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A Case Study in the Kangchenjunga Conservation Area (KCA)

The Kangchenjunga Conservation Area (KCA, Nepal) was the subject of a comparative study on land use/land cover change, using the maps and air photographs available for 2 different years (1978/79 and 1992). Digitized land use maps for 1978 (LUM78) and topographical maps for 1992 (TOPO92) were first interpreted using a Geographic Information System (GIS); this was followed by comparative interpretation of black and white air photographs from the same years. Lelep, Sekhathum–Amjilesa, Syajunma and Ramsyampati were the 4 areas selected for analysis.

The initial map interpretation of LUM78 and TOPO92 implied that considerable changes in land use/cover had occurred between 1978/79 and 1992. Forestland was shown to have decreased by 62.5% (23.15 km^2), agricultural land to have increased by 35.7% (1.49 km^2), and shrubland to have increased by 238.2% (30.16 km^2). Grazing land, with an area of 22.57 km^2 on the 1978/79 and 1992 imagery, appeared to have disappeared completely by 1992. An interpretation of air photographs for the same period, however, revealed that the actual changes were far smaller than those inferred from the map interpretation: decrease in forest and grazing lands by 14.9% (5.45 km^2) and 77.9% (2.75 km^2), respectively, and increase in agricultural and shrublands by 4.9% (0.21 km^2) and 19.7% (4.41 km^2), respectively. The results of a questionnaire survey of the local inhabitants confirmed that no significant changes had occurred. The discrepancies identified highlight the problems inherent in assigning land categories. In particular, distinctions made on the LUM78 material between shrub, grazing land, and barren land were inappropriate. Similarly, forest and shrublands were incorrectly assigned in TOPO92. Caution must be exercised when using such information; verification from other sources is needed.

Keywords: *Land use/land cover; deforestation rate; mapping; air photography; GIS; Kangchenjunga Conservation Area.*

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Introduction

Assessment of land use/land cover and its changes over time from a reliable database is crucial for planning systematic and sustainable regional development. In Nepal, various topographical and land use/cover maps have been used to develop a database. Topographical maps published by the Survey of India between 1958 and 1969 served as the sole source of such information for a long time. Various agencies in collaboration with the Topographical Survey Branch of His Majesty's Government (HMG) of Nepal published land use maps (LUM) between 1984 and 1986, and topographical maps (TOPO) between 1994 and 1996. These maps—referred to here as LUM78 and TOPO92—relied on air photographs taken in 1978/79 (under a Canadian Project) and in 1992 (Finnish/Japan International Cooperation Agency [JICA] Project), respectively. Unfortunately, no field verification was undertaken, at least in some areas, so the reliability of the assigned land cover categories depended heavily on the ability of the interpreters.

LUM78 and TOPO92 have been most frequently used to examine land use/cover changes in Nepal (eg, HMG/FINIDA 1995; Shrestha and Brown 1995; Chapagai 1996; Schweik et al 1997; Dhakal 1997; Shrestha 1997; Gautam and Koirala 1998; Shrestha 1999; UNEP 2001). The results based on the map analysis always indicated that the area of forestland had decreased more than the area in the other land use/cover categories. This is probably due to the improper identification of land use/cover types during preparation of the maps. Substantial differences in the size and shape of glaciers and lakes on topographical maps prepared by various agencies at different times were found during compilation of the glacier inventory (Mool et al 2000). Asahi and Watanabe (1998) also pointed out the inaccuracies on the new topographical maps of 1994–1996 (TOPO92). This included inappropriate assignment of land use/cover categories such as glaciers, talus slopes, grassland and forest, and of the locations of settlements and trails.

This may be due to inadequate training in air photograph interpretation, poor field data/knowledge or absence of field verification, and limitations on time for map preparation. In addition, a tendency to accept previous assumptions, such as the myth that rapid deforestation is occurring in Nepal (eg, Eckholm 1975; World Bank 1978; Karan and Iijima 1985; Allan 1986; Myers 1986; Ives and Messerli 1989) seems to have been influenced by such data, as they show a rapid decrease in forest cover.

Micro-level studies of forest cover using air photographs and satellite images, by contrast, have revealed an increase in forest cover as well as in the number of trees on private land (eg, Carter and Gilmour 1989; Fox 1993; Wayman 1993; Virgo and Subba 1994; Jackson et al 1998; Brown and Shrestha 2000), and no significant change in the extent of forest cover in the montane area (Byers 1987; Zomer et al 2001). The database of indigenous knowledge shows that there is a positive attitude towards the protection of forest resources (Johnson et al 1982; Ives 1987; Gilmour and Fisher 1991; Chhetri 1994; Gurung 1996; Thapa 1999).

