Vegetation mapping and characterization in West Siang District of Arunachal Pradesh, India – a satellite remote sensing-based approach

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Vegetation mapping is a primary requirement for various management and planning activities at the regional and global level. It has assumed greater importance in view of the shrinkage and degradation in forest cover. Usage of remotely sensed data for mapping provides a cost-effective method. In the present study vegetation cover assessment has been done using remotely sensed data in West Siang District of Arunachal Pradesh. Standard method was adopted for ground data collection by establishing the correlation between satellite data and various vegetation types. Ground data were collected extensively and sufficient information was obtained. Vegetation classification was performed using traditional methods of image recognition. The discrimination among the various forest types is restrained on satellite data owing to the environmental set-up, intermixing of species/vegetation and topography. However, to achieve higher accuracy, other methods have been considered. Hybrid approach of classification has been adopted where modification of spectral classification with the aid of ancillary data set has been found useful. The study area has been classified into twenty-three categories. The vegetation cover types extracted from classification showed good relationship with altitudinal zones. Correspondence with field-gathered GPS points for vegetation classes showed 85.29% overall accuracy. Hybrid classification approach gives an opportunity to refine the classification to acceptable limits for various activities related to management and planning.

THERE has been concern the world over on the rate of deforestation and its impact on the climate and on biodiversity, in particular. Loss of the habitat due to deforestation is the major concern. Developing countries are faced with the trivial question of development and protection and/or conservation of forests. Forest degradation is another problem in these countries, and more so in densely populated countries like India. Our country has about 6% of the total human population and about 15% of the world's cattle population. Indiscriminate resource utilization, forest as well as non-forest, is leading to change in the quality of the forest/habitat. Shifting cultivation, once said to sustainable practice, is causing serious threat to the local flora and fauna. Shifting cultivation is prevalent in northeastern region of India. Increase in the population and demand for more agricultural produce has led to reduced cycle to 3–5 years of shifting cultivation in several parts. A new dimension to the existing problem has been added by illicit felling[1]. Therefore, there is need to generate a database at different levels while the basic unit remains the local area. Up-to-date information must be available for planning and decision-making. Arunachal Pradesh, part of the eastern Himalayas, is perhaps the only state in India, which can boast of a forest cover. West Siang District still has a good forest cover. However, land cover and land use change are considerably rapid. Therefore, the assessment of the forest cover calls for the use of remotely sensed data. The vegetation maps are the key for any planning, either for protected area management (national parks and wildlife sanctuaries), sustainable development, social forestry, agroforestry, development without destruction, ecodevelopment etc., and these provide the locational information, which can be further supported by the ancillary data for more objective-oriented requirements. Hence latest forest information on spatial extent, quality and rate of change, etc. is required for a wide variety of applications like planning, management and conservation purpose.

Remote sensing with multi-spectral and multi-temporal data collection systems allows one to perform the work of data collection and integration more quickly and effectively. It also brings a great deal of knowledge about surface features. This has opened up new frontiers for conservation and sustainable use of forest resources[2]. Forest cover classification, based on satellite remote sensing provides an efficient and cost-effective method for acquiring up-to-date and accurate information that is useful to resource planners, researchers and conservationists[3]. Since long, satellite remote sensing has been used to map and classify land use and forest cover. The technology has made it possible to prepare maps of remote,

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inaccessible and mountainous regions[2–4]. Sometimes it is difficult to discriminate various vegetation cover types particularly in mountainous regions, due to a lack of unique spectral reflectance in cover types[4] and the merging of plant communities along altitudinal gradients.

National Remote Sensing Agency (NRSA) has classified forest cover in Arunachal Pradesh using phenological characteristics and visual interpretation techniques at 1:1M scale[5]. According to an estimate made by Forest Survey of India (FSI) using IRS-1B LISS-II data, the forest cover in Arunachal Pradesh was 68,621 km^2 in 1995, 68,602 km^2 in 1997 and 68,847 km^2 in 1999, of which, 11,091 km^2 and 57,756 km^2 were delineated in open and dense categories respectively. Behera *et al.*[6] attempted stratification of montane vegetation in Talle valley of Lower Subansiri District in Arunachal Pradesh through digital processing of satellite data using various band combinations. Roy *et al.*[7], have attempted stratification of montane vegetation through digital processing of Landsat MSS data using various band combinations and reported that partial shadow pattern and varying illumination conditions impart great difficulty in such a study.

The objective of the present study was to produce an improved and detailed vegetation cover-type map using digital classification technique supplemented by information collected from ground truth and surveys. The study also aimed at evaluating the hybrid digital classification methodology. Hybrid approach is an integrated approach which involves unsupervized classification, supervized classification and/or field knowledge.

