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Knowledge-based remote sensing and GIS approach for forest type mapping in Kathua district, Jammu and Kashmir

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Abstract: India is endowed with diverse physiographic, edaphic and climatic conditions that manifested in a great variety of forests, flora and fauna. No significant efforts were made in past to study the spatial distribution of forest types in India. The Forest Survey of India (FSI) undertook this task on 1:50,000 scale using a knowledge-based remote sensing and GIS approach in 2004 under the National Natural Resource Management System (NNRMS) of the Government of India. The study involved analysis of multi-layered datasets (e.g. temperature, rainfall, DEM etc.), depicting the factors responsible for forest types of a given location, and remote sensing-based classification. The maps were ground-verified for accuracy. This paper presents the methodology and results for Kathua district in Jammu and Kashmir. Kathua has one of the highest number of forest types in the country. In this first-ever exercise, 19 forest types of Kathua district were mapped. It is hoped that maps will have high utility in preparing forest management plans and various scientific studies.

Resumen: La India está dotada con un conjunto diverso de condiciones fisiográficas, edáficas y climáticas que se manifiestan en una gran variedad de bosques, flora y fauna. En el pasado no se hicieron esfuerzos significativos para estudiar la distribución espacial de los tipos de bosque en la India. En 2004 el Inventario Forestal de la India (FSI, siglas en inglés) emprendió esta tarea a una escala 1:50,000, usando un enfoque de percepción remota basada en la experiencia y un SIG, en el contexto del Sistema Nacional para el Manejo de los Recursos Naturales (NNRMS, siglas en inglés) del Gobierno de la India. El estudio involucró el análisis de conjuntos de datos de numerosas capas (e.g. temperatura, precipitación, modelo digital de elevación, etc.), representando los factores responsables de los tipos de bosque de una cierta localidad, así como la clasificación basada en la percepción remota. La exactitud de los mapas fue verificada en el campo. Este artículo presenta la metodología y los resultados para el distrito Kathua en Jammu y Kashmir. Kathua posee uno de los números más altos de tipos de bosque en el país. En este ejercicio, realizado por vez primera, se cartografiaron 19 tipos de bosque del distrito Kathua. Se espera que estos mapas sean de gran utilidad para la preparación de planes de manejo forestal y estudios científicos de varios tipos.

Resumo: A Índia foi dotada com uma diversidade de condições fisiográficas, edáficas e climáticas que se manifestam por uma grande variedade de florestas, flora e fauna. No passado não foram feitos esforços significativos para estudar a distribuição espacial dos diferentes tipos florestais na Índia. O Inventário Florestal da Índia (FSI) assumiu esta tarefa numa escala 1:50,000 usando a base de conhecimento de detecção remota em 2004 e uma abordagem em SIG sob o Sistema de Gestão dos Recursos Naturais Nacionais (NNRMS) do Governo da Índia. O estudo envolveu a análise de dados multi-camadas (e.g. temperatura, queda pluviométrica, DEM, etc.) mostrando os factores responsáveis pelos tipos de florestas de uma dada localização, e a classificação baseada na detecção remota. Para garantia de precisão, os mapas foram validados no terreno. Este trabalho apresenta a metodologia e os resultados para o distrito de

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Kathua, em Jammu e Kashmir. Kathua foi onde se encontrou o maior número de tipos florestais no país. Neste primeiro exercício, foram mapeados no distrito de Kathua 19 tipos de floresta. Espera-se que estes mapas tenham uma grande utilidade na preparação de planos de gestão e de vários estudos científicos.

Key words: DEM, forest types, ground truth, knowledge engineer, reference map.

