WORKING PAPER 213

SPATIO-TEMPORAL ANALYSIS OF FORESTS UNDER DIFFERENT MANAGEMENT REGIMES USING LANDSAT AND IRS IMAGES

Sunil Nautiyal

INSTITUTE FOR SOCIAL AND ECONOMIC CHANGE
2009

SPATIO-TEMPORAL ANALYSIS OF FORESTS UNDER DIFFERENT MANAGEMENT REGIMES USING LANDSAT AND IRS IMAGES

Sunil Nautiyal*

Abstract

Following the empirical study, cloud-free satellite data were used to study the forests in multi-temporal dimensions. Use of remote sensing data with visual observation/ground truth data is an advanced tool to study and understand the development patterns of the forests. Based on the vegetation index and land cover map a sound development has been observed in the community conserved forest (CCF) in comparison to other forests of the region. Community-based conservation would contribute to new conservation approaches that facilitate achieving the goal of sustainable landscape development in the mountains of the Indian Himalayan region.

Introduction

Every location on the earth at present is either directly or indirectly affected by human activities as the world's population has exceeded six billion. Governments are now moving to take control over the forests and forest resources for their conservation. A few decades ago, the concept of large nature conservation areas such as national parks gained wide popularity and this approach was functioning well, as it was implemented only in minimum human influence areas. However, this approach has been attracting more criticism when implemented in the areas with more human influence, leading to conflicts between different interest groups ((Liu et

---

* Centre for Ecological Economics and Natural Resources, Institute for Social and Economic Change, Dr. V.K.R.V. Rao Road, Nagarabhavi, Bangalore - 560 072, India.

Author extends sincere thanks to the anonymous reviewers for comments and suggestions on earlier draft of the manuscript. Special thanks to the Japan Society for the Promotion of Science (JSPS) for financial support for the purchase of remote sensing data. The views expressed in this article are those of the author and do not necessarily reflect the opinions of organization.

al. 1999; Liu, 2001; Chen et al. 2005). Especially in developing countries, the top-down approach for control of natural resources in the name of conservation is being criticized and found as a main cause of conflict that creates major hurdle for both conservation and development (Maikhuri et al. 2001; Stefania 2001; Chen et al. 2005). Consequently, there are increasing moves in many countries to gain a broader understanding of the notion of protected areas and to include the areas of biodiversity significance that are owned or controlled by communities with the areas of governmental designed ones (IUCN, 2002; 2004). Studies in this direction (Lewis et al. 1990; O'Connell-Rodwell et al. 2000) reported that, in some countries, community-based management systems have been established for restoring benefits. The customary laws set up within communities, with which they are successfully involved in management of forests and restoring the biodiversity, need to be incorporated with the governmental schemes aimed at conservation and management of the resources (Kothari et al. 1998; Pretty and Smith 2003). The empirical study on different forest types (viz., traditionally conserved forest [TCF], governmental conserved forest [GCF] and community conserved forest [CCF]) was conducted to test the hypothesis "that how forest structures differ from each other under above-mentioned conservation regimes and as to which conservation programme yield more fruitful results". With the help of empirical study forest, conserved through community efforts (CCF) was found to be diverse and rich followed by TCF and GCF. The results of empirical study can only envisage the structure of the forests, but not the development of the spatial dimension of the forests and vegetation dynamics. In this endeavor analysis of remote sensing data would significantly substantiate the findings as this is an effective tool for mapping and characterizing the natural landscape and provides opportunities to measure the biophysical parameters in multi-temporal dimensions (Holz 1985; Lo 1986; Jensen 1996; Walkder et al. 1992; Wang and Moskovits 2001). Study of this aspect would be helpful to emphasize better approaches for policy makers and decision makers in the highly diverse but fragile landscape of the Himalaya. Therefore, the objectives of this study are to complement, in-depth field study done in the Himalaya of India and to try to determine significant conservation approaches for forest ecosystem conservation under changing social, cultural and political environment conditions in the Indian Himalayan mountains.

Study area and climate

The present study sites are located in Pithoragarh (29°30′23″–29°32′17″N and 80°9′51″–80°14′45″ E), Chamoli (30°30′29″–30°33′25″N to 79°26′3″–70°29′37″E) and Tehri (30°19′20″–30°22′15″N and 78°19′10″–78°21′30″E) administrative districts of Uttarakhand. The study parameters are described in Table 1. The forests types located in these three administrative districts come under the category of Himalayan moist temperate forests as per Champion and Seth's (1967) classification. Three conservation regimes for forest resource management are (1) traditional conserved forests, (2) government conserved forests and (3) community conserved forests. The traditional system of conservation, by which people have been successfully conserving the forest resources with the belief in nature worship inherited from their ancestors (Khumbongmayum et al. 2006), here it is termed as traditional conserved forests (TCF). The forest located in Pithoragarh district is the example of TCF. (2) The conservation approach developed in a more scientific way and forest policies are implemented to achieve conservation goals and termed here as government conserved forests (GCF). Besides the most traditional (sacred) to new approach (implementation of forest policies) other efforts are being continued for the conservation and management of forest resources and here the name for such kind of forest is given - community conserved forests (CCF).

Table 1: Some characteristics of studied Forests of Central Himalaya

Parameters	Forests types		
	Traditional Conserved Forest (TCF)	Government Conserved Forest (GCF)	Community Conserved Forest (CCF)
Approximate area (ha)	1300	800	850
Aspect	North	North-west	North
Altitude (m)	1600-2450	1800-2300	1500-1935
Slope (degree)	30-40	35-45	25-35
Forest types	Mixed	Mixed	Mixed
Category of the forest	Moist Temperate	Moist Temperate	Moist Temperate
Biotic pressure	Moderate to high	Moderate to high	Moderate
Ground vegetation	Dense	Comparatively sparse	Moderate Dense
Management regimes	Traditional, socio-cultural	Government control	Community rules

Characteristics of studied forests of the Central Himalayas

- **Traditional conserved forests (TCF):** Traditional conserved forests or sacred forests are the patches of climax vegetation protected in the belief of keeping them "unmolested as biodiversity of these groves are offered to local deities" (Ramakrishnan 1996; Ramanujam and Kadamban 2001; Bhagwat et al, 2005, Negi 2005). The beliefs pertaining to conservation of such forest patches have been passed on to generation after generation. The TCF has been identified in many parts of the world, generally inhabited by different cultural groups and forming an integral part of the rural landscape (Ramakrishnan 1996; Ramanujam and Kadamban 2001; Bhagwat et al, 2005; Khumbongmayum et al. 2006). The number of sacred forest/groves in India is estimated somewhere between 100,000 and 150,000 (Malhotra 1998) with about 600,000 villages in the Indian countryside (Census of India 2001)—further details can be found in Bhagwat et al. 2005. The TCF located in the Pithoragarh district of Uttarakhand state is one such example of traditional conservation where people have fervently guarded their forest and biodiversity for generations (Negi 2005).

- **Government conserved forests (GCF):** Generally these forests are controlled by the forest department and the involvement of villagers in management and conservation has been excluded. Villagers adjacent to such kind of forests are required to seek the permission from the forest department for using the forest resources. This form of taking over the rich and diverse landscapes for preservation and conservation of biodiversity and resources is common all over the world since the establishment of the world's first national park "Yellowstone" in 1872 (Pretty and Smith 2004). The 1878 Forest Act laid the legal basis for the demarcation of forests as state property. The most commercially valuable tracts were chosen, and often taken over from community ownership (Khare et al. 2000; Taneja, 2001). The evolution of forestry policy in India is fully described in Bandyopadhyay et al. (2005).