Study area

The study area comprises West Siang district of Arunachal Pradesh located in the northeastern region of India (Figure 1). It lies between 27°29′–29°23′N latitude and 94°02′–95°15′E longitude. The area is bounded in the north by Tibet, on the east by East Siang and Dibang valley Districts of Arunachal Pradesh, on the south by North Lakhimpur District of Assam and on the west by upper Subansiri and lower Subansiri districts of Arunachal Pradesh[8]. District West Siang falls in the Eastern Himalayan biogeographic zone[9]. The district covers an area of 12,006 km^2, with hills towering to majestic heights ranging from 200 to 4900 msl. The climate of the area has a markedly continental character with average annual rainfall of 3000 mm. Temperature ranges from a minimum of 5°C in winter to a maximum of 38°C in summer at the foothills and plains, whereas it varies from below freezing point to 25°C at higher reaches. Various ecological zones, viz. tropical, subtropical, temperate, subalpine and alpine exist in the study area[10]. The common trees species are *Alnus nepalensis*, *Altingia excelsa*, *Duabanga grandiflora*, *Terminalia bellirica*, *Castanopsis indica*, *Quercus lamellosa, Rhododendron hodgsonii*, *Juniperus recurva* in different zones. Shrubs like *Capparis multiflora*, *Eurya japonica*, *Clerodendron wallichii*, *Rubus ellipticus* and *Croton* sp. occur along with exotic species like *Mikania micrantha*, *Ageratum conyzoides* and *Eupatorium* sp.. Several orchid species have been reported from the region.

Methodology

IRS-IC LISS-III digital data were used for classification of the vegetation cover. The data provided information in four spectral bands in the visible and infrared regions with spatial resolution of 23.5 m. Standard methodology has been followed and preprocessing (geometric and radiometric) distortions were corrected. Geo-referencing of master scene has been carried out on 1:250,000 scale using ancillary data and GPS locations. The slave scenes

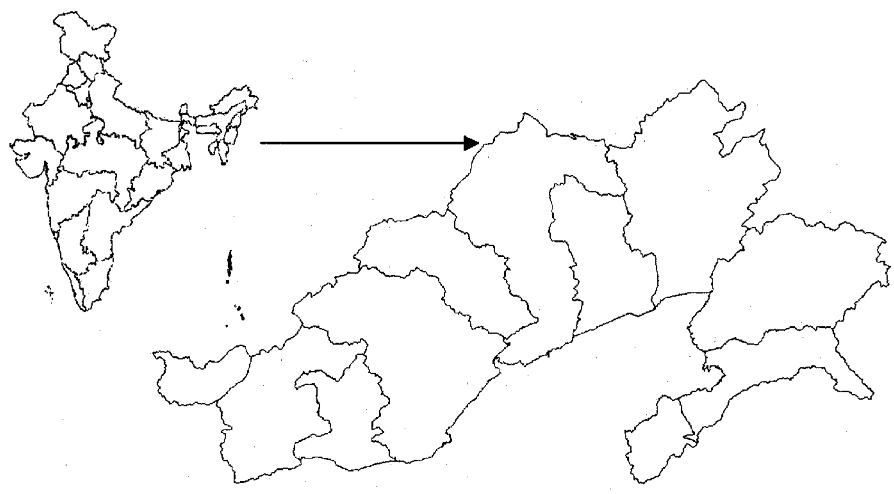


Figure 1. Location map of West Siang.

Figure 2. Satellite image of West Siang.

having common geographical area were registered with the geometrically corrected scenes and subpixel root mean square error was within acceptable limits (0.002). Geometrically corrected scenes were later mosaicked, and for radiometric balancing[11,12] band-by-band histogram matching was performed (Figure 2).

Information extraction – forest vegetation mapping

The classification scheme of forest cover types was based on the dominant vegetation associates, structure and phenological behaviour, and some of them were classified based on their physical location. Standard steps were followed; however, unsupervised classification was first performed on the image. The classes, which have high spectral separability were picked up and masked from the main image. Unsupervized classification using Isodata clustering provided clusters based on their statistical similarity/dissimilarity. The high number of clusters basically brings out the inherent spectral variability in the area and these were then successfully classified/named later on. In the second step the remaining data were put to supervized classification using image elements. Representative homogeneous areas were used as training set and supervised maximum likelihood classification[13] algorithm was applied. Such areas were then removed from the dataset. The multiple images obtained through supervized, unsupervized and region-specified classification, and area of knowledge, were overlaid and a final classified image was generated (Figure 3). Field knowledge was subsequently incorporated to improve the accuracy. This approach takes the advantages of the both the procedures and therefore is called as hybrid. It is an integrated approach comprising unsupervized classification, supervized classification and human knowledge. Vegetation classes were delineated on the basis of their spectral value. The spectral channel 3, 2, 1 (RGB) of LISS-III proved significant in the process of class separation, though the major contributor was near infrared (NIR), which showed relevant differences in spectral (DN) value of different vegetation classes (Figure 4*a*).

Accuracy assessment using GPS

Classified data were then put to accuracy estimation. A database of GPS locations taken during the field work was created. A hand-held ProMARK X-CP, 10-channel SPS code and carrier-phase code receiver (designed to collect pseudo-range and carrier-phase data) were used for this purpose[14]. A customized package Bio_CAP was used wherein the GPS-driven points were projected on the classified map[15]. The correspondence between true vegetation cover at 34 points and the classified map was computed.