Introduction

India is one of the 12 mega-biodiversity regions of the world. Forest types of the country range from evergreen tropical rain forests in the Andaman and Nicobar Islands, the Western Ghats and the Northeastern region to dry alpine scrub in the Himalaya in the north. Between the two extremes, the country has semi-evergreen, deciduous monsoon, thorn, lower montane subtropical pine forests and temperate montane forests (Lal 1989). Classification of forests into types based on physiognomy, structure and composition *vis-à-vis* physical environment is an important step towards a thorough understanding of the ecosystem for successful management and conservation. Forest type may be defined as a unit of vegetation, which possesses (broad) characteristics in physiognomy and structure sufficiently pronounced to permit its differentiation from other such units. This is irrespective of physiographic, edaphic or biotic factors. The revised forest type classification of Champion & Seth (1968) is the widely used system of forest classification in India. They classified forests into six major groups based on moisture conditions. These major groups were further divided into 16 type-groups based on temperature and moisture regimes. Some type-groups were further divided into southern and northern forms. The type-groups were classified into 46 sub-types and 200 ecologically stable formations based on the locale-specific climatic factors. A small-scale map showing geographical distribution of the 16 forest type-groups in the country was prepared by the authors.

There have been no efforts to map the spatial distribution of forest types of India at a sufficiently large scale with or without remote sensing. Such a map on 1:50,000 or larger scale, would be of high utility in preparing forest management plans and various scientific studies. It is with this primary objective that a national level project under the National Natural Resource Management System (NNRMS) was taken up by Forest Survey of India (FSI) in the year 2004. This paper reports the methodology and results for Kathua district in Jammu and Kashmir state of India.

Materials and methods

Study area

Kathua district of Jammu and Kashmir (32º 00′ 17″- 32º 00′ 55″ N and 75° 01′ 00″ to 76° 00′ 16″ E), encompasses 2,651 km² area (Fig. 1). As per the 2001 census, the total population in the district is 544,206. Forest cover in the district is 1,158 km² (FSI 2005). Altitude in the district varies from 253 to 4162 m. The annual rainfall varies from 912 to 1801 mm while annual temperature varies from 9 to 23 °C in the district.

Data and material

The data sets used in the study are given in Table 1. *ERDAS Imagine* 9.1 and *ArcGIS* 9.2 software were used for digital image processing and spatial database handling respectively. In the past four decades extensive spatial information on forests has been generated by FSI using aerial photographs, satellite data and field inventory. The same was effectively used in this exercise.

Approach

Nationwide forest cover mapping is carried out by the FSI every two years using remotely sensed data (FSI 2005). The forest cover includes all tree patches of >1 ha size, whether natural forests or tree plantations and having a canopy cover of ≥10%. The objective of the present study was to assign forest types to all the natural forest patches following the Champion & Seth (1968) system of classification (200 forest types), which is primarily