The present study aims to evaluate the reliability of available maps for assessing land use/cover changes in the montane Kangchenjunga (Kanchanjunga) Conservation Area (KCA) of Nepal. The unreliability of previous work on land cover change may relate to the entire montane area of Nepal, since livestock herding and agricultural activities are quite similar throughout this area (Uprety 1994), while map interpretation methods have been similar (LRMP 1986). For this study, the land use/cover data, which were derived from the available maps for the KCA, were compared with those obtained from air photograph interpretation. The areas of the land use/cover categories were calculated using a Geographic Information System (GIS) as an analytical tool.

Study area

The Kangchenjunga Conservation Area (KCA) in the northeastern corner of Nepal was selected for analysis (Figure 1). It lies between 27°30′–28°00′ N and 87°45′–88°15′ E, bordered by Sikkim (India) to the east and Tibet (China) to the north. The KCA has a total area of 2,017 km^2, divided administratively into 4 Village Development Committees (VDCs): Olanchungola, Lelep, Tapethok and Yamapudhin. The 4 areas of Lelep (A in Figure 1), Sekhathum–Amjilesa (B), Syajunma (C), and Ramsyampati (D) were chosen following reconnaissance trips that indicated significant changes in land use/cover since 1978 (Gautam 2002).

Methodology

The study made use of maps, air photographs and field surveys, including the following:

- Digitized maps (LUM78 and TOPO92) of the 4 areas were constructed to obtain an appropriate numerical database for determining land use/cover conditions. The area for each land category (agriculture, forest, shrubland, grass/forbs, grazing land, and barren land) was calculated using ARC/INFO software.
- Interpretation of black and white air photographs (1978 and 1992) at a scale of 1:50,000. Photographs from 1992 were interpreted using a photogrammetric instrument (Leica SD 2000) with an error allowance of ±20 m while correcting for the geo-referenced coordinates. The 1978 photographs were interpreted manually because of the lack of calibra-

