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Integrating spatial technology, local knowledge, and conventional methods in forestry research

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Abstract

This paper presents an innovative methodological framework that integrates spatial technologies, local knowledge and conventional survey methods in a single research. The methodology was used to monitor forest conditions and examine their associations with local forest governance parameters in a mountain watershed covering 153.3 km^2 in the middle hills of Nepal. The study involved two spatial scales and analytical steps. First, geomatics techniques, supplemented with local knowledge, were used to map and detect changes in major land cover types of the study area between 1976 and 2000 and to analyze relationships between forest cover changes and governance arrangements. This was followed by a micro-level analysis of the relationships between biological conditions of selected forests within the watershed and their governance arrangements using conventional survey methods and analytical tools. The findings indicate that forest cover of the watershed increased by about 15 percent during the period due mainly to forest regeneration under the protection of local forest user groups (both formally and informally organized) and afforestation programs implemented by the government and forest user groups. The rate of increase in forest cover during the period was highest in areas under a semi-government type of governance arrangement followed by the community forest areas while the community forests were generally better in present biological conditions compared to the semi-government forests. This inconsistency between the findings from the two analyses does not allow us drawing firm conclusion regarding the role of property rights in determining forest condition but indicates that the outcomes from local forest management initiatives may be more dependent on the local institutional arrangement that regulate forest use and maintenance of the resource than on type of property right arrangements. The findings also provide evidence of methodological suitability of the research approach, which can be useful to address many other research questions related to forestry and natural resources management, particularly those involving multiple spatial scales.

Key words: Forest changes monitoring, governance systems, research approach, Nepal

Introduction

Assessment and systematic monitoring of the resource condition are essential components of long-term planning and management of forest resources. These requirements can be fulfilled by using different methods and techniques. Traditionally, when the objective of forest management was mainly timber production, sample-based forest inventories were the sole methods of determining forest conditions. Aerial photographs were frequently used for forest cover mapping during the third quarter of the twentieth century. These methods still continue to be the common quantitative methods for collecting forest data despite being costly and time consuming as compared to some other methods.

Spatial technologies (including remote sensing, Geographic Information Systems, and Global Positioning System) are becoming increasingly popular in the assessment and monitoring of forest resources in recent years (e.g. Tekle and Hedlund, 2000; Schweik et al., 2003). Repeated satellite images and/or aerial photographs are useful for both visual assessment of the resources as well as dynamics occurring at a particular time and space. Geographic Information Systems (GIS) technology greatly facilitates analysis and presentation of spatial and non-spatial data from various sources. Global Positioning System (GPS) helps to georeference satellite images and aerial photographs and establish relationships between spatial and non-spatial data. Use of ancillary data and expert knowledge of the area help improve spectral classification, particularly for mountainous areas (Shrestha and Zinck, 2001).

Each of the above methods has advantages and disadvantages. For example, the spatial techniques are generally cheaper and efficient for mapping forest cover and detecting changes, particularly for larger areas (such as landscape or watershed), but these techniques can be considered less reliable compared to field-based surveys for determining forest condition at the micro level. Resolutions (both spatial and spectral) of the satellite images or scale of aerial photographs also determine the success of resource assessment efforts using remote sensing techniques. A combined use of the spatial techniques and sample-based survey could therefore be the most appropriate approach for mapping forest cover at a particular time and space and monitoring the dynamics of changes. Despite a clear advantage of combined use, the field-based methods and spatial techniques are usually being used in isolation, depending on the research interest and knowledge of the researcher.

This paper attempts to illustrate how spatial technologies, local knowledge and the conventional forest survey methods can be combined in a single research for mapping forest cover, detecting the trends of changes in forest condition over time, and understanding the association of these changes with forest governance arrangements. The objectives are to assess the role of property rights in determining forest condition and at the same time provide an appropriate methodological framework that can be used in the assessment and monitoring of forests and contribute to better planning and management of the remaining forest resources.

Study Area

The study was carried out in Upper Roshi Watershed situated in the western part of Kabhrepalanchok district in the middle hills of Nepal (Figure 1). The watershed covers an area of 15,335 hectares and is drained by three rivers namely Punyamata, Bebar and Roshi along with their numerous tributaries. Altitude varies between 1,420 m to 2,820 m above sea level (Figure 2). Climate is monsoonal with a dry season normally spanning from November to May and rainy season from June to October. Warm-temperate humid temperature and moisture regime prevails in most part of the watershed except at higher elevations (above 2000 m) where the climate is cool-temperate type. Microclimate varies considerably with elevation and aspect (ICIMOD, 1993).