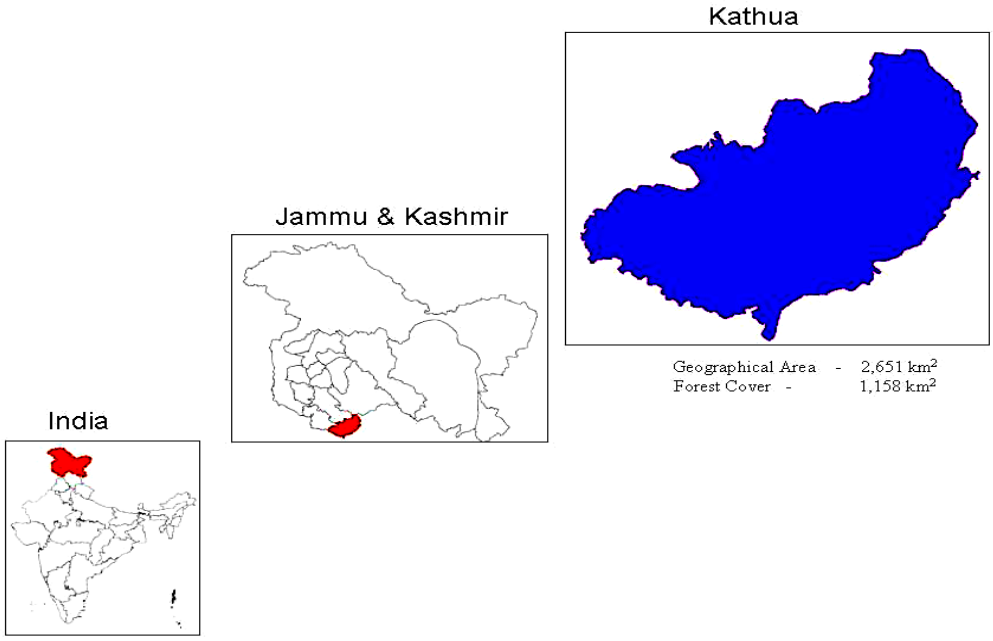

Fig. 1. Location of study area in India.

based on climate (rainfall and temperature), topography (altitude and aspect), soil types, species composition and successional stage. For assigning forest types to large numbers of widely scattered forest patches, relevant data on the parameters used by the Champion & Seth were required. Signatures based on satellite image interpretation alone were not sufficient for this purpose. Ancillary data such as digital elevation model (DEM), temperature, soil and rainfall and good ground truth are required for determining forest types in conjunction with the remote sensing data. The methodology followed in the study had five stages: (i) preparation of reference maps for gathering the existing and relevant information in the spatial form i.e. grids of 2.5′x 2.5′, (ii) pre-field classification of the satellite data, (iii) ground truthing, (iv) post-field correction and (v) field verification of the final map (Fig. 2).

Data from Forest Survey of India (FSI) and from other sources were brought together in the form of a reference map. The reference map for the purpose of this exercise was the GIS coverage of the grids of 2½′ x 2½′, covering approximately 20 km² area on ground. The attributes that were geo-referenced to the grids in the reference map were: (i) type of land cover (forest or non-forest), (ii) forest types as per thematic maps (land use maps prepared by FSI using aerial photographs) on 1:50,000 scale, (iii) altitude, (iv) temperature, (v) rainfall and (vi) soil. The reference map served the purpose of baseline information.

In the high-altitude hilly areas, altitude plays an important role in the microclimate and floral composition of the natural vegetation. To capture spectral variation in the satellite data attributable to different forest types, the satellite data was segmented in different altitude zones based on altitude description given by the Champion & Seth's classification (1968). Classification of each segment was then carried out following a K-means algorithm of unsupervised classification (Figs. 3 & 4). We superimposed classification of all the segments to generate a single 'pre-field classified map'. After analyzing the requirement for further improvement of the classification vis-à-vis conspicuous signatures, doubts and accessibility, we overlaid the points objectively on the map in such a manner that all the forest types were covered. The tonal variation of the forest types was possible only at the localized level. For this, the image segments based on altitude and climate homogeneity, yielded reasonably good separation of forest types when classified using unsupervised approach.

