Chapter 3

GIS Applications in Monitoring Land-cover / Land-use Changes

3.1 Introduction

Land is a finite resource. Population pressure beyond the carrying capacity of this resource has caused environmental problems and affected the standard of living of the inhabitants. The availability of land in the hills is said to be greater than in the plains, if population density per unit area is considered. But the effective availability of land is also actually very low, if farm holding sizes and rights of local communities to government-owned forest lands are considered.

Information on existing land use and land cover, its spatial distribution, and changes are essential prerequisites for planning (Anonymous 1992). Land-use or land-cover changes are critically linked to a combination of natural and human impacts. Changes in land cover contribute significantly to changes in the state of the biosphere and bio-geochemical cycles. These changes are driven by a complex set of interacting factors (Turner 1995). An improved understanding of the dynamics of land-use/land-cover changes provide a means for projecting the impacts of land use and future responses. Thus, land-use planning and land management strategies hold the key to development in the region. Geographic Information Systems (GIS) provide an effective tool for analysis of patterns and causes of land-use dynamics and for planning management strategies. This is even more important in mountainous regions where the physical constraints make it difficult to update the information frequently. The rural systems in the Himalayas are so diverse that careful consideration of location-specific attributes become a precondition for ensuring the success of development efforts (Saxena et al. 1994a).

3.2 Methodology

3.2.1 Building the Database

The base map was derived from the Survey of India topographic map (on a scale of 1:50,000). Broad land-use types, such as cultivated land, settlement areas, forest areas, bare rock surfaces, and wastelands, were digitised from this map. This provided the land-use / land-cover status for

1963 (Map 8). To simplify matters, only the planimetric area was considered. Visual interpretation of a geometrically corrected IRS image from 1993 provided the base for land use in the 1993 land-use / land-cover delineation (Map 9). An extensive field survey across the watershed provided the ground truth to support the visual interpretation. Two hundred and forty representative units of 0.1ha plots in the watershed were studied in detail.

3.2.2 Data Processing and Information Input

Both maps from 1963 and 1993 were digitised on common coordinates and the changes in land use were derived through overlay operations. As the extent of the study area was not too large, few errors occurred in fitting the geometrically corrected and geo-referenced RS image with the base map. Even when digitising from a remote-sensing imagery-based map, the RMS (root mean square) error was kept within a limit of 0.005. Various analyses of land-use changes in the period from 1963 to 1993 were interpreted. Statistical analysis was carried out using Arc/Info Tables and SML macros.

3.2.3 Methods of Analysis

Primary data collected from 1993 to 1995 were used to establish the database. Using overlay (UNION, INTERSECT, IDENTIFY) and Boolean operations with Arc/Info, the land-use changes from 1963 to 1993 period were identified (Map 10).

The average slope was calculated by constructing a grid of 0.5km x 0.5km squares. The number of contour intersections were counted and applied to the formula (Wentworth 1930) to derive the average slope for each square. Finally, isopleth lines were drawn to produce the 'Average Slope' map (Map 4, Table 1, Chapter 2). This map was 'intersected' with land-use maps to derive information related to slope-land use interaction.

Topographic characteristics, such as elevation zones and aspect (direction of slope face) were interpreted from the topographical sheets. Similarly, the land-use map was 'intersected' with these topographical parameters to derive the changes in distribution of various land uses with respect to these parameters over time. These changes are described in detail in the context of forest cover (Chapter 4) and agriculture (Chapter 5).

Land facing 'accelerated erosion' was identified based on present land use and average slope features (Map 11). Cleared land with moderately high slopes (greater than 25°) is likely to be vulnerable, and erosion risks increase when such land is close to human settlements or thoroughfares. Ecological habitats or '*biotic niches*' were demarcated based on an integrated consideration of temperature, slope, aspect, elevation, soil moisture levels, geological features, and so on. These limits determine the vegetation distribution, land suitability, and, most critically, the growing period which determines the production potential of the land. This system of classification was an attempt to elaborate upon the agro-ecological zoning approach to meet the needs of micro-level resource evaluation and land development planning.

3.3 Results

1) Areas under major types of land use/land cover for 1963 and 1993 are given in Tables 3 and 4. Cultivated area includes all agricultural land and settlement areas. Forest areas include Village *Panchayat* forest (a patch of forest managed by an administrative body elected by the villagers and accessible to all villagers) and forests under the jurisdiction of the Forest Department. Alpine pastures occur generally above the elevation of 3,200masl on the southerly aspects in this watershed and are interspersed with large rocky surfaces. Alpine pastures have been grouped together with bare rock surfaces as details were not

available from the 1963 topographical map. However, such differentiation was possible from interpretation of the 1993 IRS image.

2) Changes in the area under major land-use and land-cover types were derived (Map 11, Table 5). This showed a significant increase in cultivated area as a result of conversion of previous forest or pasture land to agriculture. However, some areas also revealed an opposite trend where a portion of the agricultural area was afforested.

