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This study analyzed the spatial and temporal changes in land use between 1978 and 1992 in a typical watershed covering 543 km^2 in the Middle Hills of Nepal and used GIS to compare land use changes between village development committees (VDCs) with and without formally handed-over community forests during this period. The forest handover procedure followed the specifications of the national community forestry policy of Nepal. In the watershed, the total area of forested land (defined as high forest plus shrubland) declined by about 8% during the period. However, high forest increased over the study period, whereas shrubland cover declined. Between VDCs with community forests and those without, there were large differences in the rate of total forested area loss, with community forest VDCs losing less total forested area over the 14-year period. Moreover, in the group of VDCs with community forests, high forest area increased by 77%, in comparison with 13% for VDCs without community forests. Higher shrub loss in community forest VDCs was attributable to conversion into high forest via plantation establishment and natural succession. The results of this study indicate the positive impacts of Nepal's community forestry activities on the extent of forest cover.

Keywords: *Impact; land use change; rural development; community forestry; Dhulikhel; Nepal; Himalayas.*

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Introduction

Various researchers have reported high rates of deforestation in developing countries around the world and have debated their causes and consequences (eg, Blaikie 1985; Tole 1998; Pfaff 1999). There is general agreement on the principle that conservation of rural ecosystems requires the management participation of local users who directly rely on the forest for subsistence needs (Ascher 1995; Ingles 1995; Pardo 1995; FAO 1998). Several approaches to forest management have been proposed since the early 1980s (Wiersum 1997). Community forestry, which seeks the active participation of local communities in the design and implementation of forest management activities, is recognized as a viable approach for many rural forest-dependent communities.

In Nepal, community forestry was formally introduced in 1978 with the objectives of reducing ecological degradation and increasing the supply of basic forest products for subsistence needs (Kanel 1997). It is now the major strategy in the country's forest policy and is the most prioritized forestry program (HMGN/ADB/FINNIDA 1988; Bartlett 1992). By the end of November 1999, a total of 634,182 ha of public forest in Nepal had been handed over to 8785 registered forest user groups (FUGs) comprising 976,856 households (DoF 1999). Some area-specific studies in Nepal have assessed the socioeconomic impacts of community forestry in the recent years (eg, Collet et al 1996; Kanel 1997). Yet, there is a serious deficit of quantitative information linking community forestry to land use or forest cover (or both), which can be used as an indicator of the biophysical success of such programs (but see Branney and Yadav 1998; Jackson et al 1998; Gautam 1999).

The International Centre for Integrated Mountain Development (ICIMOD) has been promoting the use of GIS to study land use changes and assist rural development planning in Nepal (ICIMOD 1992, 1994, 1997). Generally, it is difficult to link changes seen in remotely sensed data with policy or other sociopolitical issues because of the interaction of multiple vectors, but there has been some success linking biophysical changes with policy or sociopolitical factors (or both) in other countries (Sneath 1998; McCracken et al 1999). It is essential that changes in the physical environment be linked with policy and its implementation in order to ascertain which are the most promising avenues to conserve natural resources and improve rural livelihoods in Nepal.

In this study we used remote sensing and geographical information systems (RS–GIS) techniques (GIS analysis on maps interpreted from aerial photographs) to analyze land use changes over a 14-year period (1978–1992) in a watershed of Nepal's Middle Hill region and to test for the impact of Nepal's community forestry policy on forest cover. The analysis tested the hypothesis that the implementation of the community forestry strategy is an appropriate tool to increase forest cover in Nepal. The study does not undertake policy analysis; rather, it approaches the following empirical question: is there biophysical evidence that community forestry in Nepal is successful in improving forest cover? Such a basic, yet critical, research question has not been addressed for Nepal using GIS; so this research represents one of the first studies quantitatively linking formal community forestry with biophysical parameters in Nepal (see also Webb and Gautam 2001).

