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Estimation of Annual Spatial Greening Pattern of Himachal Pradesh, India using Remote Sensing Data

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ABSTRACT

Owing to the complexity and inaccessibility of many regions of the mountain state of Himachal Pradesh, it is difficult to manually measure land cover in terms of vegetation. The normalized difference vegetation index (NDVI) which is directly related to percentage ground cover, total green biomass, leaf area index and the photosynthetic activity, is based on the reflective properties of vegetation. The objective of this study was to use the remote sensing derived index (NDVI) for the spatial estimation of the annual greening pattern of the State of Himachal Pradesh. Satellite imagery sets (IRS 1D LISS 3 multi-spectral) were used to estimate NDVI for the twelve months period. The annual phenological cycle in the study area of the State was clearly visible from the analysis of the imagery sets. An increasing NDVI gradient from North Eastern to South Western districts of the State was observed. Large differences between NDVI values were observed from northern (Lahaul-Spiti) to southern (Una, Hamirpur) districts of the state. Very low NDVI (negative) values in the northern parts of the state indicated low vegetative cover (the area being rocky and remaining covered with snow for most part of the year). The North-Western part of the State (Kangra district) had NDVI values ranging from 0.3 in January to as high as 0.75 in the month of September. The North-Western part of the State also clearly indicated the presence and availability of two growing seasons (*Rabi* and *kharif*), because of NDVI peaks observed during the months of both March and September. These results have great significance in estimating and ear marking food insecure regions and deficit periods besides, being useful in framing agricultural policy for a mountainous State like the Himachal Pradesh.

Key words: Remote sensing, NDVI, greening pattern

Introduction

Satellite imagery is known to provide valuable information about the Earth's surface. The normalized difference vegetation index (NDVI) (Tucker, 1979) is a well known satellite derived parameter which is directly related to the percentage ground cover, the herbaceous or total green biomass, the leaf area index, and the photosynthetic activity of the vegetation. The NDVI is based on the characters for reflective properties of vegetation on ground. Through NDVI, distinct colors (wavelengths) of visible and near-infrared sunlight reflected by the plants are observed to determine the density of greenery (http://earthobservatory.nasa.gov/ Library/ MeasuringVegetation/).

Vegetation is known to have a low reflectance in the red part (0.6-0.7 ìm) of the electro-magnetic spectrum and very high reflectance in the near infra red (0.7-1.1 ìm) part. Bare soils however reflect moderately in both the red and the near infra red part of the spectrum. Therefore, the higher the difference between the near infrared and the red reflectance, the more is the vegetation there on the ground.

The NDVI subtracts the red reflectance values from the NIR, and then divides it through the sum of both values -

$$NDVI = (NIR - RED) / (NIR + RED)$$

The sum of the near infrared and the red indicates the total brightness ("intensity") of the image. By dividing through this sum it is avoided that differences due to overall brightness of sunlight or of surfaces (e.g. shadows) strongly influence the image. This procedure is called “normalization”.

Theoretically, the values can range from –1 to + 1. Actually measured NDVI values however range from negative values (water) through zero (bare soil) to +0.6 (dense green vegetation). Due to spectral variation of soils at low vegetation cover, vegetation of different areas/soils can be systematically compared for NDVI values higher than 0.05-0.06. A range of satellite derived vegetation indices have been widely used to classify land cover, estimate crop acreage, and detect plant stress (http://www.bom.gov.au/sat/NDVI/NDVI2.shtml)

Materials and Methods

In the case of Himachal Pradesh a time series of NDVI imagery has been analyzed. First of all the average annual greening pattern was analyzed for the entire State. For each district an average NDVI patterns per land use class was extracted and interpreted, and finally the use of NDVI time series for food security early warning was assessed.

The NDVI dataset (189 images) that have been used cover the period from April 1998 until June 2003 and is derived from the SPOT-4 and SPOT-5 vegetation (VEGETATION) instruments and comprise 10-day composites. From April 1998 until January 2003 the VGT1 sensor aboard the SPOT4 satellite has been used and from February 2003 the VGT2 sensor aboard the SPOT5 satellite has been used. Both sensors have the same spectral and spatial resolution. The red spectral band (0.61 - 0.68 ìm) and the near infrared spectral band (0.78 - 0.89 ìm) have been used here to calculate the NDVI and the imagery has a spatial resolution of 1 km. The synthesized pre-processed S10 NDVI product is used, which is a geometrically and radiometrically corrected for 10 day composite image. The periods are defined according to the legal calendar; from 1st to 10th, from 11th to 20th, from 21st to the end of each month.