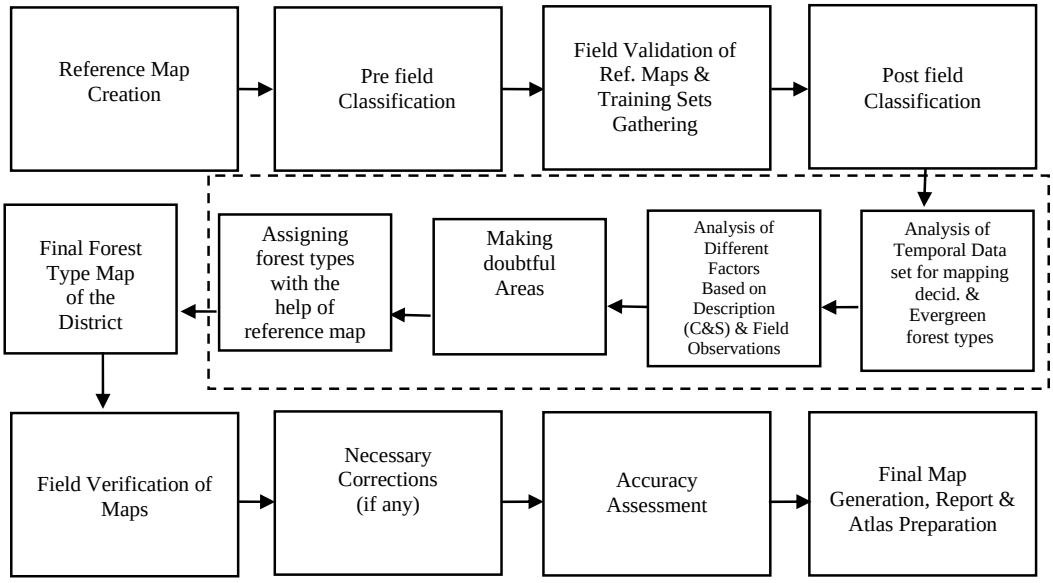

Fig. 2. Paradigm of the study.

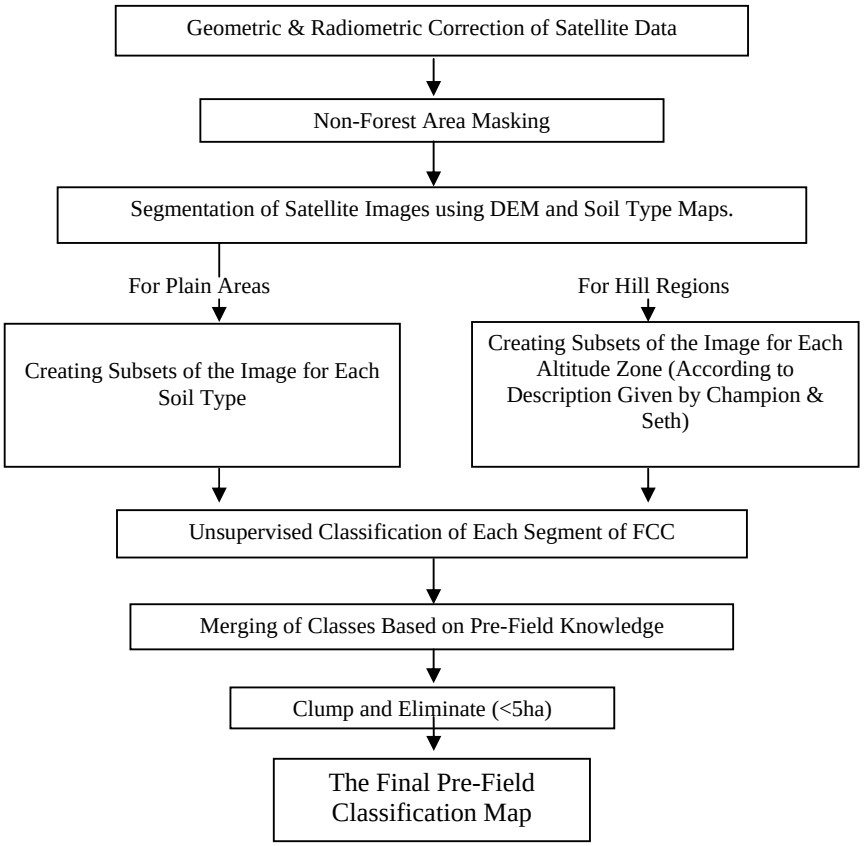

Fig. 3. Steps involved in pre-field interpretation.

