Spatial Greening Pattern Estimation of Himachal Pradesh, India Using IRS-P6 AWiFS Seasonal Data

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Abstract: ***The complexity and inaccessibility of many regions of the mountain state of Himachal Pradesh create difficulties to manually measure land cover in terms of vegetation. In this sense, the normalized difference vegetation index (NDVI), soil adjusted vegetation index (SAVI) and transformed vegetation index (TVI) which are directly related to percentage ground cover, total green biomass, leaf area index and the photosynthetic activity, are based on the reflective properties of vegetation. The objective of this study was to use the remote sensing derived normalized difference vegetation index (NDVI), soil adjusted vegetation index (SAVI) and transformed vegetation index (TVI)) for the spatial estimation of the seasonal greening pattern of the State of Himachal Pradesh. Satellite imagery sets (IRS P6 AWiFS multi-spectral) were used to estimate NDVI, SAVI and TVI for the three months period. The seasonal phenological cycle in the study area of the State was clearly visible from the analysis of the imagery sets.***

Keywords: Remote sensing, Vegetation Indices, AWiFS, NIR, Red

1. Introduction

In recent years, one of the major application of remote sensing in forestry management and decision making is the detection and quantitative assessment of green vegetation. In this sense, vegetation analyses and detection of changes in vegetation patterns and structure are keys to natural resources assessment and monitoring. To address complex global change issues requires a variety of data. Issues such as inventory of carbon stocks, estimation of above ground biomass, change in land cover in terrestrial environments and the impact of human activities require quantitative information (Lunetta et al., 1993; Cairns et al., 1995). The development of vegetation indices from brightness values is based on the differential absorption, transmittance and reflectance of energy by the vegetation in the red and near-infrared portions of the electromagnetic spectrum (Derring and Haas, 1980; Lyon and McCarthy, 1995; Jensen, 1996). Healthy canopies of green vegetation have a very distinct interaction with certain portions of the electromagnetic spectrum.

In the visible regions, chlorophyll causes strong absorption of energy, primarily for use in photosynthesis. This absorption peaks in the red and blue areas of the visible spectrum, while the green area is reflected by chlorophyll, thus leading to the characteristic green appearance of most leaves. At the same time, the near-infrared region of the spectrum is strongly reflected through the internal structure of the leaves. It is this strong contrast, particularly between the reflected energy in the red and near-infrared regions of the electromagnetic spectrum that has been the focus of a large variety of attempts to develop quantitative indices of vegetation condition using remotely sensed imagery.

2. Literature Study

Vegetation indices, particularly NDVI is a good indicator of leaf area index (LAI), which in turn is positively correlated to biomass and productivity (De Fries et al., 1995; Kale et al., 2001; Roy & Ravan 1996). NDVI coupled with energy conversion efficiency has been extensively used for biomass estimation. The slope-based vegetation indices generally use the two spectral bands, mostly red and infrared. Based on the algorithm of NDVI, Huete (1988) therefore proposed soil–adjusted vegetation index (SAVI) to minimize soil background influence by incorporating a correction factor. Further evolutions of the SAVI as the modified soil-adjusted vegetation index (MSAVI) (QI et al., 1994), optimized soil adjusted vegetation index (OSAVI) (Rondeaux et al., 1996), transformed soil-adjusted vegetation index (TSAVI) (Baret et al., 1989), adjusted transformed soil-adjusted vegetation index (ATSAVI) (Baret and Guyot, 1991), Perpendicular vegetation index(PVI) (Richardson and Wiegand, 1997) and green adjusted vegetation index (GSAVI) (Tian et al., 2005) took place. Among these soil-adjusted vegetation indices, the TSAVI, ATSAVI, and PVI were developed to minimize soil background influence by incorporating the slope and intercept of the soil line, which was established by linear regression of soil reflectance in red-NIR spectral portions. Compared with the soil-adjusted SAVI, MSAVI, OSAVI and GSAVI, the algorithms of TSAVI, ATSAVI, and PVI containing the soil line parameters greatly limit their applications due to the difficulty of obtaining the real soil line (Baret et al., 1993; Fox et al., 2004; Liu et al., 2008).

The other vegetation indices that include mid and short wave infrared regions of the electromagnetic spectrum, on the basis that vegetation has lower reflectance than the soil in these regions, a contrasts that may assist their discrimination (Kime et al., 1981; Dusk et al., 1985; Baret et al., 1988; Thenkabail et al. 1994).

