PART IV
CORRELATION OF LAND USE WITH CLIMATIC FACTORS IN GORKHA DISTRICT

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1. INTRODUCTION

The suitability of a location for specific plants and crops is particularly influenced by the temperature and moisture regimes. Temperature is a function of latitude and altitude, but it is also influenced by slope gradient and aspect, cloud formation, and rainfall. The interaction among these parameters as it impacts on the seasonal and local variation in temperature and thus, for example, on the length of growing season must be understood before any intervention in the environment or farming systems can be attempted (Whiteman 1988). However, the description of the environmental system needs to include the human factor, since different cultures have developed different approaches to the use of natural resources in a similar climatic regime (Lundberg 1992). A lot of research has been carried out to define the relationship between land cover and environmental variables. For instance, only recently Ustin et al. (1994) examined the forest distribution and topographic features in mountain forests of the Sierra Nevada in California using the GIS technique.

In this study about Gorkha District, a demonstration of some spatial relationships between altitude, aspect, agroclimatic zones, the distribution of land-use classes, agricultural land, practised cropping systems, and cropping intensities has been attempted. Furthermore, categories for cultivation were differentiated and a plan for potential areas for horticultural crops and potato production (compare Parts III and V) was established. The analysis presented here is based on the following general assumptions.

1) The relationship between temperature, moisture, aspect, and altitude is such that in subtropical areas it is mainly the moisture which is in deficit. Consequently, for intensive cropping systems on the southern aspects of these areas, irrigation facilities are necessary due to high evapotranspiration.

2) Southern aspects, without special measures, e.g., terracing, contouring, improvement of soil fertility, and ground coverage through biomass, are less fertile because of their soil properties. These predominant red soils on southern aspects have, in general, a low content of organic matter and a high bulk density; minerals are leached or washed away due to high erodibility.

3) In areas less exposed to the sun, e.g., in the west and northwest, agriculture can be intensive on level terraces without irrigation facilities if they are fed by monsoon rain.

4) With increase of altitude, temperature becomes the limiting factor, and northern to eastern aspects are less appropriate for agricultural production.

2. METHODOLOGY

The Gorkha District database, on a scale of 1:50,000 with UTM projection, was used for the analysis, including (1) the LRMP land use of 1979; (2) the agroclimatic zones based on analysis; and (3) the aspect data, derived from a DEM built with contour lines digitised at 500 feet intervals. The Arc/Info GRID module was used to relate these data.

3. ANALYSIS AND RESULTS

3.1 Land-use Classes in Relation to Agroclimatic Zones

Gorkha District can be classified into nine agroclimatic zones, from the subtropical/subhumid zone in the south of the district, where the mean annual temperature is higher than 20°C, to the arctic zone in the Great Himalayan Range, in the northern part of the district, with a mean annual temperature of less than 3°C. One specific zone, 'alpine/no data', was created due to lack of moisture data in the very northeast of the district (Table 20).

Table 20: Total District Area, Agricultural and Cropped Land, Forest and Shrubland, and Grazing in Relation to Agroclimatic Zones

Agroclimatic zone	Total area	Agricultural land		Cropped area		Forest land		Shrubland		Grazing land	
	ha	ha	% of zone	ha	% of zone	ha	% of zone	ha	% of zone	ha	% of zone
Subtropical/subhumid	70,297.1	37,023.7	52.7	17,789.8	25.3	23,319.1	33.2	7,803.6	11.1	1,199.3	1.7
Subtropical/humid	12,199.6	7,447.7	61.0	3,787.8	31.0	3,169.0	26.0	1,565.0	12.8	9.1	0.1
Warm temperate/ subhumid	21,017.7	7,921.0	37.7	3,326.5	15.8	5,501.4	26.2	4,076.2	19.4	3,181.1	15.1
Warm temperate/ humid	22,237.0	10,617.6	47.7	5,405.6	24.3	6,430.2	28.9	4,805.7	21.6	381.9	1.7
Cool temperate/ subhumid	7,938.9	552.0	7.0	222.4	2.8	5,448.9	68.6	809.1	10.2	950.5	12.0
Cool temperate/humid	36,715.4	1,469.1	4.0	599.9	1.6	27,244.0	74.2	2,041.9	5.6	3,723.3	10.1
Alpine/humid	19,275.4	43.2	0.2	17.5	0.1	8,753.5	45.4	574.8	3.0	6,507.7	33.8
Alpine/perhumid	46,044.9	434.0	0.9	205.6	0.4	9,358.7	20.3	1,626.2	3.5	18,990.9	41.2
Alpine/no data	6,889.2	341.5	5.0	215.6	3.1	310.2	4.5	645.6	9.4	3,042.1	44.2
Arctic	120,455.4					49.6		326.9	0.3	20,455.3	17.0
No data	1,549.5	159.1		100.3		155.6		24.9		48.8	
Total	364,620.1	66,009.0		31,680.0		89,740.0		24,300.0		58,490.0	

Arctic, subtropical, and alpine are the dominant temperature regimes, with an area coverage of one third, 23 per cent, and 20 per cent respectively. Warm and cool temperate regimes are both of similar size, each stretching over 12 per cent of the area. The moisture regimes are mainly subhumid (27%), followed by humid (25%) and perhumid (13%). For the arctic zone, no specific moisture regime was classified.

The total area of the district, including agricultural land, actual cropped area, forests, shrublands, and grazing land, was analysed in relation to these agroclimatic zones (Figures 5 and 6).

Agricultural land covered about 18.1 per cent of the total district area, in eight agroclimatic zones. Two thirds of the cropped land had a subtropical temperature regime and, in particular, subhumid moisture conditions. There, more than 56 per cent of the total agricultural land was encountered. A considerable area was cultivated under warm temperate conditions, whereas, in cool temperate and alpine zones, not much land was under crop production (Table 21). Most forests, covering 24.6 per cent of the total area, were located either in the subtropical/subhumid or cool temperate/humid zone. Considerable areas were also found in the alpine zones. Shrubland had its main domains in the subtropical and warm temperate regime. About 84 per cent of the pasture land was under alpine and arctic temperature conditions. Wasteland, i.e., snow and ice, rocks, boulders, and sand, was less recorded in the subtropcial and warm temperate zones, nor was much found under cool temperate conditions. Under alpine temperature regimes, the ratio of wasteland was twice as high in perhumid conditions (34%) as in humid regimes (17%). In total, wasteland covered approximately 34.5 per cent of the total district.

