Spot-Vegetation multi temporal data for classifying vegetation in South Central Asia

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Abstract

Satellite remote sensing has enabled the acquisition of Land use/ land cover and vegetation information at different spatial and temporal scales. Vegetation instrument onboard Spot 4 satellite with four spectral bands blue (0.43-0.47µm), red (0.61-0.68µm), infrared (0.78-0.89µm) and short wave infrared (1.58-1.75µm) at a spatial resolution of 1 Km and temporal resolution of 1 day meets the requirement of vegetation mapping at a continental scale.

The present study focuses on the use of multitemporal Spot Vegetation data for vegetation mapping in south central Asia. The basis of classification is temporal dynamics i.e. the pattern of change of Normalised Difference Vegetation Index (NDVI) values through a temporal domain reflects the phenology of vegetation, crop cycle and the cropping system of agricultural practices. The temporal profile of NDVI facilitates the discrimination between different vegetation types and different types of cropping pattern.

Introduction

Over the past two decades, data from Earth observation satellites has become important in mapping the Earth's features and infrastructure, managing natural resources and studying environmental changes. Remote sensing and Geographic Information Systems (GIS) provide tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of earth-system function, patterning, and change at local, regional, and global scales over time. Coarse spatial resolution (1 km resolution), combined with high temporal resolution component would allow for the early production of an actual global forest/non forest status map. This effort could provide a first hand data, which can be used in conjunction with other data sets available to define the extent of deforestation. In the present study SPOT Vegetation data has been used to prepare a land use/land cover map of South Central Asia. This initiative is part of the on going global land cover-mapping project (GLC 2000) to which Indian Institute of Remote Sensing is a collaborator with Joint Research Center (European Commission) for mapping in the South Asia. The project aims to explore the possibilities of SPOT Vegetation data sets for vegetation analysis.

Land cover information is time sensitive. The identification of crops, for instance, may require imaging on specific days of flowering and this information (phenology) may be used in the classification process to accurately discriminate vegetation types.

Phenology the science dealing with the influence of climatic and seasonal changes on the recurrence of annual phenomena of animal and plant life, such as bird migration and unfolding of leafs etc. The forest types vary in general as a function of environmental and climatic factors including temperature, rainfall, humidity, seasonality - often governed by latitude and topography. With the use of multitemporal satellite images we can detect and monitor phenological variations and timings over large areas, at a lower cost, and frequently several times each week. This information helps in the classification process to accurately discriminate vegetation types based on their growing characteristics.

The use of multitemporal images not only results in higher classification accuracy but also gives consistent accuracy in all classes being mapped. Multitemporal data is especially

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advantageous in areas where vegetation or land use changes rapidly. This offers many opportunities for more complete vegetation description than could be achieved with a single image. For example, the differences between evergreen and deciduous trees can be highlighted by the fact that the former may appear quite uniform throughout the year, whereas the latter varies widely between leaf-on and leaf-off periods. The discriminant power of multitemporal observations is based on their characterization of seasonal dynamics of vegetation growth (phenology) [1].

Vegetation indices (VIs) have been extensively used for monitoring and detecting vegetation and land cover changes[2]. The development of vegetation indices is based on differential absorption, transmittance, and reflectance of energy by the vegetation in the red and near-infrared regions of the electromagnetic spectrum[3]. Various studies have indicated that only Normalised Difference Vegetation Index (NDVI) is least affected by topographic factors. The NDVI is usually assumed to be broadly indicative of, and associated with, plant photosynthetic activity and aboveground primary production. Some investigators have attempted to sort out the complex relationships between the NDVI and various eco climatological variables.

Overall, the NDVI has been shown to be sensitive to the phenology of vegetation, including ecosystem scale cycles of plant greenup and senescence[4, 5]. It also is sensitive to the crop cycle and the cropping system pattern of agricultural land use. Observed changes in the NDVI through time are generally thought to reflect vegetation type, phenology and local environmental conditions. Therefore compared to land cover classification using single date data, multitemporal datasets are often found to improve the accuracy of classification

The Vegetation instrument onboard Spot 4 can offer a valuable tool for vegetation mapping at regional scale. The high temporal resolution of one day allows with the capability for image selection according to best quality, least cloud cover and the optimal phenological stage of vegetation cover, which plays a significant role in discriminating the vegetation types[6].