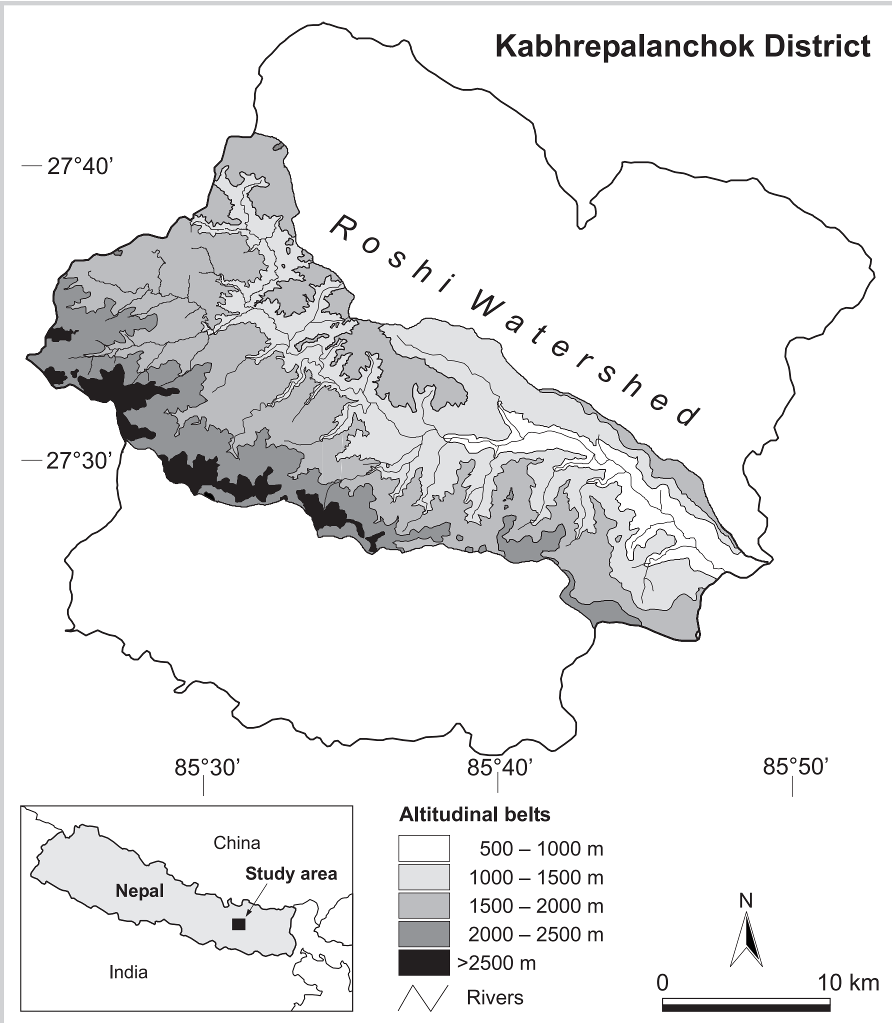


FIGURE 1 Location of the Roshi Watershed within Kabhrepalanchok District, Nepal. (Map by authors)

Study area

Changes in land use were evaluated in the Roshi Watershed (hereafter, Roshi), which is 1 of the 3 major watersheds in Kabhrepalanchok District in the Middle Hills of Nepal (Figure 1). Roshi exhibits substantial topography (540–2940 m) and covers an area of 54,336 ha (Gautam 1999). The natural vegetation in most parts of the watershed is mixed broadleaf forest with *Schima wallichii* and *Castanopsis* spp as the primary species (Jackson 1994). *Pinus roxburghii* naturally occurs on southern aspect slopes, and plantations of this species are also common. *Shorea robusta* is found in lower Roshi valleys (below 1000 m), and *Quercus* spp are common at higher altitudes (above 1700 m).

Roshi includes either part or all of 39 village development committees (VDCs) and 3 municipalities, and it is the most densely populated and economically important part of Kabhrepalanchok. The sociopolitical center of the watershed is in the northwest region, where population density is highest and infrastructure is most developed. Despite urbanization in some parts, most of the watershed is rural, with local people highly dependent upon forests for their livelihoods. Historically, high rates of fuelwood and fodder extraction have resulted from this dependence, contributing to forest degradation in Roshi (Banskota and Sharma 1995).

