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Mapping of the Forest Cover based on Multi-criteria Analysis: A Case Study on Jhargram Sector in Paschim Medinipur District

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Abstract: ***Application of Remote Sensing and GIS of vegetation can be an attractive and alternative to the traditional methods of field scouting because of the capability of covering large areas rapidly and repeatedly providing spatial and temporal information necessary for a sustainable management. The potential of remote sensing in vegetation is very high because it is able to infer about vegetation amount and its nature as a non-destructive mean. Numerous spectral vegetation indices (VIs) multi-criteria based approach has been developed to characterize vegetation canopy. Plant canopy reflectance factors and derived multispectral VIs are receiving increased attention in floristic research as robust surrogates for traditional biophysical parameters. Spectral reflectance and thermal emittance properties of soil and vegetations have been used extensively to predict ecological variables such as percent vegetation covers, plant biomass, green leaf area index and other biophysical characteristics. The basic objective of this study is to convey the potentiality of vegetation indices in the quantification of bio physical principles of forest environment and to review the remote sensing application in botanical research. Here very types of indices (GVI, PVI, and NDVI etc) are used for interpret forest and forest cover type with multi-criteria based approach.***

Keywords: Remote Sensing and GIS, sustainable management, Vegetation Indices, Forest Cover type and Multi-criteria based approach

1. Introduction

Resources that are abundant once may change to other forms or be degraded or even depleted. Natural resource such as wildlife and forests were abundant on the earth and there were no concern about wise use of such moments. As human populations continue growing rapidly, resources are becoming scares. Obviously, these resources are changed or exhausted unless wisely used. In order to mitigate the scarcity or complete loss, mankind has started to become concerned about conserving natural resources, of which one is forest resource (IFMP, 2000).

Forest is one of the most essential kinds of resources that human beings and other animals depend on. It regulates environmental and ecological changes in which soil, water climate and rainfall are in good existence in sustainable condition. Apart from its intrinsic value for many indigenous and other forest-dependent people, forests are their livelihood. Forests provide them with edible and medicinal plants, bush meat, fruits, honey, shelter, firewood and many other goods, as well as with cultural and spiritual values. Whether it is private or public property, forest is the nationally and globally mutual treasure. The value of forest resources to the world's human population is becoming increasingly evident.

Despite this, forest have been subjected to over exploitation due to human population has been growing and also clearing for agricultural activities (William, 1990).

The presence of forest in Jhargram sub-divitional area is relevant at several levels. Socially and economically speaking, forests are a traditional resource for local communities as a source for fuel wood and construction wood. In addition it is used for commercialization of non-timber product in some local market. Moreover, they represent pasture for domestic grazers. Ecologically, forests are 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, alternations in vegetation phonological cycles and modifications in plant physiology and morphology provide valuable insight into climatic edaphic, geologic and physiographic characteristic of an area (Jones et.al.1998). Scientist have 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 (Frhon, 1998; Huete and Justice, 1999).

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 other areas including West Midnapur Division since mid-eighties 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. On and from 1st April, 2006 the West Midnapur Division has been recorganized and rename as Jhargram Forest Division.

2. The Study Area

Presently the forest of Jhargram Division is situated in the civil sub-division of Paschim Medinipur District West Bengal. The sub-division cover the Civil Blocks viz. Binpur-I (the portion on the West of the Kangsabati river), Binpur-ii, Jhargram, Jamboni, Gopiballavpur-I &II. The Jhargram Forest Division lies between 21^{0}52' and 22^{0}48' North latitude sand 86^{0}34' and 87^{0}20'East longitude approximately.