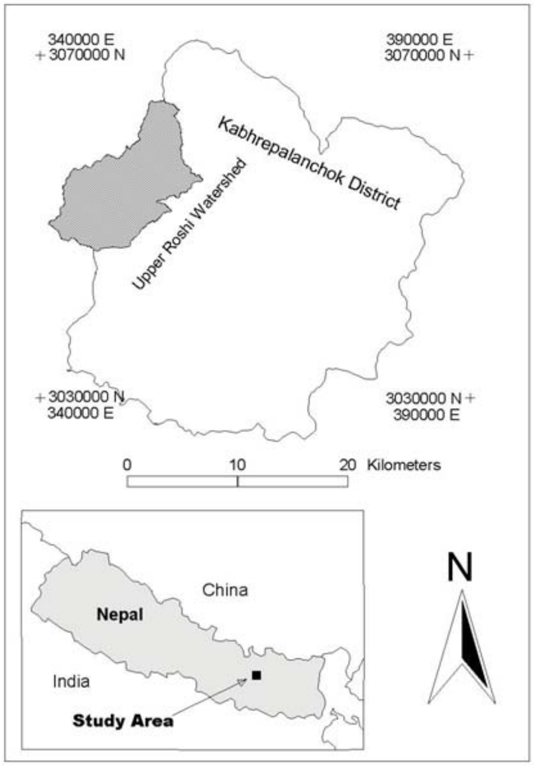


Figure 1: Location of the Upper Roshi Watershed (study area) within Kabhrepalanchok District, Nepal

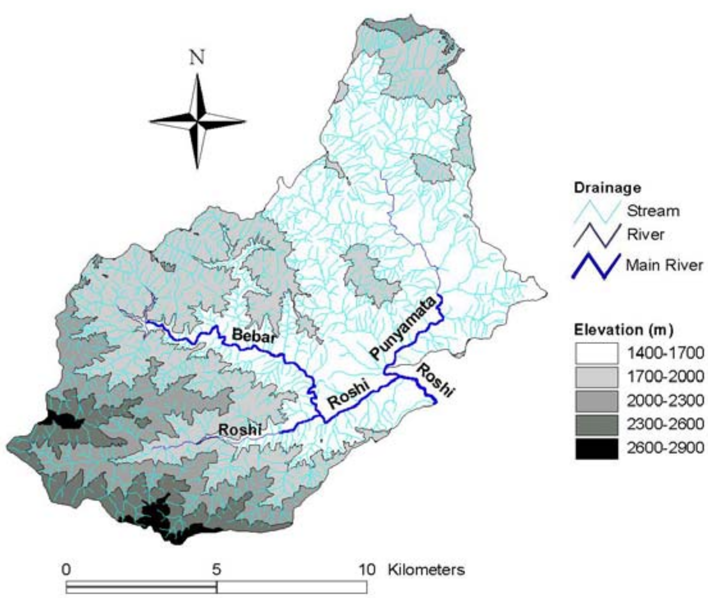


Figure 2: Drainage and elevation in the study area

The watershed can be divided into fertile, relatively flat valleys along the rivers and surrounding uplands with medium to steep slopes. Agricultural lands in the valleys are under intensive management with multiple cropping systems and are mostly irrigated. Paddy, potato, wheat and vegetables are major crops cultivated in the valley. Forests are mostly confined to higher elevations and consist of both natural mixed broadleaf forests as well as pine plantations. A single large block natural forest in the southern *Mahabharat* Mountains represents around 50 percent of the total forest area of the watershed. The rest of the forests are generally fragmented and scattered over the agricultural landscape (Figure 3).

Figure 3: A section of the Upper Roshi Watershed (Photo by Ambika Gautam)

The study area is one of the pioneer areas for implementing the government-sponsored community forestry program in Nepal. Many of the forest patches have been handed over to the local Forest User Groups (FUG) under the community forestry program. The Australian Agency for International Development has been supporting the implementation of the community forestry program through successive bilateral projects since the inception of the program in 1978. Leasehold forestry is another form of community based forest management system implemented in the area by the government since 1992 with initial supports from Food and Agriculture Organization of the United Nations and International Fund for Agricultural Development. At the time of this study some forest patches in the watershed were under a semi-government type of governance arragenment (defined below). The rest of the forests were under the direct control of the district forest office.