Community forestry is the major approach to forest management in Roshi (for a detailed discussion of the community forestry policy in Nepal, see Bartlett 1992). By the end of 1998, a total of 4974 ha of public forest in Roshi had been handed over to 160 FUGs consisting of 15,810 households (DFO 1999). The Australian Agency for International Development has been supporting the implementation of the community forestry program through successive bilateral projects since 1978.

The Roshi Watershed was selected for this research for 2 principal reasons. First, the watershed is reasonably representative of the Middle Hills: land use, population densities, forest types, and forestry-related issues in the area are typical of the Middle Hills region.

Therefore, the results of this study are expected to provide information applicable to other parts of the Middle Hills. Second, Roshi was one of the pioneer areas for community forestry implementation in Nepal. As such, the effects of community forestry on land use should be more pronounced in Roshi than in other districts with more recent implementation (eg, Chakraborty 2001).

Methods

Data sets

Spatial analysis relied on 2 land use data sets. First, 1978 data were obtained from land use maps (1:50,000 scale) compiled from ground-verified aerial photographs (1:50,000) by the Land Resources Mapping Project (LRMP), a collaboration between His Majesty's Government of Nepal (HMGN) and an external consultant (Kenting Earth Sciences Ltd, Ontario, Canada). Second, 1992 data were obtained from topographic maps (1:25,000) compiled from 1:50,000 ground-verified aerial photographs and published by the Survey Department, HMGN, in 1995 (hereafter referred to as "1992 data"). The topographic maps contained information on land use, VDC boundaries, and topography. Because land use information contained in both data sets (1978 and 1992) is based on the aerial photographs at the same scale (1:50,000), the error arising from the difference in map scale is expected to be minimal.

The maps were digitized using ARC/INFO™. While digitizing, each land use polygon was classified into 1 of 4 categories for analysis: high forest, shrubland, cultivated, and other. The analysis utilized only 4 land use classifications because: (1) the intention of the research was to evaluate the impact of community forestry on gross land use parameters only, and (2) the LRMP and the topographic map land use classes were not exactly the same. It was necessary to reclassify the 2 data systems into 1 common land use classification system in order to allow a direct comparison of land use between 1978 and 1992.

The high forest category consisted of forested land with at least 10% crown cover of trees (natural or planted [or both]). Degraded natural forests (<10% crown cover) along with areas dominated by shrubs were included in the shrubland category. High forest and shrubland together comprise a general class of "forested" land. All agricultural lands were classified as cultivated, and lands that were not included in any of the aforementioned 3 classes were classified as other. This category mainly comprised settlements, barren lands, and grazing lands. Polygons of VDC boundaries were classified as either having or not having formally handed-over community forest(s) by 1992 ($N_{\text{with community forestry}} = 13$, $N_{\text{without community forestry}} = 29$).

GIS analysis

A 1978–1992 land use change map was created by overlaying the 2 land use layers. This map showed the change in land use over the 14-year period. By overlaying the 1978–1992 land use change map with the VDC polygon theme, it was possible to compare land use changes between VDCs with and without formalized community forestry by 1992.

