PART II
ANALYSIS OF THE FEED SITUATION AND LIVESTOCK CARRYING CAPACITY IN GORKHA DISTRICT

Part II: Analysis of the Feed Situation and Livestock Carrying Capacity in Gorkha District

1. INTRODUCTION

Animal husbandry is a fundamental part of the agricultural and forestry system in Nepal. Livestock provide draught power, produce manure required for soil fertility, and are a major source of cash income and high-quality protein for the villagers (LRMP 1986e). Farmers in Nepal, in general, maintain large numbers of livestock, mainly for economic reasons. It is, in particular, feed supplies that restrict the number of animals. Often, too many are kept, and the shortage of fodder, especially in the dry season, limits animal productivity (Mahat 1987). Besides fodder from private land, forest resources, including shrubland and public grasslands, are the main sources of feed for animal nutrition. Forest-hill farming linkages have been studied recently. Forests are the external source of mineral nutrients essential for the farming system. This source is of particular importance during the dry season. It is estimated that 2.8 hectares (ha) of accessible unmanaged forest are required for one hectare of agricultural land to sustain the existing farming system Wyatt-Smith (1982). However, for most of the Middle Mountains in Nepal, the ratio between forest and agricultural land is much lower and the high livestock population exceeds the carrying capacity of existing resources.

Livestock carrying capacity is seen in the context of sustainable development, defined by the World Commission on Environment and Development (WCED) as '*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*' (WCED 1987). Factors such as rapid population growth, increase of livestock population, degradation of natural resources, unfavourable climatic conditions, and widespread poverty lead to economic and environmental unsustainability (WCED 1987; Sharma and Banskota 1992). These factors need to be quantified in order to determine sustainability parameters. In the paper presented here, the livestock system is investigated and linked to available fodder resources. The term 'livestock carrying capacity' was defined as the number of livestock that can be sustained with available and accessible natural fodder resources and crop residues.

Assessments of livestock carrying capacity have been conducted for different parts of Nepal, using various methodologies. Already, Wyatt-Smith (1982) has estimated that the overall level of livestock feeding in Nepal is not more than 50 per cent of the requirement and is steadily decreasing. Fodder from pastures, forests and fodder trees on farm holdings, as well as feed from crop residues have been identified as important components of livestock nutrition. However, livestock experts and fodder specialists have attached different significance to these sources. Other specialists have found it almost impossible to quantify fodder availability and demand accurately (Robinson 1986).

Riley (1991) estimated that, in the mid-hills of Nepal, up to 75 per cent of total feed may be obtained from forests and grassland. He estimated that only 50 per cent of the forest area is used for livestock grazing, while fodder from forests is gathered by the villagers within a radius of two hours' walking distance from the farmstead.

Panday (1991) did some in-depth studies on livestock management in the Bhardeo Community in Lalitpur District. He concluded that, in this community, 71 per cent of the fodder material was extracted from farmlands and non-cultivated private lands. About 29 per cent of the total fodder biomass was fetched from forests.

The Bagmati Zone Study Team estimated that fodder supply from different sources met about 96 per cent of the requirements in the Dhading District (ICIMOD 1993a:94). They calculated that about 47 per cent of the fodder supply came from forests and shrublands and 31 per cent from crop residues. Non-cultivated areas conceivably contributed seven per cent, and other sources (risers and bunds, plantations, fallow grazing) about 10 per cent. Fodder from private trees amounted to only five per cent in their estimate.

Gilmour and Fisher (1991) quoted studies of Mahat et al. (1987), in Sindhupalchowk and Kavrepalanchowk districts, in Central Nepal, and Metz (1989) in Kaski District, in Western Nepal, dealing with consumption of fodder, including leaf litter used as animal bedding, in the Middle Mountains. These studies presented different results with respect to the portions of fodder from forest resources and private land. In Central Nepal the authors estimated that 80 per cent of the fodder came from private land, whereas in Kaski District the figure was only 27 per cent.

A first attempt to measure feed surpluses or deficits in Nepal using a spreadsheet model linked to a Geographic Information System was recently undertaken by the IDRC Cooperative Research Programme (Shah et al. 1991a & 1991b). Their analysis focussed on the national level, thus providing information for all districts, but this is too general for the sectorwise prioritisation of resource allocation and planning needed by local decision-making bodies. Schmidt (1992) undertook a carrying capacity study for some VDCs in Dhading, a district neighbouring Gorkha. ICIMOD (1993b) conducted a GIS study in Kavrepalanchowk District in Central Nepal and developed a methodology to assess the livestock carrying capacity using GIS. This model was further elaborated upon within the framework of the Gorkha study. The advantage of using GIS technology is its flexibility. The system allows for updating/adjustment of models developed for analysis with respect to changes of data as well as frame conditions.

