Chapter 5

Application of GIS for Agricultural Development

5.1 Introduction

The Pranmati Watershed, covering 94.05sq.km. had 17.63sq.km. (about 18.74%) under cultivation in 1993. The agricultural land is mainly concentrated in the lower-middle area of the watershed (1,600-2,400masl). Agriculture is exclusively rain-fed. Irrigation facilities do exist, but these are few due to very poor maintenance and the indifference of the villagers. Almost 90 per cent of the farms are terraced (Plate 7). Only floodplain areas and lands recently brought under cultivation (for potatoes) are yet to be terraced. Previous attempts at irrigation set up by the government have failed within a short period. Most of the farming activities, except ploughing, are carried out by women.

Plate 7: Agricultural fields in broader and gently sloping areas of the watershed after the millet/ cereal cropping. The terraces are almost flat here.

Until recently, the agriculture was of a subsistence type. It is only during the last 20 to 30 years that cash cropping has acquired a place in local agriculture; and ever since the potato (*Solanum tuberosum*) has been a major cash crop. Traditionally, a number of indigenous crops (about 15) were grown here, displaying a very high diversity of cultivated crops. These crops are very suitable for the local climate and terrain. The main traditional crops are *mandua* (*Elusine corcana*) (finger millet), *chua* (*Amaranthus paniculatus*) (amaranth), *jhangora* (*Echinicloa colunum*) (millet), and beans (*bhat- Glycine max*).

There is a clear relationship between altitude, crop combinations, and crop rotation (Map 16). *Mandua - jhangora* — wheat are grown below 1,600masl. Between 1,600 and 1,850masl, rice-*jhangora-mandua* (or *bhat* / soyabean) and wheat (and mustard) — *owa* (*Hordeum spp*) (barley) and *jau* (*Hordeum vulgare*) (jau)are grown. In the 1,850-2,200masl region *chua-mandua* ('bhat'/ soyabean)-*jhangora* and potato-wheat / *owa/jau* (and mustard) are grown. In some less fertile

pockets at this elevation *chua, rajma* (*Phaseolus lunetus*) (kidney beans), and potato-wheat mustard are cultivated. Above 2,400masl, up to 2,600masl, potato cultivation is conspicuous. It is predominantly this zone that comprises the newly-extended agricultural land and soil erosion has increased for various reasons.

Soil fertility on croplands is maintained from organic inputs derived from forests (litter and foliage) and livestock (cattle dung), with almost no chemical fertilizer input. The people of the watershed have an indigenous method of preparing farmyard manure (FYM) for the fields (Plate 8).

Plate 8: Leaf litter from forest floors used as bedding material is removed from cattlesheds and put into the manure pit. It will be used on the agricultural fields eventually.

5.2 Methodology

The agricultural land in 1963 was mapped from the Survey of India topographical sheets (Map 8). IRS image data supported by a detailed survey of agricultural land in the watershed confirmed the status of agricultural land in 1993 (Map 9). Agricultural land in this area included actual area cultivated, current fallow land, homesteads (settlement area) and cattle sheds. The agricultural lands associated with each village under crop rotation practices and land tillage methods were recorded in the field. The agricultural lands for 1963 and 1993 were separately intersected with physical parameters, such as altitudinal zones, average slope, aspect, soil, and geomorphic features. The agricultural lands for the two years were also intersected to detect spatial changes during the 30-year span. Extension of agricultural land in relation to elevation, slope, aspect, and bioclimatic zone was derived through intersection and the simple macro language (SML) programme.

Studies of crop rotation and yield of indigenous (local) crops and new crops were carried out for high (above 2,200masl) and low (below 2,200masl) altitudes separately. Suitability of agricultural extensions was assessed based on physical and biological parameters.

5.3 Results

1) Distribution of agricultural land in 1963 and 1993 was analysed in detail with respect to land elevation, average slope, and topographic aspects (Maps 16, 17, and 18). The distribution of agricultural land in the three physical categories (elevation, slope, aspect) during 1993 is given in Tables 10, 11, and 12 respectively. Changes in the extent of agricultural land in different elevation zones, average slope classes, and topographic aspects between 1963 and 1993 could be derived (Tables 13, 14, and 15).

2) Extension of agriculture between 1963 and 1993 (Tables 13, 14, and 15) was

Table 10: Distribution of Agricultural Land in Different Elevation Zones in 1993

Elevation Zone (m)	Area (ha)	% of Total Area
<1,200	1.8	1.02
1,200-1,400	0.9	0.52
1,400-1,600	0.05	0.03
1,600-1,800	9.9	5.63
1,800-2,000	3.5	20.13
2,000-2,200	48.4	27.45
2,200-2,400	51.1	28.93
2,400-2,600	25.7	14.62
2,600-2,800	2.9	1.67
>2,800	nil	
Total	176.3	100

Table 11: Distribution of Agricultural Land in Different Average Slope Classes in 1993