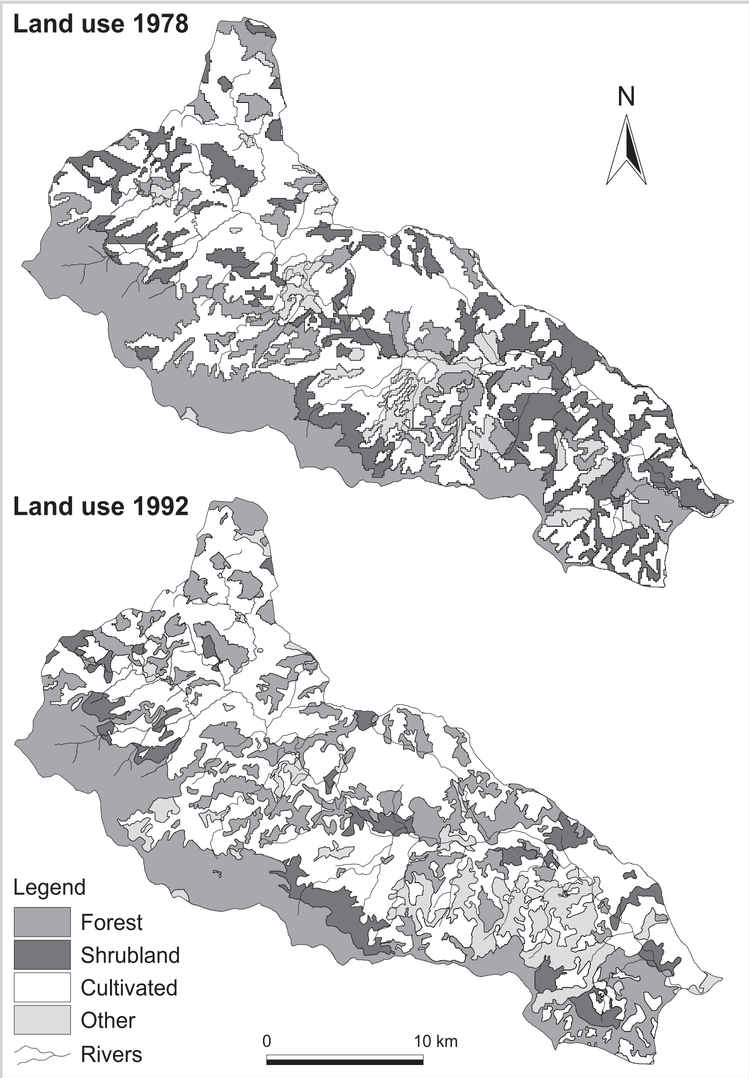
Three factors may have affected the precision of the analysis. First, community forests were not precisely mapped within each VDC, and so the analysis was conducted at the VDC level of spatial resolution. This precluded site-specific (ie, forest-specific) analyses of community forest cover change, and so the impacts (positive or negative) of community forestry were diluted in VDCs with community forestry. Second, the grouping of VDCs based on whether they had formally handed-over community forest(s) before 1992 did not acknowledge VDCs with nonformalized (ie, indigenous) community forestry practices, which are well known to occur in Nepal (Gilmour 1990; Messerschmidt 1993). Hence, VDCs that might have had such practices without formal policy implementation would have been grouped in the "without community forestry" class. Third, the generalized binary classification scheme (ie, with or without community forestry by 1992) could not capture any time-dependent land use changes resulting from community forestry. For example, the effects of community forestry on forest cover would be equally weighted for forests in which community forestry was initiated in 1978 and forests in which implementation occurred in 1990, even though a larger effect would be expected in the 1978 VDC. Hence, the mean forest change over time per VDC resulting from community forestry was averaged across VDCs with community forestry. The expected error associated with each of these factors would be to underestimate the positive benefits of the community forestry policy implementation on forest cover; that is, a Type II error (Sokal and Rohlf 1981). Thus, we argue that results implying a positive impact of community forestry on forest cover despite potential bias toward underestimation should be viewed as highly robust.

Results

Changes in land use

GIS analysis revealed a net 1981-ha decline in forested area in Roshi over the 14-year period (Figure 2; Table 1). This represents a 7.9% decline in forested area from the 1978 value (3.6% of the total watershed area). However, net forest loss consisted of a 3807-ha increase in high forest along with a 5788-ha decline in shrubland. Of the net 3807 ha of high forest added during 1978–1992, the majority (net 2949.9 ha) came from

FIGURE 2 Land use in Roshi Watershed in 1978 (top) and in 1992 (bottom). (Map by authors)



shrublands (Table 2). There was a net gain of high forest from cultivated land (+8%), with a minor loss of high forest to other uses.