3. Problem of the Study

As per the state forest department report, the state has three distinct regions: Shiwaliks (altitudes up to 1,500 m), Middle Himalayan region (1,500–3,000 m altitude) and the Himadris

(>3,000 m altitude). Tree growth is constant and is governed by elevation and precipitation. Nearly one third of the geographical area is permanently under snow and glaciers while remaining under recorded forests covering an area of 37,033 km^2 (Forest Survey of India 2010). Reserved Forests constitute 5.13 %, Protected Forests 89.27 %, and Unclassed Forests 5.60 % of the total forest area of Himachal Pradesh. The state has 35 different forest types (Champion and Seth 1968) divided into eight groups, namely, Tropical Moist Deciduous, Tropical Dry Deciduous, Subtropical Pine, Himalayan Moist Temperate, Himalayan Dry Temperate, Sub Alpine Forests, Moist Alpine Scrub, and Dry Alpine Scrub.
Forest degradation has resulted in qualitative and quantitative loss of vegetation cover and reduced productivity (FAO, 2006). Continuous anthropogenic pressure for exploitation of forest products has resulted in degradation of forests. This problem is acute as it is critically reducing the ability of the forest land to sequester carbon due to reduced forest cover. Furthermore, significant degree of uncertainty exists in carbon estimates in areas with low biomass carbon which called for a more robust and accurate method to estimate vegetation indices for effective monitoring of carbon pool in such regions. Hence, reasonably accurate, cost effective and rapid vegetation indices estimation tools are needed to effectively monitor the changes in carbon stock due to degradation of forests.

4. Methodology and Approach

4.1 The Study area

Himachal Pradesh is a mountainous state in Northern India. It is bordered by Jammu and Kashmir on the north, Punjab on the west, Haryana on the south-west, Uttarakhand on the south-east and by the Tibet Autonomous Region on the east. It covers a total area of 55,673 km^2 with the geographic extent of 30°22′ to 33°31′ N latitude and 75°15′ to 79°19′ E longitude (Fig. 1).

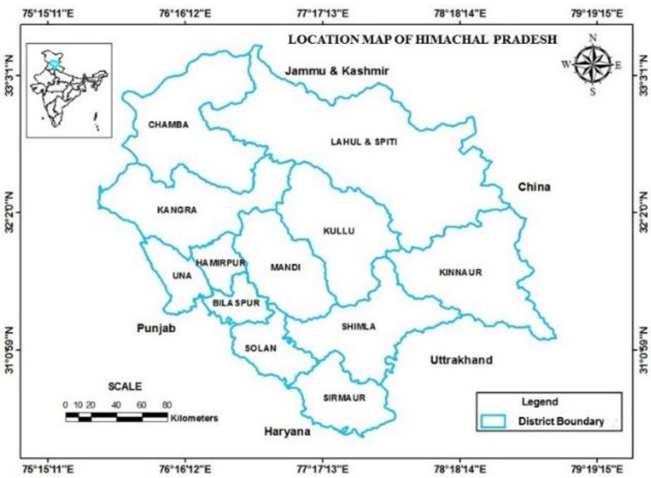

Figure 1: Map of the Study Area

The altitude varies from 146 m to 6,511 m above the mean sea level. The general physiographic divisions from south to north are, (i) the outer Himalayas (Shivaliks), (ii) the lesser Himalayas (central zone) and (iii) the Great Himalayas (northern zone).

4.2 Satellite data used

Twelve geographically selected satellite map sheets of year 2010 for HP were collected from Open data and product archive facilitates of NRSC/ISRO Bhuban store. The data sets were in date of pass on 25 march 2010, 16 August 2010 and 3 October 2010 (Table-1). The orthorectified AWiFS scenes were preprocessed for radiometric correction. The study involved the geo-spatial analysis of database generated from the satellite images.

Table 1: Major Specifications of AWiFS camera

Data Used	Map sheet	Data acquisition Month	Wavelength of Band (μm)	Spatial resolution (m)	Swath (km)
IRS-P6 AWiFS	I43V, I43W, I43Q, I43X, I43R, I44S, H43D, H43K, H43E, H43L, H43F and H44A	March August October	GREEN (0.52 - 0.59)	56	737
			RED (0.62 - 0.68)	56	
			NEAR IR(0.77 - 0.86)	56	
			MID WAVE IR(1.55 - 1.70)	56	

For getting satellite image in RGB combinations the layers of satellite data was stacked and it resulted as RGB color image. As IRS P-6 AWiFS has four bands with spatial resolution 56 meter each, the layer stacking operation was applied to all the satellite data covering the study area to get the RGB image.
After layer stacking, all satellite images of the study area were mosaicked to get a single satellite image. Then from the mosaicked image of all satellite images the study area was extracted by subset with AOI layer of the study area. The same process also applied for the all tiles of different seasonal data (March, August and October) by ERDAS IMAGINE 2014 software.