Data and Methodology

The study used a two-scale and combined approach of data collection and analysis. The spatial and temporal changes in the forests and other major land use/cover in the watershed between 1976 and 2000 and associations of the changes in forest cover with governance arrangements were first analyzed using geomatics tools and techniques. A Landsat Multispectral Scanner (MSS) image from December 1976 and an Indian Remote Sensing (IRS-1C, LISS-III) image from March 2000 were the main data used for mapping forest cover for 1976 and 2000, respectively. Eight black-and-white aerial photographs of 1:50,000 scale from 1978 were used for "ground-truth" information required for classification and accuracy estimation of classified MSS image. Four topographic maps of 1:25,000 scales published by the Survey Department, His Majesty's Government of Nepal and digital topographic data with contour interval of 20 m produced by the same agency were also used. The ground-truth information required for the classification and accuracy assessment of IRS image was collected from the field during January-April, 2001. The exact locations of the training samples in the field were determined with the help of GPS and topographic maps.

The images were classified using supervised Maximum Likelihood classification method into three land cover classes namely, forest, shrubland, and other. "Forest" included natural forests and established pine plantations with estimated 75 percent or more of the existing crown covered by trees. Land covered by shrubs, bushes, young forest regeneration, and degraded forest areas (estimated tree crown cover <10%) were included in the class "shrublands". The rest of the areas, including grasslands, cultivated lands, barren lands, settlements, roads, construction sites and other built-up areas were combined together under a single class "other".

The classified images were exported to Arc View GIS and polygons of <0.5 ha in size were "eliminated" from both the polygon themes in Arc Info. This elimination was necessary to minimize the effects of classification error arising from resolution differences between the MSS (57x57 m) and IRS (23.5x23.5 m) images while at the same time without significantly altering the area under each land cover class. The resultant land cover polygon themes for 1976 and 2000 were overlaid in Arc View and location and area of forest improvements (shublands in 1976 converted to forest in 2000), deterioration (forest in 1976 converted to shrublands in 2000), loss (forested area lost to other use) and gain (forested area gained from other use) were mapped and area of changes computed.

The polygon theme of changes in forest cover obtained from the GIS analyses was overlaid with the polygon theme of forest governance types (Figure 4) and trends of changes in forest cover within community, semi-government, and government forests were analyzed. Boundaries of community, semi-government and government forests were identified and delineated on enlarged topographic maps taking established features such as streams, roads and ridges as references and with the help of FUG leaders and local forestry staff; those boundaries were digitized latter in Arc View GIS.

The "community forest" as defined in this study includes both the FUG-managed community forests as well as the leasehold forests. Forest patches that were legally controlled by the government but under *de facto* control and claim of ownership by local communities or a municipality have been categorized as "semi-government forest". It is important to note that the district forest office had informally recognized these local claims. The forests, which were under the direct control of the district forest office, have been defined as the "government forests".

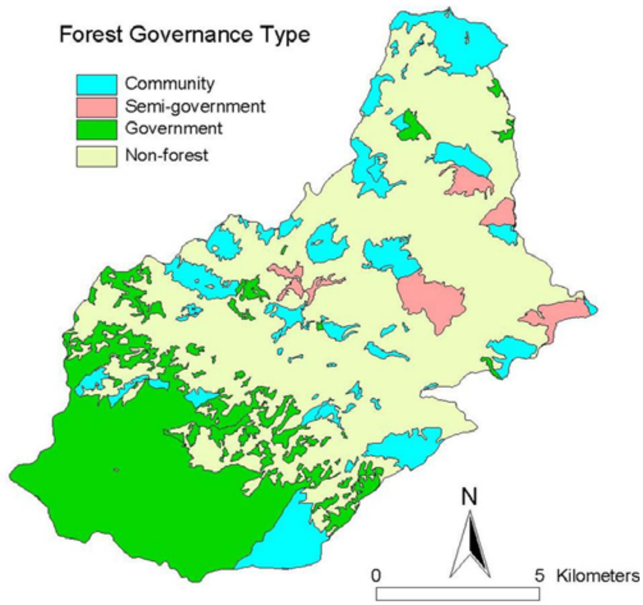


Figure 4: Location and extent of the community, semi-government, and government forests in the Upper Roshi Watershed

Building on the foundation laid by the above analyses, eight forest sites were purposively selected from within the watershed for detailed ground surveys using sample-based forest inventories (Figure 5). The site selection criteria included: i) homogeneity in ecological conditions across the sites and (ii) high forest dynamism during 1976-2000.