Figure 5: Agroclimatic Zones in Gorkha: Total Area and Agricultural Land

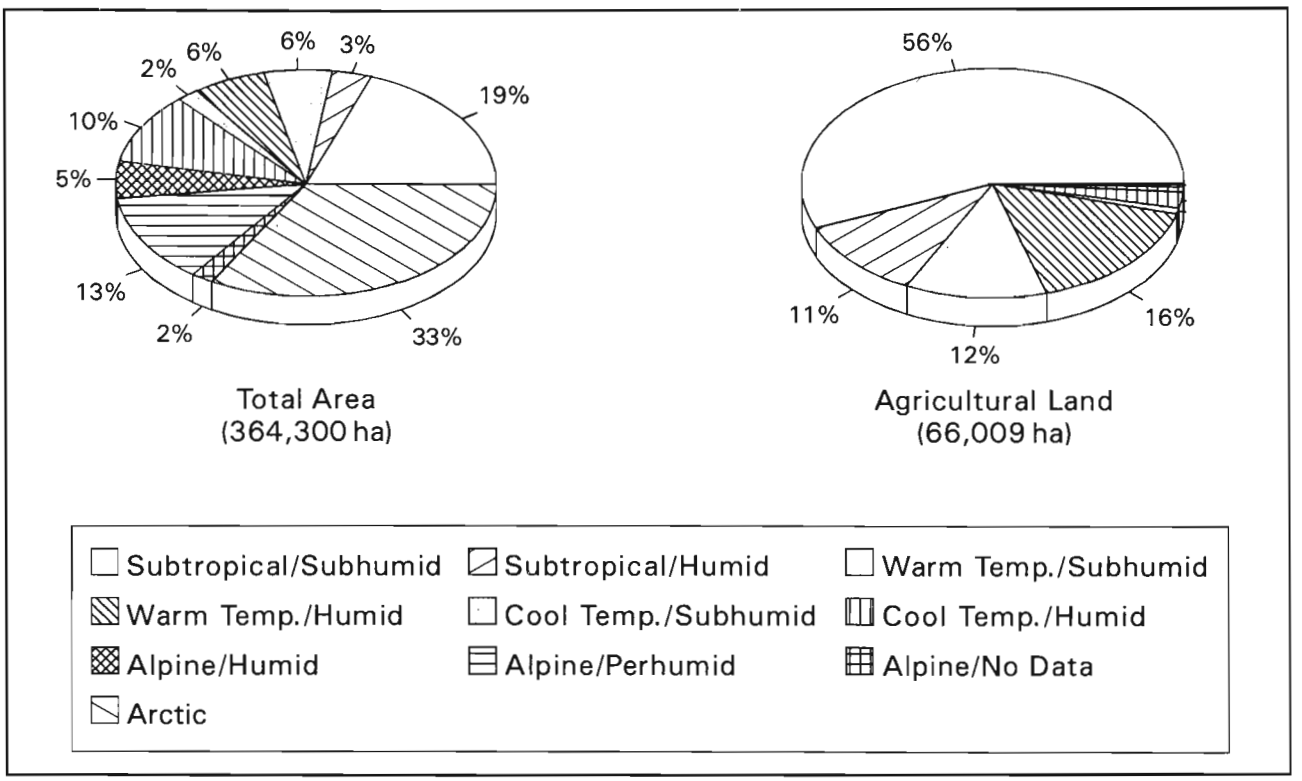


Figure 6: Agroclimatic Zones in Gorkha: Forest and Pasture Land

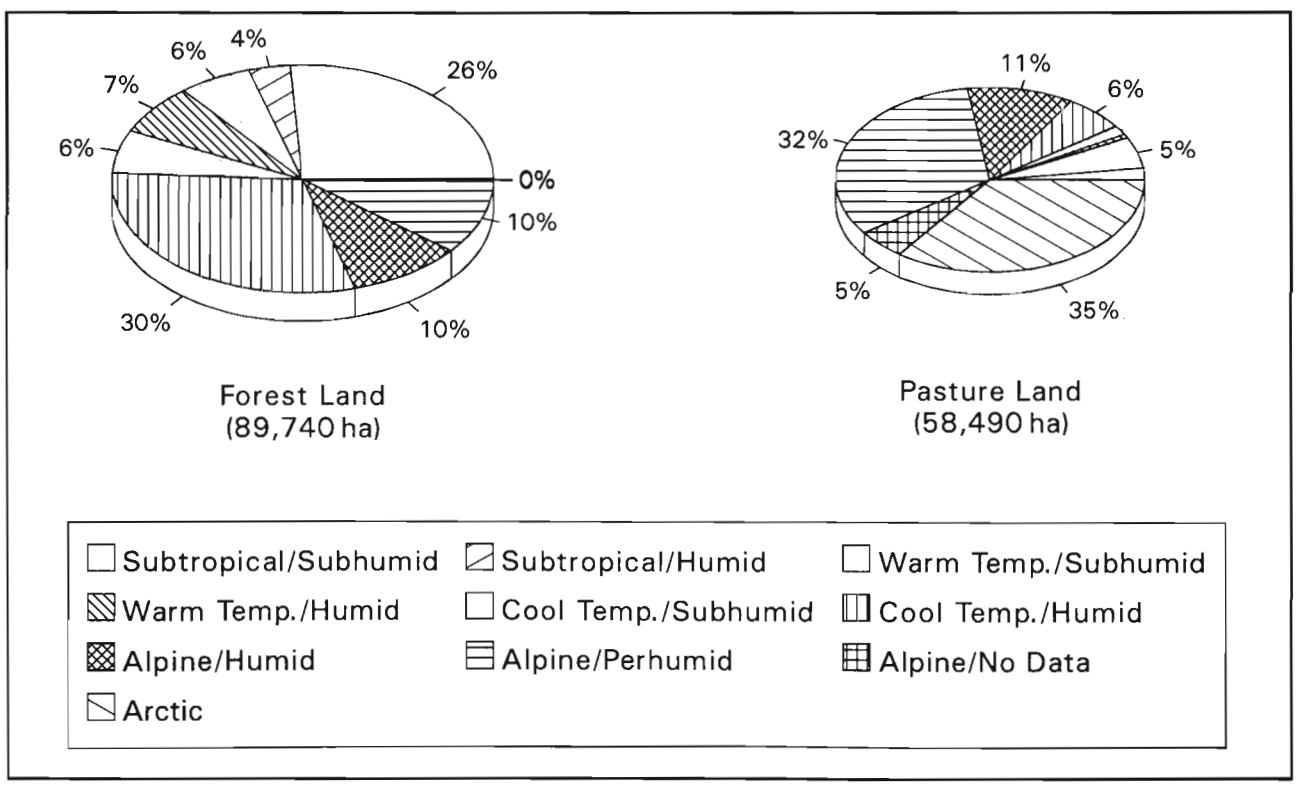


Table 21: Size of Agricultural Land in Relation to Agroclimatic Zones

Agroclimatic zone	Agricultural land		Cropped area	
	ha	% of total	ha	% of total
Subtropical/subhumid	37,023.7	56.1	17,789.8	56.2
Subtropical/humid	7,447.7	11.3	3,787.8	12.0
Warm temperate/subhumid	7,921.0	12.0	3,326.5	10.5
Warm temperate/humid	10,617.6	16.1	5,405.6	17.1
Cool temperate/subhumid	552.0	0.8	222.4	0.7
Cool temperate/humid	1,469.1	2.2	599.9	1.9
Alpine/humid	43.2	0.1	17.5	0.1
Alpine/perhumid	434.0	0.7	205.6	0.6
Alpine/no data	341.5	0.5	215.6	0.7
No data	159.1	0.2	100.3	0.3
Total	66,009.0		31,680.0	

In the subtropical zones, under both subhumid and humid moisture regimes, the portions of agricultural land (more than 50%), forest (around 30%), and shrubland (more than 10%) were similar, with slightly more forests and less cultivated areas under subhumid conditions. Under the warm temperate regime, the percentage of forests remained less than 30 per cent of the total, shrubland almost doubled, compared to subtropical zones, to about 20 per cent, and the agricultural area dropped significantly, especially under the subhumid regime, whereas under these conditions grazing lands increased remarkably to cover 15 per cent of the total land. In cool temperate areas, forests were dominant in both subhumid and humid moisture regimes, with about 69 per cent and 75 per cent respectively. Agricultural land declined drastically to much less than 10 per cent of the total area. The alpine zones were covered mainly by pastures, wasteland, and forests. However, there was quite a difference between the humid and perhumid zone. Under moist conditions less forests but more grazing areas were discovered. In the arctic zone, about 17 per cent of the area was used as pasture land; the rest was covered with snow and ice, rocks, and boulders.

In addition, forest areas were analysed with regard to crown density and maturity classes (Annex 13). In both subtropical zones there was no mature forest recorded. The forests were either degraded to shrubland or had small crown densities. This was different under subhumid conditions where medium-dense forests (40-70%) were of considerable size. Forests in warm temperate zones were in a similar condition. There, some medium-density and mature forests (6 to 7% of the total forest area) remained, but the portion of shrubland exceeded 40 per cent. Medium-density, mature forests were the biggest class in the cool temperate zones, covering almost 30 per cent of the forest area. There is an indication that the ratio was even greater because quite a sizeable area in the High Mountain Region, for which no density data are available, may have good crown coverage and large timber forests. As already mentioned, shrubland was less spread; nevertheless, forests with a low crown density and small timber accounted for 20 per cent of the forests in the cool temperate zones. In alpine zones the results seem to be similar, but the lack of data did not allow an appropriate analysis.

These results coincide with expectations, i.e., intense cultivation in the subtropics, slightly less in the warm temperate zones, and only a little agricultural production in the cooler regions. These are not only cold but less accessible and, thus, still have better forest cover. In the warm temperate zones more forests were expected, but they had degraded into shrublands, with less than 10 per cent crown cover, due to

exploitation and mismanagement. The same thing occurred under subtropical conditions, resulting in an even larger area of shrubland, but there it was a much smaller portion of the total area. Medium-density forests with good timber of considerable size were located in cool temperate and alpine zones, particularly under humid moisture regimes. By contrast, low-density forests with small timber sizes and shrubland were found to a greater extent in the subtropics and warm temperate zones where pressure on natural resources is tremendous due to large populations of both people and livestock.

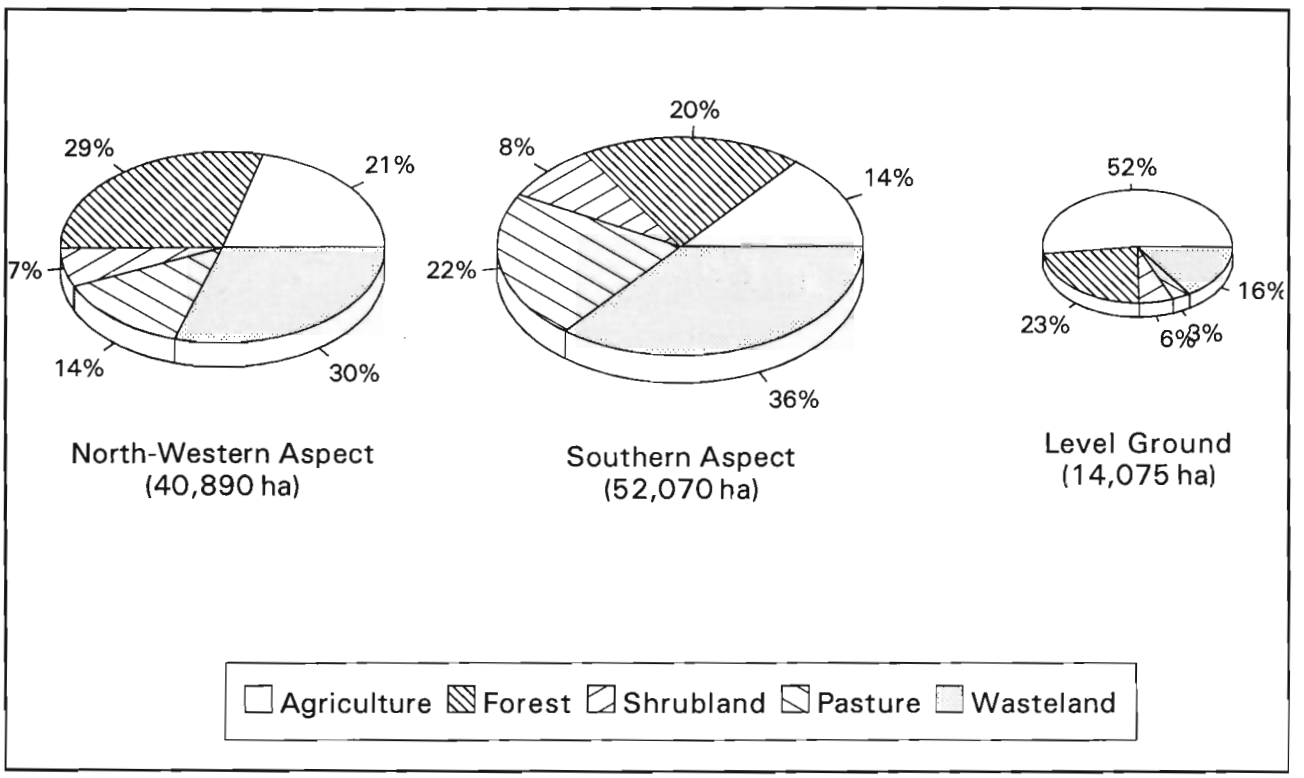
3.2 Land-use Classes in Relation to Aspects

Further, the land-use classes and their coverage areas were analysed in relation to aspects (Table 22). There are more areas with south-facing than north-facing aspects in Gorkha District. This is due to the delineation of the district boundary in the south along the valleys of the Marsyangdi and Trishuli Ganga rivers where only the southern slopes are located in Gorkha District. It is also due to the international boundary in the north which results in a similar effect. The area of level ground in the district amounts to less than four per cent of the total area. However, more than 50 per cent of this land was used for agricultural production and showed the highest intensity of cultivation, with about 56 per cent being cropped area. Northwestern aspects in total had 21 per cent under crop production. Only 14.5 per cent of eastern and southern slopes were used for agriculture. Forests were located, to a large extent, on north-facing, i.e., northern, northeastern northwestern slopes, but also on western aspects. On other aspects, i.e., southern, southeastern, eastern, and also southwestern, the proportion of forest to the total area was almost ten per cent less. It is not only these slopes in the south but those also in the west which have the highest percentage of shrubland. Degraded forests on south-facing slopes are especially difficult to recover due to their unfavourable location. Surprisingly, about 23 per cent of the level ground was covered with forests. Southern slopes had the highest proportion of pasture land, approximately 22 per cent of the area. The proportion of wasteland was biggest in the east, northeast, and southeast, amounting to about 40 per cent, and lowest on level ground and on the northwestern aspects, where it was 16 per cent and 30 per cent respectively (Figure 7).