Comparison of VDCs with and without formal community forestry

VDCs both with and without formalized community forestry lost forest area over the 14-year period (Table 3). However, VDCs that had formally handed-over community forests before 1992 sustained less total loss of forested area than VDCs without formal community forest (1.9 versus 9.9%, respectively). Importantly, the proportional increase in high forest was nearly 6 times higher in VDCs with formal community forests than in those VDCs without formal community forests (77 versus 13%, respectively). In contrast, the proportional loss of shrubland in community forest VDCs was 50% greater than that of noncommunity forest VDCs. The loss of shrublands was largely because of its regeneration to forest, either naturally or via plantation establishment (see Discussion). The conversion of shrublands to forest had mostly taken place in VDCs/municipalities toward the northern (ie, more developed) region of the watershed (Figure 2).

Discussion

The level of analysis for this study was constrained to the VDC level because HMGN so far has not mapped community forestry boundaries. Despite this limitation and the potential for underestimation of positive community forestry effects, indirect methods were successful in providing evidence of positive benefits of the community forestry program on forest cover. These results are encouraging because at the time of this study (1999), the percent of Roshi VDCs/municipalities with formally handed-over community forest(s) had increased from 31% in 1992 (13/42) to 83% in 1999

TABLE 1 Land use change analysis for the Roshi Watershed, Kabhrepalanchok District, Nepal, between 1978 and 1992.

	1978		1992		Increase–Decrease		
Land use	(ha)	% of total	(ha)	% of total	(ha)	Change from 1978 forest cover (%)	% of total watershed
Forested	24,857.5	45.7	22,876.2	42.1	–1981.3	–7.9	–3.6
High forest	14,900.7	27.4	18,707.7	34.4	+3807.0	+25.5	+7.0
Shrubland	9956.8	18.3	4168.6	7.7	–5788.2	–58.1	–10.5
Cultivated	26,412.8	48.6	26,556.5	48.9	+143.7	+0.5	+0.3
Other	3065.7	5.7	4903.3	9.0	+1837.6	+59.9	+3.3
Total	54,336	100	54,336	100			

TABLE 2 Loss or gain in forest area (ha) in Roshi Watershed, Kabhrepalanchok, Nepal, between 1978 and 1992.

	High forest		Balance	% Loss to or gain from 1978 area
	loss to	gain from		
Cultivated	1782.0	2986.7	+1204.7	+8.0
Shrub	487.1	3436.0	+2949.9	+19.8
Other	1008.1	661.5	–346.6	–2.3
Total	3277.2	7084.2	+3807.0	+25.5

(35/42). Therefore, we are optimistic that this positive trend can continue in Kabhrepalanchok and that with the appropriate implementation strategy, community forestry can have positive impacts on Nepal's Middle Hills at large.

The analysis revealed important changes in land cover that would be masked by a simple quantification of "total forested area." Indeed, total forested area declined over the 14-year period in VDCs with and without formal community forests. However, the rate of loss was lower in VDCs with community forests, and there was a much greater increase in the spatial extent of high forest.

The conversion of shrublands to high forest occurs through 3 primary pathways in the Middle Hills (Figure 3). First, communities in Roshi, with external assistance, have established numerous plantations, particularly of *P. roxburghii* and *P. patula* (Jackson 1994). The establishment of plantations has been the focus of attention for international aid agencies, particularly the Australian forestry aid projects in Nepal (Ladley 1995). With the substantial increase in plantation establishment over the past 20 years (Collett et al 1996), plantations have become major contributors to high forest cover in Roshi. Similar to aid-funded plantations is the initiation of private forestry, which also can contribute to forest cover (Jackson et al 1998). Second, high forest can arise through natural successional processes on abandoned land or through the protection of degraded land (Webb and Gautam 2001). Third, broadleaf regeneration can occur in untended, unmanaged, or failed pine plantations (Gautam 1999). All 3 regeneration pathways occur as a result of the community forestry program in the Middle Hills. We do not have quantitative data on the proportional contribution of plantations, private forestry, and successional forest to the increase in high forest cover in Roshi. We encourage future research to gather such important information.