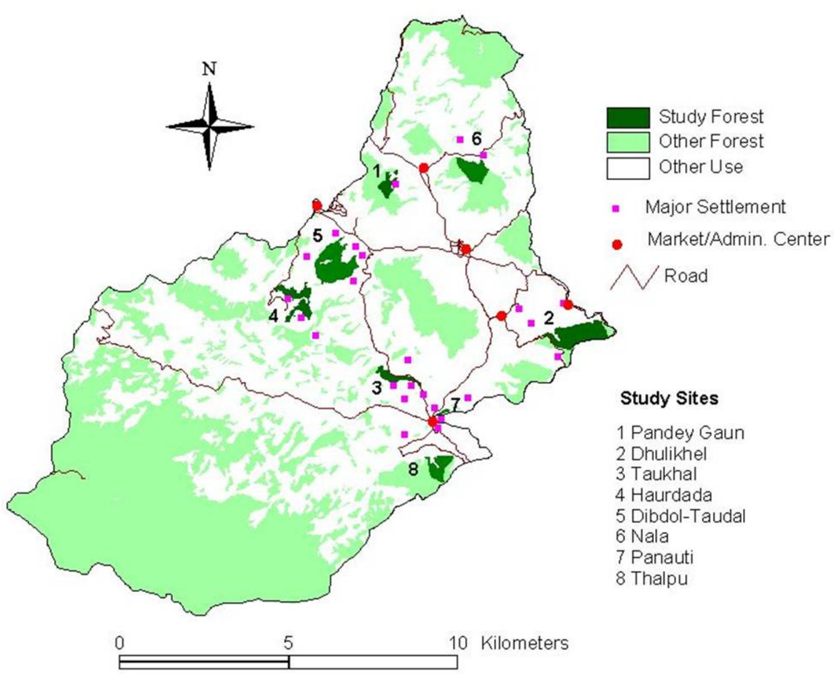


Figure 5: Location of the eight study sites within the Upper Roshi Watershed

Two of the forests selected for detailed ground survey (i.e. Dhulikhel and Haurdada) were under the semi-government type of governance arrangement while the rest six were managed by formally registered local FUGs under the community forestry program. The difference between the biological conditions of the community and semi-government forests was then statistically compared.

Botanical data required to measure the conditions of the selected forests was collected from randomly selected circular plots composed of three concentric circles of 1-meter, 3-meter, and 10-meter in radius (Figure 6). A total of 231 forest plots were sampled from the eight forests with an average sampling intensity of 2.34 percent.