Table 22: Total District Area, Agricultural and Cropped Land, Forest and Shrubland, and Grazing Land in Relation to Aspects

Aspect	Total area	Agricultural land		Cropped area		Forest land		Shrubland		Grazing land	
	ha	ha	% of aspect	ha	% of aspect	ha	% of aspect	ha	% of aspect	ha	% of aspect
Level	14,075.6	7,319.9	52.0	4,101.0	29.1	3,276.9	23.3	816.9	5.8	434.6	3.1
North	42,969.1	7,348.5	17.1	3,614.4	8.4	12,602.2	29.3	1,582.1	3.7	7,105.3	16.5
Northeast	40,351.4	6,171.9	15.3	2,790.7	6.9	11,134.0	27.6	1,202.6	3.0	6,154.5	15.3
East	40,052.9	5,812.0	14.5	2,602.0	6.5	8,909.1	22.2	1,825.1	4,6	6,746.7	16.8
Southeast	45,606.9	7,897.1	17.3	3,691.2	8.1	9,393.8	20.6	3,819.2	8.4	7,152.1	15.7
South	52,067.7	7,348.8	14.1	3,244.3	6.2	10,235.1	19.7	4,360.6	8.4	11,463.2	22.0
Southwest	45,246.5	7,921.5	17.5	3,623.1	8.0	10,469.4	23.1	3,934.2	8.7	7,873.0	17.4
West	41,808.2	7,445.6	17.8	3,560.9	8.5	11,733.0	28.1	4,011.2	9.6	5,939.3	14.2
Northwest	40,892.0	8,584.7	21.0	4,352.0	10.6	11,830.8	28.9	2,723.2	6.7	5,572.4	13.6
No data	1,549.5	159.1		100.3		155.6		24.9		48.8	
Total	364,620.0	66,009.0		31,680.0		89,749.9		24,300.0		58,490.0	

Figure 7: Distribution of Land-use Classes according to Aspect in Gorkha



Agricultural land and cropped area were related to the aspect, which included nine categories (Table 23). The results indicate that the biggest proportion of cropped area is to be found on northwestern aspects and level land, with both covering about 13 per cent of the total cultivated land. Northern, southeastern, southwestern, and western aspects showed nearly equal results, between 11 to 12 per cent. In the south, slightly less cultivated land was found. The percentage of cropped land on eastern and northeastern slopes was comparably low, each category covering less than nine per cent of the total cropped area.

Table 23: Size of Agricultural Land in Relation to Aspect

Aspect	Agricultural land		Cropped area	
	ha	% of total	ha	% of total
Level	7,319.9	11.1	4,101.0	13.0
North	7,348.5	11.1	3,614.4	11.4
Northeast	6,171.9	9.4	2,790.7	8.8
East	5,812.0	8.8	2,602.0	8.2
Southeast	7,897.1	12.0	3,691.2	11.7
South	7,348.8	11.1	3,244.3	10.2
Southwest	7,921.5	12.0	3,623.1	11.4
West	7,445.6	11.3	3,560.9	11.2
Northwest	8,584.7	13.0	4,352.0	13.7
No data	159.1	0.2	100.3	0.3
Total	66,009.1		31,679.9	

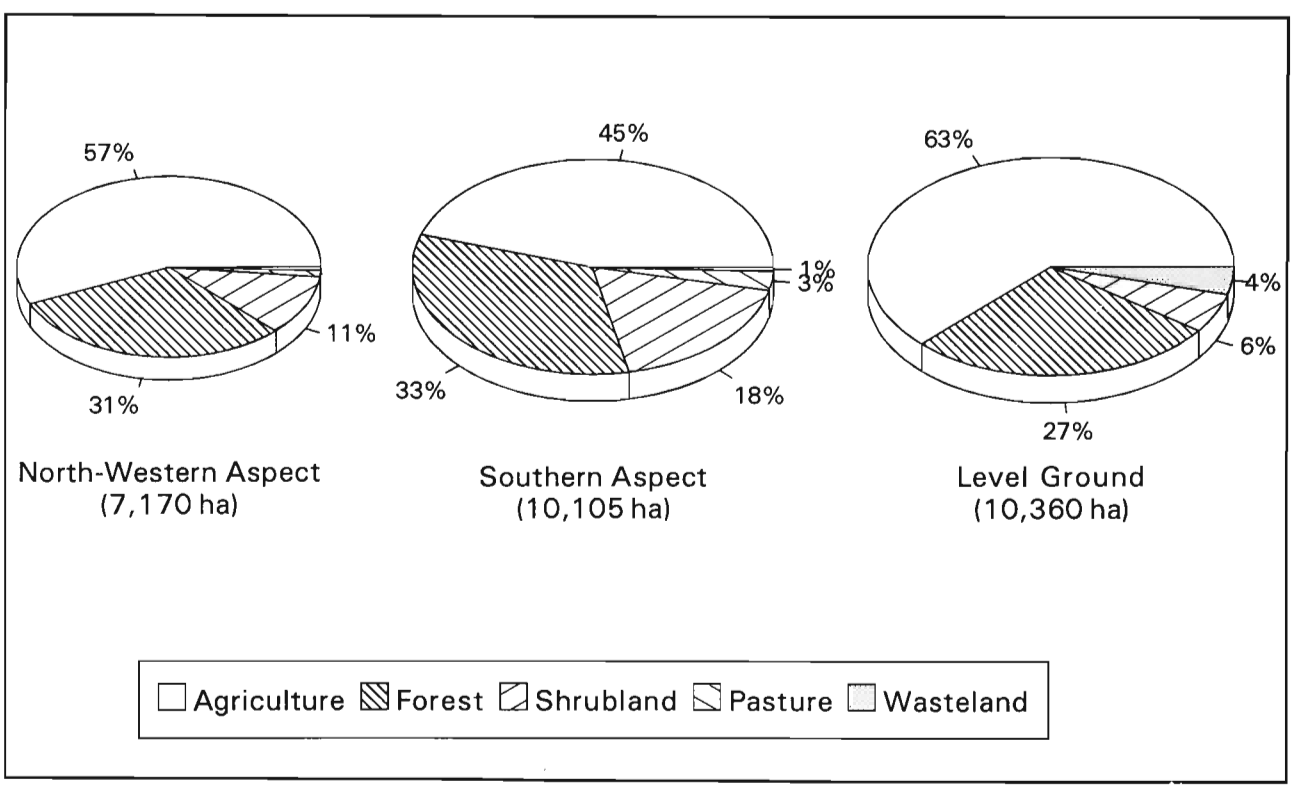
For about 22 per cent of the forest area there were no data available on crown coverage and maturity classes. Therefore the analysis of forest area in relation to aspect had some limitations. Still, a general trend was visible. The portion of shrubland was largest on southern, i.e., southern, southeastern, and southwestern, aspects and the western slopes amounted to almost 30 per cent of the total forest area on the particular aspect. The lowest values were found in the northeast and north (around 10%). A corresponding trend was given for low-density forests with small timber size, though the distribution was more balanced. In contrast, on northeastern, eastern, and northern slopes, and somewhat less on northwestern aspects, the proportion of medium-density forests with mature trees was higher than on south-facing aspects (Annex 14).

3.3 Land-use Classes in Relation to Agroclimatic Zones and Aspects

The total area, i.e., agricultural and cropped land, forests and shrublands, and grazing land was analysed in relation to both agroclimatic zones and aspects (Annex 15).

The subtropical/subhumid zone is located in the south of the district but reaches far north into the deep valley of the Budhigandaki River. Level ground and southern slopes were the dominant aspects in this zone, both occupying an area of more than 10,000ha. As already mentioned, agricultural land was the dominant land-use class in this zone, but its proportion depended on the aspect. Level ground had the highest ratio of land used for agriculture, with 62.5 per cent, followed by northern and northwestern slopes, with 57 and 56.7 per cent respectively. Southern aspects (SE, S, SW) had the lowest proportion, with less than 48 per cent. In contrast, the percentage covered by forest and shrubland areas was highest on these southern aspects and in the west, where they made up more than 45 per cent of the area. However, in these locations, large parts had degraded to shrubland. The highest ratio of forest cover was recorded on the northeastern aspect, with more than 40 per cent (Figure 8).

Figure 8: Distribution of Land-use Classes: Subtropical/Subhumid Zone

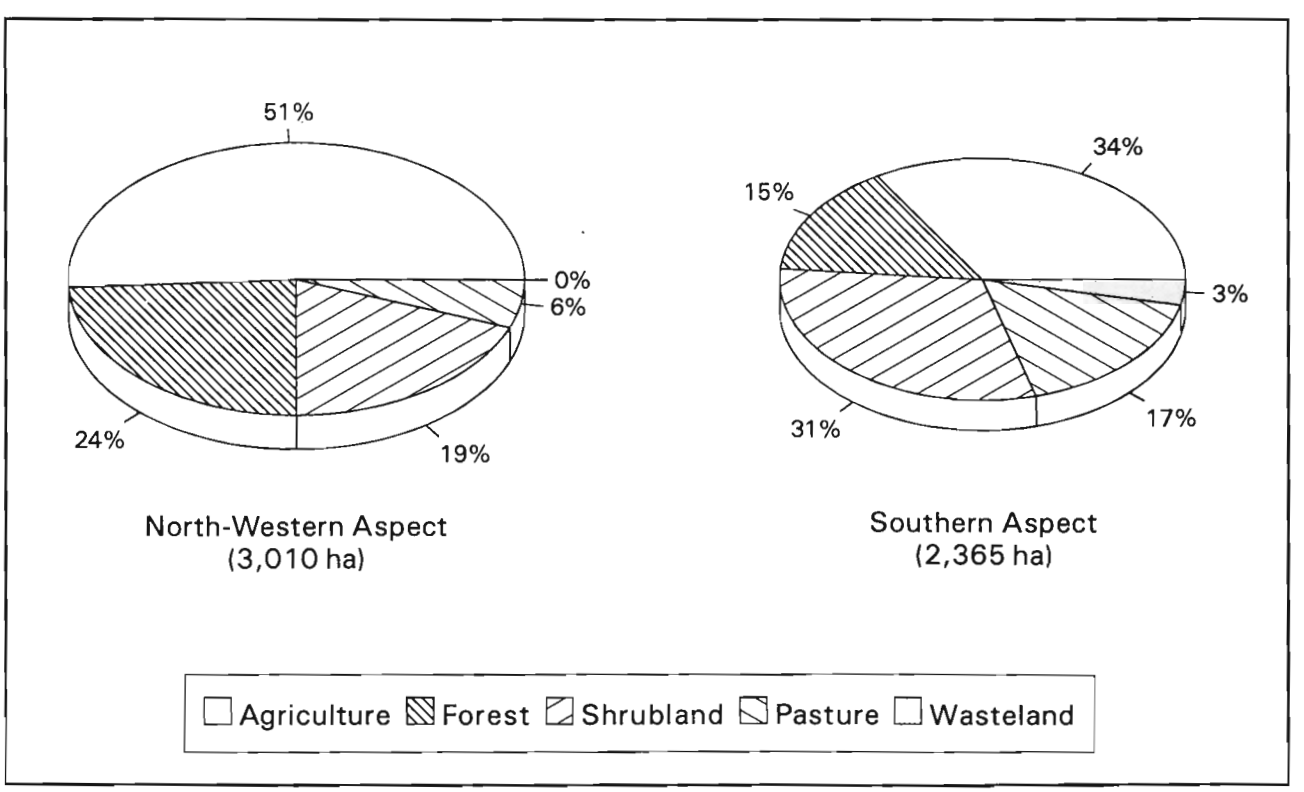


The analysis of cropped land shows that cultivation on level ground covered more than 20 per cent of the area under these agroclimatic conditions and that the intensity of cultivating was highest, i.e., more than 56 per cent of the agricultural land. In this zone, level ground is among the most fertile areas, with the potential for two rice crops or even three crops per year, if it is irrigated. The moisture deficit is high, reflecting the high evapotranspiration. If not irrigated, extensive cultivation might be practised only at these locations. The cultivated area was more or less equally distributed among other aspects, each with eight to 12 per cent of the total cropped areas under subtropical/subhumid conditions.