Results

Satellite image classification has helped to identify twenty-three major land cover types, among which eight are natural forests, eight are secondary forest types and seven non-forest classes with agriculture, snow, shadow and cloud (Table 1). The study has resulted in the satellite-based map of forest-type level at the scale of 1:250,000 using digital interpretation technique in West Siang (Figure 5; Table 2).

A description of different land use and land cover classes is given below.

Tropical evergreen forest

These forests are dominated by *Altingia excelsa*, *Anthocephallus chinensis*, *Ficus drupacea* and *Premna bengalensis*, and occur in regular pattern adjoining the Assam border and along the river. Total area covered by these forests is about 158.7 km^2.

Tropical semi-evergreen forest

This forest type is confined to the heavy-rainfall tracts adjoining the Assam border and occupies a very limited

Table 1. Characteristics of satellite-derived forest vegetation cover types and comparison with existing forest type classification given by Champion and Seth[18]

Satellite-based forest cover type	Champion and Seth[18] classification
Moist mixed deciduous	East Himalayan moist deciduous forest (3C3/Bb)
Tropical semi evergreen	Assam alluvial plains semi-evergreen forest (2B/C1/IA) Sub-Himalayan light alluvial semi-evergreen forest (2B/C1/ISI)
Tropical evergreen	Assam valley tropical evergreen forest (1/B/C1) and Upper Assam valley tropical evergreen forest (1B/C2)
Subtropical evergreen I	East Himalayan subtropical wet hill forest (8BC2)
Subtropical evergreen II	–
Temperate broad leaved	11B/C1 East Himalayan wet temperate forests 11B/CIa Lauraceae forests 11B/CIb Bak oak forests
Pine	Assam subtropical pine forests (9/C2) or subtropical pine (9/DS1)
Temperate coniferous	–
Subalpine/alpine coniferous forest	East Himalayan mixed conifer forests (14/C3a)
Subalpine/alpine scrub	Dry alpine scrub (16/C1) and dwarf juniper scrub (16/E1)
Riverain forest	–
Bamboo mixed forest	–
Abandoned shifting cultivation	–
Degraded forest	–

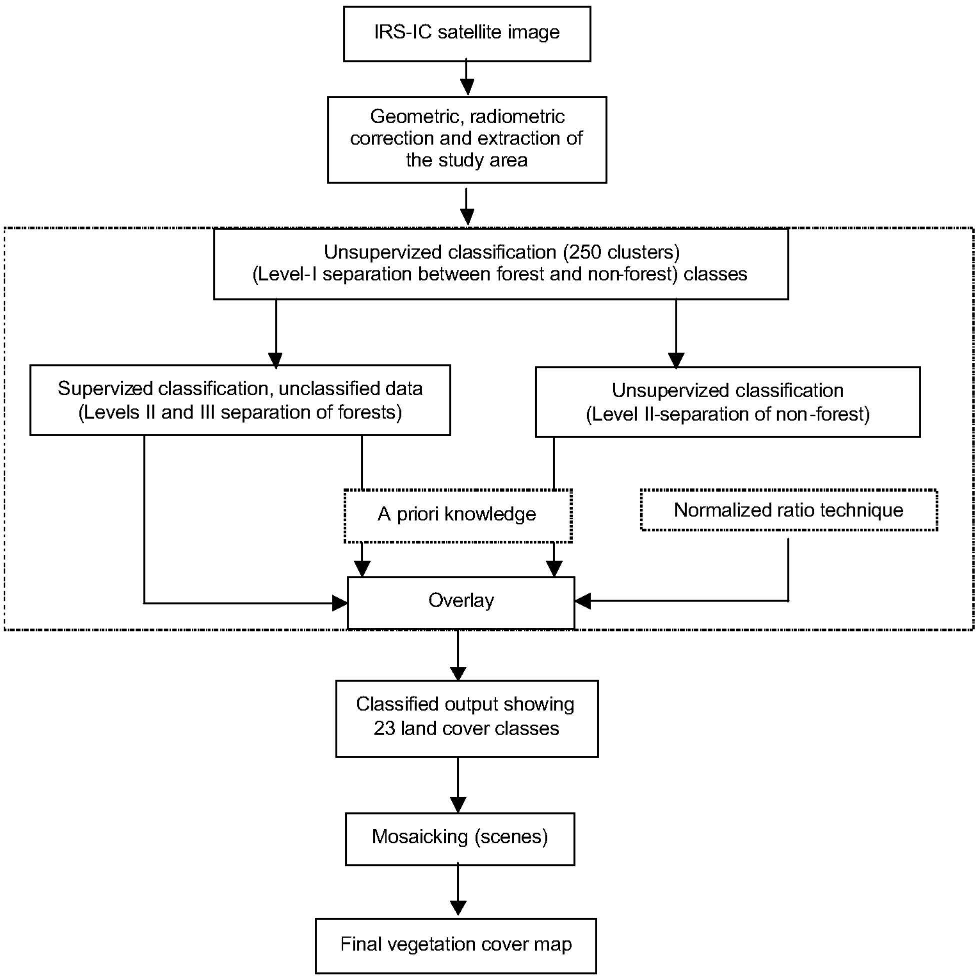
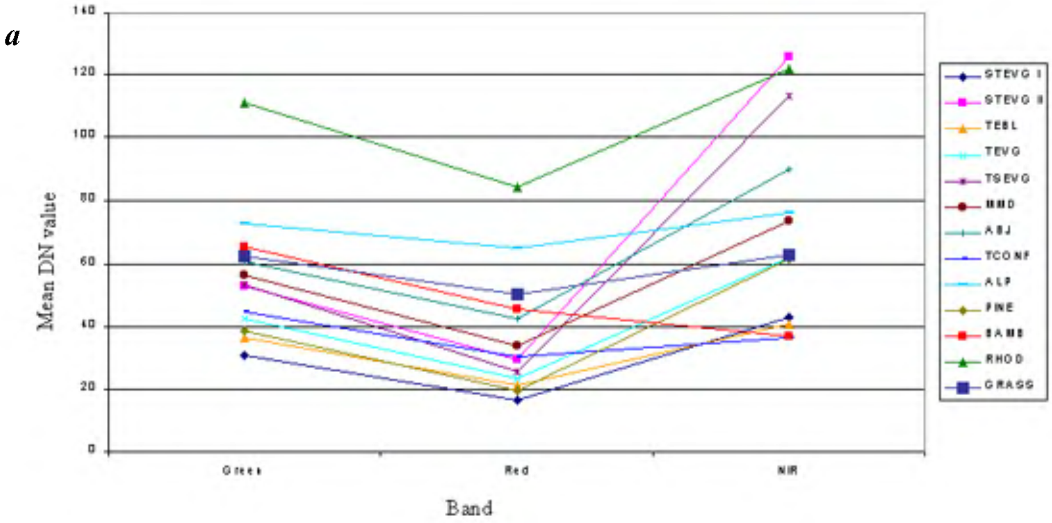