- **Community conserved forests (CCF):** In recent years, community conserved forests have been recognized in more scientific ways and have attracted the attention of conservationists, forests researchers and environmentalist seeking to understand the theory behind community-based conservation (Kothari et al. 1998). Community-based conservation is built on the theory that the conservation and development goals could be achieved simultaneously, rather than making them separate from each other. This is because that it is not necessary to have the same goal for both – the community development objectives and the conservation objectives (Berkes 2004).

Methodology

The remote sensing data were used to analyze the developmental pattern of the forests of different conservation regimes during the last three decades. This study was undertaken soon after the structure of the forests was studied based on the empirical study and received a remark that the empirical study needed further research. Visual observation with remote sensing data is a very good tool for comprehending ecosystem studies (Wang and Moskovits 2001) while emphasizing the interaction between anthropogenic and natural resource systems in the past few decades. This gives geographic and temporal information regarding land use and land cover change analysis and is helpful to understand the extent of human dimensions on environmental change and the outcome of human actions across the landscape. The earliest cloud-free data for the study region were rectified "Landsat [acquisition date 26-10-1972; 26-10-1979 (path/ row-156/039; Multi-Spectral Scanner-MSS); IRS (22-10-1992 (path/ row-027/046; Linear Imaging and Self Scanning-LISS-1); 23-10-2002 (path/row-145/039 Enhanced Thematic Mapper-ETM+ (path/row-145/ 039)) to cover TCF and GCF and "Landsat (14-11-1972, 14-11-1979 (path/row-157/039; MSS) and 08-10-2000, 13-04-2005 (path/row-157/039 ETM+)]" to cover the CCF. The image rectification was completed and images rectified and restored manually using the ENVI image to map registration method. A satellite differential GPS was used in the field (accuracy ˜ 2 m) to collect geo-referenced information for geometric correction of the satellite imagery using the ground control points (GCPs). Easily recognizable landscape features—such as confluence of the rivers, water channels, agriculture, village, different forest types—were recorded and used to correct the images with the help of ArcGIS 9.0. An example of ground truth data for overlaying vector on image is shown in Table 2. The ETM+ imagery of the region was selected as a base map of the area. Once the coefficients for the equations were determined, the distorted image coordinates for map position could be precisely estimated, expressing this in mathematical notation (Lillesand et al. 2004).

$$x = f1(X,Y) \quad y = f2\ (X,Y)$$

where (x,y) = distorted-image coordinates (column, row); (X,Y) = correct (map) coordinates;

f1, f2 = transformation functions

After the geometric correction, the Normalized Difference Vegetation Index (NDVI) was calculated while using the following formula (Rouse et al. 1974).

$$NDVI = \frac{NIR - \mathrm{Re}\, d}{NIR + \mathrm{Re}\, d}$$

where "NIR" is value of Near-Infrared Radiation from a pixel. NDVI data were used to develop the land cover maps.

Table 2: Landscape characteristics recorded with the help of GPS for land use land cover classification (an example)

Point ID	Latitude	Longitude	Elevation (m asl)	Landscape characteristics
41	30°,23′,55″	79°,19′,38″	1027	Chamoli Town (An administrative district of Uttarakhand state)
301	30°,31′,50″	79°,29′,23″	1428	Vegetation dominated by pine
302	30°,31′,45″	79°,29′,30″	1854	Village settlement and agriculture
310	30°,32′,09″	79°,27′,32″	2127	Village settlement and agriculture
298	30°,31′,36″	79°,28′,33″	2330	Rhododendron-Oak (Quercus) patches
412	29°,31′,38″	80°,12′,21″	2313	Degraded site in the forest
407	29°,31′,32″	80°,12′,56″	2330	Old Quercus patches
414	29°,31′,28″	80°,12′,36″	2354	Old Quercus patches
415	29°,31′,21″	80°,13′,01″	1840	Vegetation dominated by pine
426	29°,31′,29″	80°,12′,08″	1945	Shrubs with few tree
439	29°,31′,37″	80°,13′,10″	2017	Shrubs with few tree
476	29°,31′,31″	80°,12′,45″	2522	Mixed tree vegetation having dense canopy
455	29°,31′,39″	80°,13′,11″	2312	Open land
443	29°,31′,48″	80°,13′,45″	2134	Agricultural fields
465	29°,31′,39″	80°,11′,46″	2008	Agricultural fields and settlements
487	29°,34′,53″	80°,12′,27″	1660	Pithoragarh Town (Administrative district of Uttarakhand state)
502	30°,20′,01″	78°,20′,29″	1868	Shrubs with few tree
512	30°,20′,17″	78°,20′,18″	1620	Agricultural fields and village settlements
515	30°,20′,12″	78°,20′,22″	1860	Open land
519	30°,20′,03″	78°,20′,28″	1972	Quercus patches
534	30°,20′,10″	78°,20′,32″	1960	Mixed tree vegetation having dense canopy

All the information generated here were interpreted with GCPs, field data, field observation, in-depth knowledge of the area and plant communities. With the help of ArcGIS 9.0, the ground truth data was converted into a shape file and was overlaid on the image as a vector file precisely in order to minimize errors in the categorization of land cover in the forest areas. The decision tree classification was followed for forest cover classification. The decision tree classifier performs multistage classifications by using a series of binary decisions to place pixels into classes (Friedl and Brodley 1997). The example is presented in Figure 1.

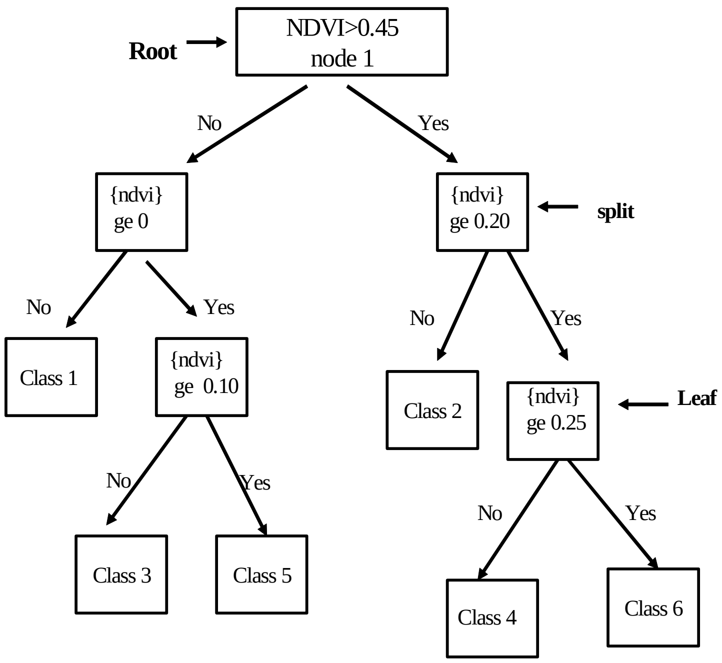
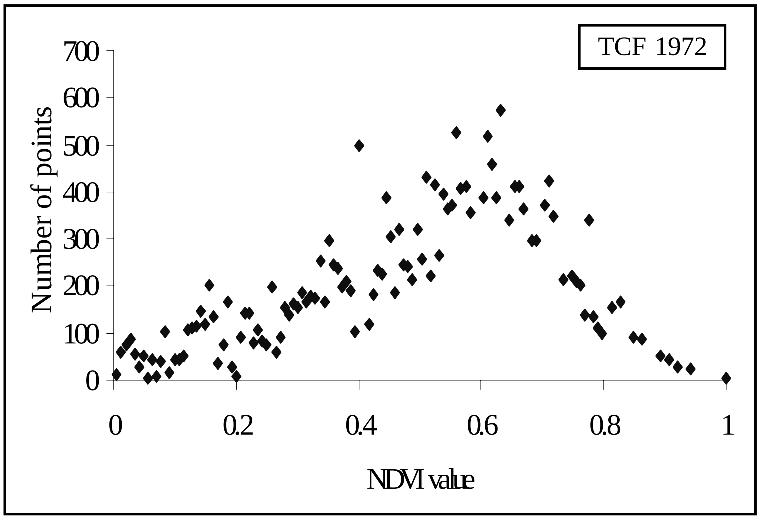
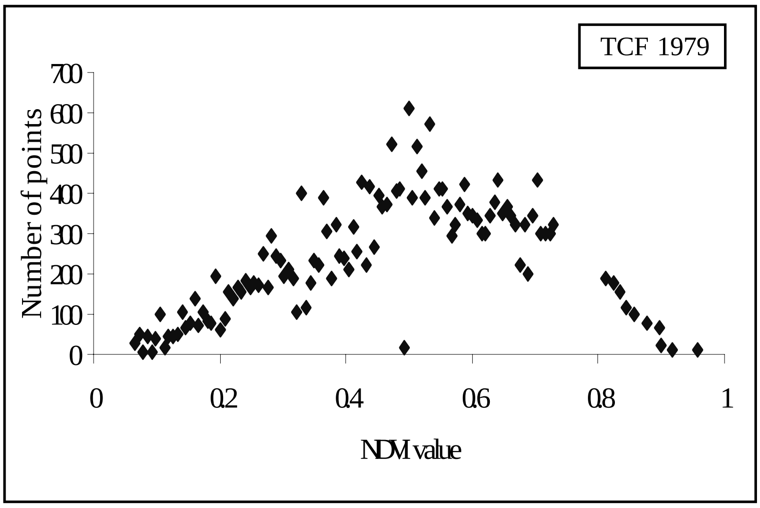