The subtropical/humid zone mainly covers the two upper valleys of Daroundi *Khola* and Chepe *Khola*. The highest ratio of agricultural land was found on the northeastern and northern slopes: 86 and 78 per cent respectively. As under the subhumid moisture regime, the southern aspect had the lowest portion of cultivated land and the lowest cultivation intensity, but it had the highest portion of shrubland. Due to the intense cultivation on northeastern aspects, little forest cover was noted. Agriculture was practised most intensively on northern, northeastern, and northwestern aspects, with around 54 per cent of the agricultural land being cropped.

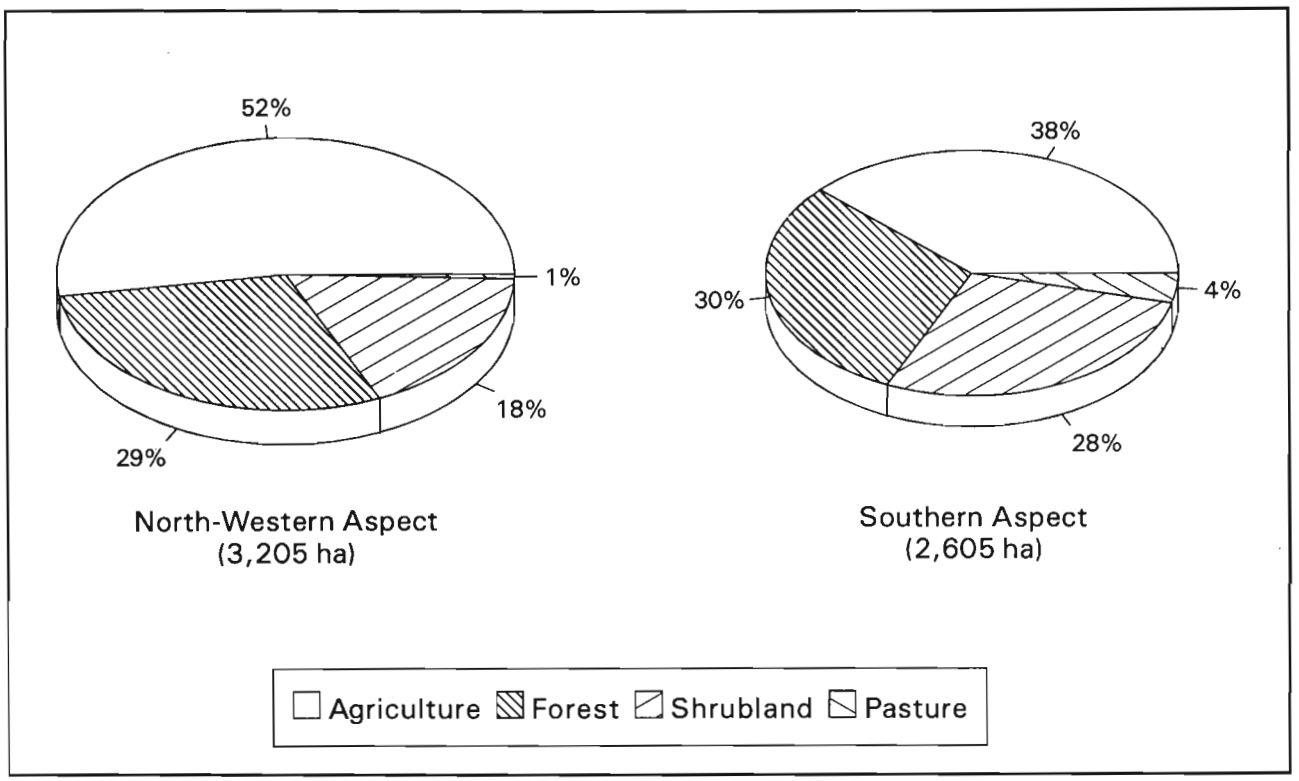
The warm temperate/subhumid zone stretches along the Budhigandaki River and Machha *Khola*. In the middle of the Budhigandaki, the zone is high above the valley, and, further north, at the valley bottom. Areas on level ground are small in this zone. Besides level ground, the highest ratio of agricultural land was on the north-western slopes with about 51 per cent. Again, southern slopes, particularly those facing southwest and south, as well as the eastern aspects, had the lowest proportion of agricultural land. Northern and northeastern aspects had high ratios of forest cover, above 40 per cent, whereas the southern aspect, again, had the smallest percentage of forests but the highest of shrubland, amounting to 15 and 31 per cent respectively. In this agroclimatic zone, remarkably large portions of the area were covered by pastures, especially in the east and southwest (Figure 9).

Figure 9: Distribution of Land-use Classes: Warm Temperate/Subhumid Zone



The warm temperate/humid zone is about the same size as the subhumid zone. It covers the area above the two valleys of the Chepe and Daroundi *Khola*(s). Unlike in the other zones, the south-exposed slopes were less used for crop production (less than 40%), especially the southern and southeastern aspects, and they had the biggest proportion of shrubland. Again, the northern aspects (NE, NW, N) and also western slopes (W, SW) had a high ratio of agricultural land (more than 50%). Forests were spread, to a large degree, on the northern and northeastern aspects. In contrast to the subhumid zone, there were only a few pasture areas in the humid moisture zone (Figure 10).

Figure 10: Distribution of Land-use Classes: Warm Temperate/Humid Zone



The small cool temperate/subhumid zone is also located along the Budhigandaki River, but high above the valley bottom. On all aspects, forest was the dominant land-use class, but it covered only 46 per cent of the south-facing slopes. The percentage of shrubland decreased on all aspects; only on the western slopes did the proportion remain steadily above 15 per cent. Crop production played a minor role in this zone, whereas grazing lands, particularly on the southern and southwestern slopes, were of importance.

The cool temperate/humid zone covers a large area along the Budhigandaki River and the ridge between it and the Daroundi *Khola*. Forests expanded to over almost 90 per cent of the area on the northern aspects and to over more than 80 per cent on western ones. Slopes facing south, southeast, southwest, and east had fewer forest areas, but more pastures and grazing land (Figure 11).

The alpine/humid zone is dominated by forests and grazing areas. Only on the southern aspects was the proportion of pasture land larger than that of forests. Wasteland amounted to about 15 to 20 per cent in all categories (Figure 12). In the alpine/perhumid zone, pastures became the major land-use class, while forest ratios decreased by more than 50 per cent compared to the humid regime. The wasteland ratio went up to 25 to 40 per cent (Figure 13).