Figure 3. Steps followed in vegetation cover



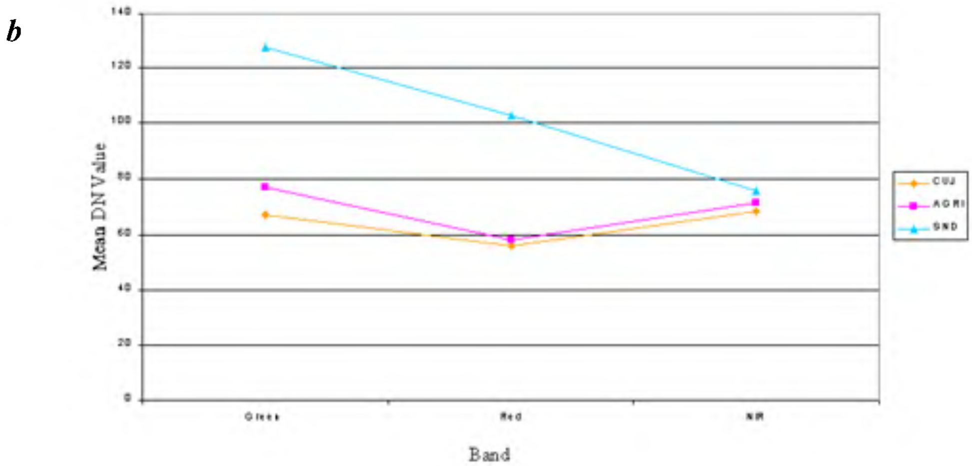


Figure 4. ***a***, Spectral pattern plot of mean digital number (DN) value for vegetation type. STEVG, Subtropical evergreen; TBL, Tropical broad leaved; TEVG, Tropical evergreen; TSEVG, Tropical semi evergreen; MMD, Mixed moist deciduous; ABJ, Abandoned jhum; TCONF, Temperate coniferous; ALP, Alpine pasture; BAMB, Bamboo; RHOD, Rhododendron; GRASS, Grassland. ***b***, Spectral pattern plot of mean digital number (DN) value for non-vegetation type. CuJ, Current jhum; AGRI, Agriculture; SND, Sand.

area. It occurs in areas receiving 3000–6000 mm rainfall or having high humidity. Due to their accessibility, these are exposed to large-scale exploitation and destruction as a result of shifting cultivation. Common species occurring in this forest type are *Terminalia myriocarpa*, *A. excelsa* and *Albizzia procera.* It covers 46.16 km^2 of the total area of the district.

Mixed moist deciduous forest

This forest type is also confined to flood plains bordering Assam. The dominant species are *Terminalia myriocarpa*, *Duabanga grandiflora* and *Albizzia lebbek*. Because of accessibility and timber value of the species, these forests are also exposed to large-scale destruction.