The processing encompasses the extraction of the region of interest, format conversion, calculation of NDVI values from digital numbers, and the application of a simple cloud correction algorithm. The region of interest was extracted using the CROP-VGT software, and the format was converted in ArcView GIS. The NDVI was calculated from 8-bit digital numbers (DN) to NDVI values between 0 and 1 according to the following specified equation;

$$NDVI = -0.1 + 0.004 X DN$$

Clouded pixels in the image that needed correction were linearly interpolated using the preceding and subsequent images. The algorithm was only applied when both preceding and subsequent image pixels were cloud free. Dekadal averages, based on either 5 or 6 years, were calculated in ArcView, which resulted in one annual average NDVI pattern captured in 36 images. Based on the 36 images 12 monthly averages were calculated to study the annual greening pattern.

Using a land use map and 36 dekadal averages NDVI time series were extracted for two example districts and for one district the NDVI series were extracted for the main land uses in the district. The results were compared and interpreted.

Results and Discussion

Figure 1 shows the annual greening pattern of entire state of Himachal Pradesh. The 12 monthly images give a clear overview of the annual phenological cycle in the state. There is an increasing NDVI gradient from North Eastern to the South Western districts, and the peak of the NDVI falls within the month of September. There is a large difference between NDVI patterns across the State. The mountainous part in the North (Lahaul-Spiti district) has very low NDVI values throughout the year and has a permanent snow cover for prolonged periods resulting in negative NDVI values. The South Western part of the State (Kangra district) has NDVI values varying from 0.3 in January to as high as 0.75 in September. The South Western