For many years mapping at regional scale has been carried out using NOAA- Advanced Very High Resolution Radiometer (AVHRR). NOAA being a meteorological satellite suffers certain limitations on calibration, geometry, orbital drift, limited spectral coverage and variations in spectral coverage has restricted its utility by introducing substantial errors into various stages of processing and analysis. The Vegetation instrument overcomes these restrictions[7]. It is one of the first sensors designed specifically for global vegetation monitoring.

Study Area

South Asian region extending from 1.1^{o}N to 37.5^{o}N latitude to 60^{o} E to 105^{o}E Longitude is characterized by high biological diversity and climatic variations. Generally there are two broad climatic seasons, summer (April- June) and winter (October- February). The area with diversified relief has annual rainfall varying from 100 mm in desert area to 11,000mm in Northeastern hills. The mean annual temperature varies from 2^{o}C to 50^{o}C defining the landmasses into different zones viz. tropical, subtropical, temperate and alpine.

Most of the Indian subcontinent falls in the biotic region of tropical deciduous forest and tropical scrub forest. Tropical evergreen and patches of rainforest occupies a narrow belt along the western coast, northeast Himalayas and islands. Champion and Seth[8] (1968) have classified the vegetation into 16 major groups in parts of this sub continent.

The subcontinent is a confluence point of major terrestrial biogeographical realms (Indo-Malayan, Eurasian and Afro tropical) and Antarctic realms for marine biogeography. For the convenience of vegetation/ ecological studies the region can be sub divided into seven ecological zones viz. Northeast, Western Himalayas, Central Himalayas, Eastern Ghats, Western Ghats, Central Highlands and Myanmar[9].

Methodology

In the study an attempt has been made to classify vegetation in the south Asian region using distinct phenological growth stages and spectral characteristics at mesoscale.

Multidate SPOT Vegetation data has been used for this purpose. SPOT Vegetation data with four spectral bands blue (0.43-0.47μm), red (0.61-0.68μm), infrared (0.78-0.89μm) and short-wave infrared (1.58-1.75μm) at a spatial resolution of 1 Km and temporal resolution of 1 day meets the requirement of vegetation mapping at a continental scale using phenological variability in vegetation.

The raw data was received from Joint Research Center (JRC), ISPRA, Italy as a part of the collaborative project between Indian Institute of Remote Sensing and JRC. The data received was geometrically rectified and georeferenced.

The data has stripes of missing data at regular intervals due to inherent sensor characteristics. These stripes shift daily by a constant factor. Basic preprocessing of the data has been carried out to overcome this error by generating five-day composite image. Threshold values are used for a preliminary level correction for thick clouds.

For classification the general approach used consisted first of an analysis of the temporal NDVI values, followed by a development of methods to discriminate forest from non-forest and the to discriminate among various forest types and land cover classes.

To reduce noise, daily data have been transformed into maximum-value composites (MVCs) (the term noise is used in a broad sense indicating disturbances in the time-series signal, and no statistical distributions are assumed). For each five-day period, the highest NDVI is selected to represent the period. The method reduces negatively biased noise due to interference of clouds and atmospheric constituents. However, residual atmospherically related noise, as well as some noise due to other factors, e.g., surface anisotropy, will remain in the data. Further a monthly maximum NDVI composite was generated from nine months data sets ranging from November1999, December 1999, January 2000, February 2000, March 2000, April 2000, May 2000, October 2000 and December 2000. The composites produced not only provided maximum information of vegetation but also gave the phenological variation among the different vegetation types and thus giving precise discrimination among different vegetation types. Figure 1 shows the color composite of MVC images for the month March 2000, October 2000 and November 1999. The areas in white are regions with high NDVI values in all the three months.

Temporal curves were constructed to examine seasonal profile of the land cover types. The plot revealed a strong temporal pattern for vegetation throughout the growing season. A separation between land cover classes like agriculture, forest types and grasslands were apparent. The phenological cycle of vegetation becomes important in interpreting the graphs. In examining the temporal pattern of NDVI values among crops a general pattern emerged as well.