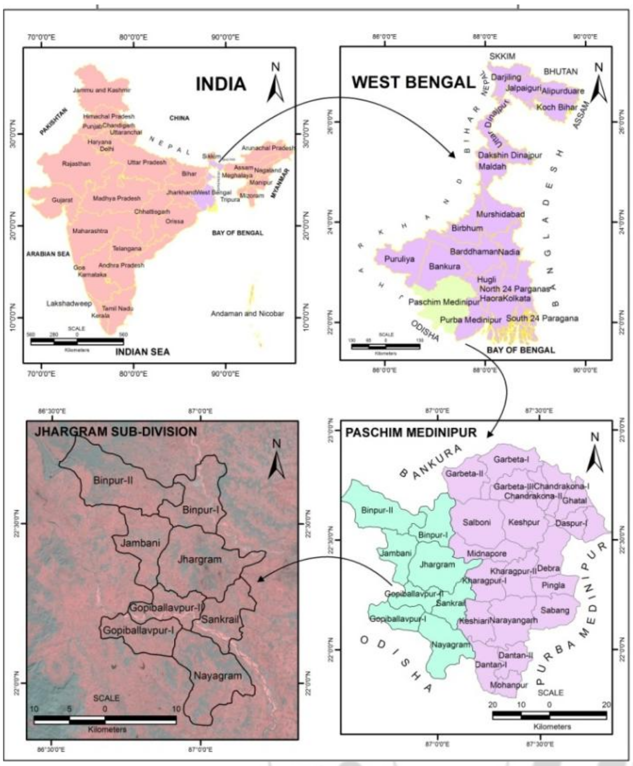


Figure 1: Location of the study area

3. Objectives of the Study

The basic objectives of the present study area are-

- To show the potentiality of remote sensing in vegetation study.
- Implementation of spectral indices and MCA instead of traditional method in vegetation study.
- To show the importance of digital remote sensing techniques as an advanced mapping system.

4. Physical Aspects of the Study Area

- **Geology:** Geologically, the area constitutes beyond the Genetic plains of West Bengal, India, with dominance of metamorphic rocks, Gneisses, Schist and recent to sub recent alluvium.
- **Physiography:** Physiography the study area located of undulating topography culminating in hill ranges of Belpahari, Kankrajhor in the North to the Subarnarekha River in South, with elevation ranging from MSL 81m.
- **Soil:** The parent rock is a mixture of metamorphic rock of sedimentary origin and igneous rock both basic and acidic. Laterite, the characteristic formation of the occupies a large tract. The thickness of the laterite varies from place to place but is not known to exceed 15m in this area. The sandy loam and loamy soil of reddish brown colour covers the upper layers of all most the whole area.
- **Altitude:** The general ground configuration is having gentle slope towards east. Hilly terrain occurs in the north-western portion of the Division. Kankrajhore area is having the highest altitude of around 300 m and Gopiballavpur is having the lowest altitude of around 65 m. The altitude of Jhargram town is around 80m. There are local variations in the slopes of the land within the division
- **Climate:** Climatically, the study area is subtropical and sub-humid, with hot wet summers and cool dry winters. It has an annual average precipitation of 1400 mm, the rainy season spreads over June to September due to south-west monsoon and highest rainfall occurs in July and August. The rainfall starts decreasing from October and dry winter sets in. The dry season lasts till May. However during this time this division gets some sporadic showers.
- **Drainage:** Theimporntriver of this division are the Kangsabati (popularly known as Kasai), the Tarafeni, the Subarnarekha and the Dulung. Apart from the above rivers there are several rivulateviz, ‘Deb’, ‘Papala’, ‘Rangium’, and ‘Kupon’ etc. Most of the above rivers flow from west to east as the western side of the division is having higher altitude.
- **Vegetation:** The forest under Jhargram sub-division falls under Northern tropical dry deciduous forest. The natural forests are mostly of mixed nature. Mostly coppice Sal forest mixed with miscellaneous species like Palash, Kusum, Mahua, Neem, and Kendu are the major source for timber, pole, small wood, fire wood, and medicinal plant to local people.

5. Methodology and Data Collection

The digital image processing has been done using computer based of DIP software package on windows 8 environment. In this investigation different kinds of environmental aspects have been modeled using linear band combination and sequential band orthogonalisation. These models involve bio-spectral phenomena modeling & analysis utilizing data derived from different indices like Green Index (GI), Perpendicular Vegetation Index (PVI), Bareness Index (BI), Shadow Index (SI) & NDVI.

Landsat TM satellite data collected to the selected study area was produce from USGS, united state. The specification of the satellite and its products are described in table-1.