Figure 11: Distribution of Land-use Classes: Cool Temperate/Humid Zone

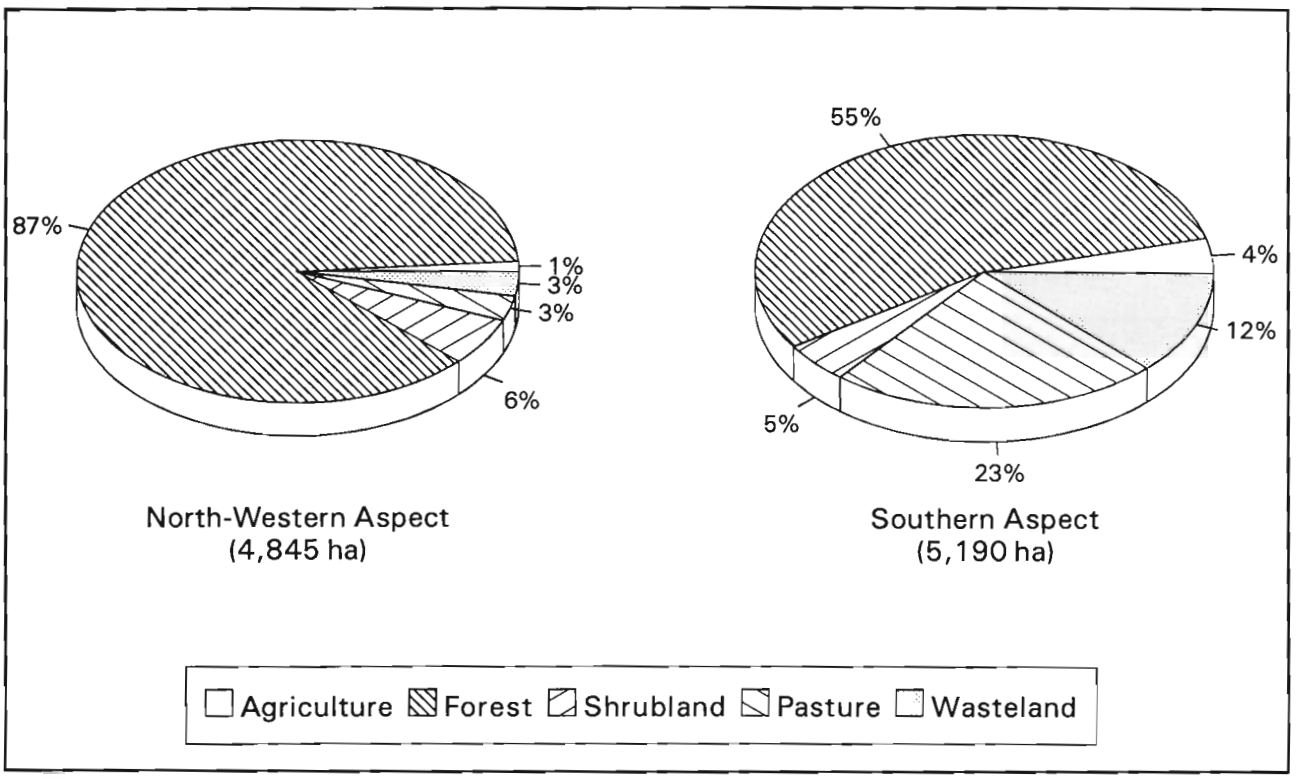


Figure 12: Distribution of Land-use Classes: Alpine/Humid Zone

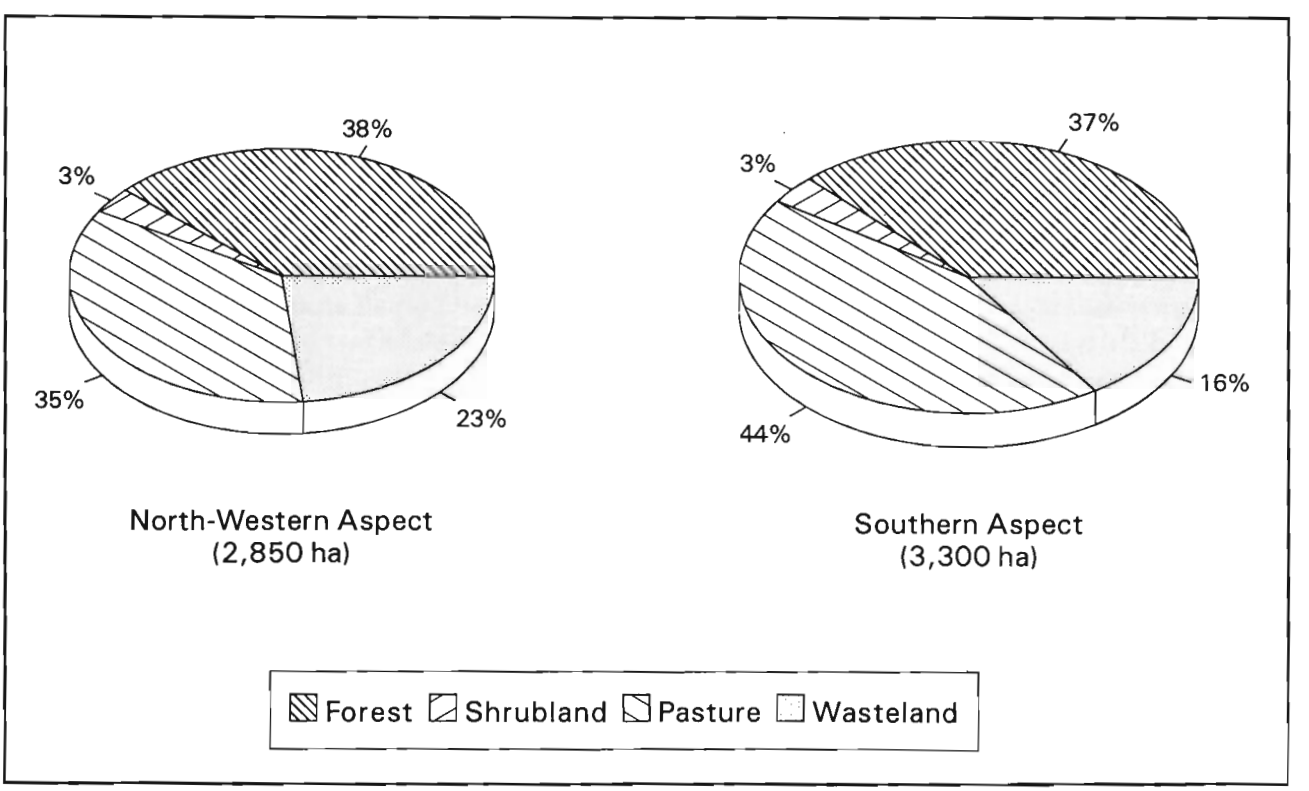
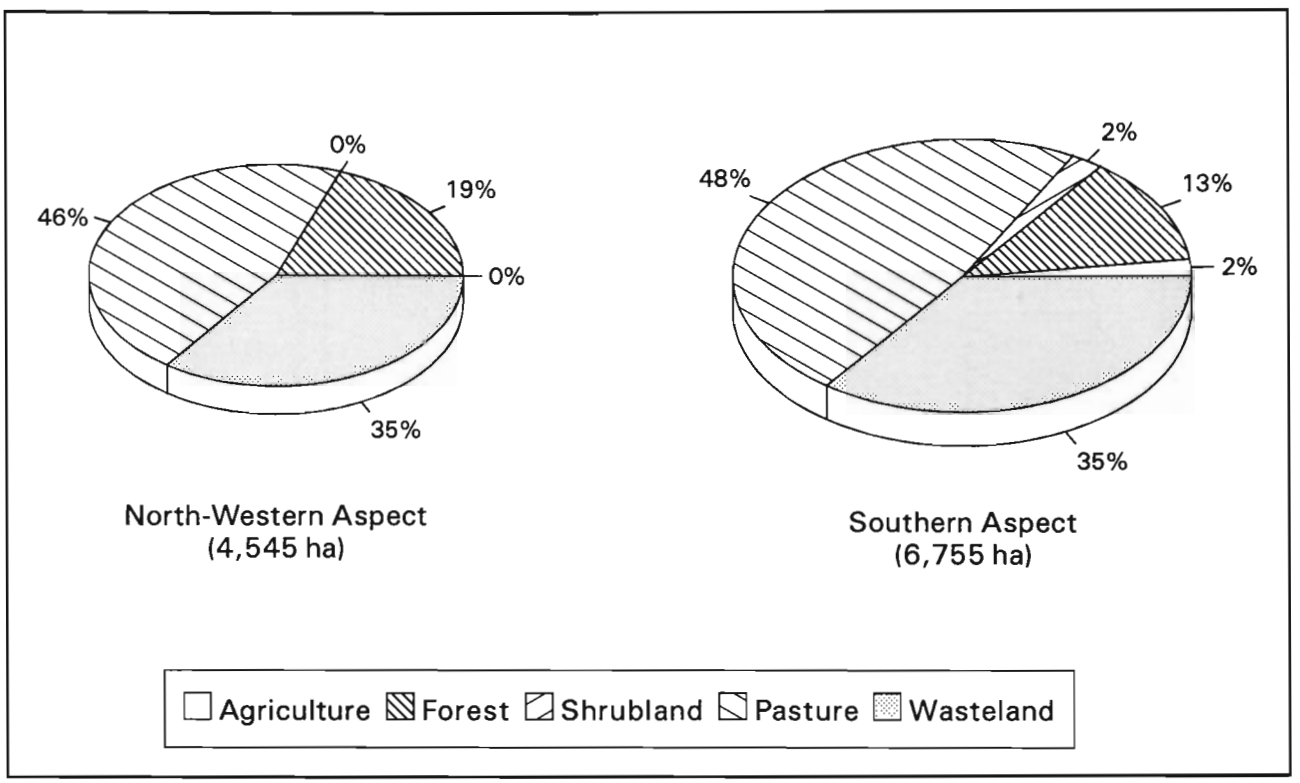


Figure 13: Distribution of Land-use Classes: Alpine/Perhumid Zone



Furthermore, forest density classes and their relation to aspects were analysed in the subtropical and warm temperate zones, including both subhumid and humid moisture regimes. Emphasis was placed on the distribution of low-density forests covering two classes of shrubland and forests with up to 40 per cent crown cover. In the subtropical/subhumid zone, where the largest forest area in total figures was recorded, low density forests covered more than 60 per cent of the forest area on all aspects except on level ground and southwestern slopes. Nevertheless, medium-density forests of considerable size were found in this zone; on level ground, these categories amounted to more than 50 per cent. The humid zone was much smaller and forests covered less area. Still, we did not expect to find low-density forests covering such a large proportion. In the warm temperate zone, where forests were spread over areas of corresponding sizes in both subhumid and humid zones, a similar trend was visible. There seemed to be no obvious reason for this phenomenon, although this trend correlated with the higher areas of agricultural land and cropped area. In both humid zones, the proportion of cropped area was higher than in the subhumid zones of the corresponding temperature regimes. This fact may lead to the conclusion, which has to be proven in the field, that intense cultivation, i.e., a high percentage of cropped area, has a negative impact on forest use. Programme activities, e.g., intensification or extension of agricultural production, would then have to be planned with this effect in mind (Figures 14 and 15).

There is an indication that the location of agricultural land is related not only to agroclimatic zones but also to aspects. In the subtropical and warm temperate zones, the portion under agricultural production is, in general, higher on level ground and on northern aspects (NW, N) than on south-facing slopes, particularly under humid moisture conditions. As already mentioned above, this result is to be expected, due to unfavourable ecological conditions for crop production on south-facing slopes. However, on the northern, northeastern, and northwestern aspects also, the moisture regime has a considerable effect on what portion is under crop production. There, agricultural areas under subhumid moisture regimes cover less ground than areas under humid moisture conditions in both subtropical and warm temperate zones. In general it can be stated that the suitability of these zones for cultivation is similar in terms of temperature, but not in terms

Figure 14: Distribution of Low Density Forest and Net Cultivated Area on the Northwestern Aspects