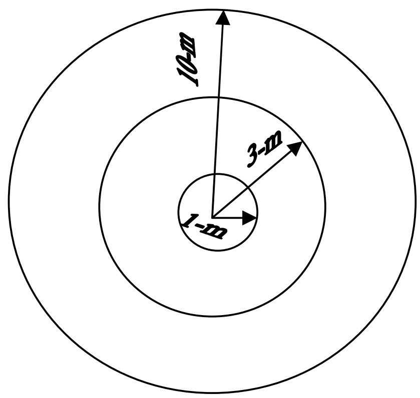


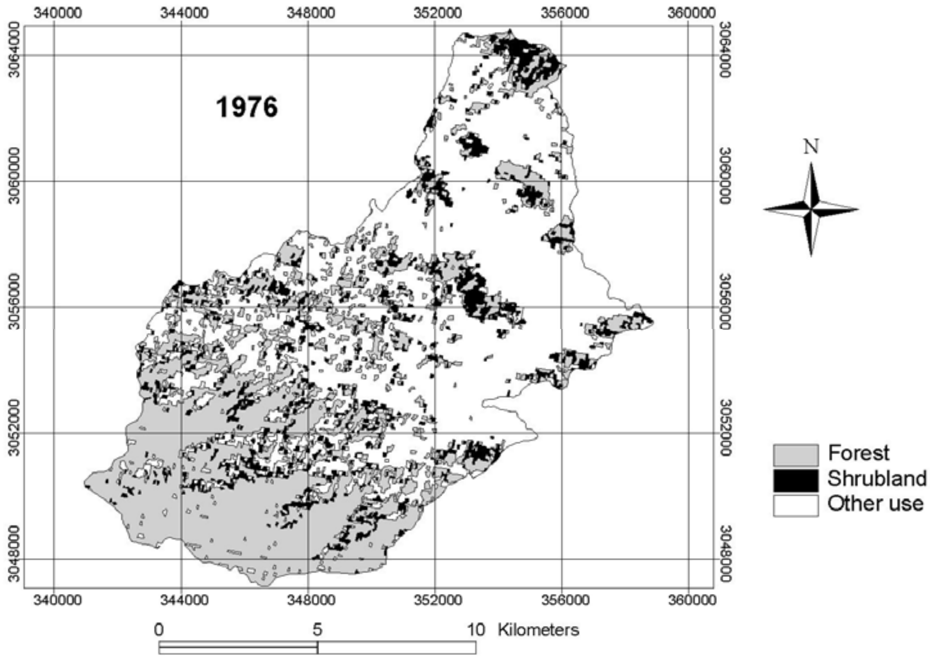
Figure 6: Structure and dimensions of the forest plot

In the innermost circle (1-m radius), woody seedlings and herbaceous ground cover was sampled. In the next circle (3-m radius), shrubs, saplings, and climbers were identified and counted and also the diameter at breast height (DBH) and heights of woody stems between 2.5 and 10 cm in diameter was recorded. In the largest circle (10-m radius), stems of equal or greater than 10 cm in DBH were identified, counted and DBH and height measured.

Results and Discussion

Forest cover changes

The results show that forest area in the watershed increased by about 15 percent of its 1976 area and the area under shrub and other use declined between 1976 and 2000 (Figure 7; Table 1). Further investigation on changes in the forested area (forests plus shrublands) of the watershed revealed that of the total 6658.2 ha. of forest and shrub area in 1976, 64.3 percent remained unchanged until 2000, 12.6 percent improved, 4.1 percent worsened, and 19.1 percent lost to other use. The high loss of forested area, however, was compensated by gain from other use and there was an overall 7.6 percent net gain in forested area during the period (Figure 8).



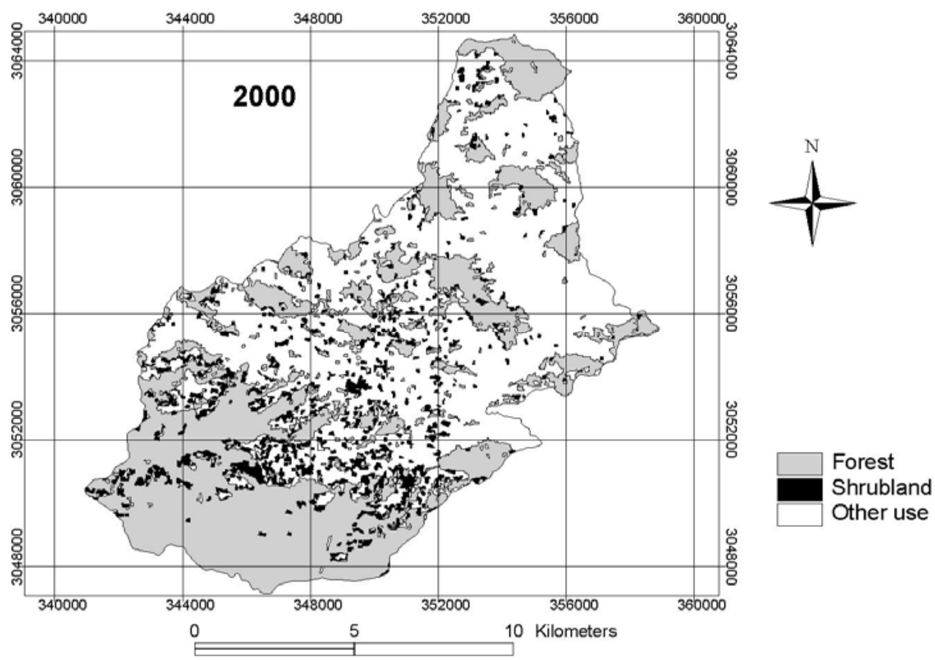


Figure 7: Area under forest, shrubland, and other use in the Upper Roshi Watershed in 1976 (top), and 2000 (bottom)