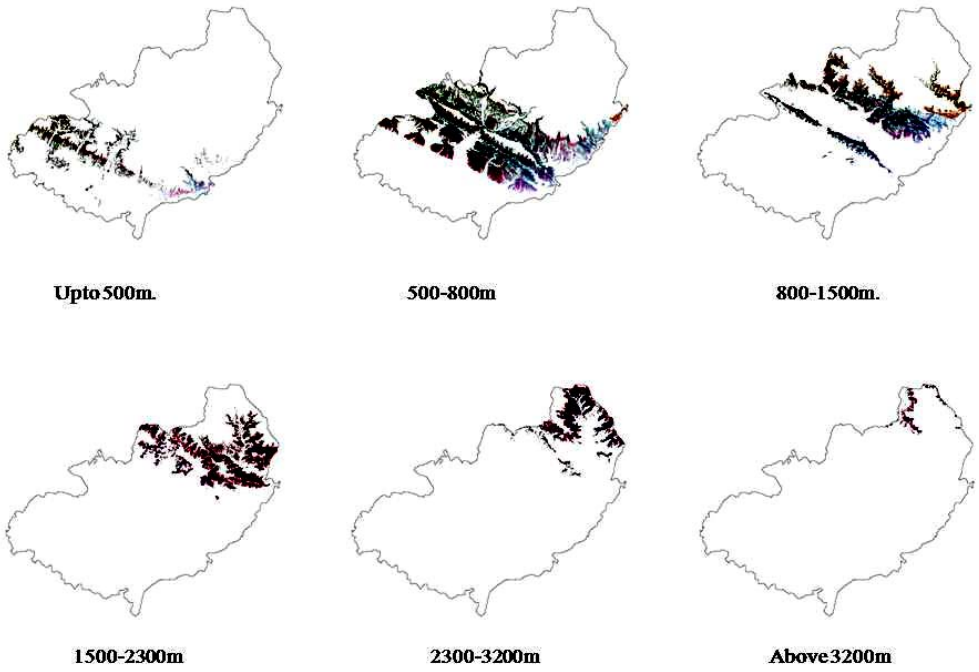

Fig. 4. Segments of FCC in different altitudinal zones.

Ground truthing of the pre-marked points on the classified maps provided useful information for necessary refinement, wherever warranted. The marked areas represented all the types on the map. The information available with State Forest Department on species composition, forest types,

Table 1. Spatial and non-spatial data used to delineate forest types in Kathua district.

Map	Sources*	Scale
Satellite data of IRS/1D (LISS-III) with spatial resolution of 23.5m x 23.5m	FSI	1:50,000
Land use maps based on aerial photo interpretation	FSI	1:50,000
Forest cover maps based on satellite data of 2003	FSI	1:50,000
Soil map	NBSS&LUP	1:5,000 scale
Digital Elevation Model (SRTM)	GLCF site	-
Political district boundaries	FSI	-
Climate (temp, rainfall) and elevation data	Center for Ecological Studies, Bangalore	10′x10′ grid size
Field inventory reports	FSI	-
Grid coverage * (2.5′x2.5′)	FSI	-

* India has been divided into 171,028 vector grids of size 2.5' x 2.5' (i.e. a vector grid of polygons with latitude and longitude intervals of 2.5 minutes each). Each grid is filled with information of forest cover density class from FSI forest cover maps, thematic information of forests from FSI's thematic maps based on aerial photographs, broad forest type as per FSI inventory on 1:1 million scale, soil information from National Bureau of Soil Survey and Land Use Planning (NBSSLUP), point coverage of temperature, rainfall, and elevation received from Indian Institute of Science, Bangalore. Forest Survey of India (FSI), Global Land Cover Facility (GLCF).

soil, climate, past treatment etc. was also collected. We created GIS coverage of the ground truth points by attaching the observations and photographs recorded on the points as attributes. This coverage was a good reference source for confirming the interpretation on the doubtful locations. After classification of the satellite data in the above manner, every patch was analyzed with respect to temperature, rainfall, soil and textual description available from other data sets (Table 1). Species composition described in the forest working plan was useful in identifying the forest types on ground.