Subtropical evergreen forest I

Spatially, the forest shows irregular pattern, small and fragmented patches at lower altitude, and accessible site, contiguous and large patches on the inaccessible and higher reaches. It has been noticed that this forest type has been subjected to more degradation. The dominant species *Saurauia roxburghii*, *Trevasia palmata* and *Q. lemellosa*. It covers 1886.24 km^2 area of the district.

Subtropical evergreen forest II

The subtropical evergreen II class derived in this area has a great ecological implication. This type was found occurring at an altitude of above 1000 m up to 1600 m. It

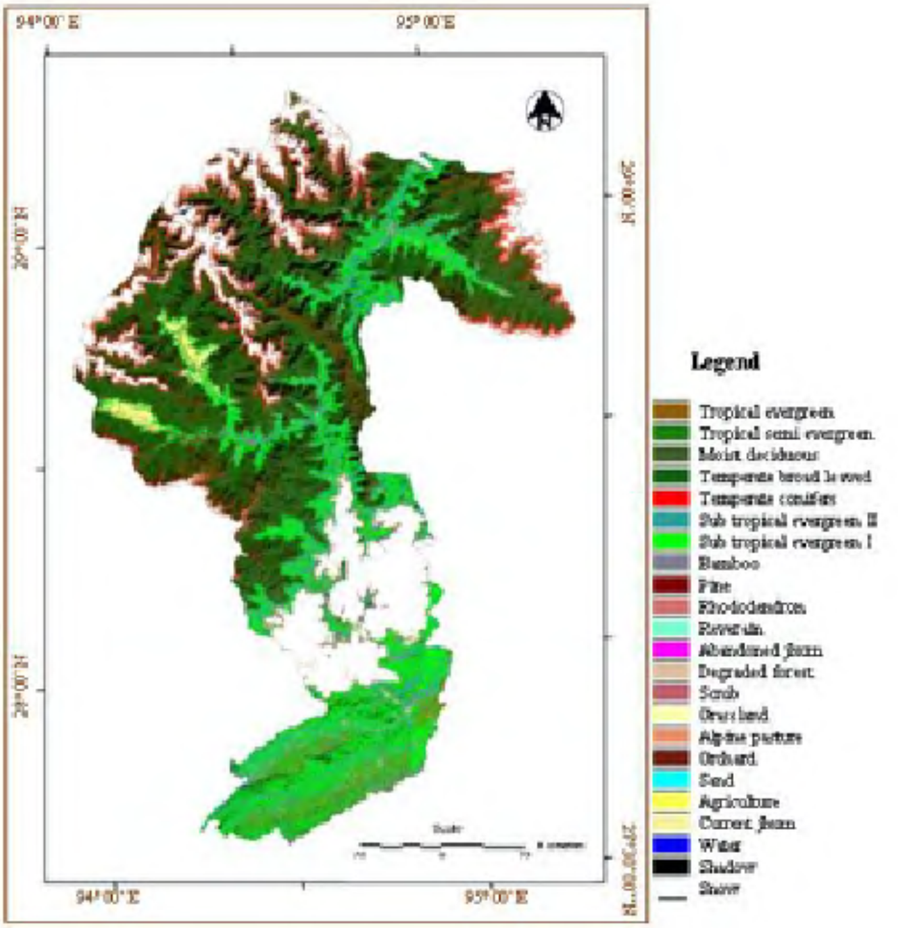


Figure 5. Vegetation cover and land use map of West Siang.

was observed mainly distributed along the riverbanks. Since some amount of open space exists, this patch of vegetation could receive some sunlight. This could have led to a special degree of microclimate, giving rise to variation in species composition. Common species are *A. excelsa*, *Bischofia javanica*, *Lagerstroemia speciosa*, *Olea dioica*, *T. myriocarpa*, *Shorea assamica* and *Mangifera sylvatica*. Majority of these species were noticed to be deciduous in nature (Figure 6).

This has thus imparted a distinct spectral response on the satellite imagery from among the surroundings. The species composition on ground was enumerated to confirm the class. These forest type covered 956.68 km^2 of the district.

Temperate broad-leaved forest

The number of dominant species is limited; in fact, more or less pure crops are more frequent than mixed ones, and the species distribution depends mainly on altitude and aspect. Common species in these forests are *Castanopsis indica*, *Phoebe cooperiana*, *Q. lemellosa*, *Castanopsis hystiix*, *Rhododendron grande* and *Syzygium tetragona.*

This type of forest is found in the higher reaches beyond 1800 m elevation and is comparatively less disturbed, because of its inaccessibility and complex nature of the terrain. Total area covered by this forest is 3592.7 km^2.

Coniferous forest

Under this type, all the conifers like temperate, subalpine and alpine have been classified together, as they impart almost similar spectral signature on the satellite image. But field samplings done separately have indicated minute differences. Total area covered by this forest is 587.776 km^2.

Subalpine/alpine scrubs

The chief characteristic is ample snowfall, the snow lying till the air temperature during the day is quite warm. Since the vegetation is devoid of stratification, species composition is low in this category. The distribution is patchy and thus irregular. It forms an area of about 238.6 km^2 in the district.