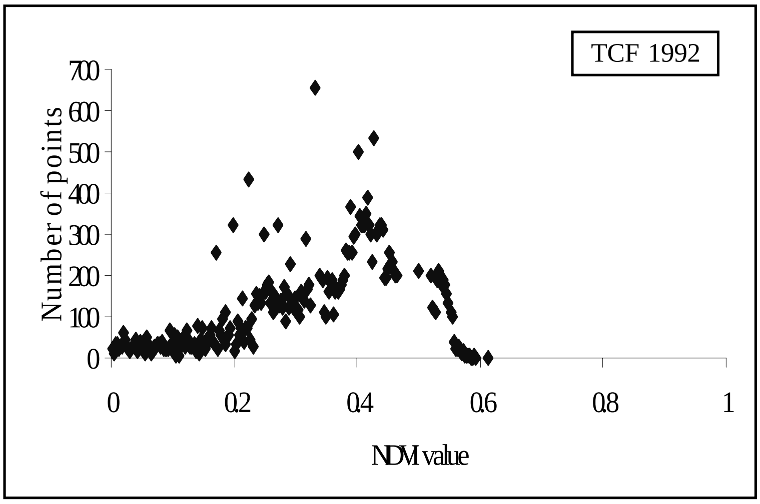
Figure 1: Example showing decision tree classification procedure (Nautiyal and Kaechele, 2007a)

Results and Discussion

The empirical study showed that community conserved forest "CCF" is comparatively richer at present. However, to emphasize any such recommendation for the conservation approaches it is necessary to generate the long history as to how such forest has achieved its current state and structure. Remotely sensed data has considerable significance for estimation of forest stand parameters with large areas—not only through spatial transformation of results but also as an instrument to analyze temporal development to provide research-based recommendations (Sandstrom et al. 2003; Nautiyal and Kaechele 2007a). In this endeavor remote sensing with multi-temporal data collection allows one to perform integration more quickly and effectively (Wang and Moskovits 2001; Singh et al. 2002). The advantage of this approach is more noteworthy in missing historical ground data. The field-based study done here in different forests under different conservation regimes concluded that diversity and density are two important indicators for assessment of the quality of natural forests. However, by using only field-based data, it is hard to conclude the pattern of development of forests conserved under different management regimes during previous years. The output of remote sensing data analysis is able to show the changes in vegetation index clearly at different points of time. The field-based study supported this analysis by use of satellite data. Among all the studied forests, the pixels of CCF are showing positive results with the passage of time. However, the pixels of TCF and GCF showed negative results in the vegetation index with increasing time period (Figures 2–4).


TCF 1972
Number of points
700
600
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
NDVI value


TCF 1979
Number of points
700
600
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
NDVI value



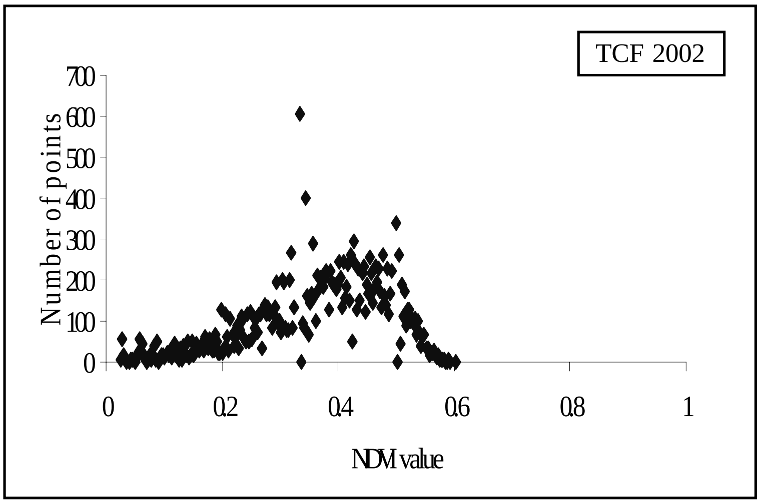
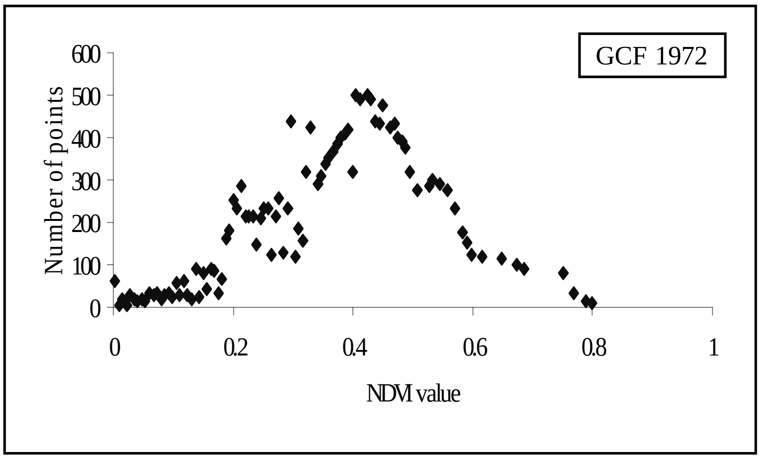
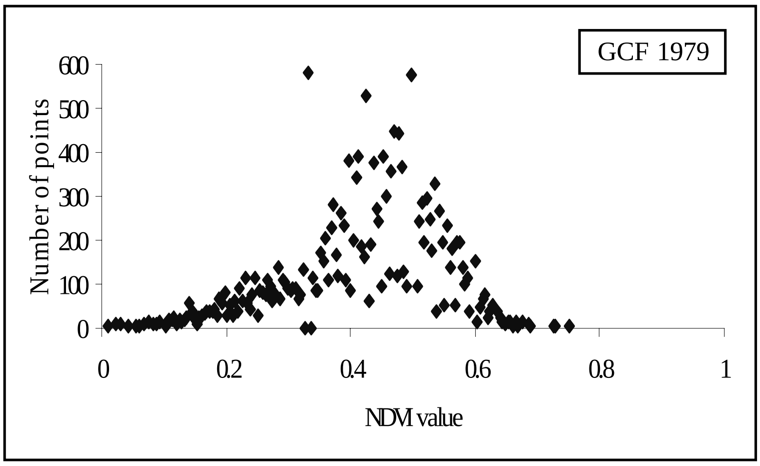