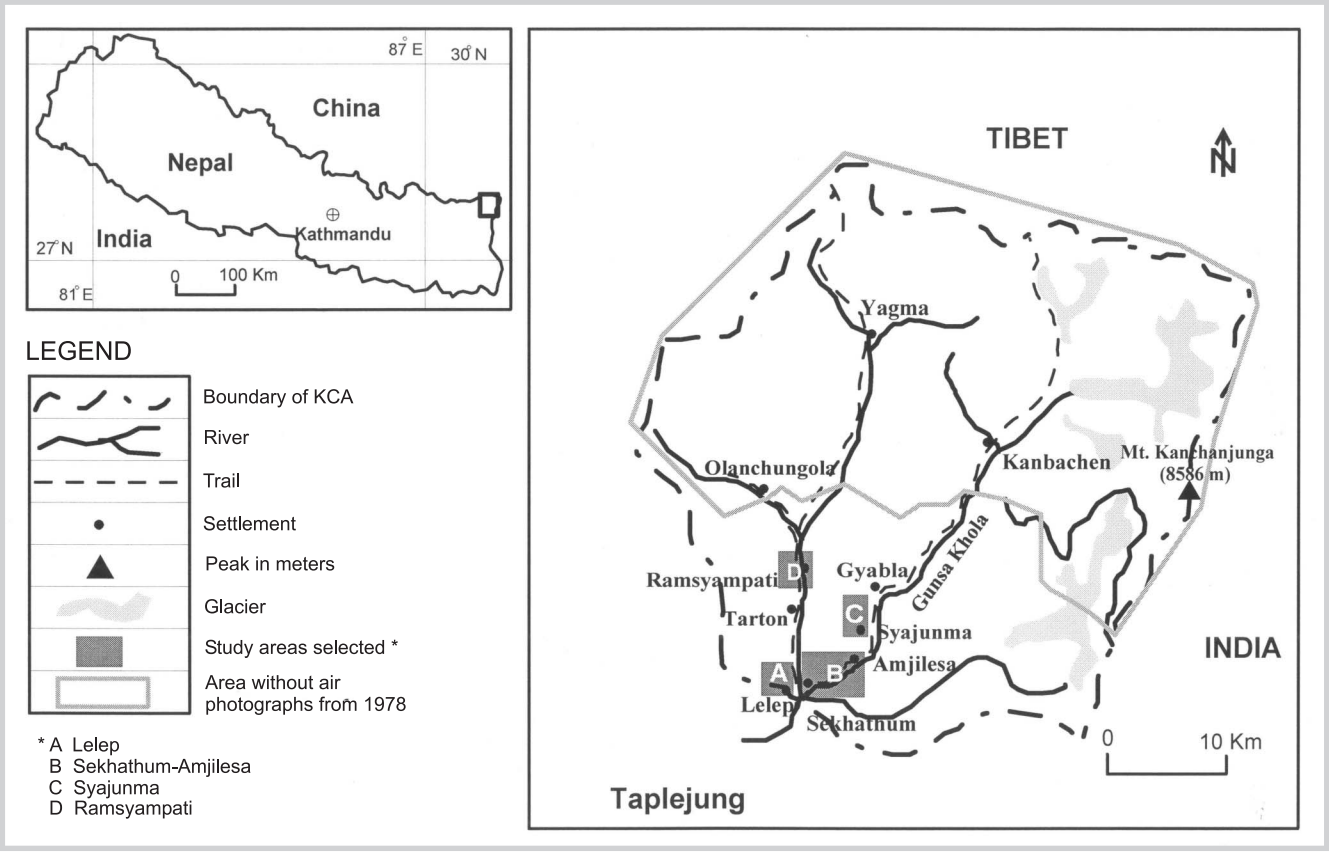

FIGURE 1 Location of the Kangchenjunga Conservation Area in Nepal. (Map by authors)

tion. Six land use/cover categories, as defined on the land use maps for 1978 (LUM78), were identified on the air photographs (Table 1).

- Following completion of air photograph interpretation and map analysis, fieldwork was conducted in April 2001 to verify the present-day boundaries of land use/cover types in the selected areas. In addition, an oral questionnaire survey was conducted with the local people to obtain information on their perception of land use/cover changes over time.

Results from the fieldwork were compared with results based on map analysis and air photograph interpretation. This led to an evaluation of the reliability of the maps.

TABLE 1 General description of land use/cover categories. (Source: LRMP 1986)

Land use/cover	General description
Agriculture	Area of crop production, including settlements
Forest	All land with forest cover used only for forestry
Shrubland	Same as forest but without well-defined stems or covered by *Arundinaria falcate* (Nepali: *niyalo*)
Grass/forbs[a]	Area covered by grass and small plants used locally as livestock fodder
Grazing land[b]	Area used for livestock production
Barren land	Area characterized by features such as ice, rock, glacier, water-bodies and landslides

[a] not included in LUM78
[b] not included in TOPO92

Results

Land use/cover changes in the 4 areas

Figure 2 is an example of the land use/cover maps produced by the GIS-assisted analysis of the LUM78 and TOPO92 (top) and by interpretation of the air photographs of 1978 and 1992 (bottom) for the 4 areas selected. Data in each land use/cover category are given for the 4 areas in Tables 2–5. The results based on the maps and the air photographs are compared below.