Table 2. Vegetation characteristic on standard FCC of West Siang District (February)

Forest and non forest class	Tone	Texture	Site	Location	Area (km^2)	Area (%)
Tropical evergreen	Dark red	Smooth	Lower altitudes	Near Assam border	185.7	1.54
Tropical semi-evergreen forest	Pinkish-red	Medium	Outer Himalayas	Near Kayeng, Basar	46.155	0.36
Mixed moist deciduous forest	Dark red to reddish-brown	Medium	Flood plains	Near Assam border	12.14	0.1
Subtropical evergreen I	Bright to dark red	Smooth to medium	Middle Himalayas	Upper ridge of Lising, Payum	1886.24	15.85
Subtropical evergreen II	Dark red	Medium to coarse	Middle Himalayas	Tuting, Biji, Payum, Mouling National Park	956.68	8.04
Temperate broad leaved	Brown	Smooth	Inner Himalayas	Lising, Molling National Park	3592.7	30.2
Coniferous forest	Dark brown	Fine	Inner Himalayas	Molling National Park	587.776	4.924
Subalpine/alpine scrubs	Pink red	Coarse	Inner Himalayas	In interior	238.6	1.98
Alpine pasture/grassland	Dull yellow	Smooth	Inner Himalayas	Mechuka	458.71	3.856
Pine forest	Maroon	Coarse	Middle Himalayas	Near Mechuka	13.26	0.11
Rhododendron forest	Bright red	Smooth to medium	Inner Himalayas	Mouling National Park	4.94	0.041
Riverain forest	Dark cyan	Medium to coarse	River valley	Molo	10.434	0.08
Bamboo mixed forest	Pinkish to light red	Smooth	–	Ramsing	4.8	0.041
Abandoned shifting cultivation	Pinkish red	Medium to coarse	Lower altitude to Middle Himalayas	Kayeng, Along, Bomdo, Basar, Assam border	214.364	1.802
Degraded forest	Light maroon with cyan tinge	Medium to coarse	Lower altitude and Middle Himalayas	Near Assam border	1.22	0.0103
Current jhum	Grey to dark grey to light pinkish	Medium to coarse	Lower altitude to Middle Himalayas	Kayeng, Along, Bomdo, Basar, Assam border	182.748	1.536
Agriculture (fallow)	Cyan to white	Medium to coarse	Valley and river bed	Mechuka, Along, Kayeng	39.55	0.332
Agriculture (standing crop)	Light pink	Medium	Valley and river bed	Mechuka, Along, Kayeng		
Sand/river bed	Cyan white	Fine	Siang river bank, Siyom river bank	Siang river bank, Siyom river bank	5.24	0.044
River/water body	Light blue to dark blue	Very smooth	Siang river, Siyom river	Siang river, Siyom river	15.8	0.13
Hill shadow	Black	Very smooth	–	–	1217.08	10.23
Cloud/snow	White	Very smooth	Inner Himalayas	High altitude area	1922.25	16.16

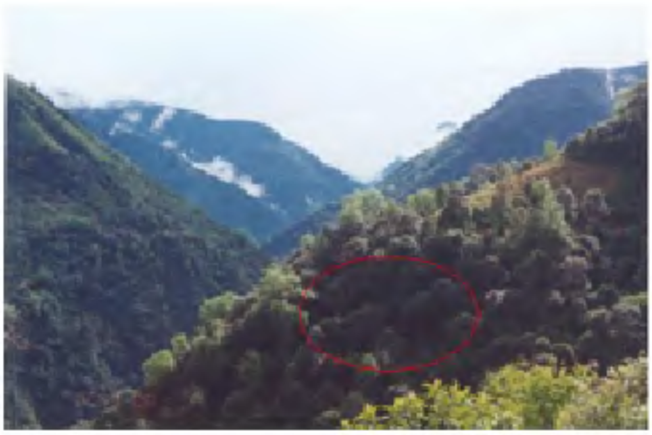


Figure 6. Patch of subtropical evergreen II in West Siang.

Alpine grasslands/pastures

This vegetation is continuous and differs only in having a shorter snow-free period and in floristic detail. The meadows are composed mostly of perennial mesophytic herbs, with very little grass. These are confined to the upper reaches of the district, near the China border. Total area covered by this vegetation type is 458.71 km^2.

Pine forest

The characteristic feature of this forest is the recurrent fire, which wipes out all the undergrowth. Pure strands of *Pinus kesiya*, often mixed with *P. roxburghii* and *Quercus* sp. are found here. Total area under this forest type is 13.26 km^2.

Rhododendron scrub

This forest patch was found distributed as subalpine and alpine scrub along with some conifers. Common associates of *Rhododendron* spp. are *Cupressus torulosa* and *Juniperus recurva*. It covers an area of 4.94 km^2.

Riverain forest

This type of vegetation exists along the riverbanks, riverain plains and swamps. The trees in this vegetation type are generally deciduous, buttressed and lack dense canopy. Its covers an area of 10.434 km^2.