Figure 2: Vegetation index of TCF at temporal dimensions

Figures 2–4 are showing normalized diversity vegetation index values of each studied forest at four points of time. From these results it is clearly seen that NDVI values are decreasing with increase of time for the traditional sacred forest "TCF" and the government forest "GCF" (Figure 3 and Figure 4). During 1972 the forest cover of TCF was very good as vegetation index was found to be very sound and the number of points for vegetation index value (>0.6) for this forest was noted as being the highest. From 1972 to 1979 the vegetation index was almost similar but it was noted that the number of points increased with decreasing vegetation index. But for the period 1979 to 1992 it was noted that the vegetation cover and dynamics had decreased to a great extent and the value for vegetation index has been observed to be 0.61, down from the value of 0.92. The vegetation index found to have changed between 1992 and 2002, but not as negatively as was noticed for the period of 1979 and 1992 (Figure 3).





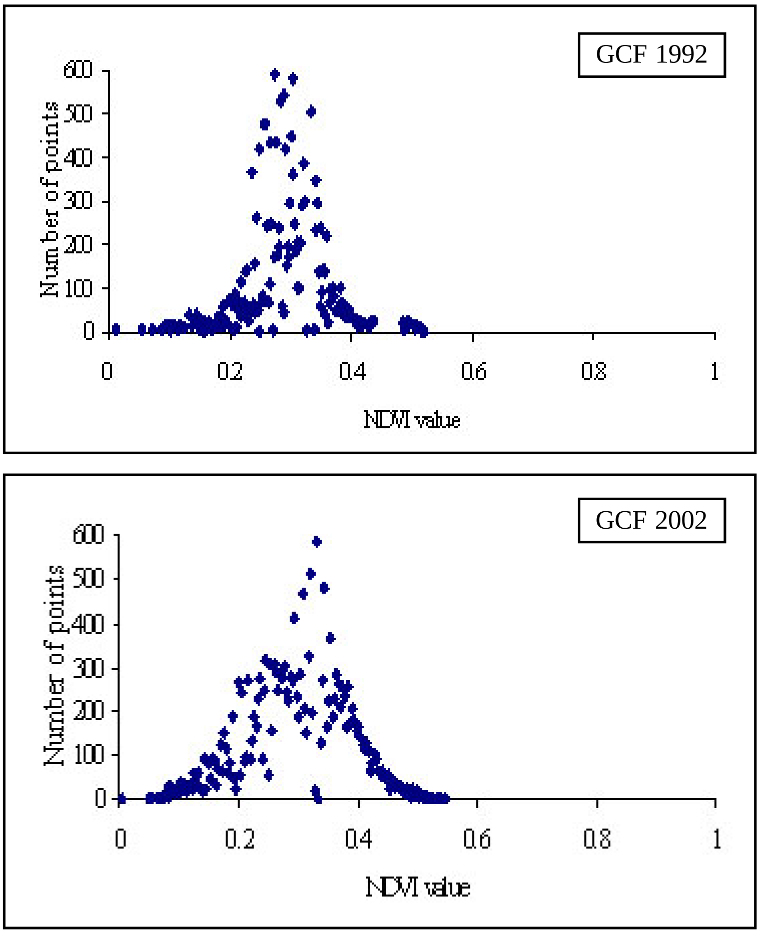
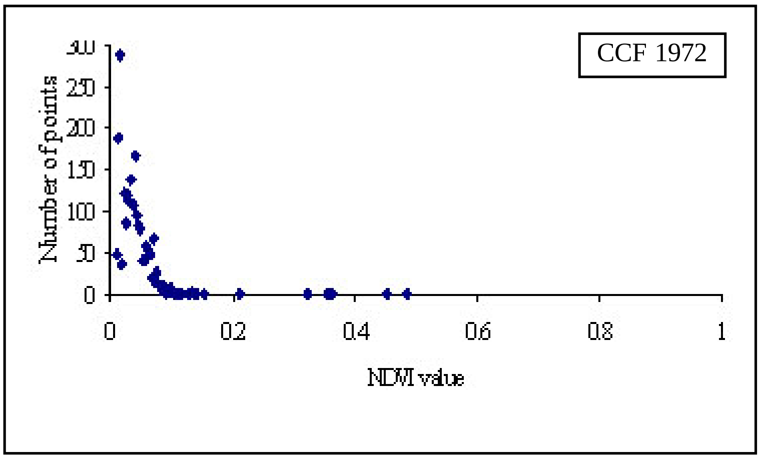
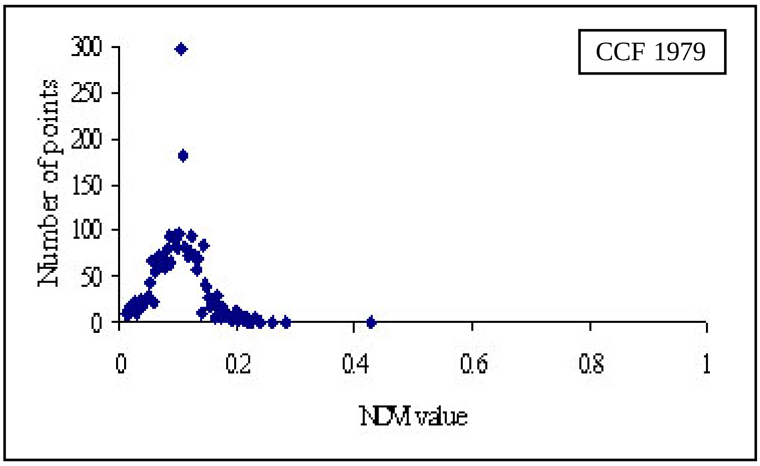
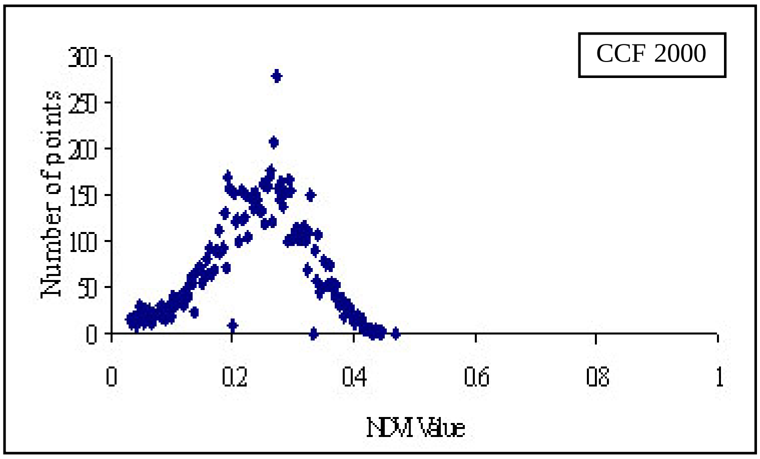


Figure 3: Vegetation index of GCF at temporal dimensions

For the GCF the change in vegetation dynamics was noticed as seen for TCF with a very sharp decline in vegetation index for the period of 1979 to 1992. The vegetation index between 1992 and 2002 was found changed for GCF but not as high as was found for this forest between 1979 and 1992 (Figure 4). In contrast to TCF and GCF we have found positive change in vegetation index for the CCF. The vegetation index of CCF for the period of 1972 showed very poor vegetation cover in that forest with the value for the whole forest being <0.2, an indication of poor vegetation cover. From the period of 1972 to 1979 it was noted that the index had increased. But surprisingly, the vegetation cover of CCF from 1979 to 2000 and also for the period 2005 was found increasing (Figure 4). Based on the results presented in Figures 2–4 the vegetation cover map was developed for the period of 1979 and 2002 for TCF and GCF and for the period of 1972 and 2000 for CCF.