Slope Class (in degrees)	Area (ha)	% of Total Area
<15	16.7	9.6
15-20	45.1	25.9
20-25	50.9	29.2
25-30	40.7	23.3
30-35	19.1	11.0
35-40	1.1	0.6
40-45	0.6	0.4
>45		-
Total	176.3	100

Table 12: Distribution of Agricultural Land in Different Topographic Aspects in 1993

Aspect	Area (ha)	% of Total Area
N	0.2	0.1
NE	1.8	1.0
NW	31.4	18.0
W	40.2	23.1
E	26.4	15.1
SE	40.0	21.2
SW	34.4	19.7
S	3.0	1.7
Total	176.3	100

Table 13: Extension of Agricultural Land in Different Elevation Zones (1963-1993)

Class	Elevation (m)*	Area (ha)	% of Total Area
1	<1,200	0.35	0.36
2	1,200-1,400	0.41	0.44
3	1,400-1,600	0.06	0.06
4	1,600-1,800	2.68	2.82
5	1,800-2,000	9.74	10.25
6	2,000-2,200	26.26	27.63
7	2,200-2,400	30.08	31.65
8	2,400-2,600	22.51	23.69
9	2,600-2,800	2.95	3.10
10	>2,800	nil	0.0
	Total	95.04	1000.00

* Elevation in metres above mean sea level

Table 14: Extension of Agricultural Land in Different Average Slope Classes (1963-1993)

Class	Slope (in degrees)*	Area (ha)	% of Total Area
1	<10	11.06	11.6
2	10-20	18.31	19.36
3	20-25	25.13	26.57
4	25-30	25.09	26.53
5	30-35	13.35	14.12
6	35-40	1.01	1.07
7	40-45	0.62	0.66
8	>45	nil	0
	Total	95.04	100.00

* Average slope of land calculated as per the Wentworth (1930) method over 0.25 km^2 grid squares

Table 15: Extension of Agricultural Land in Different Topographic Aspects (1963-1993)

Class	Aspect	Area (ha)	% of Total Area
1	N	0.20	0.21
2	NE	0.65	0.39
3	NW	13.05	13.80
4	W	22.25	23.53
5	E	14.95	15.81
6	SE	26.87	28.41
7	SW	13.60	14.38
8	S	3.04	3.18
	Total	95.04	100.00

found to be highest in the 2,200-2,400masl zone. Extension of agriculture to the 2,200-2,400masl range has been mainly in the form of cultivation of potatoes as a cash crop (Plate 9). Maximum extension occurred on the 20°-30° slopes as limited land was available in lower slope classes, while steep slopes are not conducive to agriculture (Map 19). With respect to the topographic aspect, maximum extensions were on southeast and west facing slopes. Warmer aspects are preferred for agriculture, hence, after the southerly slopes, east and west facing slopes that have moderate temperatures and moisture regimes are preferred for agriculture. Northern or northerly slopes are least preferred because of cool temperatures which limit yields in the prevailing ecological conditions (Map 20).

Extension of agricultural land into different bioclimatic zones was also investigated (Map 21).

Plate 9: Encroachment of open patches in the forests for potato cultivation at higher elevations. The stone wall demarcates the extent of individual encroachments and within are small patches of potatoes.

3) Crop rotation and production: There seems to be an overemphasis on potato cultivation in almost all villages, especially at high altitudes. Potatoes are the predominant crop and cover 60 per cent of the total cropped land at high altitudes (>2,200m). In the lower elevation areas, due to greater diversity of crops grown, the share of potatoes decreased to around 50 per cent (Fig. 2). Rice, though not predominant, is an important crop at lower altitudes where some irrigation is available (Fig. 3).

Figure 2: Area (%) under Crops (above 2,200m)

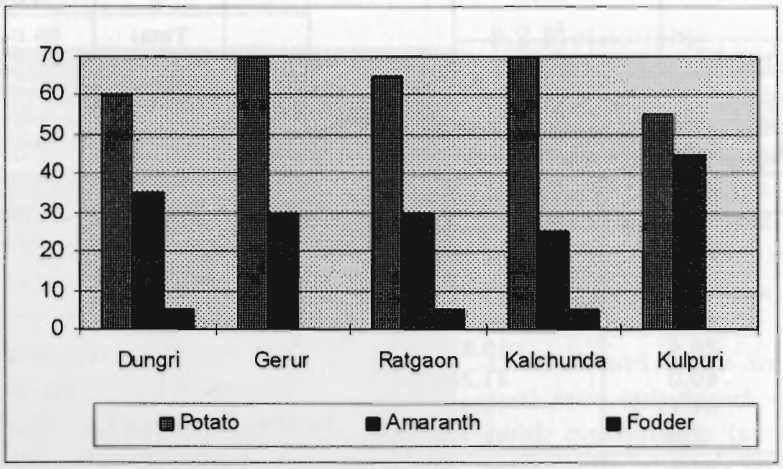
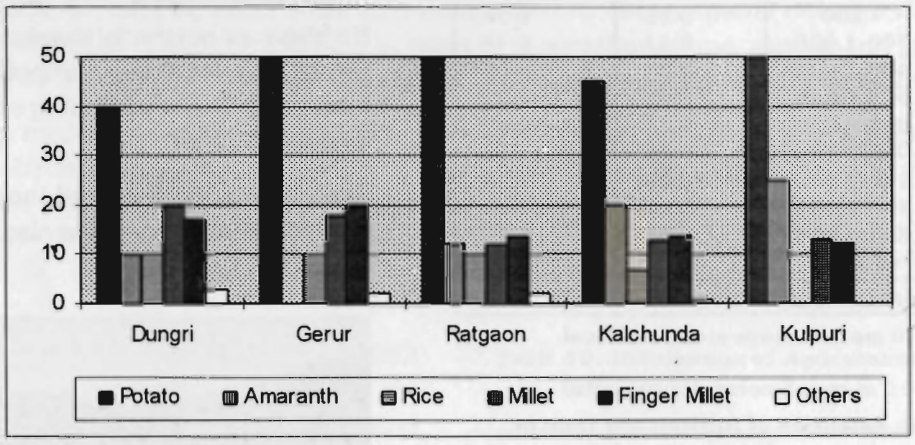