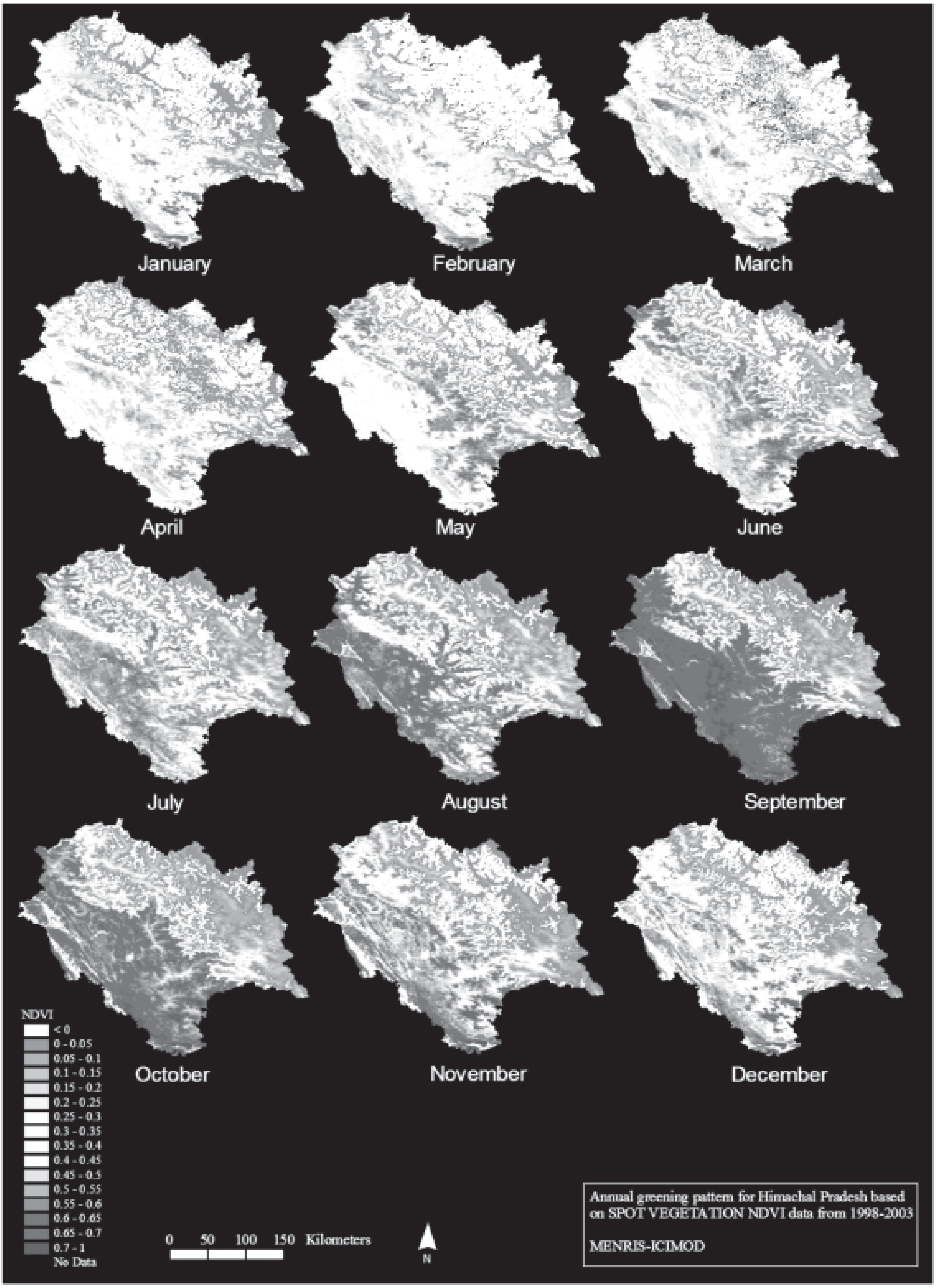

Fig. 1. Annual greening pattern Himachal Pradesh

area also clearly shows two growing seasons; as there is a NDVI peak in March and another more distinct peak in September. Annual NDVI patterns can also be used to establish the length of the growing season, which is an important input in many agro-meteorological models (Groten and Ocatre, 2002).

Indirectly the vegetation index as an indicator of green vegetation has been used to estimate the cumulative effective rainfall over a certain period, rangeland carrying capacity, the crop yields for different crop types and the quality of the environment as habitat for various animals, pests and diseases. Often it is not directly the value of a single image which is used as an indicator, but a value ("NDVI parameter") representing selected characteristics of a time series.

Figure 2 shows the annual average NDVI pattern for Kinnaur district in the eastern part of the state. As part of the state is mountainous, and part of it is cultivated and forested the standard deviation is quite high. The maximum NDVI is around September and is just over 0.2, which is quite low. The growing season starts half February and ends around September when the NDVI increments turn negative again.

Figure 3 shows the annual average NDVI pattern for Mandi district which is geographically located in the middle of the state and has a relative large area of under cropping, without snow-capped mountains. This results in relative high values throughout the year ranging from 0.4 in January to nearly 0.7 in September. NDVI values start increasing from February onwards indicating a longer growing season than for example in the Kinnaur district. There is also a considerable area with a double cropping land use pattern, however this is not clearly resolved and visible in Figure 4, because it is based on an average for all land uses in the district.

Figure 4 shows the reflective properties of different land covers. Healthy green vegetation has a spectral reflectance that is quite different from e.g. dry soil, clear water or snow. We observe that green vegetation has a low reflectance in the visible portion of the spectrum. This occurs because chlorophyll strongly absorbs energy in the wavelengths centred about 0.45 and 0.67 µm. We also notice that the reflectance from healthy green vegetation increases dramatically as we reach the near infrared portion of the spectrum. The reflectance on the near-infrared plateau varies with vegetation type, water content,