Table 1: Specification of the satellites & its products

Sensor	TM
Spatial Resolution	30, (Thermal 120)
Radiometric Resolution	8 bit
Temporal Resolution	16 Days
Swath	185
Spectral band	(Band 1)0.45-0.52
	(Band 2) 0.52-0.60
	(Band 3) 0.63-0.69
	(Band 4)NIR: 0.76-0.90
	(Band 5)NIR: 1.55-1.75
	Band 6)Thermal: 10.40-12.50

5.1 Material Used

Table 2: Materials used for study

Data Used	LANDSAT TM 11.08.2011(P/R 138/45)& (P/R 139/44)
Data Source	USGS / www. earth explower.usgs.gov.in www.glcf.org
Software Used	ERDAS Imagine of Leica Geosystem ARC GIS

Utility of Spectral Indices in Vegetation Study

Vegetation monitoring is usually accomplished by simple regression approach, modeling approach using remote sensing data and by computing vegetation indices (VIs). A vegetation index should (Running et al., 1994; Huete and Justice, 1999):

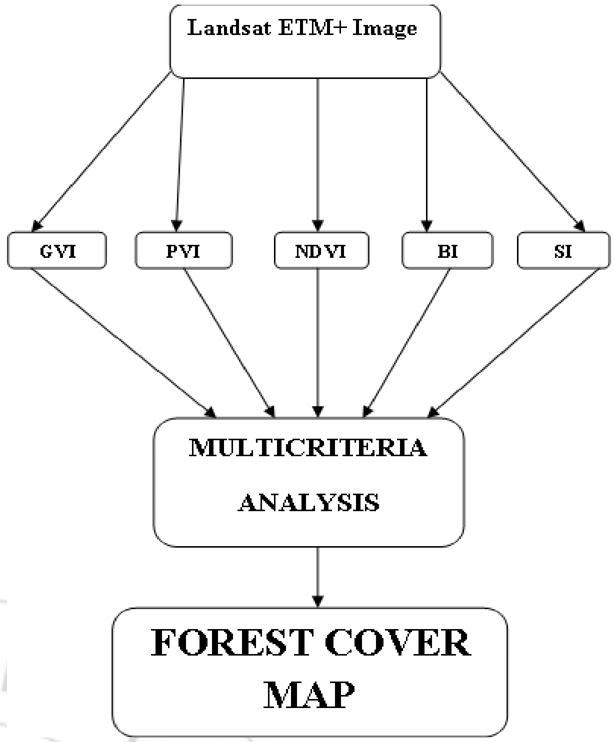
Table 3: Spectral Indices with formula

Name	Index	Formula
Normalized difference vegetation index	NDVI (Rouse et al.1973)	(NIR-R)/(NIR+R)
Perpendicular vegetation index	PVI(Richardson and Wiegand, 1977)	$(NIR-aRED-b)/(\sqrt{1+a^2})$
Bareness Index	BI (Huete 1988)	(band 4+band2) - band 3 / (band 4+band2) + band 3
Modified Soil Adjusted Vegetation Index	MSAVI (Qi et al. 1994)	ρNIR -ρred / (ρNIR+ρred+L) (1+L)
Perpendicular Vegetation Index	PVI (Crippen, 1990)	1/√a2+1 (ρNIR- aρred -b)

Maximize sensitivity to plant biophysical parameters, preferably with a linear response in order that sensitivity be available for a wide range of vegetation conditions and to facilitate validation and calibration of the index;

Normalize or model external effects such as sun angle, viewing angle and the atmosphere for consistent spatial and temporal comparisons. Normalize internal effects such as canopy background variations, including topography (slope and aspect), soil variations and differences in senesced or woody vegetation (non photosynthetic canopy components). Be coupled to some specific measurable biophysical parameter such as biomass, LAI or APAR as part of the validation effort and quality control. Several vegetation indices have been developed by linear combination or ratios of red, green and near infrared spectral bands. Vegetation indices are more sensitive than individual bands to vegetation parameters.

5.2 Flow Diagram



5.3 Green Vegetation Index

Using LandsatTM imagery it is represent the Greenness of the study area. According to the Tasseled Cap Transformation Technique Greenness conveys information concerning abundance and vigor of living vegetations. In figure it is seen that the greenness value of lower ranges represent the low vagueness, where the value represent (0 – 69), moderate range represent the moderate vagueness (77 – 84), and higher range represent the high vagueness (93 – 13).