Results and discussion

It is important to mention here that the intent of the exercise was limited to spatial identification of the forest types described by Champion & Seth leading to forest type map of the district; it was out of the purview of this study to explore any new forest type or redefine any forest type. The knowledge-based approach was used in classification of satellite data prior to visiting the field for ground truth. The criteria mentioned by Champion and Seth were used as rules for the classification (Table 2). Altitude was found to be the predominant factor in determining forest types in the study area. An attempt was also made to use the given set of criteria of altitude, rainfall, temperature and soil (Champion & Seth 1968) for identifying the forest types on the image using the "knowledge engineer" tool of *ERDAS Imagine*. The approach, however, did not facilitate the correct identification of all forest types. This could be attributed to the coarse resolution (i.e. large grid size) of the temperature and rainfall data. Visual on-screen analysis using the relevant layers along with the ground truth data and matching the same with the descriptions given by the Champion & Seth was found to be more appropriate.

The patch-wise analysis of the classification in this manner was done to generate the forest type map of the district (Fig. 5). Spatial analysis of the combination of data layers (Table 1) in conjunction with the ground details led to mapping of 19 forest types (Table 2). Description of the district's forest types given by Champion & Seth (1968) was particularly helpful in matching the climate and physiographic factors with the observed vegetation in different locations. Alpine scrub vegetation occurs throughout the Himalayas above 3000 to 3600 m altitude. The moist temperate forests are distributed along the entire length of Himalaya between 2100 and 3352 m altitude (Puri 1960). The extent of each forest type is given in the Table 3. Northern Dry Mixed Deciduous Forest (5B/C2) is the predominant forest type in the district occupying 25.2% of the total forest area. The main tree species of this forest are *Anogeissus latifolia* Wall., *Bombax ceiba* L., *Acacia catechu* Willd,

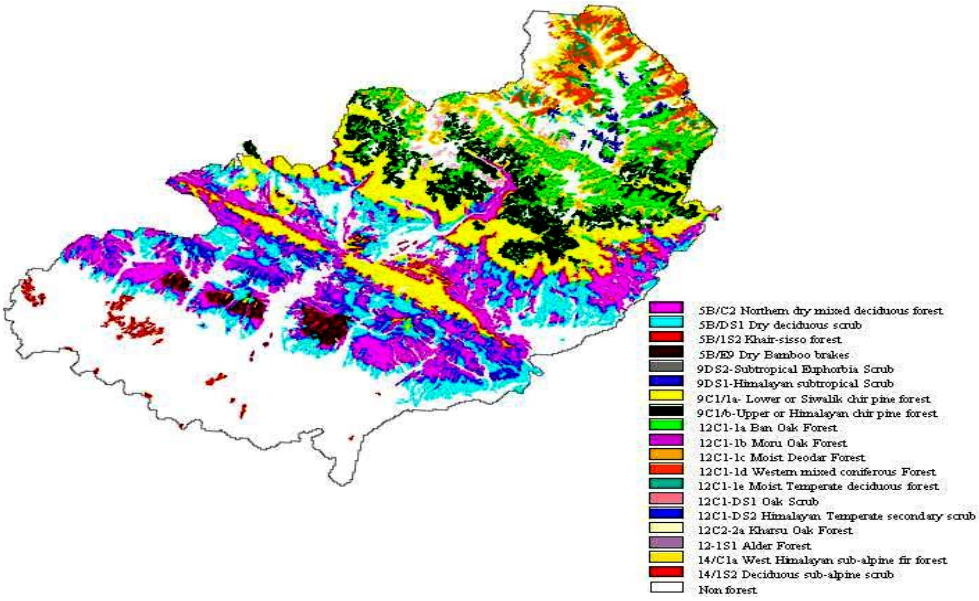

Fig. 5. Forest types mapped in Kathua district.

Table 2. Climate, soil and topography associated with different forest types.