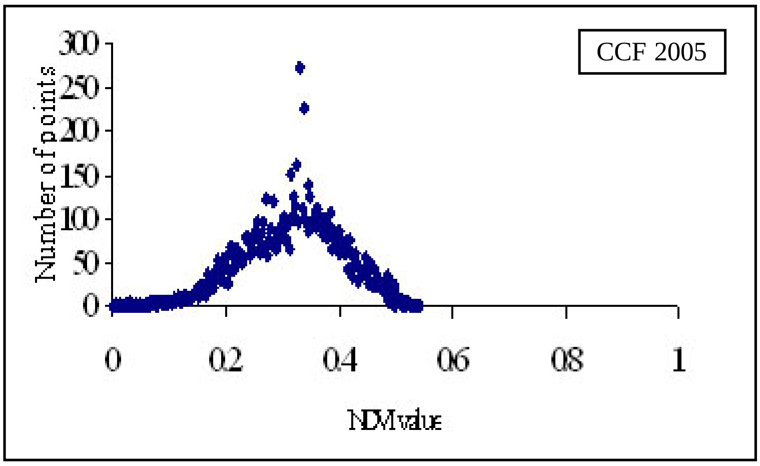
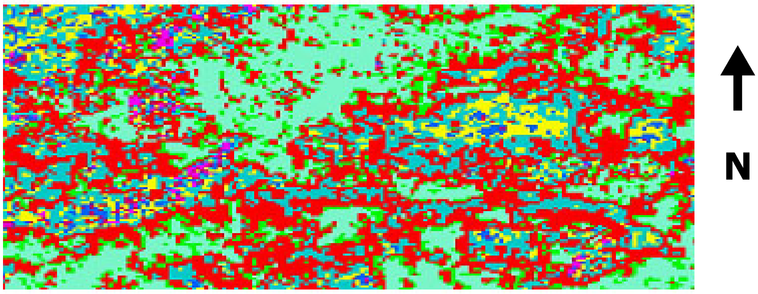


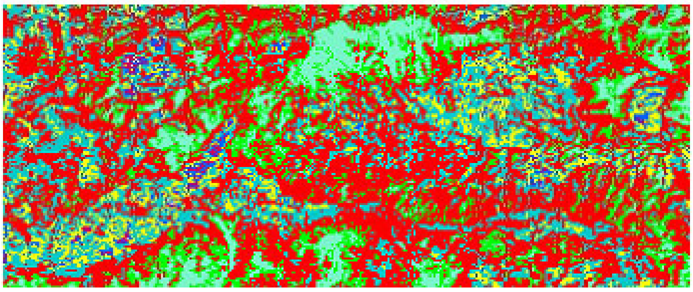
Figure 4: Vegetation index of CCF at temporal dimensions

In the Himalayan region, besides providing economically valued resources the forests are the basis for sustainability of agriculture as traditional agriculture in the mountains is entirely dependent on the productivity and quality of the forests. Hence, there is an urgent need to analyze the demand on resources to meet the requirements of agricultural production. Lack of awareness among the people; ecosystem degradation arising from traditional practices of litter collection, for maintaining agricultural soil fertility and unsustainable harvesting; and overexploitation of the resources such as fuel, fodder and timber are all threats to forest biodiversity (Singh et. 1984; Pilbeam et. al. 2000). The conservation, management and development of the forests and resource utilization from these reservoirs are currently crucial issues in different parts of the world. This needs additional attention as the forests of the mountains equally affect the lowland landscape (Saxena et al. 2001; 2005). The pressure on forests can be assessed by analyzing the use of their major resource types such as collection of forest resources for fodder, fuel, timber and use of leaf litter for preparation of manure; collection of plants, mainly branches of trees, for fencing the agricultural crops and for agricultural tools. At present it is difficult to quantify the resources from the studied forests but the land cover classification can help to visualize and understand the pressure on the abovementioned resources in the forests of different conservation regimes. The vegetation index has decreased for TCF and GCF due to a variety of reasons. Regarding TCF, the empirical studies of this aspect indicates that changes in socio-cultural and religious beliefs, and migrants with different cultural value systems and beliefs, can adversely affect such kinds of traditional reservoirs—consequently they are no longer noticeable as unscathed ecosystems (Saikia 2006). Lack of awareness, restrictions on traditional usufruct rights of the local people over the forest resources and overexploitation have been identified as some of the main factors responsible for degradation of the Himalayan forests (Sen et al. 2002; Wakeel et al. 2005). Unfortunately, minimal efforts are being made to improve conservation of the forests, such as TCF, especially if exploitation of the resources has commenced from such previously untouched ecosystems.

From the land cover map of the studied forests the changes are clearly seen. For example, the TCF forest was highly dominated by *Quercus–Rhododendron* and *Quercus* patches till 1979 due to the strict protection given to preservation of the resources from this reservoir and which have now started getting disturbed. When comparing the classification results of 1979 with the classification results of 2002 it is clearly be seen that most of such patches are being removed and being converted into other class forms (Figure 5). The land cover map developed here shows the conversion of dense canopy to sparse canopy and invasion of pine population in the forest that is a threat to the vegetation dynamics which were once part of the unmolested ecosystem of the Central Himalayas. The picture shows the same observation for GCF as patches of *Quercus* and *Rhododendron* have been heavily exploited recently and there is increasing expansion and invasion of conifer dominated patches and land mark shrubs with few trees (Figure 6). However, this seems to be comparatively higher in GCF than the TCF. The exploitation of these forests is an indication of unsustainable forest management of the Central Himalayas. At temporal dimensions the land cover map for CCF shows a very positive result (Figure 7). The forest was once categorized as open land, degraded sites, shrubs with few trees and only few small patches that were covered by vegetation dominated by conifer trees (classification results 1972 image). However, when comparing the results of 1972 with those of 2000, it can now be visualized that the CCF forest is now fully covered by diverse vegetation. The development of forest showed a very positive change at the temporal development and the forest that was once totally degraded, has converted into very diverse and rich forest of the Central Himalayas following community efforts (Figure 7).



