and Agriculture Organization of the United Nations, Rome.

Foody, G.M. and Cutler, M.E.J. 2006. Mapping the species richness and composition of tropical forests from remotely sensed data with neural networks. *Ecological Modelling*, 195, pp. 37–42.

Franklin, S.E., Hall, R.J., Smith, L. and Gerylo, G.R. 2003. Discrimination of conifer height, age and crown closure classes using Landsat-5 TM imagery in the Canadian Northwest Territories. *International Journal of Remote Sensing*, 24, pp. 1823–1834.

Gill, S.J., Biging, G.S. and Murphy, E.C. 2000. Modeling conifer tree crown radius and estimating canopy cover. *Forest Ecology and Management*, 126, pp. 405–416

Hall, R.J., Skakun, R.S., Arsenault, E.J. And Case, B.S. 2006. Modeling forest stand structure attributes using Landsat ETM+ data: application to mapping of aboveground biomass and stand volume. *Forest Ecology and Management*, 225, pp. 378–390.

Hay E S, D.J. and Cohen, W.B. 2006. Spatial, spectral and temporal patterns of tropical forest cover change as observed with multiple scales of optical satellite data. Remote Sensing of Environment, 106, pp. 1–16.

Htun, N.Z., Mizoue, N. And Yoshida, S. 2011. Classifying tropical deciduous vegetation: a comparison of multiple approaches in Popa Mountain Park, Myanmar. International Journal of Remote Sensing, doi: 10.1111/j.1744-7429.2011.00753.x.

Huete and Justice, 1999. Modis Vegetation Index (Mod 13) Algorithm Theoretical Basis Document Version University of Virginia Department of Environmental Sciences Clark Hall Charlottesville.http://modis.gsfc.nasa.gov/data/atbd/atbd_mod13.pdf.

Huete, A. R. 1988. A soil adjusted vegetation index (SAVI), Remote Sens. Environ., 25:295-309.

Jennings, S.B., Brown, N.D. and Sheil, D. 1999. Assessing forest canopies and understory illumination: canopy closure, canopy cover and other measures. *Forestry*, 72, pp. 59–74.

Jones, P. D., Briffa, K. R., Barnett, T. P. and Tett, S. F. B., 1998. High-resolution palaeo climatic records for the last millennium; interpretation, integration and comparison with general circulation model control-run temperatures, The Holocene, 8, 455-471.

Joshi, C., Leeuw, J.D., Skidmore, A.K., Duren, I.C.V. and Oosten, H.V. 2006. Remotely sensed estimation of forest canopy density: a comparison of the performance of four methods. *International Journal of Applied Earth Observation and Geoinformation*, 8, pp.84–95.

Kauth, R. J. and Thomas, G. S. 1976. "The Tasseled Cap - A Graphic Description of the Spectral-Temporal Development of Agricultural Crops as Seen by LANDSAT" LARS Symposia. Paper 159. http://docs.lib.purdue.edu/lars_symp/159.

Koy, K., Mcshea, W.J., Leimgruber, P., Haack, B.N. and Aung, M. 2005. Percentage canopy cover using Landsat imagery to delineate habitat for Myanmar's endangered Eld's deer (Cervus eldi).Animal Conservation, 8, pp. 289–296.

Kumar, A., Uniyal, S.K. and Lal, B. 2007. Stratification of forest density and its validation by NDVI analysis in a part of Western Himalaya, India using RS and GIS techniques. *International Journal of Remote Sensing*, 28, pp. 2485–2495.

Kushwaha C.P, Singh, K.P. 2005. Diversity of leaf phonology in a tropical deciduous forest in India. *Journal of Tropical Ecology,* 21:47-56.

Lambin, E.F. 1999. Monitoring forest degradation in tropical regions by remote sensing: some methodological issues. Global Ecology and Biogeography, 8, pp. 191–198

Laurance, W.F. 2007. Forest destruction in tropical Asia. Current Science, Special Section: *Asian Biodiversity Crises*, 93, pp. 1544–1549.

Lefsky, M.A., Hudak, A.T., Cohen, W.B. and Acker, S.A., 2005. Patterns of covariance between forest stand and canopy structure in the Pacific Northwest. *Remote Sensing of Environment*, 95, pp. 517–531.

Lu, D. and Weng, Q. 2007)A survey of image classification methods and techniques for improving classification performance. *International Journal of Remote Sensing*, 28, pp. 823–870.