4.3 The Slope-Based Vegetation Indices

Slope-based VIs are combinations of the visible red and the near infrared bands and are widely used to generate vegetation indices. Their values indicate both the state and abundance of green vegetation cover and biomass. The slope-based VIs include the RATIO, NDVI, SAVI, RVI, NRVI, TVI, CTVI, TTVI, and EVI.

In this study three types of vegetation indices had been used for the study of vegetation patterns and those are NDVI, SAVI and TVI. The mathematical transformations for the experimental vegetation indices (VIs) are given below.

$$NDVI = \frac{NIR - R}{NIR + R}$$; *Rouse et al. (1974)*

$$SAVI = \frac{NIR - R}{NIR + R + L} \times (1 + L)$$; *Huete (1988)*

$$TVI = \sqrt{NDVI + 0.5}$$; *Deering et al. (1975)*

Where, NIR = near infrared, R = red and L = Soil adjustment factor

In the case of Himachal Pradesh a time series of NDVI, SAVI and TVI imagery had been analyzed. First of all the three vegetation indices were analyzed for the entire State. For each vegetation the statistical data was extracted and interpreted. Several changes were observed directly from the three seasons. Those included forest to snow cover.

5. Results and Discussion

5.1 Normalized Difference Vegetation Indices (NDVI)

Three different time-period NDVI images have been shown representative for seasonal changes (Figure 2). The NDVI images show the foliage cover in the respective time-period. The bounded values of NDVI range from –0.39 to 0.52 (March), –0.37 to 0.49 (August) and –0.43 to 0.52 (October).

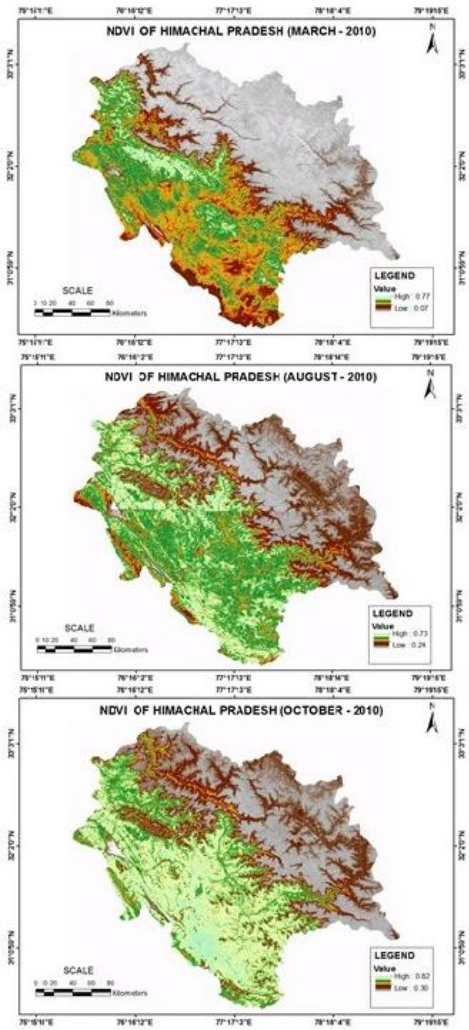

Figure 2: NDVI of March, August and October 2010

5.2 Soil Adjusted Vegetation Indices (SAVI)

The SAVI was performed on the same dataset. SAVI ranged between 0.07 to 0.79, 0.24 to 0.75, and 0.31 to 0.84 for March, August and October respectively. SAVI map of study area of different season is given in Figure 3.