Figure 3: Area (%) under Crops (below 2,200m)



4) Crop yield: In general crop productivity in Garhwal district is quite low, even when compared with similar ecological regions of India such as Himachal Pradesh or Kumaon in Uttar Pradesh. Moreover, there has been little improvement over the years. This also reflects that the farmers in the area have not benefited from government policies for improving yields.

The yields for potatoes and amaranth (*chua*) at higher elevations are generally high, whereas yields of wheat are higher at lower elevations.

5) Suitability classes of agricultural land: Three suitability classes of all agricultural land, differentiating post - 1963 extensions, could be made: (i) the area suitable for cultivation

with no sustainability risks; (ii) the area where there is a need to improve crop and soil management practices; and (iii) those areas not suitable, thus the cessation of agriculture should be encouraged.

6) Soil characteristics from the farmers' perspective: Depth and texture are two basic parameters which normally guide farmers in identifying the land suitable for agriculture. Most of the area had a sandy loam to loamy sand texture. Some relatively flat areas had clayey loam. Soil depth was mostly of 20 to 80cm. In general, the soil could be considered moderately fertile from a regional perspective. A decline in soil fertility had been noticed by farmers over the past few decades. The decline in soil fertility is likely to have been caused by overuse of shallow soils and fall in input of organic manure per unit area of agricultural land, largely due to degradation. In comparison, soil depth exceeding 50cm, according to the farmers' perspective (Map 22) and that actually found by the terrain mapping unit (TMU) method, matched well. Subtle differences in soil quality are not fairly distinguishable by farmers. As a whole, it can be said that the farmers' perspective soil map is fairly well-matched with the TMU soil map. For a small-scale reconnaissance survey of large hilly terrain, a map based on the farmers' perspective could be a cost-effective means of soil mapping.

5.4 Conclusions

Diversity of agro-ecosystems (in terms of number of crops cultivated) is generally greater at higher altitudes (Rao and Saxena 1994). This diversity is gradually being reduced with the trend of growing more cash crops. The habit of eating wheat flour and milled rice purchased from the market has gradually become a status symbol. This has led to a reduction in crop diversity and increased the emphasis on cash crops. Soil erosion is aggravated by various agricultural features such as outward sloping terraces and cultivation on non-terraced slopes. There is a high degree of land fragmentation and the consolidation of holdings is not an easy task, keeping in mind the diverse agro-ecosystems and social impediments.

Various measures have been suggested to the villagers to check soil erosion and reduce sediment load in the streams (Ghosh et al. 1995). These include: (a) to restrict agricultural practices at high altitudes (above 2,600m) and regeneration of vegetation to save the lower lands; (b) to flatten the sloping terraces; (c) to ensure proper drainage of terraces which are not susceptible to erosion and which should be able to accommodate peak runoff; (d) to protect ridge tops with grass, shrubs, and tree plantation according to suitability and prohibiting cultivation on such sites as far as possible; (e) to make earth dams on channels and gullies on lower hill slopes; (f) to switch over from potatoes to alternative traditional or profitable cash crops; (g) to divert paths from gullied areas undergoing high rates of erosion; and (h) to check extension of agricultural fields to the edges of cultivable slopes by maintaining bunds and promoting hedge growth on the bunds and field peripheries.

Horticulture should be encouraged and provided with better orchard management technology in this region. This would promote growth of fruit and nut trees with exceptional possibilities. The World Bank Review (1987) of Horticulture in the North West Hill Region has suggested strategies for this.

Encroachment of cultivation on to marginal lands is taking place due to the increasing population pressure and growing importance of cash incomes (Plate 9). Increasing yields with the help of technological inputs would reduce the pressure on marginal lands. But, increasing crop yields and introducing the means of generating more income is not enough to prevent encroachment on marginal lands. Public awareness and decisions at village level concerning soil conservation and environmental protection must be firmly promoted.