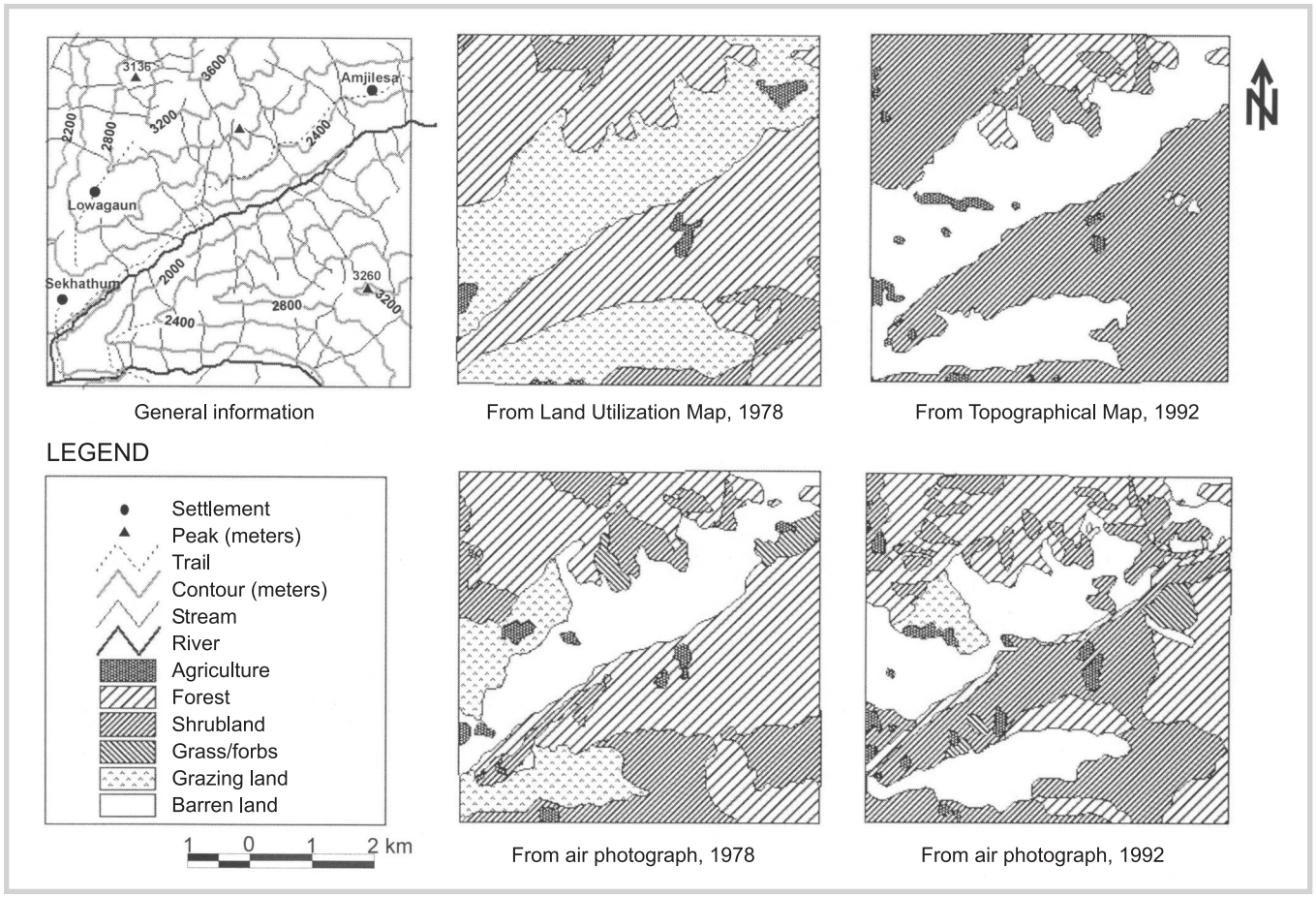

FIGURE 2 Comparison of land use/land cover in Sekhathum–Amjilesa (Area B in Figure 1), in 1978 and 1992, as established by 2 methods.

TABLE 2 Comparison of areal distribution of land use/cover in Lelep, KCA.

Land use/cover type	Area based on map analysis (km²)				Area based on air photograph interpretation (km²)			
			Difference				Difference	
	LUM78	TOPO92	km²	%	1978	1992	km²	%
Agriculture	3.41	4.78	1.37	40.18	3.59	3.45	–0.14	–3.90
Forest	4.93	2.36	–2.57	–52.13	4.23	6.30	2.07	48.94
Shrubland	2.09	9.17	7.08	338.76	8.03	5.17	–2.86	–35.62
Grass/forbs	0.00	0.18	0.18	–	0.71	1.62	0.91	128.16
Grazing land	6.40	0.00	–6.40	–100.00	0.00	0.00	0.00	0.00
Barren land	0.00	0.47	0.47	–	0.29	0.26	–0.03	–10.34
Total	16.83	16.96	0.13	–	16.85	16.80	–0.05	–

TABLE 3 Comparison of areal distribution of land use/cover in Sekhathum–Amjilesa, KCA.