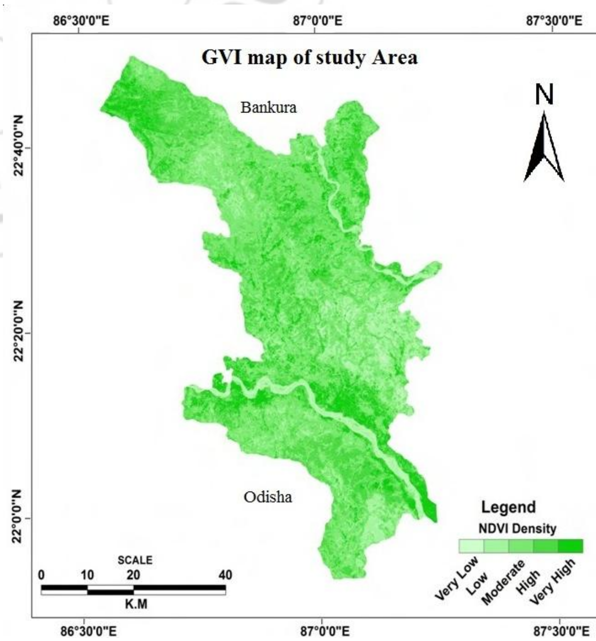


Figure 2: GVI Map of the Study Area

5.4 Perpendicular Vegetation Index

It is distance based vegetation indices are designed to eliminate the effect to the background soil wetness and only to detect the feature of vegetation covers. It is basically a soil line related index. In this index the soil line concept is a linear regression of NIR against Red band for pixel of bare soil.

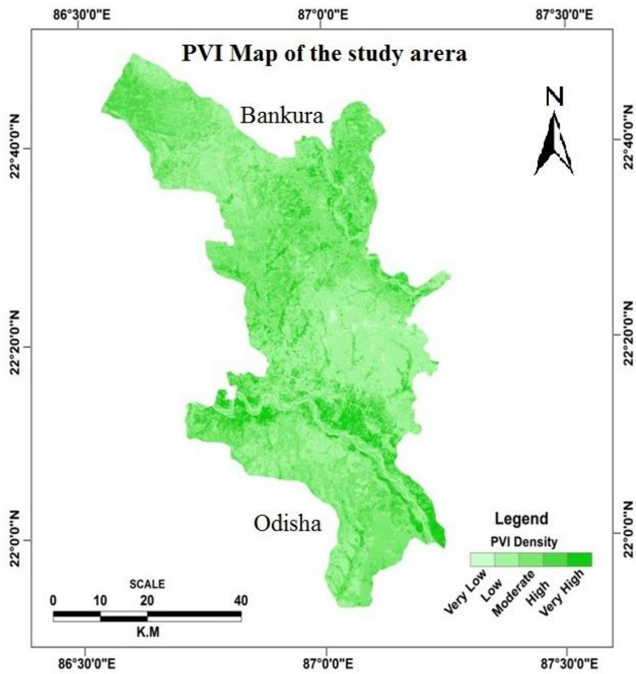


Figure 3: PVI Map of the Study Area

Richardson and Wiegand (1977) use the perpendicular distance to the soil line as an indicator of plant development. In fig. this seen that the PVI values range between -13 to 83. This whole range is classified here as presence of wet soil and low, partial and full vegetal canopy cover.