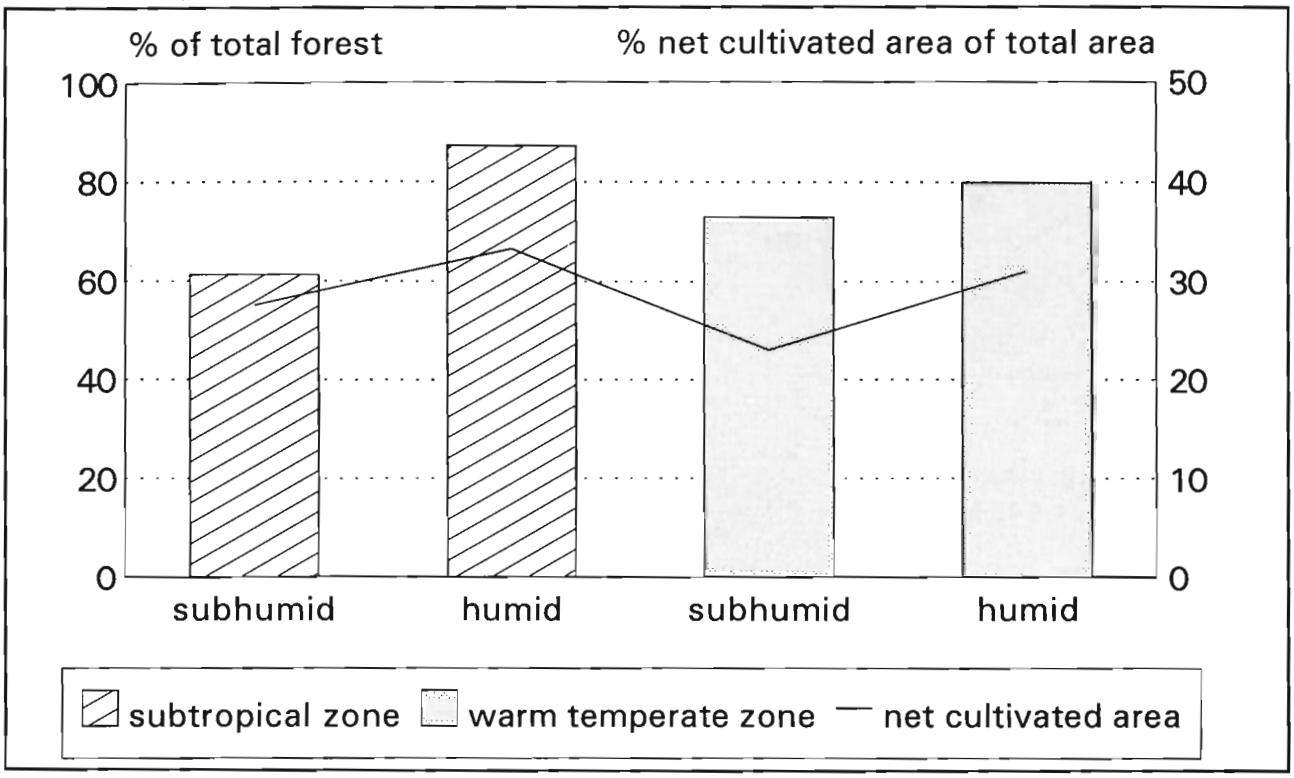
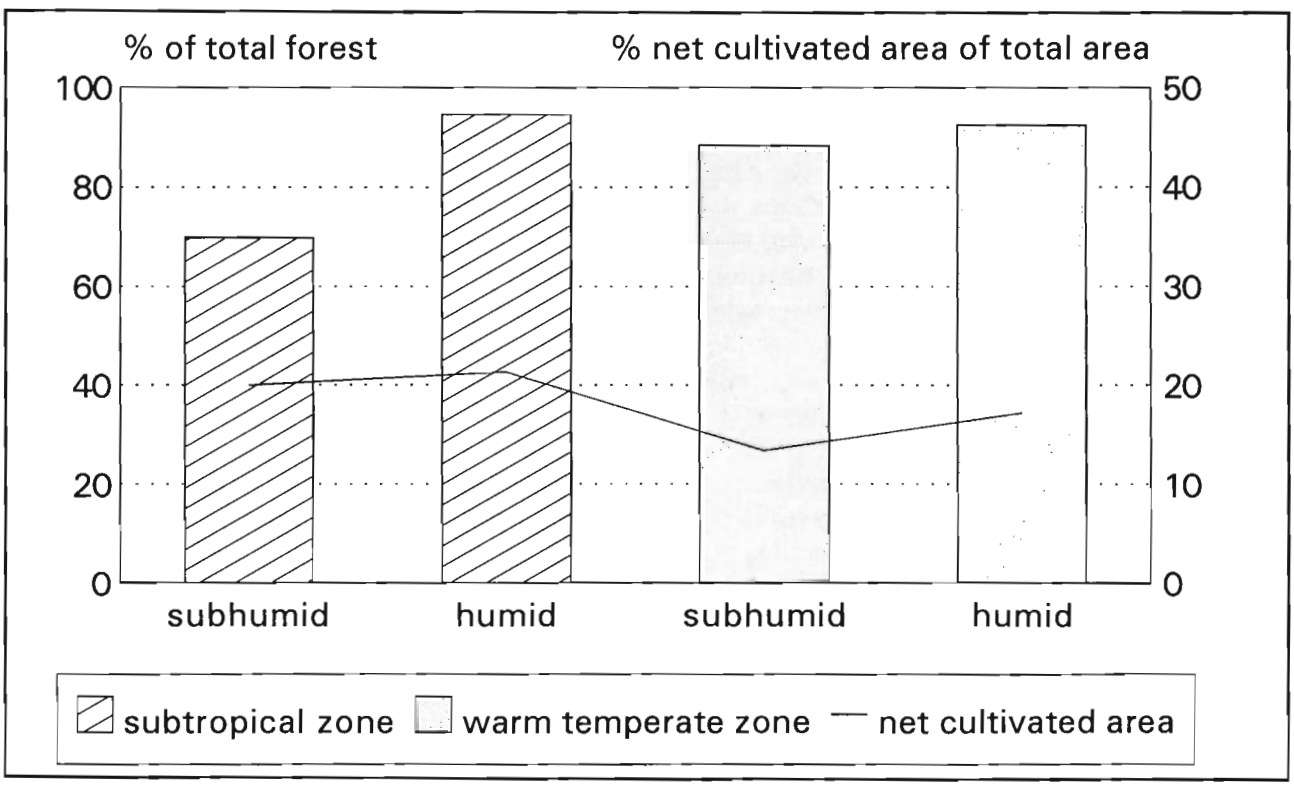


Figure 15: Distribution of Low Density Forest and Net Cultivated Area on the Southern Aspects



of moisture and soils. Therefore, these locations have always more often been traditional forest areas in case there were no possibilities of establishing irrigation systems. Due to the productive conditions, these forests can recover much better from overutilisation and mismanagement than others. This is proven by the fact that, on northern and northeastern aspects, the proportions of shrubland in subtropical and warm temperate zones are much lower than on southern slopes. In high mountainous areas, it is not the moisture but the temperature which becomes the debilitating factor for crop production. However, the ratio of agricultural land is only slightly higher on southern aspects in cool temperate zones.

3.4 Agricultural Land and Cropped Area in Relation to Aspect, Cultivation Type, and Cropping Intensity

Further, agricultural land and cropped areas were related to aspects and type and intensity of cultivation. Agriculture is practised on either sloping terraces (C), level terraces (T), tars, alluvial fans, and lower foot slopes (F), and valley floors (V). Level terraces are the dominant cultivation type in the district and cover about two thirds of the agricultural land.

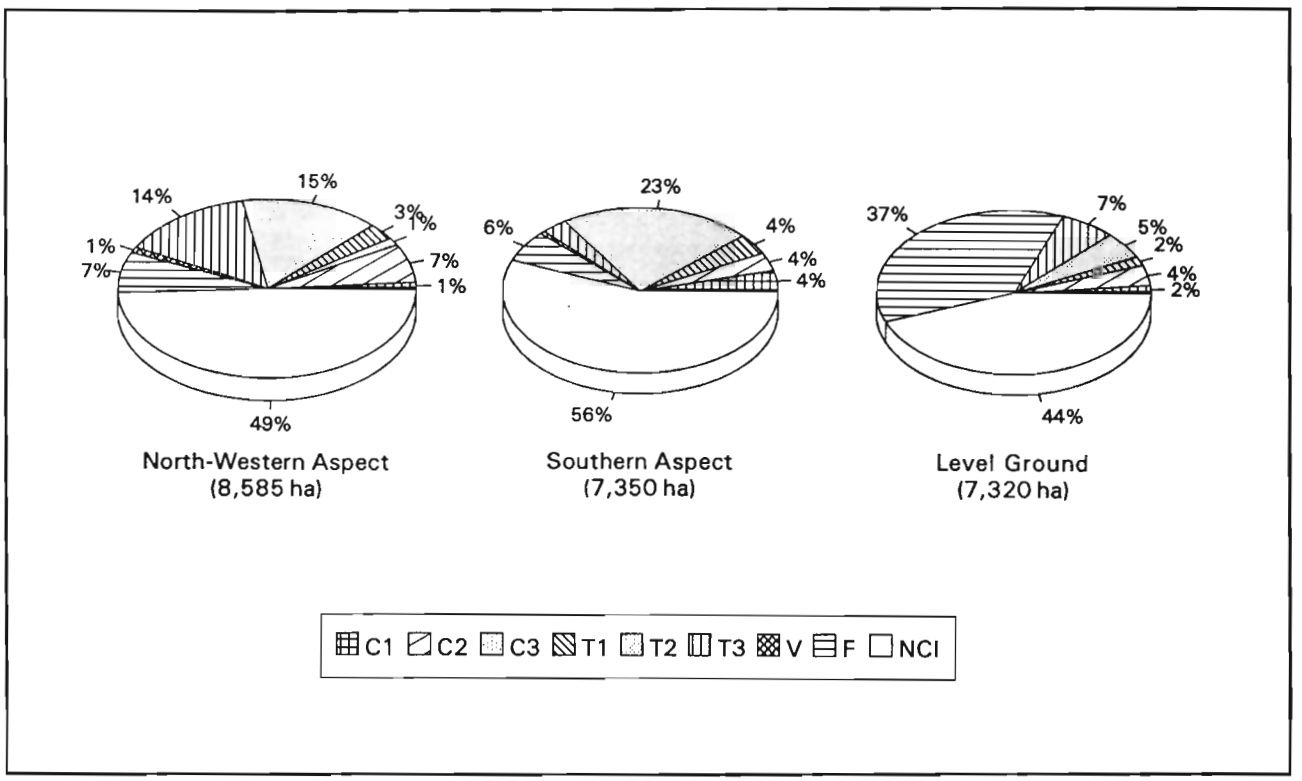
Wide areas of cropped land on level ground, amounting to 65 per cent of the total, were found on tars, alluvial fans, and lower foot slopes. On northern and northwestern aspects mainly medium-density and intensely cultivated level terraces were registered. On the other aspects it was, in particular, level terraces with medium density cultivation that covered most of the area. Looking from another perspective and at specific cultivation types, it is remarkable that lightly cultivated sloping terraces occurred, not only on southern and southwestern aspects but also on northeastern ones. High proportions of agricultural land on sloping terraces with medium-density cultivation were recorded on the northern and northwestern slopes. The percentage of level terraces with light cultivation was remarkably high on eastern aspects (E, NE, SE); on level ground and north-facing slopes it was much lower. In south-facing areas, more than 50 per cent of the cropped land was found on level terraces with medium-density cultivation. The highest proportions of intensely cultivated areas on level terraces were located on northern and northwestern aspects, with 30.3 and 28.4 per cent of the cropped area respectively. The intensely cultivated area was much smaller on the southern aspect than on all other aspects. The proportion of non-cultivated inclusions was lowest on level ground, with 44 per cent, and highest on south- and east-facing slopes, amounting to more than 55 per cent of the agricultural land. This again reflects the unfavourable conditions for cultivation and crop production on south-facing slopes (Figure 16) (Annex 16).