Land use/cover type	Area based on map analysis (km²)				Area based on air photograph interpretation (km²)			
			Difference				Difference	
	LUM78	TOPO92	km²	%	1978	1992	km²	%
Agriculture	0.49	0.58	0.09	18.36	0.57	0.86	0.29	50.88
Forest	16.07	1.80	–14.27	–88.79	14.27	9.50	–4.77	–33.43
Shrubland	2.65	17.45	14.80	558.49	6.42	11.62	5.20	81.00
Grass/forbs	0.00	0.00	0.00	0.00	0.71	0.69	–0.02	–2.82
Grazing land	13.28	0.00	–13.28	100.00	3.53	0.78	–2.75	–77.90
Barren land	0.00	12.71	12.71	–	7.37	9.18	1.81	24.55
Total	32.49	32.54	0.05	–	32.87	32.63	–0.24	–

Lelep (Area A): Based on the map analysis, agricultural land increased by 1.37 km² (40.18%) between 1978 and 1992 (Table 2). According to the air photographs, however, no significant changes occurred between 1978 and 1992. Distinct differences in the areas mapped as forest can be seen between the 2 methods. According to the map analysis, forestland decreased by 2.57 km² (52.13%). This contrasts with an actual expansion of 2.07 km² (48.94%) as determined from interpretation of air photographs (Table 2).

There is also a considerable difference in the distribution of shrub and grass/forbs on the LUM78 and TOPO92 maps compared with air photograph interpretation for the same period. According to map analysis, shrubland increased by 7.08 km² (338.76%) while grazing land decreased by 6.40 km² (100%) (Table 2), whereas according to air photograph interpretation, shrubland decreased by 2.86 km² (35.62%) while grass/forbland increased by 0.91 km² (128.16%).

Sekhathum–Amjilesa (Area B): The forestland existing in 1978 was almost completely converted to shrubland, according to the map analysis, while the grazing land was shown as barren land. The area of grazing land in LUM78 was 13.28 km², although it was classified as barren land in TOPO92. According to the maps, forest cover had decreased by 14.27 km² (88.79%) between 1978 and 1992. Air photograph interpretation indicated a much smaller decrease in forest cover, by 4.77 km² (33.43%) only. Grazing land is also apparent on both the 1978 and 1992 photographs. Air photograph interpretation shows that the 2.75 km² (77.90%) of grazing land had been converted into barren land and that the change in agricultural land was not significant (Figure 2 and Table 3).

TABLE 4 Comparison of areal distribution of land use/cover in Syajunma, KCA.

Land use/cover type	Area based on map analysis (km²)				Area based on air photograph interpretation (km²)			
			Difference				Difference	
	LUM78	TOPO92	km²	%	1978	1992	km²	%
Agriculture	0.27	0.30	0.03	11.11	0.12	0.18	0.06	50.00
Forest	7.36	4.53	–2.83	–38.45	7.55	6.80	–0.75	–9.93
Shrubland	2.97	7.18	4.21	141.75	4.36	5.16	0.80	18.35
Grazing land	1.51	0.00	–1.51	–100.00	0.00	0.00	0.00	–
Barren land	0.00	0.00	0.00	–	0.00	0.12	0.12	–
Total	12.11	12.01	–0.10	–	12.03	12.26	0.23	–

TABLE 5 Comparison of areal distribution of land use/cover in Ramsyampati, KCA.

Land use/cover type	Area based on map analysis (km²)				Area based on air photograph interpretation (km²)			
			Difference				Difference	
	LUM78	TOPO92	km²	%	1978	1992	km²	%
Forest	8.69	5.21	–3.48	–40.05	10.51	8.51	–2.00	–19.03
Shrubland	4.55	9.02	4.47	98.24	3.62	4.89	1.27	35.08
Grass/forbs	0.00	0.33	0.33	–	0.52	0.95	0.43	82.69
Grazing land	1.38	0.00	–1.38	–100.00	0.00	0.00	0.00	–
Barren land	0.00	0.29	0.29	–	0.00	0.29	0.29	–
Total	14.62	14.85	0.23	–	14.65	14.64	–0.01	–

Syajunma (Area C): According to map analysis, forestland decreased by 2.83 km² (38.45%), whereas shrubland increased by 4.21 km² (141.75%). Air photograph interpretation does not detect such significant changes: forestland decreased by 0.75 km² (9.93%) while shrubland increased by 0.80 km² (18.35%) (Table 4).

Ramsyampati (Area D): Map analysis suggested a significant change in forest and shrubland. Forestland decreased by 3.48 km² (40.05%) while shrubland increased by 4.47 km² (98.24%) between 1978 and 1992 (Table 5) and grass/forbland increased by 0.33 km². By contrast, air photograph interpretation shows a decrease in forestland of 2.00 km² (19.03%) and an increase in shrubland of only 1.27 km² (35.08%).