The concept of biophysical carrying capacity is not acknowledged unanimously as applicable for demonstrating the situation in the livestock sector. Rai and Thapa (1993: iv) fear that imposing an alien technique may lead to deregulation in the livestock sector and the dismantling of indigenous pasture management systems.

A comprehensive version of this case study was already presented at a GIS conference in Indonesia (Trapp 1994). The model of livestock movements was further developed and certain parameters and figures were changed, e.g., buffaloes were included in the semi-nomadic movement model; productivity values of risers and bunds and temperate pastures were increased; and accessibility of pasture land was also included.

2. METHODOLOGY

The analysis of the feed situation was based on secondary data from different sources. The model was based on the assumption that the area of each VDC functioned as a closed system in terms of feed requirements and feed supply, without interlinkages to other VDCs. There were two exceptions to this with regard to sheep and cattle husbandry.

1) Sheep farming is performed under a semi-nomadic grazing system called transhumance. In mountain nomadism, seasonal movements proceed vertically.[4] All sheep are taken to high mountain pastures for grazing for six months during the summer season (May to October). There is not much area-based information available. However, it is known that there are indigenous pasture management systems and

4 "Transhumance is a form of migratory livestock industry in which the livestock are generally accompanied by hired men and also by owners and their relatives, but rarely by a whole family, on a long migration or transit between at least two seasonal ranges. This seasonal movement is caused by the different characteristics of the ranges in terms of altitude, thermic, hygric or agro-economical conditions." (Rinschede 1988). The author mentioned that this form of ascending transhumance in the extra-tropics is mainly due to the intensive cultivation on the farmlands, which does not allow grazing during the main vegetation period. Also grazing on mountain pastures favours the health and meat quality of the livestock.

shepherds have traditional rights for specific areas only.[5] It is assumed that herds are spread equitably over pastures in relation to the fodder production. The high mountain pastures are located approximately above 2,000masl. For the analysis, the isoline of 15°C mean annual temperature was used as a boundary, separating warm temperate and cool temperate climatic zones. Later in the text, these zones will be referred to as warm and cool climatic zones. During winter or the dry season, the semi-nomadic pastoralists descend to the southern middle mountains to graze their animals on the stubble of cereal crops and obtain manure for the fields. It is assumed that sheep from VDCs located in the cool climatic zone do not stay in Gorkha District during the winter season but graze in Dhading and Lamjung districts.

2) In general, cattle and buffaloes stay in the VDC area all year round. Fifteen VDCs are located in both climatic zones. It is natural that, in these villages, cattle and buffaloes are also kept, under a transhumance system, grazing on the high mountain pastures and forests (*kharka*) of the VDCs for four months during the summer season.[6] Yak (*Bos grunniens*) and *chauri*[7] herds stay in the high mountain area all through the year.[8]

The feed balance in Gorkha District was analysed by determining the feed requirements per VDC and comparing these with the available feed resources of the VDC.

The VDCs were clustered into three different feed situation categories:

- <u>surplus areas</u> where feed supply is more than 120 per cent of feed requirements,
- <u>sufficiency areas</u> where feed supply is 80 to 120 per cent of feed requirements, and
- <u>deficit areas</u> where feed supply is less than 80 per cent of feed requirements.

2.1 Analysis of Feed Requirements

In general, the total feed requirement of all livestock types per VDC was based on the total number of livestock in the particular VDC, the total number of livestock units (LU) per livestock type, and the particular consumption of each type.

---

5 The most detailed description of the migratory system of sheep rearing int he Gandaki Zone of Nepal is given by N.P.S. Karki (1985). Recently Rai and Thapa (1993) have published a review of indigenous pasture management systems in high altitude Nepal. The authors give detailed descriptions of the pasture management systems and explain different cycles of animal herd movements in Nepal, citing various sources. Kaltenborn et al. (1989:104) describe grazing systems in the Manaslu - Ganesh region, including areas of Gorkha and Lamjung districts. Warth (1993b:42) provides some related information for northern Gorkha. A detailed study on management practices of herders' association in Pangsing and Nyak is available, only in Nepali however.

6 The differences between the two transhumance systems are that (1) small livestock, e.g., sheep, graze in big herds and are accompanied by hired persons instead of family members; (2) sheep graze at higher altitudes in summer; (3) movements are faster with sheep and they are not kept in permanent stations for longer periods in the high mountains, whereas big livestock are stationed in *kharka* where the villagers have built shelters with wooden frames and bamboo matting (*goth*) at different altitudes (in the upper Daroundi *Khola* Valley these *goth* are well established and include big stalls with a massive wood construction, shingles for house roofing, and a floor made of either blankets or big stones); (4) small livestock travel much longer distances while grazing and descending to the winter pastures; and (5) in contrast to cattle and buffaloes many of the sheep, at least those owned by people from the high mountains, do not graze on the owners' farmland in the winter season.