TCF 1979



TCF 2002

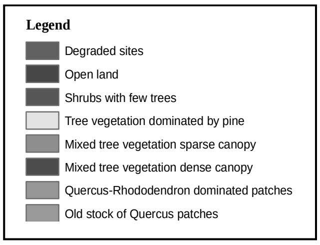
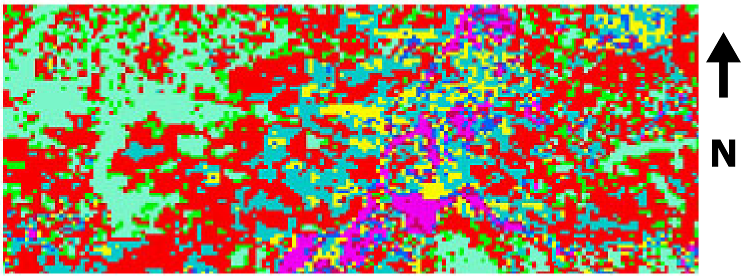
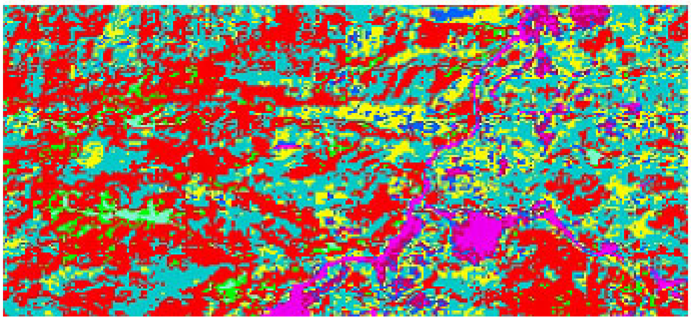


Figure 5: Land cover map of TCF at two paints of time.



GCF 1979



GCF 2002

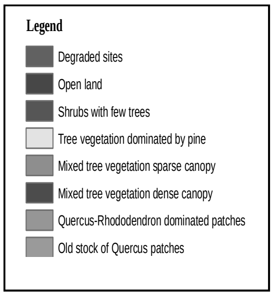


Figure 6: Land cover map of GCF at two paints of time.

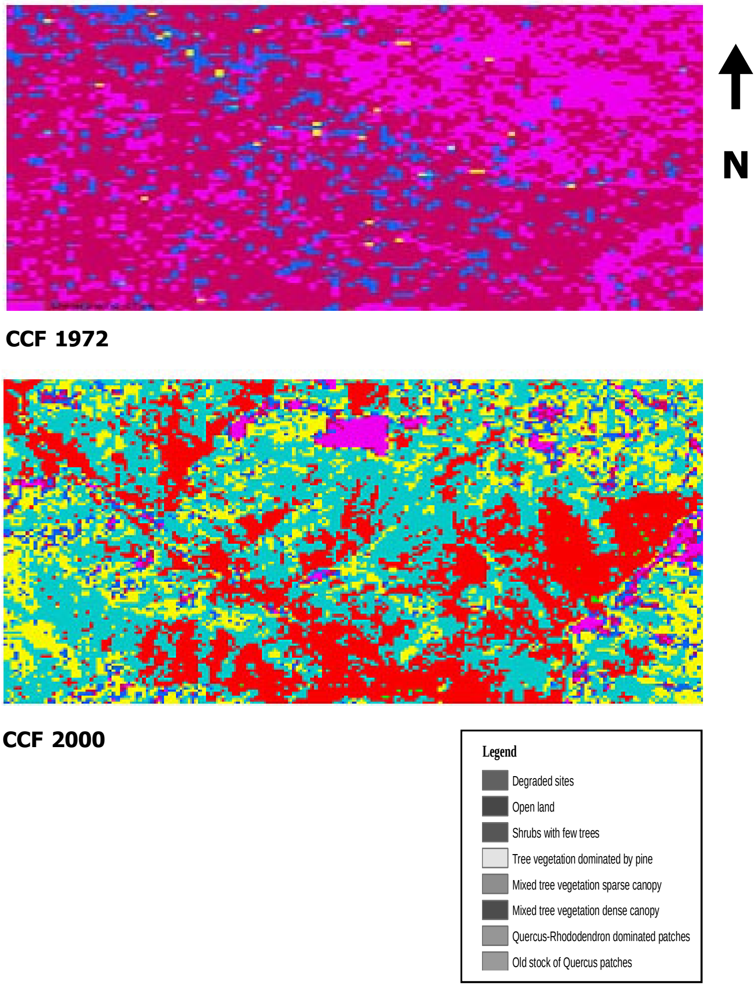


Figure 7: Land cover map of CCF at two paints of time.

Data for vegetation dynamics in different points of time for the studied forests are presented in Table 3. Results indicate that the forests managed through traditional rules and belief and through governmental schemes are getting disturbed and thus degraded form the viewpoint of forest quality. However, the community forests show better conservation, having good vegetation cover with positive spatial expansion of vegetation cover over an increasing time period. The degraded sites/open land in TCF and GCF has increased over time. The value for these classes for TCF was noted to have increased from 0.97 to 2.38 and for GCF from 0.45 to 2.75 for the period of 1979 and 2002 respectively. However, these values have reduced greatly for CCF and presently remain at only 9.09% of the land cover being open and degraded however, at one stage during 1972 it was recorded at about 87%. These are very surprising results and emphasize the positive aspect of the community-based conservation for better management of the Himalayan forests. The values for other vegetation classes are also increasing for CCF. The spatial dimension of mixed tree vegetation classes has been recorded to increase from up to 44.54% for CCF (Table 3). For GCF the *Quercus* and *Quercus–Rhododendron* dominated patches, and for TCF *Quercus* patches, have reduced to a great extent. The spatial dimension for *Quercus* patches had shrunk from 38.52% to 11.21% for TCF and 30.44% to 0.31% for GCF. The cover of *Quercus–Rhododendron* dominated patches has reduced to 2.08% however, once such patches provided about 16% of vegetation cover in CCF, but for TCF this vegetation cover class has expanded by 3% in area from 1979 to 2002. Consequently, the vegetation is dominated by conifers (mainly pine) in this area. Studies have reported the degradation of oak (*Quercus*) in forests that were managed by government forest departments, but not in the forest managed by the communities (Wakeel et al. 2005). Research results showed that a variety of factors in TCF and GCF have been responsible for increasing the forest cover, which is predominately dominated by pine. For the period of 2002 it is noticed that 9.92% and 4.57% cover of GCF and TCF, respectively, covering of vegetation dominated by pine. However, in 1979, 1.29% and 3.41% of the forest was covered by vegetation dominated by pine in TCF and GCF respectively. The forests of *Quercus,* which is a late successional and climax species, when disturbed by various anthropogenic means (i.e., lopping, cutting burning etc.) are invaded by the early successional species (light demanding species) such as chir-pine (*P. roxburghii)* due to changed microclimatic conditions. Opening of the canopy in oak forests provides an opportunity for early successional light demanding pines (low nutrient demander and shade intolerant species) to invade and this may be responsible for the ecological imbalance of this region (Singh et al. 1984; Singh et al. 1997). Research results illustrate that the quality of TCF is still maintained and managed and not in jeopardy. In a short span of time, however, the decline in *Quercus* patches from these kinds of untouched ecosystems warns of the need to think critically about the conservation and management of resources of such forest patches in the Himalayas of India. The overall results presented here reveal that the rate of degradation in GCF is comparatively higher than that reported for TCF. CCF is able to prove, in general, the positive aspect of the community conservation regimes that need to be encouraged for Himalayan landscapes (Table 3).

Table 3: The spatial extent of different vegetation classes of the studied forests of the Himalayas in temporal dimensions (all values in percentage).