Comparison of results from LUM78 and the 1978 air photographs

For the areas selected in this study, the land use/cover derived from the available LUM78 maps clearly differs from that derived from the air photographs of 1978. On the LUM78 maps, the problem of assigning land categories was largely restricted to shrubland, grass/forbland and grazing lands. In the area surrounding Lelep, a large area of shrubland was mistakenly identified as grazing land on LUM78. According to the local people, this area has been used/covered by shrubs and grass/forbs ever since their migration into the area.

In Sekhathum–Amjilesa, the major problem appears to have been the definition of grazing and barren land on LUM78. In the last 2 areas, the same problem is evident in distinguishing shrub and grazing land. In Syajunma and Ramsyampati, the area under *Arundinaria falcate* (*niyalo* in Nepali), a shrub species, was included as part of the grazing land on these maps. The identification of agricultural land also seems to be rather poor throughout the LUM78 maps when compared with the air photographs of the same period (Figure 2).

Comparison of results from TOPO92 and the 1992 air photographs

There is a great difference in the areas of forestland and shrubland derived from TOPO92 when compared

TABLE 6 Change in land use/cover in 4 areas between 1978 and 1992 in the KCA.

Land use/cover type	Area based on map analysis (km²)				Area based on aerial photograph interpretation (km²)			
	1978	1992	Change in km²	Change in %	1978	1992	Change in km²	Change in %
Agriculture	4.17	5.66	1.49	35.73	4.28	4.49	0.21	4.91
Forest	37.05	13.90	–23.15	–62.48	36.56	31.11	–5.45	–14.91
Shrubland	12.66	42.82	30.16	238.23	22.43	26.84	4.41	19.66
Grass/forbs	0.00	0.51	0.51	–	1.94	3.26	1.32	68.04
Grazing land	22.57	0.00	–22.57	–100.00	3.53	0.78	–2.75	–77.90
Barren land	0.00	13.47	13.47	–	7.66	9.85	2.19	28.59
Total	76.06	76.46	0.40	–	76.40	76.33	–0.07	–

with the 1992 air photograph determinations (eg, Figure 2). If forestland and shrubland are combined, TOPO92 and 1992 air photograph analyses provide similar results for all 4 areas. This clearly demonstrates that forestland and shrubland have not been correctly distinguished on TOPO92. This was confirmed by the local people. In spite of the inaccuracy in assigning forestland and shrubland on TOPO92, the other categories of land use/cover do not seem to have been as extensively misinterpreted as on LUM78.

Discussion

The results of the LUM78 and TOPO92 analyses in the selected areas showed great changes in each category of land use/cover: decrease in forestland by 62.48% (23.15 km²); increase in agricultural land by 35.73% (1.49 km²); and increase in shrubland by 238.23% (30.16 km²) between 1978 and 1992 (Table 6). Grazing land was shown to have been completely eliminated (22.57 km²) during the same period. However, from air photograph interpretation and from the opinions of local people ascertained during fieldwork, the actual change was not so great as suggested by the map analysis above. Forestland, for instance, had decreased by only 14.91% (5.45 km²) from the area recorded in 1978. And agricultural land and shrubland had increased by 4.91% (0.21 km²) and 19.66% (4.41 km²) of their area in 1978, respectively (Table 6). Grazing land had decreased by 77.90% (2.75 km²).

Air photograph interpretation, knowledge of the local people, and field observations in April 2001 to cross-check the results of map and air photograph interpretation suggest the existence of a serious problem in assigning land to different categories (shrub, grazing and barren lands) on LUM78. For TOPO92, the problem was more narrowly related to incorrect classification of forest, shrub and grass/forblands. Therefore, it is recommended that these maps be used with great caution for any future land use/cover change studies. In addition, previous conclusions drawn from such interpretation should be revised.

Table 6 summarizes the changes in land use/cover in the 4 areas between 1978 and 1992, based on the 2 methods. The map analysis indicated that extensive deforestation and abandonment of grazing land had occurred, resulting in an increase in the shrub and agricultural land categories. However, the actual changes derived from air photograph interpretation greatly contradict this result (Table 6). Actual change from forest to shrubland was found to have occurred in the northern and southern parts of Sekhathum and in the southern parts of Amjilesa (Figure 2). A few areas of Syajunma and Ramsyampati (Tables 4 and 5) were also affected. The forestland, however, increased in the areas surrounding Lelep and Lunthun (Table 2). In the Lelep area shrubland has been converted to forestland on the initiative of the local people in efforts to conserve natural resources (eg, wildlife and forest). Ultimately, the total change (decrease) in forestland was only 14.9%, not the 62.5% suggested by the mapping (Table 6).