Table 1: Area under the three land cover classes in 1976 and 2000 and changes

Land cover	1976		2000		Change 1976-2000	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	5339.3	34.8	6133.3	40.0	+794.0	+14.9
Shrubland	1318.9	8.6	1031.4	6.7	-287.5	-21.8
Other	8677.0	56.6	8170.5	53.3	-506.5	-5.8

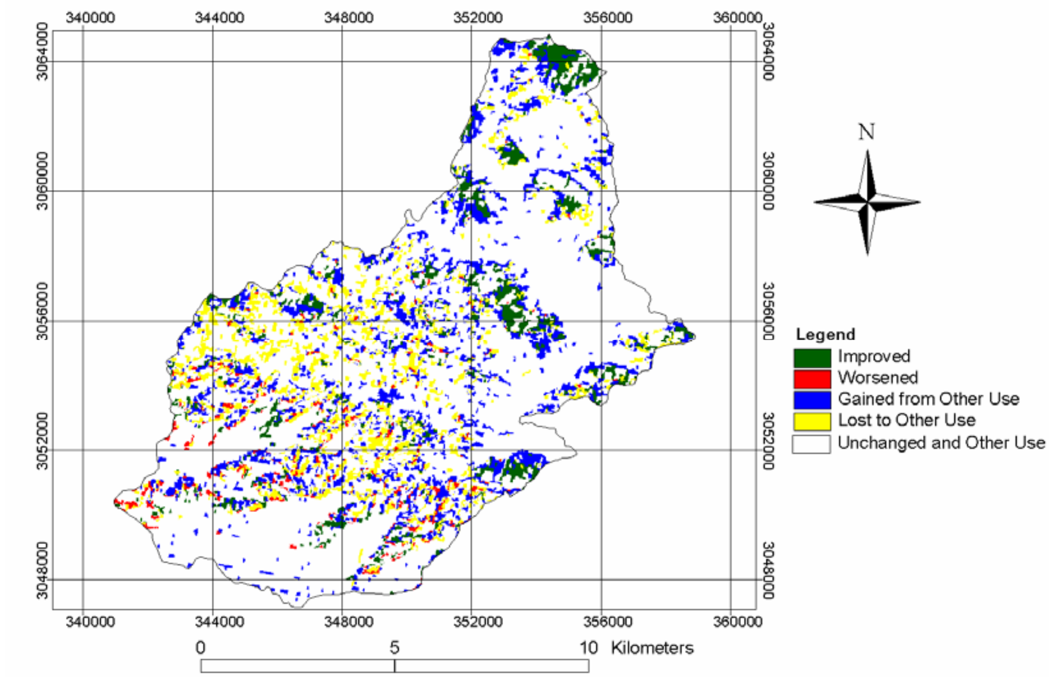


Figure 8: Location and extent of changes in forest cover of the Upper Roshi Watershed in between 1976 and 2000

Three major factors are speculated to have contributed to the positive changes in forest cover: (i) forest protection by local FUGs under the community forestry program, (ii) afforestation programs of the forest department and FUGs with supports from the successive bilateral aid projects of the Australian government, and (iii) abandonment of some unproductive agricultural plots by farmers in recent years due to problems of rapid soil erosion, nutrient depletion, and labor shortage caused by increasing attraction of male members towards wage laboring in Kathmandu and other places.

Associations of changes in cover and biological condition of forests with governance arrangements

The results obtained by overlaying the polygon theme of changes in forest cover with the polygon theme of forest governance arrangements showed that the proportional net improvement as well as gain to the forested area between 1976 and 2000 was highest in the semi-government forests followed by the community forests (Table 2, 3). The government forests, which were located mostly in the southern high mountains, remained relatively stable during the period although deterioration was substantially higher compared to the improvement in elevations above 2300 m (Gautam, 2002).