7 Offspring of yak-cattle crosses

8 Traditionally, Nepalese yak herders had grazing rights on Tibetan pastures. In northern Gorkha these rights were used for winter grazing. In the 1950s, China suggested the border be closed for grazing animals towards the end of the 1960s. However, nothing occurred until 1983, when an agreement between Nepal and China was signed, and this practice was formalised for another five years until 1988, when the border was to be closed completely (Archer 1990:1). Nevertheless, Warth (1993b:40) mentions that yak herders from northern Gorkha still cross the Chinese border to Tibet for winter grazing, but there are no detailed figures available.

2.1.1 *Number of Livestock and Livestock Units*

Estimates of livestock body weight and their daily intake vary among different authors. Also, there are differences in the determination of LUs. Various authors use different standardised livestock units. The factors used to convert livestock types to standardised livestock units also often differ. For example, Panday (1982) assumed that, in the Middle Mountains of Nepal, adult cattle weigh between 240kg and 340kg; LRMP (1986a: 64) took a weight of 300kg. Robinson et al. (1986) mention that the average weight of adult cattle in the Koshi Hills of Nepal is only 187kg. They also quoted Karki (1984), who suggests an average weight of 250kg for adult female cattle.

This study used two sets of indicators, the ideal and the present situation, for the analysis of feed requirements. The first set of indicators reflected annual feed requirements on the basis of ideal feed supply and well-nourished livestock. It was assumed that feed rations are equal to those needed for sustaining high productivity for one LU of cattle and buffalo weighing about 400kg. The second set of indicators tried to display the present feed situation in the district. Instead of ideal feed requirements, a smaller amount of feed is considered to be available with one LU having an average body weight of 250kg.

Livestock figures are based on the ward-level survey conducted by GDP. For the feed requirements per LU of specific livestock types (cattle, buffalo, yak, sheep, pig, and poultry) and the conversion of livestock numbers into standardised livestock units (LU), factors given by the Promotion of Livestock Breeding Project (PLBP) (1993) were used.

2.1.2 *Feed Requirements per Livestock Unit*

The annual feed requirement per livestock unit (LU) is given in metric tonnes of dry matter (mt DM) since the quality of feed could not be taken into account. According to PLBP, the application of 'Total Digestable Nutrients' (TDN) is not feasible for cattle with an annual milk production of less than 800kg (Dahl, PLBP; personal communication).

PLBP assumed that feed rations are equal to those needed for sustaining high productivity for one livestock unit weighing about 400kg and that cattle, buffaloes, goats, and sheep have an intake of feed of about two two per cent of body weight per day. This means one livestock unit of 400kg needs eight kilogrammes DM per day or an average of 2.92mt DM per annum (cattle, buffaloes, yaks, goats, and sheep). The value for poultry and pig feed is adjusted with factors of 1.8 and 1.6 respectively due to higher feed value.

The second set of indicators assumed that one livestock unit only has a body weight of 250kg and requires an intake of at least five kilogrammes DM per day or an average of 1.83mt DM per year. The body weight of sheep, goats, poultry, and pigs, and consequently their feed requirements, are the same as in the first set of indicators.

2.1.3 *Development of a Model Incorporating Semi-nomadic Forms of Sheep, Cattle and Buffalo Farming*

As already mentioned above, two exceptions were made, i.e., sheep and cattle/buffalo farming, in assuming that each VDC is a closed system in terms of feed requirements and feed supply. These livestock types are not kept in the same VDC or climatic zone throughout the year. For the analysis of feed requirements, incorporating the livestock movements in the district, three categories of VDCs were distinguished: (1) VDCs (7) which are entirely located in the cool climatic zone, i.e., Chhekampar, Prok, Lho, Samagaun, Bihi, Chumchet, and also a very small area along the gorges of the Budhigandaki River and Shyar *Khola* in the warm zone and Laprak; (2) VDCs (15) which are located in both cool and warm zones, i.e., Kerauja, Kashigaun, Manbu, Sirdibas, Uhiya, Gumda, Lapu, Thumi, Aru Arbang, Barpak, Swara, Saurpani, Ghyachok, Simjung, and Kharibot; and (3) VDCs (47) which are totally located in the warm climatic zone (Map 10).