Changes in agricultural land have always been dynamic, although the total area is small. Expansion of agricultural land seems to have been very slow compared to the rate of decrease shown for forestland. This slow expansion of agricultural land may be attributed to the practice of slash-and-burn farming (Figure 3). Under such a regime, the location of the individual cultivated patches changes from year to year and from place to place, and the abandoned cultivated (fallow) areas revert to forest, as confirmed by the local people during the field visit. As a result, changes in the area of agricultural and forestlands are difficult to estimate quantitatively. This tendency may be accentuated because local people prefer to cultivate cardamom and

FIGURE 3 Forest near Lowagen affected by slash-and-burn maize cultivation. After harvesting maize, the cultivated field is usually abandoned. Recently, people have started cultivating *chiraito* (*Swertia* spp.) with maize. (Photo by Chinta Mani Gautam)

chiraito (*Swertia* spp.) as cash crops. Dynamic changes in forest/agricultural lands in the Middle Mountains of Nepal are also discussed by Kollmair and Müller–Böker (2002). This important topic should be studied systematically in the future.

Problems in over-estimating rates of deforestation

Previous studies analyzing land use/cover change in various parts of Nepal based on maps have almost invariably led to the conclusion that the rate of land use/cover change is high (Thapa and Weber 1990; HMG/FINIDA 1995, 1996; Chapagai 1996; Dhakal 1997; Schweik et al 1997; UNEP 2001). LUM78 and TOPO92 have been the sole sources for developing the forest inventory at the national level until recently. Formulation of forest policies (Forest Master Plan in 1988) is actually based on the interpretation of LUM78. Various agencies, such as HMG/FINIDA (1995, 1996), DFRS (1999a, 1999b) and UNEP (2001) have compared their findings with those derived from LUM78, especially in the evaluation of changes in forest cover from 1978/79 onward. For example, DFRS (1999a) concluded that forest area has decreased at an annual rate of 2.3% between 1978/79 and 1994 in the hilly area of Nepal. These rates are always higher than those derived from the interpretation of air photographs (Virgo and Subba 1994; Tamrakar 1995; Shrestha and Brown 1995; Tamrakar 1996; Jackson et al 1998) or analysis of satellite imagery (Zomer et al 2001); this is especially true for forestland. It is clear from the analysis undertaken in this project that the greatest problem lies in defining forest and shrubland on TOPO92. No objective definition seems to have been used for these categories when preparing the topographical maps (Khanal 2001).

Such a problem in the classification of forest and shrub cover for interpretation of LUM78 and TOPO92 strongly suggests the need for field verification. It also illustrates that, for Nepal, any policy formulation for systematic planning and sustainable regional development requires a much more reliable method for determination of the extent and quality of the natural resource base, especially in the case of forests.

Conclusions

The comparison between land use/cover changes in the Kangchenjunga Conservation Area in eastern Nepal

based on map analysis and those derived from air photograph interpretation suggests that the former method produced a much higher assumption of land use/cover change than the latter. There are several explanations for the poor quality and unreliability of the earlier map interpretations. The forestland and shrubland categories on the existing topographical maps of 1994–1996 are inaccurate because no objective criteria seem to have been used in differentiating them. Land categories, such as shrubland, grass/forbland, grazing land, and barren land are not always correctly delineated on the land use map of 1984–86.

Because of the shortcomings in delineating the land use/cover categories on the available maps, previous studies based on these maps have over-estimated the decrease in the area under forest. The amount of decrease shown is almost twice as much as the actual change. Such bias naturally continued to support the myth of massive deforestation in Nepal. It is recommended that the land use/cover patterns on the topographical maps and land use maps be reclassified (Gautam et al 2002) and that their suitability for assessing actual land use/cover in other areas of Nepal be reassessed. It is also recommended that air photograph interpretation be incorporated in the assessment process for any future determination of land use/cover changes. With the passage of time, much more accurate maps, air photographs, and satellite imagery have become available. Nevertheless, a problem will remain if determinations of land use/cover based on newer data are compared with data from LUM78 and TOPO92.

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