Table 2: Forested area within the geographical spaces that were under different governance arrangements in 2000

Governance type	1976		2000	
	Forested area (ha.)	Percent	Forested area (ha.)	Percent
Community	1516.1	22.8	1842.6	25.7
Government	3433.6	51.6	3523.2	49.2
Semi-government	327.9	4.9	403.5	5.6

Table 3: Percent changes in forested area in between 1976 and 2000 within the geographical spaces that were under the three governance arrangements in 2000

Governance type	Percent of forested area in 1976 compared to the area in 2000				
	Unchanged	Improved	Deteriorated	Lost to other use	Gained from other use
Community	62.3	28.4	2.1	7.2	28.8
Semi-government	45.3	37.5	0.9	16.2	39.3
Government	82.7	5.4	3.7	8.2	10.7

The finding that forest regeneration was higher in the group of semi-government forests compared to the community forests indicates less importance of legal transfer of resource ownership for successful forest conservation at the local level when the collective efforts of local users and their *de facto* rules have received informal recognition by the concerned government authorities. A relatively stable condition of the government forests during the study period can be explained by their general remoteness, far from the settlements and less amount of extraction pressure compared to other forests rather than effective monitoring or enforcement by the forestry staff. Interviews with local forestry staff and local people revealed that the forested areas under the government control were virtually open access as the district forestry staff members were mostly engaged in community forestry activities after the implementation of the community forestry program.

Further investigation was designed to statistically compare the present biological conditions of the selected community and semi-government forests. Four dependent variables, including average basal area of the trees, average density of trees, average density of saplings plus shrubs, and richness of plant species were chosen to represent the forest conditions. The results show that average richness of plant species and average density of saplings plus shrubs were significantly higher and average density of trees was also higher in the group of community forests compared to the semi-government forests. The two groups of forests had similar average basal area of trees (Table 4).

Table 4: Comparison between the biological condition of the community and semi-government forests. N denotes the number of forest plots.

Dependent variable	Community (N=161)	Semi-government (N=70)	P value (t-test; 0.05 level)
Basal Area of trees (m^2/ha)	7.3	7.4	.777
Density of trees (number/ha)	414	398	.785
Density of saplings plus shrubs (number/ha)	2477	1415	.018
Richness of plant species (number of species/plot)	11.7	10.4	.006

The significantly higher species richness and density of saplings plus shrubs in the group of community forests might have been resulted due to species manipulation and other silvicultural activities such as bushes clearing, thinning, pruning and enrichment plantation by user groups in the process of forest management plan implementation. Bush clearing, which was being done regularly in most of the community forests, may also have created favorable condition for the germination of tree seeds and growth of seedlings thus contributing to the increase in number of smaller individuals in community forests compared to the semi-government forests. The semi-government forests did not receive similar treatments because of lack of officially approved forest management plan and legal basis for implementing such activities by the user groups. As the community forests and semi-government forests included in this study are located in very similar ecological and socioeconomic settings, these findings suggest a relative superiority of local institutions in the community forests compared to the semi-government forests.

Conclusions

This study has demonstrated how an integrated use of the spatial technologies, local knowledge and conventional survey methods provide an ideal research framework that can be used for quantitative assessment and monitoring of forest conditions and to identify their associations with other factors of interest. Similar research framework can be used for analyzing many other forestry and natural resources management related issues, particularly in situations where time-series data on biological forest condition is lacking and the research question involves multiple spatial scales.

The finding of positive change in forest cover during the study period supports the findings of some earlier studies (e.g. Virgo and Subba, 1994; Jackson et al., 1998; Gautam et al., 2002) that the government-sponsored community based forest management programs have been successful in reversing the deforestation trend in some parts of the Nepalese middle hills. Forestation programs and agrarian changes that took place over the years might also have contributed to the increase in forest cover in the study area.

The finding that forest regeneration took place at higher rates in the semi-government forests compared to the community forests suggests that formal handover of forest ownership is not a strong determinant of successful forest conservation at the local level when the rights to organize and manage forests for the community benefits are recognized by concerned authorities. In other words, *de facto* rules are more important than *de jure* rules in the study area and this may be applicable to other local settings. The findings that the community forests were generally better in biological conditions compared to the semi-government forests, however, do not fully support the above conclusion but indicates the relative superiority of institutional arrangements in community forests compared to the semi-government forests. This inconsistency between the findings from the two analyses (i.e. the watershed-level and the sites-level) does not allow us drawing a firm conclusion regading the role of local governance arrangement in determining forest condition but indicates that the outcomes from local forest management initiatives may be more dependent on the local institutional arrangement that regulate forest use and maintenance of the resource than on type of property right arrangements.

The above conclusions are based on the assumption that the initial conditions (at the commencement of community based management) of the community and semi-government forests included in this study were similar. The absence of time series data on biological condition of those forests did not allow for quantitative detection and comparison of over time changes between the two groups of forests.

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