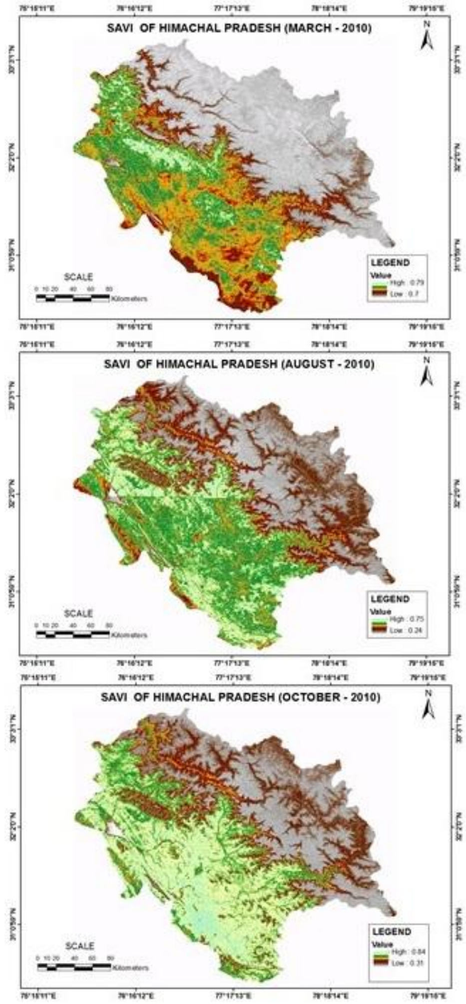

Figure 3: SAVI of March, August and October 2010

5.3 Transformed Vegetation Indices (TVI)

In the present study the TVI of the October month showed some data gap in some water body. The study showed that the value of range of TVI was in between 0.31 to 1.14, 0.56 to 1.10 and 0.60 to 1.13 for March, August and October respectively. TVI map of study area of different season is given in (Figure 4) respectively.

The quantitative criteria which was used in this study, is the statistical variance with respect to mean, median, mode and standard deviation of the image of each vegetation index.

The TVI vegetation index produces images with a strong contrast. The vegetation areas appear in very clear tones. On the other hand, the spatial variation of the tonality of the NDVI image is stronger than that of the TVI and the SAVI. The signal to noise ratio of the NDVI, SAVI and TVI images increased with the ratio near infrared reflectance to red reflectance.

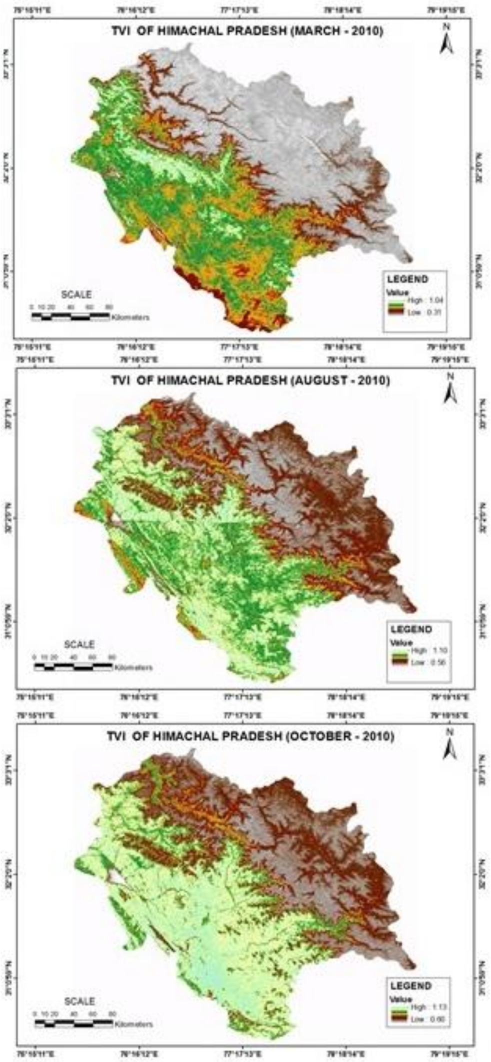

Figure 4: TVI of March, August and October 2010

5.4 Comparison among NDVI, SAVI and TVI

So far, previously a number of vegetation indices had been introduced for the study of the conditions of quality and quantity specifications of plant cover, but the selection of the best index for quantitative analysis of plant cover was one of the important problems for the users. The Operational method for this study could be suggested for integration of remote sensing data for the estimation of vegetation pattern. The features extracted from the satellite image was correlated by means of vegetation pattern with statistical analysis between mean, median, mode and standard deviation.

In the current study, there was no technical difference between NDVI and TVI. These two indices had drawbacks of light scattering due to presence of aerosols in the atmosphere, which directly affected the results obtained through vegetation indices. Light reflected from the soil also had significant effect on NDVI values. Another problem of TVI was the observed value of indices ranged from 0 to slightly more than 1.

The study also showed, SAVI was outperformed than the other two indices. It minimized the soil background effect (a major limiting factor in statistical analysis geared towards the quantitative assessment of above ground biomass in spectral vegetation indices) using red and near infrared band. But it couldn't solve the problem of atmospheric scattering due to the presence of aerosol (Table 2, 3 and 4).