5.5 Normalized Difference Vegetation Index

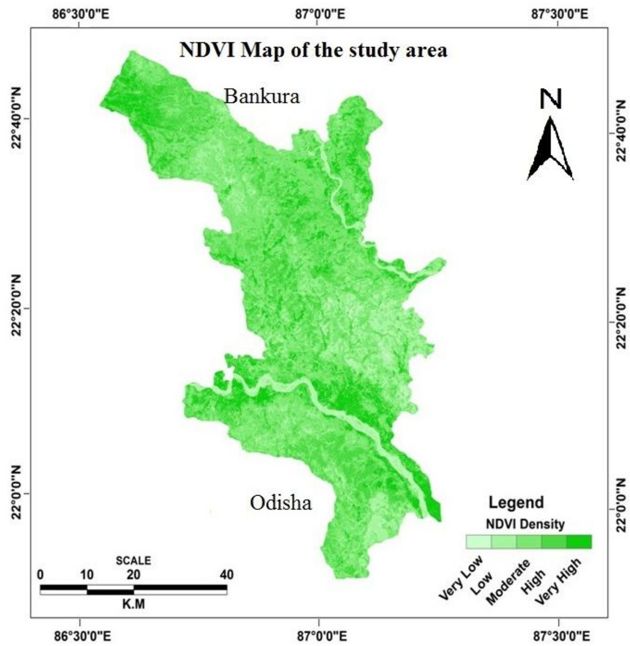


Figure 4: NDVI Map of the Study Area

The Normalized Difference Vegetative Index (NDVI,) is a calculation, based on several spectral bands, of the photosynthetic output (amount of green stuff) in a pixel in a satellite image. It measures, in effect, the amount of green vegetation in an area. In this exercise, you will use MultiSpecÕs ability to create new ÒchannelsÓ in an image to display the NDVI for an image.NDVI calculations are based on the principle that actively growing green vegetation strongly absorb radiation in the visible region of the spectrum while strongly reflecting radiation in the Near Infrared region.

5.6 Bareness Index

The bare soil areas, fallow lands, vegetation with marked background response are enhanced using this index. Similar to the concept of AVI, the bare soil index (BI) is a normalized index of the difference sums of two separating the vegetation with different background viz. completely bare, sparse canopy and dense canopy etc.

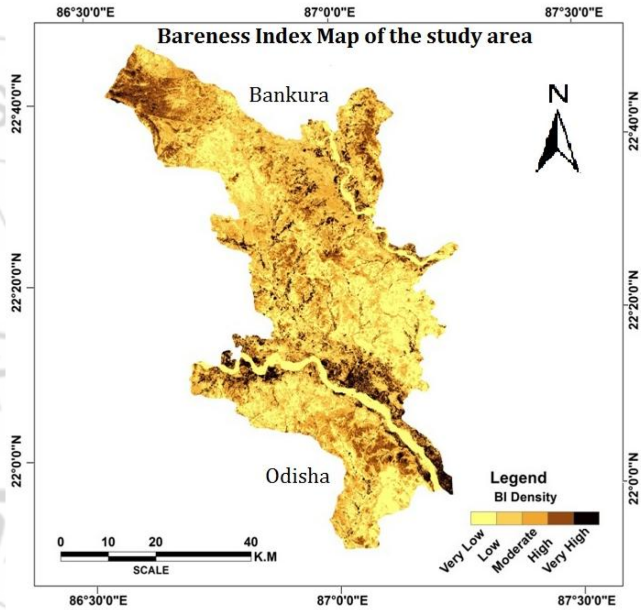


Figure 5: BI Map of the Study Area

5.7 Shadow Index

The crown arrangement in the forest stand leads to shadow pattern affecting the spectral responses. The young even aged stands have low canopy shadow index (SI) compared to the mature natural forest stands. The later forest stands show flat and low spectral axis in comparison with open area.