At preliminary level the data was divided into the seven ecological zones in order to overcome the large amount of variability in the vegetation classes in the region and to avoid misclassification. Then analyzing the maximum NDVI composite spanning from November 1999 to December 2000 the image was stratified into vegetated and non-vegetated lands. NDVI time-series profile is an ideal reflector to vegetation growing regularity and therefore vegetation classification based on NDVI time–series is more feasible than spectral classification. An unsupervised clustering algorithm (ISOCLASS) on the nine-month MVC images was used to define classes within the vegetated and non-vegetated stratum. The data from Defence Mapping Meterological Sattelite Program (DMSP)[10] was used as a reference for mapping the urban areas in the SPOT Vegetation data set. As per the requirement of the GLC 2000 project the FAO Land cover classification scheme was adopted for defining the classes, the primary objective it being to provide with a uniform and consistent data set, which is comparable across the regions and countries. Finally a mosaic of all the land use/ land cover classes obtained in the different ecoregions was generated (Fig 4).

Ground truth, available vegetation maps and field work has been undertaken through a network established under the project. The network had its first meeting through a workshop on "Tropical Forest Cover Assessment and Conservation Issues in Southeast Asia" organized at Indian Institute of Remote Sensing, Dehradun from 12th to 14th February wherein all these maps and information were shared and deliberated[11]. In addition to this information has also been supported by the TREES Phase I Report on Mapping in Myanmar and Northeast India[12]. The post classification refinement criteria were done using interactive techniques.

Results and Discussion

Phenological analysis of vegetation classes.

In the present study an attempt has been made to stratify the different vegetation classes using the temporal data set and also to observe the phenological variations among the different types of forest in the different regions. The temporal NDVI images provide the rhythmic growth of vegetation and hence enable to distinguish the same species type occurring in different ecological and climatic conditions.
Temporal plots were selected for each vegetation class and analyzed for the study area. The representative sites selected for each cover type indicate the internal variations of the NDVI response. For each location, the average NDVI value was plotted. Figure 2 shows the temporal plots for the vegetation classes in the seven ecological zones

Central Himalayas
In general the vegetation types in the region follow the phenological pattern, which is characteristic of each vegetation class, however a sharp decline is observed in the temporal profile of temperate conifer in the month of March, which is attributed to the presence of snow in the region.

North east
The variation in the NDVI values for the Northeast India is governed by the phenological variations and seasonal variability. The tropical evergreen forest shows higher values in the January and February with a sudden drop in the values during March. The suppressed values in the march are attributed to the snow cover and cloud in the region. The Tropical semi evergreen forest also depicts the similar patter with lower NDVI values. Temperate forest has shown the lower NDVI values due to morphological and anatomy of the vegetation. The forest shows lower values in March and April. Subtropical forest follows the similar trend as semi evergreen forest. The NDVI values during the January and February have been found uniform with lower values during April. The temperate conifer follows the pattern of Tropical evergreen forest with lower values in March.

Western Ghats
The temporal profiles of the NDVI are representative of the phenological variations and seasonal variability of the land cover classes in the region. The evergreen, semievergreen and moist deciduous have relatively similar phenological variation with almost equal reflection. The March and April datasets provide the delineation among the classes. The dry deciduous has lower NDVI value with sharp offset in April, discriminating it from other classes.

Central Highlands
The deciduous forests of the central highlands have been found with a unique and distinct phenological variation. The Moist deciduous forest and dry deciduous forest follows the same phenological variation with high NDVI values for the moist deciduous forest. Both the vegetations have low foliage cover in the month of April in the studied time period. The dry deciduous forests of Rajasthan have been found with low foliage cover as comparison to the central India. It gives a clear distinguished phenology of the vegetation types in the different bioclimatic regions.

Myanmar
The NDVI curves of the vegetation in the Myanmar are the true representative of the phenological variations in the region. The Tropical evergreen and semi evergreen forest shows the similar trend with the offset from the January onwards. The moist and dry deciduous species have a characteristics curve with higher foliage cover in the in moist forest.

Eastern Ghats
The vegetation classes in the region follow the phenological variations. Due to the presence of high moisture content the mangroves show a constant pattern. Eastern Ghats also shows the similar set of phenological variation as Western Ghats. The availability of mangrove and relatively less NDVI values differentiate it from Western Ghats. The mangroves have almost similar reflectance in March, April and May. The other vegetation types show similar trends with semi-evergreen, moist deciduous and dry deciduous in decreasing order of NDVI values.