3) *Land vulnerable to accelerated erosion.* Significant proportions of agricultural and grazing land are likely to be facing accelerated soil erosion (Plate 3) due to overuse of sloping land (more than 25° average slope). Land protection measures are necessary in these areas (Map 11). Such measures include building very gently sloping (less than 4°) terraces for cultivation, promoting grass growth together with tree plantation on steep slopes, agroforestry in moderate slope areas, and proper tillage practices for soil conservation.

4) Since details of sub-classes of forest cover were not available for 1963, changes in forest cover density or type could not be derived. However, it can be inferred that total forest cover has decreased from almost 75 per cent in 1963 to 65 per cent in 1993.

5) However, details of changes in agricultural land and settlements could be analysed through comparison of their spatial distributions in 1963 and 1993. Changes in land-cover/land-use were found to be greater near settlements (Map 12). Agricultural and settlement areas increased from 12 per cent in 1963 to 19 per cent in 1993 due to population pressure.

Table 3: Land Use / Land Cover 1963

Type	Area (ha)	% of total area
Cultivated	113.26	12.04
Pastures	10.96	1.16
Forests	704.15	74.87
Bare rock and Alpine meadows	112.13	11.93
Total	940.50	100.00

Table 4. Land Use / Land Cover 1993

Type	Area (ha)	% of Total Area
Cultivated	176.26	18.74
Pastures	18.84	2.00
Forests	615.60	65.00
(degraded forests)	(65.20)	(6.90)
Bare rock	62.34	6.63
Alpine meadows	52.00	5.53
Total	940.50	100.00

Table 5. Land-use / Land-cover Changes 1963-1993

Change in Land Use	Area (ha)	% of Total Area
New agricultural lands	9.504	10.10
New pastures	1.578	1.68
Loss of forest areas (to agriculture/pasture)	1.514	1.61
Regenerated forests	3.297	3.50

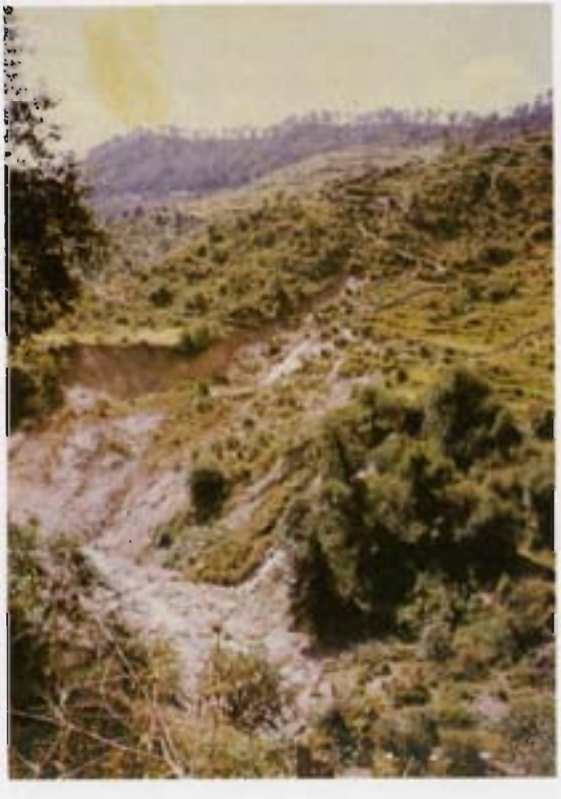

Plate 3: Erosion threatening agricultural activities

6) Sixteen micro habitats or *biotic niches* were discernible in the watershed (Map 13). These are distinguished by different temperature and moisture regimes and, thereby, their vegetational characteristics. This map can be used to determine the bioclimatic conditions of different categories of land, such as agricultural extensions and regenerated forests, and for crop suitability tests for agriculture and forestry.

3.4 Conclusions

Changes in land use were inferred for the period from 1963 to 1993. Cultivated land had increased significantly at the expense of forests and pasture land. Large tracts of degraded forests were located adjacent to newly-extended agricultural lands, but degradation could not be specified spatially or quantified due to the lack of data for 1963. The extension of agriculture to higher altitudes has been mainly brought about by increase in potato cultivation for economic development. Various aspects of agricultural land extension have been discussed in the following chapters.

The encroachment of government forest areas was found mainly to have been practised by rich villagers. The fact that the offenders employ labourers to set up stone walls to fence the encroached land suggests that the economic conditions of the concerned people are good. On the other hand, new settlements have been established on village wastelands and open forests within the village, mainly by the poor and scheduled castes. The government policy to support scheduled castes led the poor to unite and migrate to uninhabited villages (as in the case of Darmola Chak Dungri during the last 15 years) and bring uncultivated village land (cultivable wastes) under agriculture.