3.5 Cropping Systems in Relation to Agroclimatic Zones and Aspects

Crop-dominated farming systems are, in general, encountered in the middle mountain areas of Nepal. These systems include livestock raising as an integral part. Livestock-dominated systems are recorded in the high mountains (Sharma and Jodha 1992). In Gorkha both systems are practised. In the south, crop-dominated systems with a predominance of cereals are found, with a maize-based cropping pattern predominating in hill-slope cultivation and rice-based cropping patterns on lowlands. Both cropping systems include other crops as well, and there is some cultivation of both rice and maize in crop rotation. The cropping practices were analysed in respect to agroclimatic zones and aspects.

The main rice-based cropping systems in the district are rice - fallow (a), rice - oilseeds (b), rice - pulses (d), rice - cereal (e), and maize - rice - fallow (u); each system covers more than 2,000ha of cropped land per year. Double rice cropping systems, i.e., rice - rice - fallow (a2), and rice - rice - cereal (e2) are of less importance. The area size covered by each cropping pattern was analysed in relation to agroclimatic zones and aspects. The vast area of rice-based cropping systems is found in the subtropical/subhumid zone to some extent, but more particularly in the subtropical/humid zone and the warm temperate/humid zone (Annex 17).

Figure 16: Distribution of Agricultural Land (Net cultivated and Non-cultivated Area) according to Aspect in Gorkha



The main maize-based system in Gorkha was a maize - millet (j2) cropping pattern which covered about 38 per cent of the total cropped area. Other cropping systems of importance were maize - rice - fallow (u), maize - pulses (w), maize - cereal (l), maize - rice - winter crop (r), maize - mustard (k), and maize or millet - fallow (j). All maize-based cropping systems, including the pattern with 'maize - rice', covered about 65 per cent of all cropped areas. Maize-based and rice-based cropping systems were equally spread in both subtropical zones and in the warm temperate/humid zone. In the warm temperate/subhumid and the cool temperate/subhumid zone, maize-based cropping systems were dominant (Figures 17 and 18) (Annex 18).

In the subtropical/subhumid zone, rice- and maize-based cropping systems covered 43 and 46 per cent of the cropped area respectively. The more intensive system with 'maize - rice' amounted to about 11 per cent. Approximately 67 per cent of all areas under rice-based systems and almost 50 per cent of all land cropped with maize-based systems were found in this zone. The cropping systems of rice - fallow (a), rice - pulses (d), and maize - rice - fallow (u) were, in particular, applied on level ground, where they covered half of the cropped land. Maize-based systems were recorded less frequently. On the east-facing slopes, the results were just the opposite with a high proportion of maize-based systems and a lower percentage of rice-crop areas. On the northwestern aspects, there was a balance between both systems. Again, on level ground, a comparably large area was under double rice cropping (a2; e2) and an even more intensive system with maize - rice - winter crops (r). Not much intensive cropping with rice was recorded on sloping land. On northwestern slopes, about 55 per cent was covered by rice-based cropping systems, and on all other aspects in the subtropical/ subhumid zone it was around 50 per cent. Also, on the northwestern slopes, a considerable area was cultivated with rice - pulses (d). The area was similiar in size to the figure for level ground (Figure 19).

Figure 17: Distribution of Cropping Systems in the Subtropical Zone

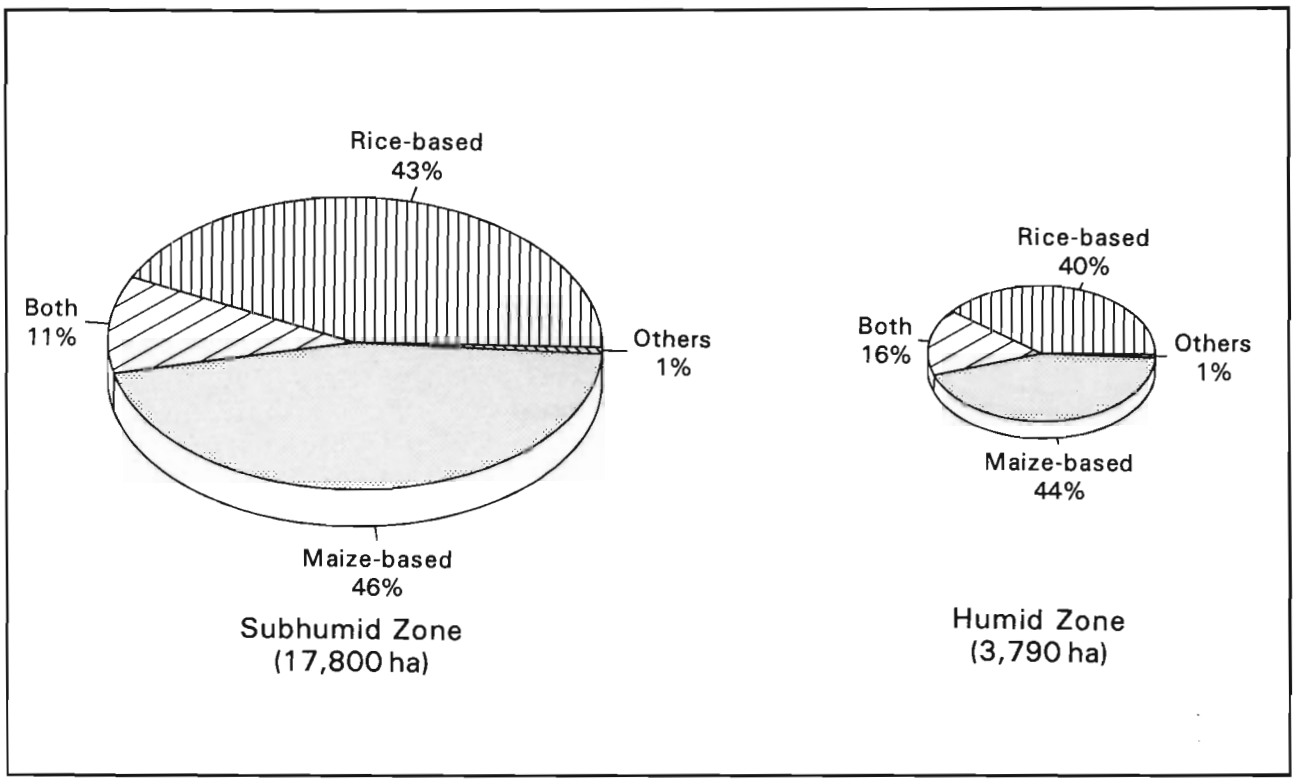


Figure 18: Distribution of Cropping Systems in the Warm Temperate Zone

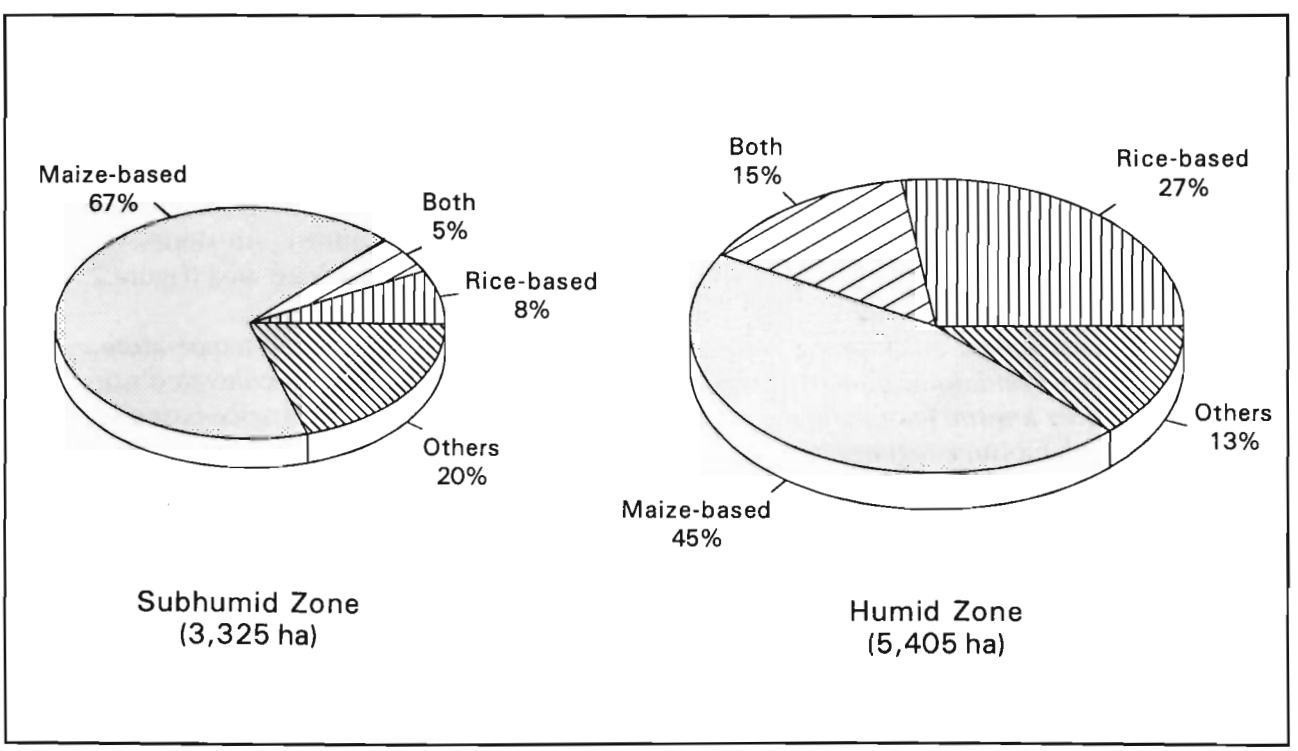
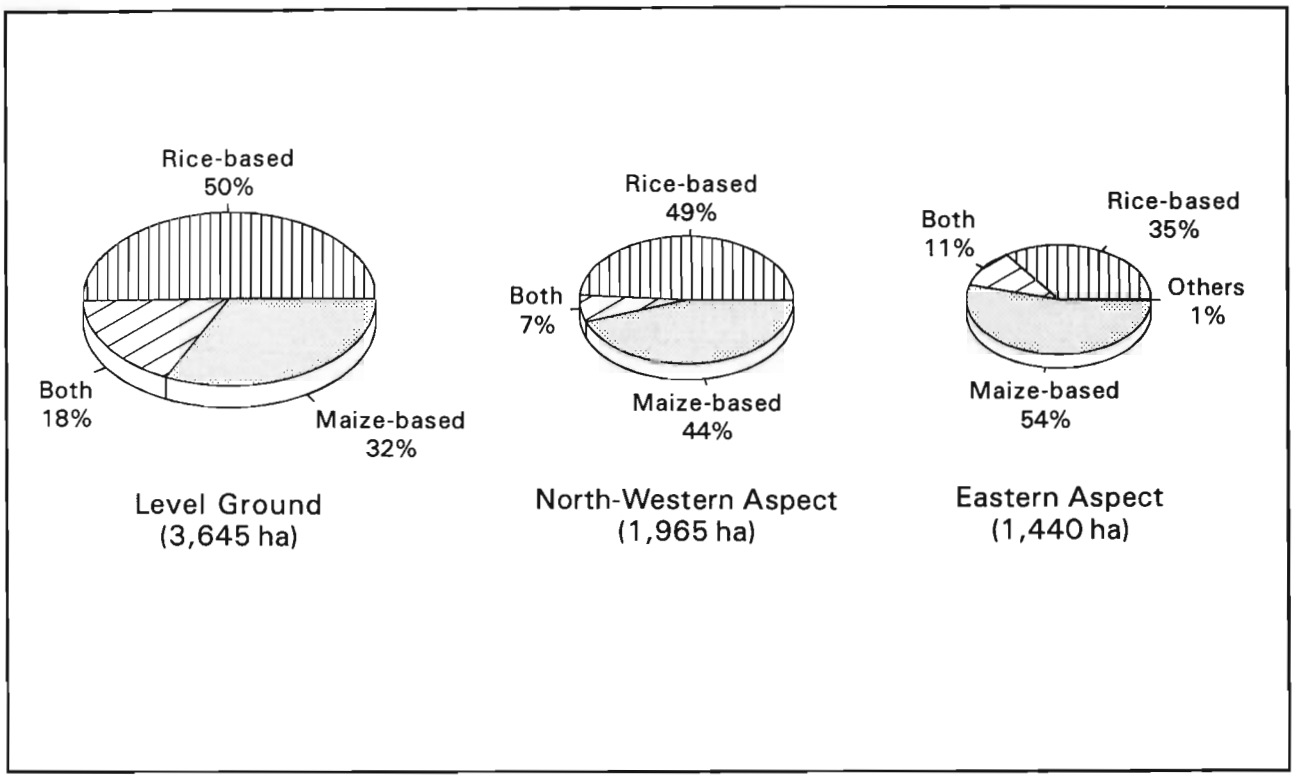