Forest type	Species	Soil and topography	Aspect	Altitude (m)	Rainfall (mm)	Temperature (°C)
5B/C2 Northern Dry Mixed Deciduous Forest	*Lannea coromandelica, Anogeissus latifolia, Bombax ceiba, Acacia catechu, Emblica officinalis, Termilalia tomentosa, Acacia modesta, Cassia fistula, Ficus* sp.	Alluvial soil	South	300-1200	900-1500	24-27
5B/DS1 Dry Deciduous Scrub	*Acacia catechu, Cassia fistula, Lannea coromandelica, Euphorbia royleana, Randia* sp. , *Carissa* sp., *Woodfordia fruticosa*	Alluvial soil		300-1200	900-1150	24-27
5B/E9 Dry Bamboo Brakes	*Dendrocalamus strictus, Anogeissus latifolia, Lannea coromandelica*	Alluvial soil mostly dry		300-1200	900	24-27
5B/1S2 Khair-Sissoo Forest	*Dalbergia sissoo, Acacia catechu*	Sandy or gravelly alluvium		below 400		24-27
9C1/1a- Lower or Shiwalik Chir pine	*Pinus roxburghii, Terminalia chebula, Mallotus philippensis, Acacia catechu*	Shiwalik zone		below 1000		15-20
9C1/b-Upper or Himalayan Chir pine	*Pinus roxburghii, Quercus incana, Shorea robusta*			1200-1800	900-2500	15-20
9DS1-Himalayan Subtropical Scrub	*Carissa* sp., *Dodonea* sp., *Rhus parviflora* with northern mixed deciduous species	Dry and Shallow soil		1200-1800		
9DS2-Subtropical Euphorbia Scrub	*Euphorbia royleana, Carissa* sp., *Dodonea* sp., *Rhus parviflora*	Rocky ridges		1200-1800		
12C1-1a Ban-Oak Forest	*Quercus incana, Rhododendron arboreum, Lyonia* sp., *Ilex dipyrena*	Good soil rich in humus	Southern	1800-2300		4-5
12C1-1b Moru Oak Forest	*Quercus dilatata, Quercus incana, Abies pindrow, Cedrus* sp., *Rhododendron arboreum, Lyonia* sp., *Ilex dipyrena*	Moist soil		2000-2500		4-5
12C1-1c Moist Deodar Forest	*Cedrus deodara, Pinus wallichiana, Quercus incana*	Steep rocky Limestone Slopes		1700-2500	1100-1800	4-5
12C1-1d Western Mixed Coniferous Forest (spruce, blue pine, silver fir)	*Abies pindrow, Picea smithiana, Cedrus deodara, Pinus walichiana, Quercus dilatata, Q. incana, Taxus buccata, Betula alonoids*			2400-3000	1000-1140	4-5
12C1-1e Moist Temperate Deciduous Forest	*Acer caesium, Betula* sp., *Q. semecarpifolia, Ulmus* sp., *Abies pindrow*			1800-2750		4-5
12C1-DS1 Oak Scrub	*Rhododendron arboreum, Lyonia ovalifolia, Pyrus pashia, Q. dilatata, Q. incana, Q. semecarpifolia*	Severely eroded		1800-2300		4-5

Contd....

Table 2. Continued.

Forest type	Species	Soil and topography	Aspect	Altitude (m)	Rainfall (mm)	Temperature (°C)
12C1-DS2 Himalayan Temperate Secondary Scrub	*Quercus incana* forest, *Plactranthus rugosus, Berberis asiatica, Caratagus cernulata*		South	1800-2200		4-5
12C2-2a Kharsu-Oak Forest	*Quercus semecarpifolia. Picea smithiana, Pinus wallichiana, Rhododendron arboreum, Ilex dipyrena*		South	2500-3300		4-5
12-DS2- Himalayan Temperate Parklands	*Grasses, Acer* sp., *Rumex nepalensis, Juglans regia*					4-5
12-1S1 Alder Forest	*Alnus nitida, Populus ciliata, Ulmus villosa, Celtis* sp., blue pine			1000-3000		4-5
12-2S1 Low level Blue Pine Forest	*Pinus wallichiana, Q. dilatata, Q. incana*	Alluvial deposits near rivers		1500-2400		4-5
14 - 1S2 Deciduous Sub-alpine Scrub	*Betula, Alnus, Syringa emodi, Salix* sp., *Lonicera* sp.			2900-3500		
14 - DS1 Sub-alpine Pastures	*Grasses, Agropyron longearistatum, A. semicostatum, Brachypodium sylvaticum, Bromus asper, B. japonicus, Dactylis sp., Danthonia* sp., *Festuca* sp., *Milium effusum, Oryzopsis* sp., *Phleum* sp., *Poa* sp., *Betula utilis, Acer* sp.			2900-3500		
15C2- Deciduous Alpine scrub	*Betula utilis, Syringa emodi, Salix* sp., *Lonicera* sp.			2900-3500		
15C3- Alpine Pastures	*Mesophytic herbs with grasses, Primula* sp., *Anemone* sp., *Fritillarea* sp., *Iris* sp., *Gentiana* sp., *Ranunculus* sp.			3000-3700		