Vegetation Classes	Forests					
	TCF		GCF		CCF	
	1979	2002	1979	2002	1972	2000
Degraded sites	0.09	1.29	0.19	1.47	20.95	5.75
Open land	0.97	1.09	0.26	1.28	66.40	3.34
Shrubs with few trees	1.41	1.88	0.64	2.27	11.78	5.34
Tree vegetation dominated by conifers	1.29	4.57	3.41	9.92	0.55	18.26
Mixed tree vegetation sparse canopy	13.00	16.13	10.32	36.14	0.13	44.54
Mixed tree vegetation dense canopy	31.91	48.11	38.94	46.53	0.16	22.21
Quercus-Rhododendron dominated patches	12.81	15.72	15.8	2.08	0.00	0.039
Old stock of Quercus patches	38.52	11.21	30.44	0.31	0.038	0.52

The role of humans in conservation is an important factor in the debate on rethinking conservation issues (Kothari et al. 1998; Berkes 2004; Manuel-Navarrete 2006). In the conservation debate two poles are recognized—preservation and sustainable continuum. At one extreme, bans and natural science-based, top-down management for preservation are used. At the other extreme is community-based, multidisciplinary management for sustainable resource use and livelihood (Manuel-Navarrete et al. 2006). More research is needed to develop the goal of conservation and sustainable development. However, a top-down approach for conservation has not got approval, particularly in developing countries where human–ecosystem interaction is more complex (Nautiyal and Kaechele 2007b). Understanding the impact of human behavior and interactions between natural resources and the environment is a crucial component in constructing effective management strategies (Roberts et al. 2002) and helpful to provide a better approach to illustrate the complex behavior of human–landscape interactions within a spatial framework of the conservation objectives (Drogoul and Ferber 1995; Findler and Malyankar 1995 Bawa et al. 2002; Zhang et al 2005). The main issue of controversy in conservation and development is the dissimilarity in the objectives of community development and objectives of the conservation goal (Berkes 2004). Therefore, this is the point that requires rethinking about how both goals could be achieved simultaneously. Remote sensing data provide exceptional comparisons of vegetation cover and are able to provide a quantitative tracking of the ecosystem health (Wang and Moskovits 2001).

Developing a land cover map or vegetation mapping is a primary requirement for creating a management plan and designing the activities for resource use patterns. Methods are needed to quantify aspects of spatial patterns that can be correlated with the scenario development and changes in time (O'Neill et al. 1988; Turner 1990). This has greater importance in view of the shrinkage and degradation in forest cover

(Singh et al. 2002). However, the study on temporal dimensions of this aspect is of great significance to understand the process and pattern of development, as well as the human influence on forest management. This study is an initiative to seek a way for better conservation and management of the Himalayan forests for sustainable development of the region in the context of the global agenda. The results presented here may be helpful for policy makers and decision takers to redesign and reframe the policies for the forest ecosystem conservation and management in the Himalayas as these forests and biodiversity are in jeopardy and facing rapid devastation. Current research would encourage to rethink the approaches and mind-set behind community-based conservation (Berkes 2004). The importance of knowledge and values of local communities are being revealed as valuable for conservation of biological resources. A variety of factors—such as common rules, norms, reciprocity and exchange, trust and involvement—in societies are what strengthen the social capital and consequently the outcome of action of an individual achieve positive goals towards the biodiversity conservation and management (Pretty and Smith 2004). Therefore, a form of 'Fusion Knowledge', neither strictly local or traditional, nor external or scientific, may be most useful in developing locally appropriate (in terms of culture and resources) and adaptive systems of managing diverse biological resources (Brown, 2003).

Conclusion

Various scientific studies done in the Himalayas have reported and proved that there are many factors leading to substantial decline of Himalayan forests. This is a threat at local, regional and national levels and from the viewpoint of biodiversity, it has implications at the national and global perspective. Estimation of spatial distribution of above-ground biomass in forests using the remotely sensed data has considerable significance for sustainable management and utilization of natural resources. Hence, it would be helpful for better understanding the theory behind each conservation regime to redesign and improve the policies to be implemented in the Himalayas. Unfortunately, the problem of forest resource degradation is emerging as a big problem in the Himalayas where about 10% of land cover is protected towards the goal of conservation and sustainable development. Therefore, there is an urgent need to identify the proper means for conservation and management of the Himalayan forests and to recognize which conservation regimes is best suited for conservation. In this direction the study done here would be helpful to promote significant approaches to conservation of Himalayan forests and biodiversity. The empirical study and remote sensing analysis at spatial and temporal dimensions showed that community conservation (CCF) has led to an increase of diversity and vegetation cover. Every conservation regime has its own significance in view of particular objectives hence further research in this endeavor is needed that would help in achieving the conservation and development goal.

References

Bandyopadhyay, S., Soumya, H.B., Shah, P.L. 2005. Community Stewardship and Management. Beyond NEP 2004: Institutions, Incentives and Communities. Centre for Civil Society, New Delhi, India. http:// www.ccsindia.org/ ccsindia/pdf/forests_briefing_paper.pdf

Bawa, K., Rose, J., Ganeshaiah, K.N., Barve, N., Kiran, M.C., Umashankar,R. 2002. Assessing biodiversity from space: an example from the Western Ghats, India. Conservation Ecology 6, 7. URL: http://www.consecol.org/vol6/iss2/ art7.

Berkes, F., 2004. Rethinking community based conservation. Conservation Biology 18, 621-630.

Bhagwat, S.A., C.G. Kushalappa, P.H. Williams, and N.D. Brown. 2005. A landscape approach to biodiversity conservation of sacred groves in the Western Ghats of India. Conserv Biol 1853-1862.

Brown K (2003) Three challenges for a real people-centered conservation. Glob Ecol & Biogeo 12: 89-92.

Census of India. 2001. Total number of villages by state and union territories (in 2001 and 1991 censuses). Office of Registrar General, New Delhi, India. Available from http://www.censusindia.net/results/no_villages.html

Chen, Z. G., Yang, J.Y., Xie, Z.Q. 2005. Economic development of local communities and biodiversity conservation: a case study from Shennongjia National Nature Reserve, China. Biodivers. Conserv. 14,2095-2108.

Drogoul, A., Ferber, J. 1995. Multi-agent simulation as a tool for studying emergent processes. In: Gilbert, Doran (Editor), Simulating Societies: The computer Simulation of Social Phenomena. UCL Press, pp. 127–142.

Findler, N.V., Malyankar, R.M. 1995. Emergent behavior in societies of heterogeneous, interacting agents; alliances and norms. In: Gilbert, Nigel, Conte, Rosaria (Editors), Artificial Societies: The Computer Simulation of Social Life. UCL Press, pp. 212–236.

Friedl, M. A., Brodley, C. E. 1997**.** Decision tree classification of land cover from remotely sensed data. Rem. Sen. Environ. 61, 399-409.

Heute, A.R. 1988. A soil adjusted vegetation index. Remote Sensing of Environment 25, 295-309.

Holz, R.K. 1985. The surveillant science: Remote Sensing of Environment. 2nd edition. Wiley, New York.

IUCN, 2004. IUCN red list of threatened species: A global species assessment. Gland.

IUCN. 2002. Parks. Vol 12, no. 2, Local Communities and Protected Areas. Protected Area Programme of the World Conservation Union.

Jensen, J.R. 1996. Introductory digital image processing: a remote sensing perspective. Prentice-Hall, Upper Saddle River, New Jersey.

Khare, A., Madhu,S., Saxena, N.C., Subhabrata, P., Seema, B., Farhad, V.,. Satyanarayana, M. 2000. Joint Forest Management: policy practice and prospects. Policy That Works for Forests and People series No.3. International Institute for Environment and Development. London. And WWF- India, Delhi.

Khumbongmayum, A.D., Khan, M., Tripathi, R.S. 2006. Biodiversity conservation in sacred groves of Manipur, northeast India: population structure and regeneration status of woody species. Biodivers Conserv 15: 2439-2456

Kothari, A., Pathak, N., Anuradha, R.V. ,Taneja, B. (eds.) 1998. Communities and Conservation: Natural resource management in South and Central Asia, Sage Publications, New Delhi.

Lewis, D.M., Keweche, G., Mwenya, A. 1990. Wildlife conservation outside out side protected areas-lessons from an experiment in Zambia. Conserv. Biol. 4, 171-179.