Bamboo mixed forest

This type is more or less a continuous cover of one or two species of tall clumped bamboo. They are found to be pioneer in the abandoned shifting cultivation areas. The thorny bamboo brakes are often formed by *Dendrocalamus hamiltonii* with its characteristic low spreading habit.

Abandoned shifting cultivation

Tribals predominantly practice shifting cultivation in the northeastern hill regions of India. The impact of slash and burn during and after jhum leaves behind a large tract of barren and unproductive area, which is clearly visible on the satellite imagery.

Degraded forest

This type of forest owes it origin to various adverse factors, viz. biotic (shifting cultivation) and natural (landslide, fire, etc.) occurring up to an altitude of 3000 m. It accounts for 1.22 km^2 of the total area.

Non forest classes

Agriculture, river bed, sand, water, snow, cloud, shadow and current jhum classes are classified in this category.

Accuracy assessment

The accuracy assessment procedure has recorded the presence/absence of forest vegetation class mapped using 34 GPS registered points. Overall accuracy of 85.25% was observed for the vegetation class, when compared with the GPS measurement point (Table 3).

Discussion

The satellite data provided a wider view to trace the qualitative as well as quantitative status of the vegetation. The application of aerospace technology to monitor land surface features has increased with near coarse resolution satellite data to high-resolution data sets. Introduction of the IRS series has offered an advantage of competitive spatial, spectral and temporal resolutions for vegetation studies. For the region like northeast India, satellite data have been found useful with their ability to present the prevailing high dynamics nature of the tough terrain and landscape. Himalayan vegetation types have been marked by altitudinal and aspect control (Figure 7). The natural and anthropogenic forces, including shifting cultivation, illegal felling, clear felling, encroachment and gradual degradation require instantaneous field of view coverage for assessing the status of land-cover features. Though the satellite data provide a most convenient and efficient way of monitoring and assessment, each pixel provides a wide range of ground information and conditions, which may create complexity in interpretation of components at the pixel level. Certain areas are almost covered with continuous low-altitude cloud cover, even in non-rainy seasons. The study has emphasized the role of aerospace technology for vegetation monitoring, which can be further used in conjunction with extensive ground truth to provide quantitative forest resource information.

In the present study, forest cover area has been estimated as 70.44% of the geographical area while FSI has reported the cover estimate as 87.25% of the geographical area. The reason for this change in values of classification is due to mapping of the subtropical evergreen II class as a separate category owing to the ecological significance, and this is due to a distinct reflection even for this small pocket of forest. The differences in the estimates are primarily attributed to small patches of shifting cultivation (could not be mapped as non forest). The abandoned shifting cultivation patches (also could not be categorized separately) and the degraded slopes which

Table 3. Correspondence between true vegetation cover at 34 validation points and forest vegetation cover map of West Siang prepared using IRS LISS-III satellite data

Forest type	TEVG	TSEVG	STEVG I	STEVG II	TBL	ABJ	PINE	SHADOW	SNOW	Total	Agreement (%)
TEVG	2									2	100
TSEVG		2								2	100
STEVG I			8		1			1		10	80
STEVG II				4						4	100
TBL			2		6					8	75
ABJ				2	2	5			1	10	50
PINE							2			2	100
SNOW								–		0	
SHADOW									–	0	
Total	2	2	10	6	9	5	2	1	1	34	
Agreement (%)	100	100	80	100	75	50	100	0	0		85.29%