Table 2: Comparison among Statistical Data of NDVI

MARCH_2010_NDVI					
Minimum	**Maximum**	**Mean**	**SD**	**Median**	**Mode**
0.07	0.77	0.267	0.2	-1	-1
AUGUST_2010_NDVI					
Minimum	**Maximum**	**Mean**	**SD**	**Median**	**Mode**
0.24	0.73	0.274	0.2	-1	-1
OCTOBER_2010_NDVI					
Minimum	**Maximum**	**Mean**	**SD**	**Median**	**Mode**
0.30	0.82	0.297	0.2	0.3201	0.002

Table 3: Comparison among Statistical Data of SAVI

MARCH_2010_SAVI					
Minimum	**Maximum**	**Mean**	**SD**	**Median**	**Mode**
0.7	0.79	0.284	0.2	-1	-1
AUGUST_2010_SAVI					
Minimum	**Maximum**	**Mean**	**SD**	**Median**	**Mode**
0.24	0.75	0.312	0.2	-1	-1
OCTOBER_2010_SAVI					
Minimum	**Maximum**	**Mean**	**SD**	**Median**	**Mode**
0.31	0.84	0.342	0.2	0.3201	0.002

Table 4: Comparison among Statistical Data of TVI

MARCH_2010_TVI					
Minimum	**Maximum**	**Mean**	**SD**	**Median**	**Mode**
0.31	1.04	0.267	0.2	-1	-1
AUGUST_2010_TVI					
Minimum	**Maximum**	**Mean**	**SD**	**Median**	**Mode**
0.56	1.10	0.267	0.2	-1	-1
OCTOBER_2010_TVI					
Minimum	**Maximum**	**Mean**	**SD**	**Median**	**Mode**
0.60	1.13	0.297	0.2	0.3201	0.002

The spatial distribution of NDVI, SAVI and TVI values had been dominated by the high values in October followed by august and march. The comparative analysis revealed the influence of seasonal variation on the vegetation. During March, the vegetation showed a constant growing trend. During senescence period from March to September, the rapid increase in NDVI, SAVI and TVI values was seen in the study area, due to improvement in vegetation health, which was observed on the basis of pixel values. The influence of monsoon is very much dominated in August and October. Again the cyclic reduction in NDVI values has been analysed and decline in foliage cover has been observed in March season. The maximum NDVI image has been computed to represent the maximum foliage cover in the time period of October.

6. Conclusion

The remarkable developments in remote sensing technology have made efficient management of environment and forestry and assessment for better characterization of vegetation at regional scales with frequent intervals. Remote sensing data help policy and decision makers to assess the current situation, judge long-term trends and help to manage forest resources sustainably. In this context, IRS P6 AWiFS has emerged as the most optimal means for monitoring and management of forest resources on a regional scale with a resolution of 56m. The repetitive coverage helps in selecting the required season period data for phenological states of vegetation, phytogeographical region, and land use practice. Each pixel provides a wide range of ground information and conditions, which may create complexity in interpretation. With automated classification, studies carried out using AWiFS data recommended for annual forest cover mapping, save time and money while providing equally efficient forest cover data

6.1 Scope for further studies

More research can be done in future towards the selection of better vegetation indices which can help the estimation biomass more precisely. Other vegetation indices such as Atmosphere Resistant Vegetation Indices (ARVI), Soil Atmosphere Resistant Vegetation indices (SARVI) can be also used for the study of biomass and carbon stock estimation.

6.2 Recommendations

The pre-calibration of satellite image influences in extracting spectral indices for the study. The degradation of sensor calibration also effect the spectral indices. Thus an improve method of sensor calibration of satellite images can be found which will enhance the spectral indices better. And also the use of high resolution satellite images may result better vegetation indices which ultimately will help in vegetation monitoring and estimating biomass and carbon stock in the desired study area with more precision.

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Mr. Ajit Kumar Swain received his B.Sc. in Physical Sciences from Ravenshaw University, Cuttack, Odisha in 2011 and Post Graduate Diploma in Remote Sensing and GIS from Utkal University, Odisha in 2012. During 2012-13, he started working in CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, India as a Research Assistant in the field of Remote Sensing with application to Mining and Mineral field area. He is now pursuing his M.Tech. in Geo Spatial Technology from Sambalpur University, Jyoti Vihar, Burla (Odisha), India and working as a research trainee in Indian Institute of Remote Sensing, Indian Space Research Organization, Dehradun, UK, India.

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