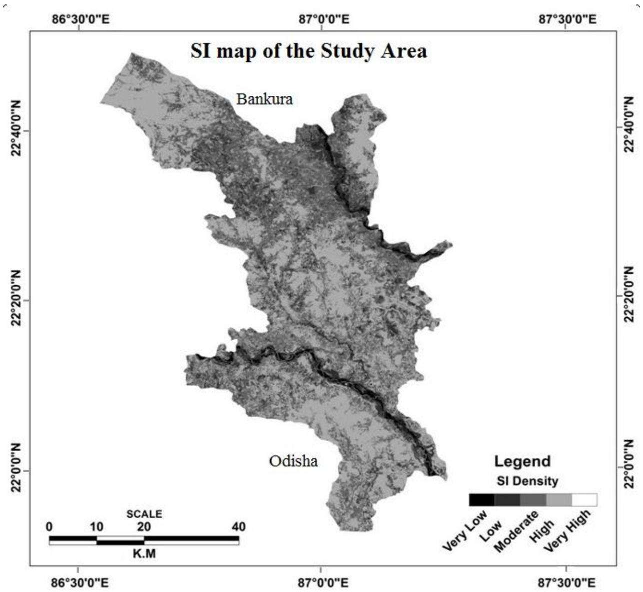


Figure 6: SI Map of the Study Area

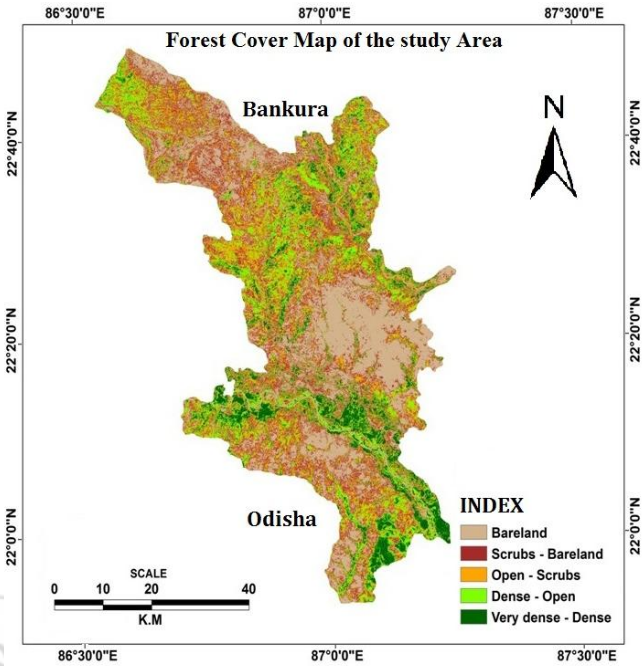


Figure 7: Forest Cover Map of the Study Area

5.8 Multi-criteria Analysis and forest cover map

Table 4: Multi-criteria Analysis (GVI, PVI & SI)

GVI		PVI		SI	
Grade	Score	Grade	Score	Grade	Score
Very low	1	Very low	1	Very low	1
Low	2	Low	1	Low	1
Moderate	5	Moderate	4	Moderate	3
High	9	High	9	High	9
Very high	10	Very high	5	Very high	10

Table 5: Multi-criteria Analysis (BI & NDVI)

BI		NDVI	
Grade	Score	Grade	Score
Very low	10	Very low	1
Low	9	Low	1
Moderate	3	Moderate	5
High	1	High	9

Table 6: Multi-criteria Theme Weight Analysis

Categories	*Theme weight*
GVI	0.30
PVI	0.25
SI	0.10
BI	0.15
NDVI	0.20

Forest cover map is the map by which we find the forest density and forest cover type. In above forest cover map we find five categories-

(a) Bare land,
(b) Scrubs – Bare land
(c) Open – Scrubs
(d) Dense – Open
(e) Very dense – Dense.

After studying all the above VI's, multi criteria based weightage analysis has been done to map the forest cover of the study area. All the indexed rasters like GVI, PVI, SI, BI, and NDVI were assigned respective theme weights and class weights.

The individual theme weights are multiplied by its respective class weights and then all the raster thematic layers are aggregated in a linear combination equation in Erdas Imagine environment. The equation is set up as: Forest Cover Type= (GVI*0.3+PVI*0.25+SI*0.1+BI*0.15+N

The final cumulative map was further reclassified into five categories of forest cover types viz; 'very dense to dense', 'dense to open', 'open to scrubs', 'scrubs to bare land' and 'bare land'.