Western Himalayas
All the forest types have shown almost the similar phenological trend. The alpine pastures have shown relatively lower NDVI values. Sub tropical forest has shown the similar pattern with higher values. The juniper has shown in variably higher values in the April.

Analysis of Scatter Plot between NDVI values of wet and dry seasons

The seasonal spectral profile of different vegetation and land cover classes has been used as a discriminant in the classification approach[13]. It is for the first time on this continent such kind of spectral profile has been generated with authentic ground data. The spectral profile clearly indicates possibility of discriminating features.

An attempt has been made to assess the NDVI values between wet (November1999-January 2000) and dry (March 2000-April 2000) seasons for forest types (Fig.3a). The scatter plot clearly indicates the separability among the different classes. The high altitude forest types evergreen and semi evergreen are discriminated from the deciduous types. The high altitude vegetation of cold desert viz. alpine pastures and junipers have low NDVI values. However the tropical evergreen forest have similar values to that of subtropical forest, which may be, attributed to the presence of secondary forests in the region.

It also evident from scatter plot (Fig.3b) that there is differentiation among the vegetation types based on the ecoregions i.e. vegetation types occurring in similar geographical conditions are clustered together. The evergreen and semi evergreen forests are separate from that of the Northeast. The deciduous forest type for arid and semi arid regions show different phenological pattern than that of the tropical regions.

A similar plot for the agricultural classes in the region was generated Fig 3c and was observed that the different agriculture classes are also separable. The study highlights the potential of multi temporal resolution satellite images for understanding the phenological variations of the land cover features

Classification

The region is endowed with vast natural resources in the form of tropical evergreen, semi evergreen, subtropical evergreen, temperate broad leaved, moist deciduous, temperate conifer, alpine scrub, varied cropping pattern etc. To classify this a hierarchical classification approach was adopted, at the first level the major forest and non-forest classes were obtained followed by the detailed classification using unsupervised approach. A total number of 45 classes based on the FAO land cover classification scheme (LCCS) were obtained. Table 1 shows the area statistics for the land cover classes. The mapped classes are compared to the corresponding classes described by Champion and Seth (1968) [8] and are shown in Table 2.

Table 1. Area Statistics of the land cover classes

S.No.	Major Forest Classes	% Area	S.No.	Major Non-forest Classes	% Area
1	Tropical Evergreen	1.84	18	Bush	2.62
2	Subtropical Evergreen	0.17	19	Shrubs	0.08
3	Temperate Evergreen	0.68	20	Plain Grasslands	1.17
4	Tropical Montane Forest	0.001	21	Slope Grasslands	3.05
5	Semi-evergreen	5.47	22	Desert Grasslands (cold desert)	1.76
6	Temperate Conifer	3.68	23	Alpine Grasslands	6.24
7	Subtropical Conifer	0.35	24	Alpine Meadows	8.83
8	Moist Deciduous	4.95	25	Rangelands/Sparse vegetation (cold areas)	1.23
9	Dry Deciduous	4.17	26	Rangelands/Sparse vegetation (hot areas)	0.88
10	Northern Tropical Thorn Forest	1.01	27	Gobi	1.14
11	Southern Tropical Thorn Forest	1.69	28	Cold Desert	2.20
12	Dry Woodland	0.05	29	Thorn Scrub/Hot desert	1.84
13	Mangroves	0.10	30	Coastal Vegetation	0.18
14	Junipers	0.08	31	Abandoned Jhum	1.37
15	Savannah Grassland	0.07	32	Current Jhum	0.08
16	Degraded Forest	0.50	33	Irrigated agriculture(single crop)	16.80
17	Sparse Woods	0.21	34	Irrigated Intensive agriculture	10.02
			35	Slope Agriculture	1.53
			36	Rain-fed agriculture	2.07
			37	Snow	4.48
			38	Water Body	1.20
			39	Swamp	0.08
			40	Salt Pans	0.14
			41	Mud Flats	0.12
			42	Barren	3.22
			43	Bare rock	2.23
			44	Coral reefs	0.006
			45	Settlement	0.33