There was a small net gain of forest from cultivated land during the study period. This may be because of the abandonment of legally or illegally cultivated marginal lands by farmers. Findings of earlier research support this speculation. For example, Collett et al (1996) and Jackson et al (1998) found that households in Kabhrepalanchok are becoming gradually less reliant on farm income and subsistence farming because male family members are pursuing more off-farm income-generating activities outside the district. Also, the active involvement of some FUGs in removing illegal cultivation in their community forests (Gautam, unpublished data) may be contributing to the conversion of some agricultural lands to forest.

Our results show an increase in forest cover related to community forestry implementation in Roshi and therefore support the hypothesis that the formalized implementation of community forestry can increase forest cover. Upon establishment of a community forest (either as a plantation or as a degraded forest), our experience indicates that most user groups implement strict protectionist strategies over the resource, thereby improving the chances of plantation success or natural regeneration. Thus, protection of community forests would lead to a higher rate of forest regeneration and to the results we present here.

In addition to the RS–GIS evidence presented here, there is qualitative evidence that the community forestry

TABLE 3 Comparison of land cover among VDCs with and without formalized community forest before 1992.

Formalized community forestry status	Area (ha)						% Change in area		
	1978			1992			1978–1992		
	High forest	Shrub	Combined	High forest	Shrub	Combined	High forest	Shrub	Combined
VDCs with community forest (*N* = 13)	2850.4	3053.8	5904.2	5054.2	739.7	5793.7	+77.3	–75.8	–1.9
VDCs without community forest (*N* = 29)	12,050.3	6903.0	18,953.3	13,653.7	3428.9	17,082.6	+13.3	–50.3	–9.9
Total	14,900.7	9956.8	24,857.5	18,707.7	4168.6	22,876.3	+25.5	–58.1	–7.9

FIGURE 3 Land use and conversion to high forest in Roshi Watershed at 1500 m. The 3 main pathways of high forest regeneration are visible on this hillside. On the right toeslope is a successful *P. roxburghii* plantation, with a minor component of broadleaf regeneration. On the central slope (rear) is mixed broadleaf successional forest arising on formerly degraded land. On the left toeslope is mixed broadleaf forest that regenerated within a *P. roxburghii* plantation and is now dominant on that site. (Photo by E. Webb)

program in Roshi is succeeding at improving forest cover and condition. Field observations made by one of the authors (A.P.G.) during January–February 1999 found that local residents were skilled at explaining how degraded forests converted to high forests within a few years of protection. At some locations, residents noted a recent increase in livestock loss because of leopard predation. This change was attributed to improved leopard habitat (ie, forest recovery). Other communities in Roshi noted a recent increase in the availability of some of the forest products, including fuelwood (Gautam 1999). In the same study, local key informants expressed improvements in the "overall environmental condition" during the last 10 years, despite a decrease in agricultural productivity (Gautam 1999). The improvement in overall environmental condition was attributed to improvements in forest condition. The perceptions of local forest users provide another avenue of support for the positive biological impacts of implementing Nepal's community forestry program.

Conclusions

Quantitative evidence from this study indicates that formalized community forestry activities have contributed positively toward restoring forests in the Roshi Watershed. The increase in high forest cover was likely the result of better protection of forests by FUGs under the community forestry program being implemented in the study area since 1978. This is in agreement with direct or indirect evidence from earlier studies (Jackson et al 1998; Gautam 1999). Further investigation should integrate land cover changes with demographic, social, economic, legal, institutional, or policy changes (or all). Such a challenging task would provide an even more complete picture of the impacts of Nepal's community forestry program on the biophysical environment as well as on the livelihoods of the local communities. Moreover, this study should be replicated in other parts of Nepal or in countries where formalized community forestry is being promoted.

Finally, it should be reiterated that although our results indicate beneficial effects of community forestry on forest cover in Roshi, these results must be qualified both in space and time. The applicability of these results to other situations depends upon the comparability of community forestry implementation strategy, implementation investment, and socioeconomic, political, and cultural factors in other districts or countries.

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