Class	Sl. No.	Lat.	Long.	GVI	PVI	NDVI	SI	BI
Very Low	VL1	86º 39'	22º 47'	78	13.52	0.06	213.471	0.317
	VL2	86º40'	22º 46'	77	15.579	0.055	225.991	0.313
	VL3	86º40'	22º 38'	78	19.478	0.124	227.499	0.351
	VL4	87º 0;	22º21'	51	-2.164	-0.052	219.997	0.3
	VL5	87º2' 17"	21º52' 46"	75	18.821	0.063	222.499	0.305
Average				71.8	13.0468	0.05	221.8914	0.3172
Low	L1	86º 36' 25"	22º48' 12"	84	19.872	0.024	214.979	0.295
	L2	86º42' 37"	22º43' 20"	79	18.47	0.067	220.997	0.323
	L3	87º3' 4"	22º 26' 6"	78	22.019	0.166	224.997	0.388
	L4	87º1' 37"	22º 6' 49"	76	21.712	0.16	228.486	0.385
	L5	87º 3' 57"	21º52' 44"	75	22.851	0.177	229.486	0.4
Average				78.4	20.9848	0.1188	223.789	0.3582
Moderate	M1	86º37' 25"	22º45' 48"	82	24.691	0.144	220.494	0.376
	M2	86º52' 26"	22º35' 24"	82	23.596	0.138	228.495	0.364
	M3	87º8' 36"	22º19' 32"	86	16.893	0.005	226.997	0.282
	M4	87º3' 53"	22º 2' 34"	79	27.627	0.215	229.486	0.426
	M5	87º3' 13"	21º52' 42"	83	20.661	0.043	224.494	0.303
Average				82.4	22.6936	0.109	225.9932	0.3502
High	H1	86º 34' 56"	22º45' 25"	82	28.985	0.242	231.495	0.435
	H2	86º58' 20"	22º34' 53"	91	26.488	0.089	222.499	0.336
	H3	86º51' 53"	22º22' 00"	84	27.977	0.156	223	0.373
	H4	87º10' 24"	22º12' 24"	92	20.047	0.005	222.997	0.287
	H5	87º 1' 33"	22º3' 16"	92	21.274	0.039	225	0.303
Average				88.2	24.9542	0.1062	224.9982	0.3468
Very High	VH1	86º35' 54"	22º45' 26"	88	38.404	0.323	231.991	0.494
	VH2	87º 1' 57"	22º 36' 1"	95	47.648	0.391	215.979	0.538
	VH3	86º49' 57"	22º12' 48"	102	61.755	0.386	216.997	0.53
	VH4	87º5' 23"	22º 9' 9"	112	62.938	0.45	215.485	0.57
	VH5	87º6' 30"	21º56' 13"	102	28.722	0.05	221.499	0.301
Average				99.8	47.8934	0.32	220.3902	0.4866

In above forest categories are categorized on the basic of five types of class value, and the given table is shows the value of various indices with five sub-categorized which are used for forest cover mapping. The values are collect from different five fixed point on different indices.

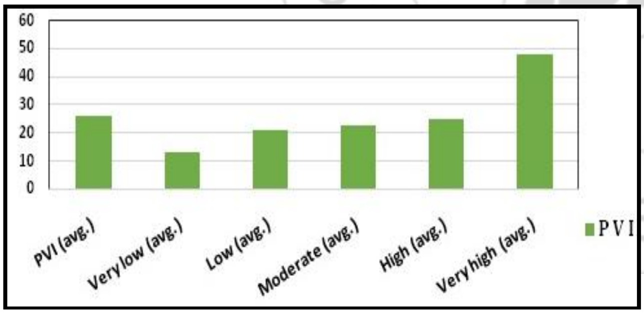


Figure 8: Perpendicular Vegetation Index (PVI)

Five different indices are used for mapping forest cover, where forest density is very high there should be high value represent in GVI, PVI, and NDVI, and where GVI, PVI, and NDVI value are low there are low density of forest cover. The bar diagram are shows the vegetation indices value variation.

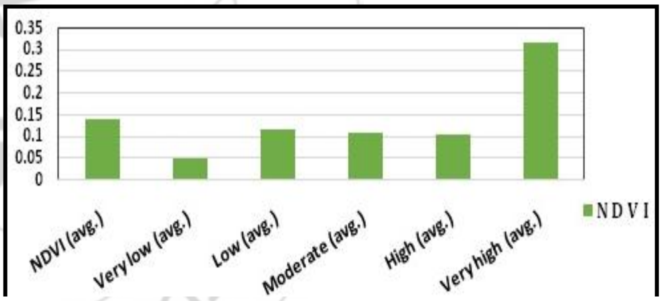


Figure 9: Normalized Difference Vegetation Index

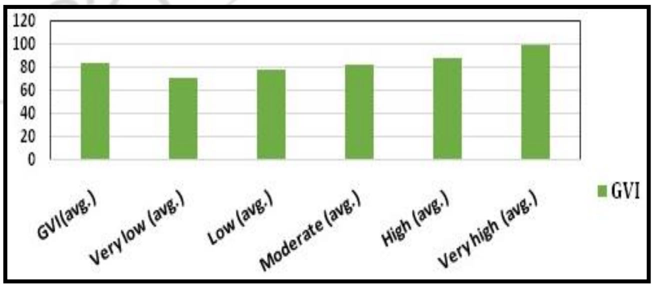


Figure 10: Greenness Vegetation Index (GVI)

In this diagram represent that in the high forest density areas are represent high bareness value of soil. The bare soil areas, fallow lands, vegetation with marked background response are enhanced using this index. Similar to the concept of AVI, the bare soil index (BI) is a normalized index of the difference sums of two separating the vegetation with different background viz. completely bare, sparse canopy and dense canopy etc.