Table 2 Comparison of LCCS classification with Champion and Seth (1968) classification Scheme

S. No.	LCCS classification scheme		Champion and Seth classification scheme	
	Land Cover Class	Classifiers	Land Cover Class	Classifiers
1	Tropical Evergreen Forest (Broadleaved)	A3A10B2C1D1E1-010	Tropical Wet Evergreen (Southern and Northern Tropical Wet Evergreen) Tropical Dry Evergreen	1A and 1B $7C_1$,
2	Tropical Semi-Evergreen Forest	A3A10B2C1D1E1-E4-01	Southern Tropical Semi-Evergreen and Northern Tropical Semi-Evergreen	2A and 2B
3.	Moist Deciduous Forest (Broadleaved Climate: Tropics-Humid)	A3A10B2C1D1E2-01014	Andaman Moist Deciduous, South Indian Moist Deciduous and North Indian Moist Deciduous	3A, 3B and 3C
4	Dry Deciduous Forest, (Broadleaved) Climate: Tropics-Dry semi-arid	A3A10B2C1D1E2-01011	Southern Tropical Dry Deciduous and Northern Tropical Dry Deciduous	5A and 5B
5	Sub tropical Evergreen Forest (Broadleaved)	A3A10B2C1D1E1-02	Northern Sub-Tropical Broadleaved wet hill Forests	8B
6	Subtropical Conifer (Needleleaved Forest, Climate: Subtropics)	A3A10B2C1D2E1-02	Himalayan Sub-tropical Pine Forests, Assam Sub-tropical Pine Forests	$9C_1$ and $9C_2$
7	Temperate Evergreen Forest (Broadleaved Evergreen Forest, Climate: Temperate Continental)	A3A10B2C1D1E1-B7-05014	East Himalayan Wet Temperate Forest	$11BC_1$
8	Temperate Conifer (Needleleaved Evergreen Forest, Climate: Temperate Continental)	A3A10B2C1D2E1-050	Himalayan Moist Temperate and Himalayan Dry Temperate	12C and 13C
9	Mangroves (Broadleaved Evergreen Medium High Forest On Water Logged Soil, Water Quality: Saline)	A3A12B2C3D1E1-B6-R3	Tidal Swamp Forests	4B
10	Northern Tropical Thorn Forest (Aphyllous Woodland, Climate: Tropics-Dry semi-arid)	A3A11B2C1D3-01011	Northern Tropical Thorn Forest	6B
11	Southern Tropical Thorn Forest (Aphyllous Woodland, Climate: Tropics-Moist semi-arid)	A3A11B2C1D3-01012	Southern Tropical Thorn Forest	6A
12	Tropical Thorn Scrub (Aphyllous Sparse Medium High Trees, Climate: Tropics)	A3A14B2C3D3-B6-01	Euphorbia scrub, Acacia senegal forest, Rann saline thorn Forest, Salvadora scrub, Desert dune scrub	$6E_1$, $6E_2$, $6E_3$, $6E_4$, $6S_1$
14	Savannah Grassland (Grassland with Trees, Climate Tropics)	A6A10B4C1E525F2F5F10G2-E7-01	Low Alluvial Savannah	3_IS_1

Conclusion

SPOT Vegetation data with its high temporal resolution has potential for use with regional land cover mapping and the high frequency of coverage enhances the likelihood for cloud-free observations and makes it possible to monitor change in land cover conditions over short periods, such as a growing season. These datasets are useful for monitoring land cover transformations at a wider scale.

The study demonstrates the utilization of multi-temporal satellite data for assessment of phenological status of different types vegetation. The study of these phenological patterns and foliage activity monitoring through NDVI will help in understanding vegetation dynamics in terms climate change impact, carbon sequestering process and earth- atmosphere energy interactions.

The datasets generated are of invaluable significance for geosphere-biosphere studies, climate change and monitoring large-scale landuse/landcover change. The results indicate that SPOT Vegetation data has immense potential for generation of landuse/landcover at regional level and the interaction among the institutions/experts at regional level helped in creating a firm base line data in the Asian region. Existing data can be used as preliminary base line data for further landuse/landcover studies. The study will be further refined with the use of representative data sets of the other phenological periods.

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