Maiti, K.K. Mondal S, Chakravarty, D. Bandyopadhyay, J 2015. Assessment of Vegetation Canopy Using Geo-Spatial Techniques Over Mining Areas of Pandabeswar In Barddhaman District, West Bengal, India, *International Journal of Remote Sensing & Geoscience (IJRSG)*, ISSN No: 2319-3484 Volume 4, Issue 4, pp. 18-22) www.ijrsg.com

Mayau X, P., Holmgren, P., Achard, F., Eva, H., Stibig, H.J. and Branthomme, A. 2005. Tropical forest cover change in the 1990s and options for future monitoring. *Philosophical Transactions of the Royal Societ*y, 360, pp. 373–384

Mon, M.S., Kajisa, T., Mizoue, N. and Yoshida, S. 2010. Monitoring deforestation and forest degradation using FCD Mapper in Bago Mountain areas, Myanmar. *Journal of Forest Planning*, 15, pp. 63–72.

Mondal, I. Bandyopadhyay, J. Jana, M.K 2013. Mangrove Zonation and Succession Pattern of Fazergange and Bakkhali area at Sundarban, W.B., India Using Remote Sensing & GIS Techniques, Indian Cartographer, Vol. XXXIII, 2013.

Myat Su Mon, Nobuya Mizoue, Naing Zaw Htun, Tsuyoshi Kajisa & Shigejiro Yoshida, 2012. Estimating forest canopy density of tropical mixed deciduous vegetation using Landsat data: a comparison of three classification approaches, International Journal of Remote Sensing, 33:4, 1042-1057, DOI: 10.1080/01431161.2010.549851.

Paletto, A. and Tosi, V. 2009. Forest canopy cover and canopy closure: comparison of assessment techniques. European Journal of Forest Research, 128, pp. 265–272.

Panta, M., Kim, K. and Joshi, C. 2008. Temporal mapping of deforestation and forest degradation in Nepal: applications to forest conservation. *Forest Ecology and Management*, 256, pp. 1587–1595.

Phua, M.H. and Saito, H. 2003. Estimation of biomass of a mountainous tropical forest using Landsat TM data. *Canadian Journal of Remote Sensing*, 29, pp. 429–440.

Prasad, P.R.C., Nagabhatla, N., Reddy, C.S., Gupta, S., Rajan, K.S., Raza, S.H. and Dutt, C.B.S. 2009. Assessing forest canopy closure in a geospatial medium to address management concerns for tropical islands – Southeast Asia. *Environmental Monitoring and Assessment*, 160, pp. 541–553

Puhr, C.B. and Donoghue, D.N.M. 2000. Remote sensing of upland conifer plantations using Landsat TM data: a case study from Galloway, South-west Scotland. International Journal of Remote Sensing, 21, pp. 633–646.

Qi, J., A. Chehbouni, A. R. Huete, Y. H. Kerr, and S. Sorooshian, 1984. A Modified Soil Adjusted Vegetation Index, © Elsevier.

Richardson, A. J., and C. L. Wiegand, 1977. Distinguishing vegetation from soil background information: *Photogrammetric Engineering and Remote Sensing*, v. 43, 1541-1552.

Rikimaru, A. 1996. Landsat TM data processing guide for forest canopy density mapping and monitoring model. In ITTO Workshop Proceedings on Utilization of Remote Sensing in Site Assessment and Planning for Rehabilitation of Logged-over Forest,30 July–1 August, Bangkok, Thailand, pp. 1–8

Rikimaru, A. and Miyatake, S. 1997. Development of forest canopy density mapping and monitoring model using indices of vegetation, bare soil and shadow. In18th Asian Conference on Remote Sensing, 20–24 October, Malaysia.

Ronald Eastman J. 2003. IDRISI Kilimanjaro Guide to GIS and Image Processing, Clark Labs Clark University 950 Main Street Worcester, MA 01610-1477 USA.

Rouse, J.W. 1974. Monitoring the vernal advancement of retrogradation of natural vegetation. NASA/GSFC, Type III, Final Report, Greenbelt, MD, pp. 371.

Sivanpillai, R., Smith, C.T., Srinivasan, R., Messina, M.G. and Wu, X.B. 2006. Estimation of managed loblolly pine stand age and density with Landsat ETM+data. *Forest Ecology and Management*, 223, pp. 247–254.

****