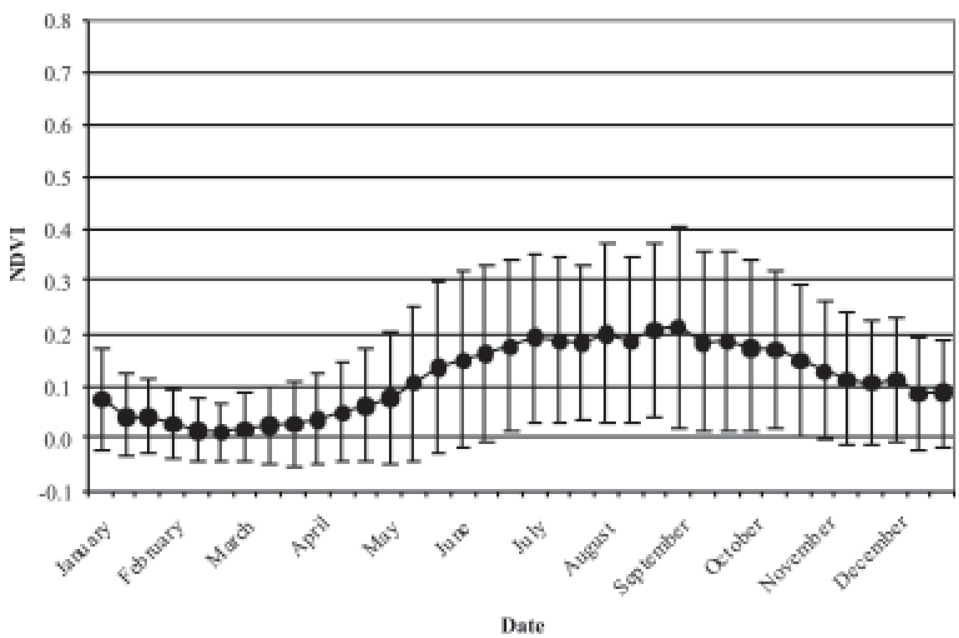

Fig. 2. Annual average NDVI pattern for Kinnaur district

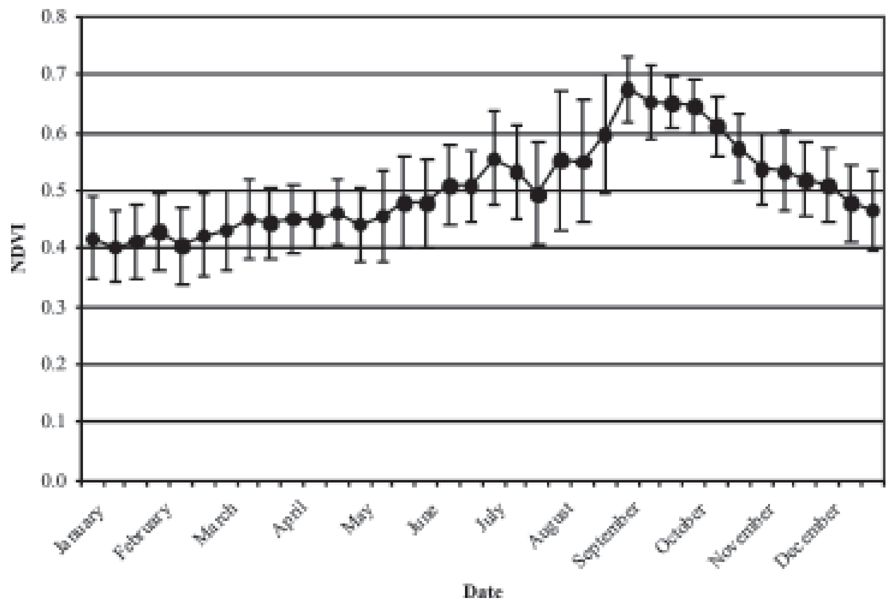

Fig. 3. Annual average NDVI pattern for Mandi district

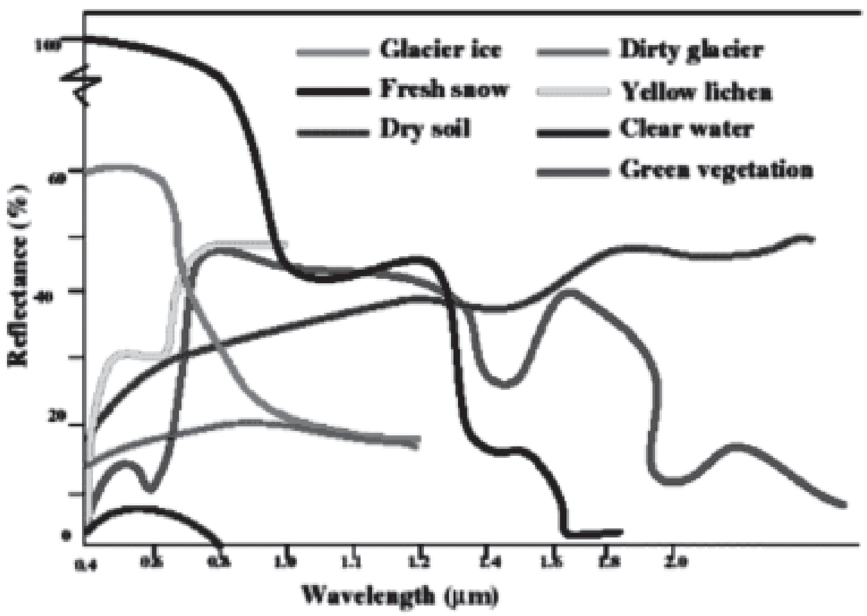

Fig. 4. Spectral properties of different land covers

and canopy architecture. In contrast, bare soil has approximately the same reflectance in both the visible and near-infrared portion of the spectrum. The reflectance characteristics in the visible and the near infrared bands have been used to monitor vegetation with multispectral remote sensing images.

Figure 5 shows the average NDVI curves per land use for Kangra district. Kangra is located in the South West part of the country and also has relative high NDVI values throughout the year. On average the NDVI values are ranging from 0.3 in January to about 0.6 in September. The double cropping land use curve clearly shows two peaks; one in March and other in September, which