Lillesand, T.M., Kiefer. R.W., Chipman. J.W. 2004. Remote sensing and image interpretation (fifth edition), John Wiley & Sons, Inc. New York

Liu, J. 2001. Integrating ecology with human demography, behaviour, and socioeconomics: Needs and approaches. Ecol. Modell. 140, 1-8.

Liu, J., Ouyang, Z., Tan, Y., Yang, J., Zhou, S. 1999. Changes in human population structure and implication for biodiversity conservation. Popul. Environ. 21, 45-58.

Lo, C.P., 1986. Applied remote sensing. Longman, New York.

Maikhuri, R.K., Nautiyal, S.,. Rao, K.S., Saxena, K.G. 2001. Conservation policy and people conflicts: a case study from Nanda Devi Biosphere Reserve (a World Heritage Site), India. For. Pol. Econ. 2, 355-365.

Malhotra, K.C. 1998. Anthropological dimensions of sacred groves in India: an overview. Pages 423-438 in P. S. Ramakrishnan, K.G. Saxena, and U.M. Chandrashekara, editors. Conserving the sacred for biodiversity management. Oxford and IBH, New Delhi.

Manuel-Navarrete D., Slocombe, S., Mitchell, B. 2006. Science for place-based socioecological management: Lessons from the Maya forest (Chiapas and Peten). Ecology and Society, 11 (On line): URL http://www.ecologyandsociety.org/vol11/iss1/art8/

Nautiyal, S., Kaechele, H. 2007b. A modeling approach for complex interactions between humans and eco-systems for natural resource management in nature protection areas of Himalayas, India. Mana Environ Qual 19, 335-352.

Nautiyal, S., Kaechele, H. 2007a. Adverse impact of pasture abandonment in Himalayas of India: Testing efficiency of a natural resource management plan (NRMP). Environ. Imp. Assess. Rev. 27, 109-125.

Negi, C.S. 2005. Socio-cultural and ethnobotanical value of a sacred forest, Thal Ke Dhar, central Himalaya. Ind J Trad Know 4: 190-198.

O'Connell-Rodwell, C.E., Rodwell, T., Rice, M.,. Hart,L.A. 2000. Living with the modern conservation paradigm: can agricultural communities co-exist with the elephants? A five-year case study in east Caprivi, Namibia. Biol. Conserv. 93, 381:391.

O'Neill, R.V., Krummel ,J.R., Gardner, R.H., Sugihara,G., Jackson, B.,. DeAngelis, D.L.,. Milne, B.T., Turner, M.G., Zygmunt, B., Christensen, S.W., Dale, V.H.,. Graham, R.L. 1988. Indices of landscape pattern. Land. Ecol. 1, 153-162.

Pilbeam, C.J., Tripathi, B.P., Sherchan, D.P., Gregory, P.J., Gaunt, J. 2000. Nitrogen balances for households in the mid-hills of Nepal. Agric. Ecosyst. Environ. 79, 61–72.

Pretty, J., Smith,D. 2004. Social capital in biodiversity conservation and management. Conserv. Biol. 18, 631-638.

Ramakrishnan, P.S. 1996. Conserving the sacred: from species to landscapes. Nat. Resou. 32, 11-19.

Ramanujam, M.P., Kadamban D. (2001). Plant biodiversity of two tropical dry evergreen forests in the Pondicherry region of south Indian and the role of belief system in their conservation. *Biodiv Conserv.* 10:1203-1217.

Roberts, C.A., Stallman, D., Bieri, J.A. 2002. Modeling complex human-environment interactions: the Grand Canyon river trip simulator. Ecol. Modell. 153, 181-196.

Rouse, J.W., Haas, R.H., Scell,J.A., Deering, D.W.,. Harlen, J.C. 1974. Monitoring the vernal advancement of retrogradiation of Natural Vegetation, NASA/GSFC, Type III, 371.

Saikia, A. 2006. The hand of God: Delineating sacred groves and their conservation status in India's far east. Survival of the Commons: Mounting Challenges and New Realities," the Eleventh Conference of the International Association for the Study of Common Property, Bali, Indonesia.

Sandstrom, P., Pahlen, T.G., Edenius, L., Tommervik, H., Hagner, O., Hemberg, L., Olsson, H.,Baer,K., Stenlund, T., Brandt, L.G., Egberth,M. 2003. Conflicts resolution by participatory management: Remote sensing and GIS as tool for communicating land-use needs for Reindeer herding in Nothern Sweden. AMBIO 23, 557-567.

Saxena K. G., Maikhuri, R.K., Rao, K.S. 2005. Changes in agricultural biodiversity: implications for sustainable livelihood in the Himalaya. J. Moun. Sci. 2, 23-31.

Saxena, K. G., Rao, K.S.,. Sen, K.K., Maikhuri, R.K., Semwal,R.L. 2001. Integrated natural resource management: approaches and lessons from the Himalaya. Conservation Ecology, 5. URL: http:// www.consecol.org/vol15/iss2/art14].

Sen, K.K., Semwal, R.L., Rana, U., Nautiyal, S., Maikhuri, R.K., Rao, K.S., Saxena, K.G. 2002. Patterns and Implications for Land Use/ Cover Change: A case study in Pranmati Watershed (Garhwal Himalaya, India). *Mountain Research and Development* 22, 56-62.

Singh J. S., Chaturvedi, O.P., Rawat, Y.S. 1984. Replacement of oak forest with pine in the Himalaya affects the nitrogen cycle. Nature 311, 54-56.

Singh, J.S., Rawat, Y.S.,. Garkoti, S.C. 1997. Failure of brown oak (Q. semicarpifolia) to regenerate in Central Himalaya: a case of environmental semisurprise. Curr. Sci. 73, 371-374.

Singh, T.P., Singh, S., Roy, P.S., Rao. B.S.P. 2002. Vegetation mapping and characterization in west Siang District of Arunachal Pradesh, India-a satellite remote sensing-based approach. Curr. Sci. 83, 1221-1230.

Stefania, A. 2001. A critique of development and conservation policies in environmentally sensitive regions in Brazil. Geoforum 32, 551-565.

Taneja, B. 2001. Biodiversity Planning Support Programme Integrating Biodiversity into the Forestry Sector:India Case Study. "Integration of Biodiversity in National Forestry Planning Programme" held in CIFOR Headquarters, Bogor, Indonesia on 13-16 August (URL): http://www.unep.org/bpsp/Forestry/Forestry%20Case%20Studies/India.pdf

Turner, M.G. 1990. Social and temporal analysis of landscape pattern. Land. Ecol. 4, 21-30.

Wakeel, A., Rao, K.S., Maikhuri, R.K, Saxena, K.G. 2005. Forest management and land use/cover changes in a typical micro watershed in the mid elevation zone of central Himalaya, India. For Ecol Manage 213: 229-242.

Walkder, R.E., Stoms, D.M., Estes, J.E., Cayocca, K.D. 1992. Relationship between biological diversity and multi-temporal vegetation index data in California. ASPRS ACSM Albuquerque, New Mexico, Ame Soci Photogra Rem Sens, Bethesda, MD 3-7 March 1992, pp 562-571.

Wang, Y., Moskovits, D.K. (2001). Tracking fragmentation of natural communities and changes in land cover: Applications of Landsat data for conservation in an urban landscape (Chicago Wilderness). Conserv. Biol. 15, 835-843.

Zhang, B., Valentine, I.,. Kemp. P.D. 2005. A decision tree approach modelling functional group abundance in a pasture ecosystem. Agricul. Ecosys. Environ. 110, 279-288.