Figure 19: Distribution of Cropping Systems in the Subtropical/Subhumid Zone according to Aspect



In the subtropical/humid zone, the overall situation was about the same as under the subhumid moisture regime, with the exception of the eastern, southeastern, and southwestern aspects where the percentage of the area under a rice-based cropping system was found to be 10 to 15 per cent higher.

In the warm temperate/subhumid zone, about two thirds of the cropped area was under a maize-based system. Only a very limited area was planted with rice. Other cropping systems, in particular, 'cereal - fallow,' were more predominant on northern, northwestern, and western aspects (Figure 20).

In the warm temperate/humid zone, the portion covered by a rice-based cropping system was considerably higher than in the subhumid moisture regime. Still, it was much lower on all aspects than in the subtropical zones, but not on the northern, northwestern, and northeastern slopes where the proportion of area under rice amounted to about 50 per cent of the total cropped area (Figure 21).

The distribution of rice-based cropping systems is, in the first place, related to the temperature regime. Under subtropical conditions, a higher proportion of the agricultural land was cultivated using these systems than under a warm temperate regime. The percentage of area devoted to rice-based systems is similar under both moisture regimes in the subtropics. However, a higher cropping intensity in spring is recorded in subhumid conditions, including double rice cropping and the spring maize - rice system. Both facts lead to the conclusion that, in the subhumid regime, large areas are irrigated, and, in humid conditions, the areas are primarily rainfed. Nevertheless, also in humid conditions, various areas planted with 'maize - rice' may be irrigated.

In contrast to the subtropics, in the warm temperate climate maize was the predominant crop, particularly in subhumid moisture conditions. Fewer irrigation facilities seem to exist, proved by the low proportion of cropped land in less humid conditions. The establishment of irrigation facilities may not be economically feasible in this zone. In warm temperate conditions there is little level ground, which usually has better access to irrigation.

Figure 20: **Distribution of Cropping Systems in the Warm Temperate/Subhumid Zone according to Aspect**

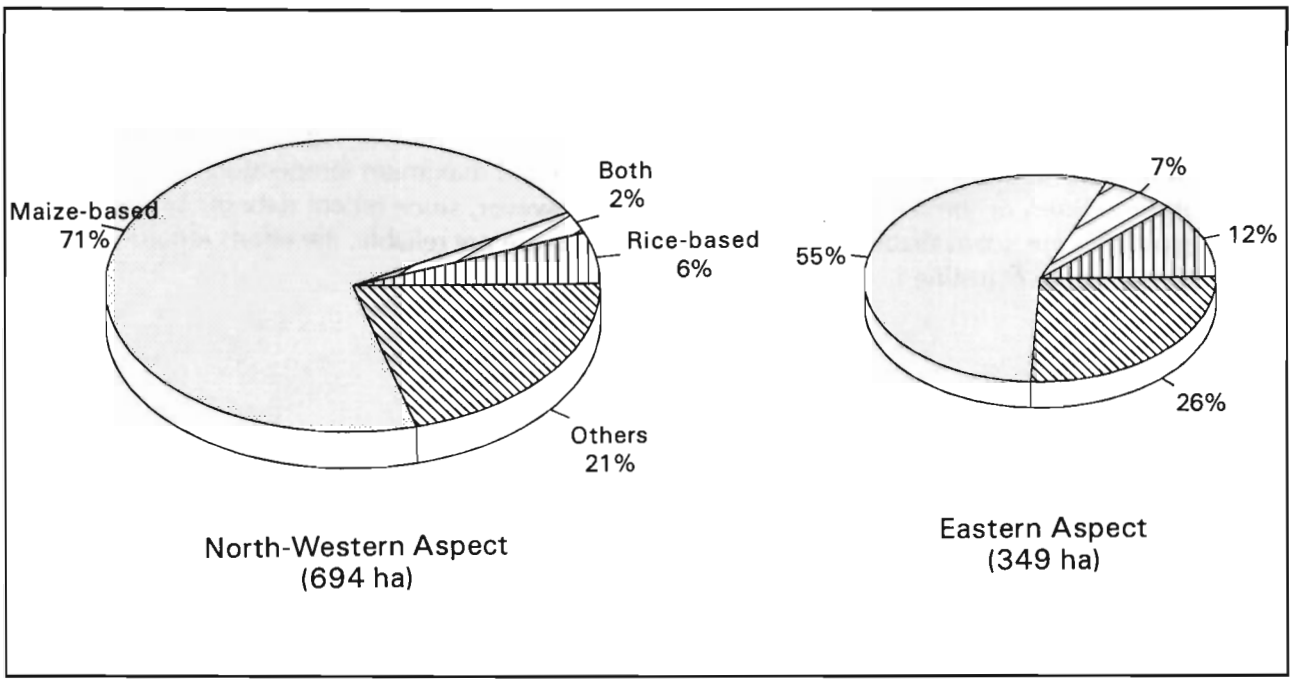
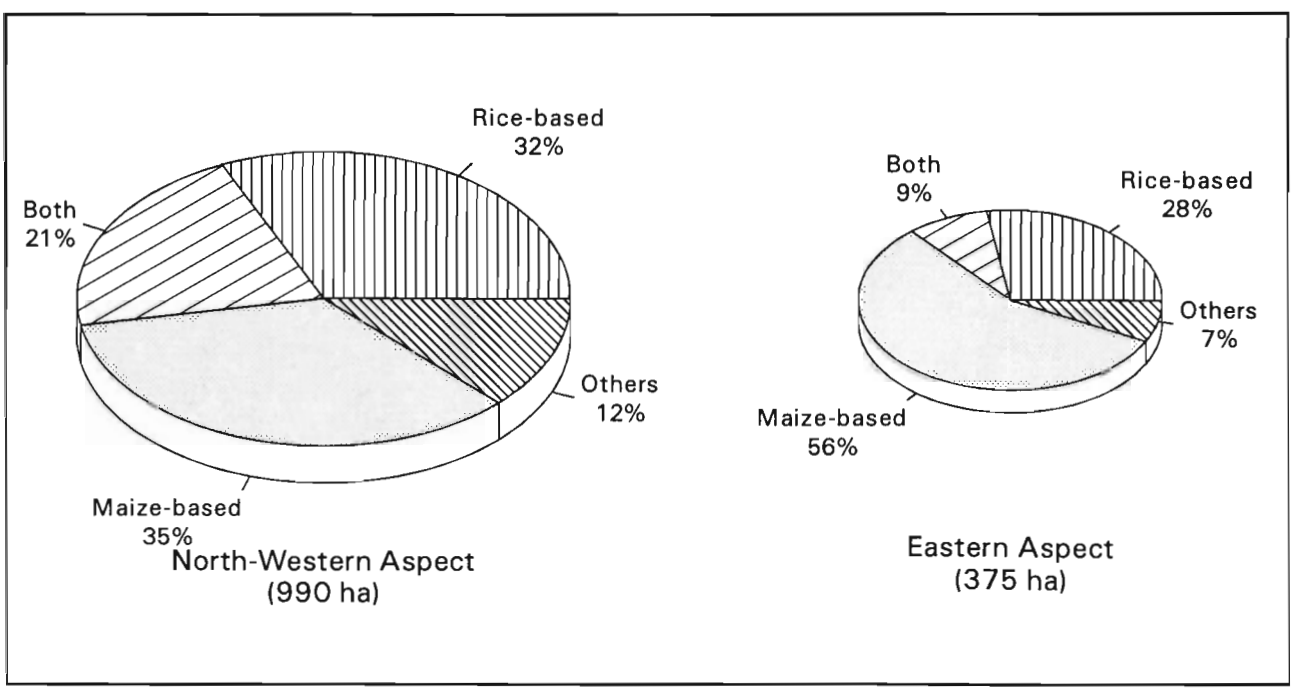


Figure 21: **Distribution of Cropping Systems in the Warm Temperate/Humid Zone according to Aspect**



4. CONCLUSIONS

The GIS database established for Gorkha District is useful for a specific kind of analysis. It helps us understand the combined effect of temperature, moisture, and aspect on the land cover and human use of the natural resources, from a general perspective. This is sufficient a tool for planning on a regional level. The database is also suited to drawing particular conclusions on a local scale; however, there are some deficiencies in data quality and accuracy on this scale. At the present stage, the methodology can only be improved upon by using mean monthly minimum and maximum temperature values to assess temperature regimes or the length of growing period. However, since recent data on land cover and cropping patterns are not available and data on precipitation are not reliable, the efforts required for such an exercise are not yet justified.