Table 3. Forest types and their extent in Kathua district.

Forest Type	Area (km^2)	Area (%)
5B/C2 Northern Dry Mixed Deciduous Forest	290	25.2
5B/DS1 Dry Deciduous Scrub	188	16.4
5B/E9 Dry Bamboo Brakes	24	2.1
5B/1S2 Khair-Sissoo Forest	1	0.1
9C1/1a- Lower or Shiwalik Chir Pine	190	16.6
9C1/b-Upper or Himalayan Chir Pine	127	11.0
9DS1-Himalayan Subtropical Scrub	48	4.1
9DS2-Subtropical *Euphorbia* Scrub	2	0.2
12C1-1a Ban Oak Forest	102	8.9
12C1-1b Moru Oak Forest	2	0.2
12C1-1c Moist Deodar Forest	66	5.7

Contd....

Table 3. Continued.

Forest Type	Area (km²)	Area (%)
12C1-1d Western Mixed Coniferous Forest (spruce, blue pine, fir)	48	4.2
12C1-1e Moist Temperate Deciduous Forest	13	1.1
12C1-DS1 Oak Scrub	8	0.7
12C1-DS2 Himalayan Temperate Secondary Scrub	9	0.8
12C2-2a Kharsu Oak Forest	2	0.1
12-1S1 Alder Forest	1	0.1
14/C1a West Himalayan Sub-alpine Fir Forest	26	2.3
14/1S2 Deciduous Sub-alpine Scrub	1	0.1
Total	1,148	100.0

Emblica officinalis Gaertn., *Terminalia tomentosa* Wight & Arn., *Acacia modesta* Wall. and *Cassia fistula* L.. The forest types seen in the district largely confirmed to the topographic and climatic conditions described by Champion & Seth (1968). At several locations, the forests were found in the varying stages of degradation. Regeneration of forest was also observed wherever protected, which indicates that the forests have adequate regenerative capacity and can be restored through long-term protection-facilitated natural succession.

Conclusions

The present study culminated in the first-ever forest type map of the district on 1:50,000 scale. The study demonstrated effective role of the spatial technologies *viz*., remote sensing, GIS and GPS in mapping forest types. The study showed that synergistic use of remote sensing and physico-climatic data facilitates in mapping of the forest types; latter should have appropriate resolution. The spatial tools in GIS framework effectively facilitate multi-layer analysis of spatial data and there is no alternative to detailed and objective field observations in such an exercise. A follow-up of this study could be a detailed inventory of trees, shrubs and herbs in each forest type of the district to prepare suitable plans specific to each forest type for conserving and promoting biodiversity

References

Champion, H.G. & S.K. Seth. 1968. *A Revised Survey of the Forest Types of India.* Govt. of India Publications, New Delhi.

FSI. 2005. *State of Forest Report 2003.* Forest Survey of India, Ministry of Environment & Forests, Government of India, Dehradun.

Lal, J.B. 1989. *India's Forests: Myths and Reality***.** Natraj Publishers, Dehradun, India.

Puri, G.S. 1960. *Indian Forest Ecology - A Comprehensive Survey of Vegetation and its Environment on the Indian Subcontinent.* Vol. I. Oxford Book & Stationary Co., New Delhi.