correspond to the annual two harvests. The evergreen forest curve shows one in October, and a smaller range between minimum and maximum NDVI which can be explained by lesser dependence on rainfall and a greater resilience of

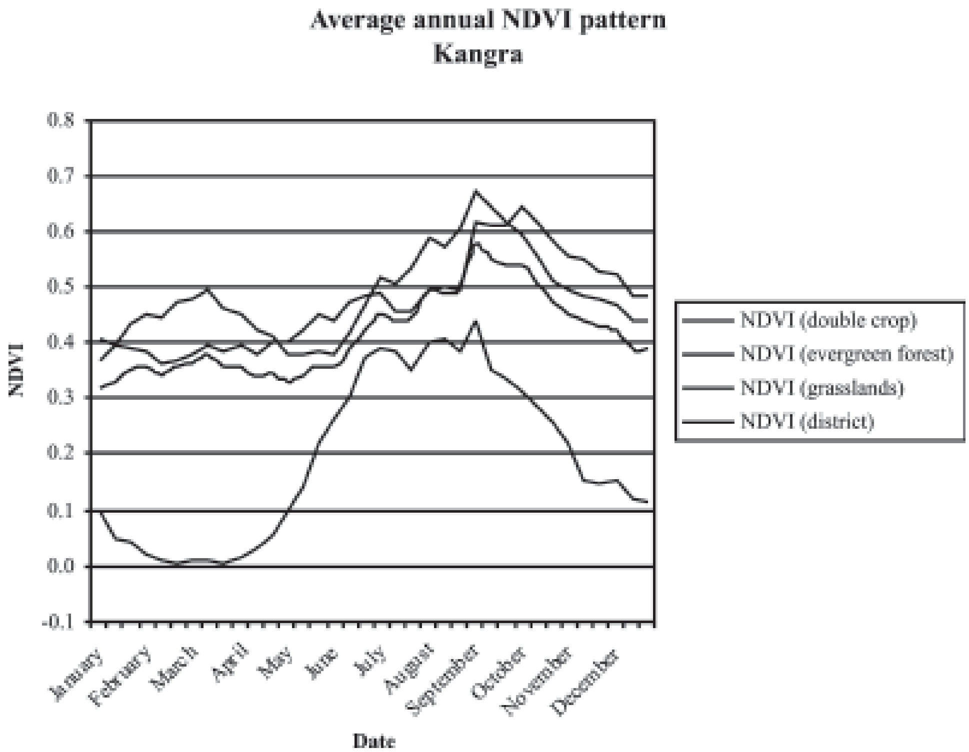

Fig. 5. Annual average NDVI curves per land use for Kangra district

trees. The grassland curve shows a greater dependence on precipitation and large range between maximum and minimum NDVI.

It has been shown that NDVI time series can be used to monitor vegetation growth and depletion throughout the year. Its analysis can be used in deriving important inputs for agro-ecological modelling. The near real-time availability of the imagery can be used for assessing food security by comparing annual curves with long time averages. By detecting NDVI anomalies early in the growing season mitigating measure can be taken to prevent crop losses.

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