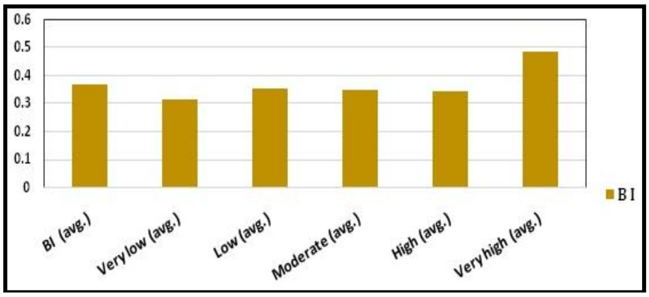


Figure 11: Bareness Index (BI)

The young even aged stands have low canopy shadow index (SI) compared to the mature natural forest stands. The later forest stands show flat and low spectral axis in comparison with open area. Where forest density is high there the shadow value is low because there young aged tree very high. In the bar diagram represent the variation of shadow value with compressing with NDVI, PVI, GVI, and BI.

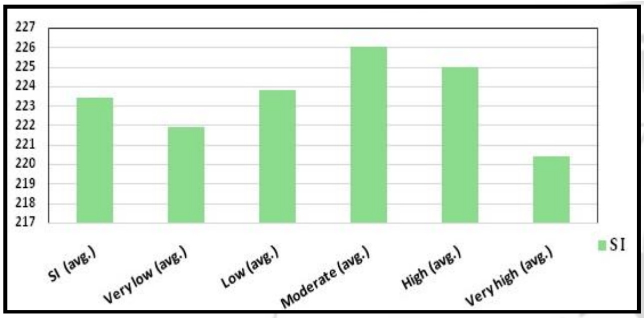


Figure 12: Shadow Index (SI)

Recommendation

It may be broadly concluded that during the conflict period access to NTFPs (Non-Timber Forest Products) was better for the destitute groups (because they could harvest their usual NTFPs from the forest periphery) as compared to the very poor and the poor groups (which had inhibitions in accessing dense forest areas) while the non-poor groups (who did not venture out to the forest being primary targets of violence) saw a sharp fall in their NTFP earnings. Based on the above analysis it may be concluded that by and large local forests raised by community-based protection constitute important providers of livelihoods for the poor groups during critical times. Though forests are important providers there are other crucial factors such as price rise of forest and non-forest products, timely rainfall, produce from one's own land, opportunities for agriculture laour, outmigration and access to funds, which are also important drivers of local livelihoods. However, it may not be unreasonable to mention that in case of armed conflicts over extended period, much uncertainty can creep into the system and it may become difficult to ensure the length of such support from local forests with little or no communication between local communities and forest department and uncertainty in consciously protecting forests by local Forest Protection Committees. This could lead to major breakdown in rules and procedures, where key arrangements and contracts with forest authority tend to lose their validity and can no longer be respected or automatically enforced. However, that is not the subject of discussion in this paper though that constitutes a critical issue over the medium and the long term and more evidence –based research is suggested.

6. Conclusion

It is crucial to have baseline data and evolve indicators on different socio-economic and political aspects of any participatory forest management process though the Forest Department is more focused on the bio-physical changes.

Last but not the least people's views and grievances need more space and more opportunities to include them in decision-making. Forestry needs a new framework. It is not only to be seen as a biological resource for its own sake but also in the context of the sociological world that it is related to. In today's world forests are crucial but also equally crucial are the lives, livelihoods and aspirations of those who dwell in and around the forests. The fault lines of JFM are now clearly visible especially in the current years when confronted with the armed conflict and its future has become almost unpredictable. There is a long way to go in participatory, inclusive and sustainable forestry and much though is required as to how to protect and manage forest in partnership with local communities. There is no short-cut to this exercise for saving forests and forest-related communities.

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