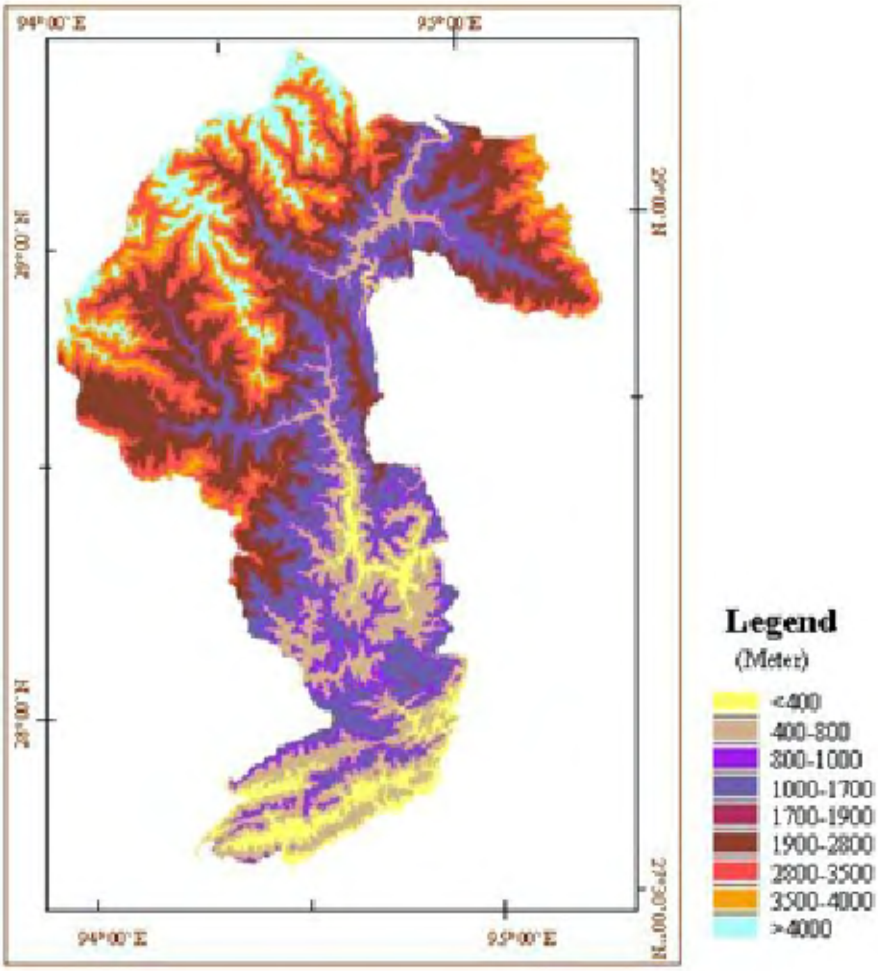


Figure 7. Digital elevation model of West Siang.

get covered by thick annual shrub and herbaceous vegetation could not be separated. Moreover, extensive areas are influenced with partial hill shadows, which prevent accurate classification in the region. The hybrid approach of classification has provided the best results.

Conclusion

Satellite remote sensing with substantial ground truth has enough potential to classify land cover/use. Forest mapping in bio-rich areas using remotely sensed data on a long-term basis would be desirable for understanding the pattern and dynamics of the vegetation. Digital image processing techniques enable speedy and accurate interpretation of the multispectral data received from remote sensing satellites. This has helped in a major way in the operational use of satellite remote sensing to monitor forest resources, at the global level. Digital technology with the knowledge-base is found to enhance mapping capabilities of forest cover type of the rugged terrain using normal multispectral data set. Extensive area is influenced with partial hill shadows, which prevent accurate classification in the region. Himalayan vegetation type is governed by altitudinal and topographic variation. In their study, Kaul and Haridasan[16] have related distribution of various forest types with the altitudinal ranges. When compared with physiography, the present classification reveals that the distribution of various forest cover types is restricted to a particular zone (Figure 7) which has been shown as (a) moist tropical forest, (b) montane subtropical forest, (c) montane temperate forest, (d) subalpine forest and (e) alpine scrub in the given landscape (Figure 3). Each vegetation zone has an intermixing ecotonal extent of about 50 to 100 m. The pattern distribution observed to be very diverse may be because of their location at the tri-junction of Afro-tropic, Indo-Chinese and Indo-Malayan biogeographic regions, and dispersal across various barriers, speciation and mutation. Altitudinal control of vegetation is a characteristic of Eastern Himalaya, in particular Arunachal Pradesh, but the relationship is not a simple one.

Satellite-based, stratified random sampling in various forest types further helps in classifying them up to community level. This study has demonstrated vegetation cover mapping methodology that relates the reflectance information contained in multispectral imagery to tradition.

Remote sensing has made a great contribution to the terrestrial ecosystem function through the relationship between reflectance and vegetation structure[7,17]. The main approaches used here are (a) development of a classification system for biological richness assessment, (b) use of knowledge-base classification to extract more useful classes, (c) allusion of spectral reflectance curve to analyse the function of vegetation cover to electromagnetic spectrum, and (d) use of GPS locations for classification accuracy assessment of vegetation cover classes. Finally, reliable reference information and ground truthing are essential for better accuracy, because this will minimize errors which may have occurred due to forest succession.

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MEETINGS/SYMPOSIA/SEMINARS

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Date: January 27–29 January 2003
Place: Kanpur, India

The aim of the workshop is to bring scientists on one platform to account the changes observed after the Gujarat earthquake. Some of the leading Geologists, Geophysicists, Seismologists, Space, Atmospheric scientists, Oceanographers, Astrophysicists, Surveyors on one platform to discuss the causes of the observed changes on land, ocean, atmospheric parameters. The space sensors onboard numerous satellites may prove to be useful in monitoring changes in land, ocean and atmospheric parameters as a result of earthquakes which may prove to be potential precursors of future earthquakes.

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INDO–US Workshop on Molecular Biology and Biotechnological Applications of Mycorrhizal Fungi

Date: 23–26 March 2003
Place: New Delhi

and

National Congress on Molecular Symbiosis

Date: 27–28 March 2003
Place: New Delhi

Proposed activities: Theme lectures—state-of-the-art; Taxonomy: where do we stand in today's scenario?; Why do we study taxonomy and it's relevance?; Signalling mechanisms in mycorrhizal symbiosis; Molecular taxonomy of symbiotic fungi; Molecular genetics of mycorrhizal symbiosis; Genetic engineering of mycorrhizal fungi; Biotechnological applications of the fungi; Relevance and impact of genetic engineering; Frontal areas in molecular biology; Person-to-person contact for establishment of research co-operation, Interface of science, industry, management and corporate sectors.

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