In the category 1 VDCs (cool zone), mainly yaks and *chauri*, sheep, and some cattle were kept by the villagers. It was assumed that yaks and *chauri*, as well as cattle, were kept in the VDC area for the whole year. During the winter season, cattle are fed in stalls with hay, etc prepared during the summer season. The information given by Warth (1993a: 31), that in winter these animals are partly moved further down to the middle hills, was not included in the analysis due to the lack of spatial information. Sheep, mainly owned by Gurung families from these VDCs, graze on pastures in the cool zone for six months in summer; "*for the winter grazing, the flocks are taken down to the Middle Mountains, where the herders have corresponding families in Besisahar (Lamjung), Arughat, Dhading, Rasuwa, and Nuwakot Districts. These families grant grazing rights against receiving manure from the animals*" (Warth 1993b: 42). Therefore, it was assumed that all sheep of this category grazed in other districts in winter for six months. A model was developed to simulate the distribution of sheep grazing over the total pasture land and accessible forest area in the cool zone and to calculate the feed requirements of sheep per VDC in this zone. The total area of the cool zone was used for the analysis, since the main assumption was that the sheep were spread over that area, only dependent on the different fodder productivity of the feed sources. The main criteria of this model were (1) the total number of sheep in the district; (2) the potential sizes of pastures and grazing areas of different forest types in the VDCs and their particular fodder production, regardless of the actual access to pasture areas (compare Chapters 2.2.2 and 2.2.3); and (3) the feed requirements per sheep LU. On the basis of this model, a factor was calculated for each feed source, reflecting the number of LU sheep grazing on one hectare of pasture or forest land. These factors then were applied to the calculation of feed requirements in each VDC (Table 8)[9].

Table 8: Calculation of Factors Applied to the Analysis of Sheep Grazing in the Cool Climatic Zone in the Gorkha District

Feed Type	Potential Area ha	Potential Feed Supply mt DM/year	Potential Feed Supply Per cent	Feed Demand mt DM/year	LU sheep Total	LU sheep Per ha
1. Pasture						
- Temperate	1,140	5,130	4.5	2,405.7	565.0	0.4956
- Cool temperate	2,558	7,671	6.8	3,598.7	845.2	0.3304
- Subalpine	23,292	46,584	41.2	21,845.4	5,130.4	0.2203
- Alpine	26,715	40,073	35.4	18,791.8	4,413.3	0.1652
2. Forest grazing						
- Hardwood	7,390	5,616	5.0	2,633.8	618.5	0.0837
- Mixed	8,422	3,285	2.9	1,540.3	361.7	0.0430
- Shrubland	2,813	4,810	4.3	2,255.7	529.8	0.1883
Total	72,330	113,172	100	53,071.5	12,463.9	0.1723

9 The model reflects the reality to some extent only. It is known that there are disputes over pasture areas between VDCs in northern Gorkha, e.g., Bihi and Prok, and even between wards, e.g., in Samagaun, where Samdo village was founded only in 1962 by Tibetan refugees. The latter brought large livestock herds into the area, which then led to serious overgrazing and degradation of pasture land (Warth 1993b:41).

For the VDCs in category 2 (area in both cool and warm zones), the feed requirements were calculated for each zone separately. Sheep grazing in the cool zone were analysed according to category 1. The fodder demands of cattle and buffaloes were divided into two categories: (1) fodder from high mountain pastures and forest grazing during four months in the summer and (2) feed from the warm zone during the rest of the year. It was assumed that these livestock stayed the whole year in the area of the VDC where the owners lived and that sheep were kept for six months in the warm zone of the VDC.

For the VDCs in category 3 (warm zone), feed requirements were calculated based on the number of livestock units only. It was assumed that, besides sheep, all livestock types were kept in the VDC area for the whole year; sheep owned by the people of these VDCs were expected to graze for six months in that particular VDC area only and the other six months on pasture land and in forests in the cool climatic zone.

2.2 Analysis of Feed Supply and Feed Resources

The feed supply was calculated based on the total amount of various feed sources, either from private or public land. The following feed resources were distinguished, computed separately, and then summarised to obtain the total amount of feed supply:

- feed from crop residues,
- fodder from forests and shrubland,
- fodder from grazing land/public grasslands/pastures,
- fodder from private trees,
- soilage fodder from risers and bunds,
- fodder from non-cultivated areas within the agricultural land, and
- fodder from grazing on fallow land.

The sizes of the areas of these feed sources were retrieved from land utilisation maps surveyed by the LRMP in 1978/79. The productivity of each source was based on data provided by Panday (1982), LRMP (1986a:64p), and figures given by the PLBP (1993).

The amount of feed concentrates used by the farmers was not included in this study due to lack of data. To some extent, these concentrates were considered in the analysis, e.g., wheat bran and rice polish, both produced on farms and either directly fed to the livestock or sold locally[10].

2.2.1 *Feed from Crop Residues*

Crop residues, i.e., straw, maize stalks, bran, and cobs are an important source of animal feed, especially during the winter months. The feed available in the form of crop residues in Gorkha was calculated based on the crop yield data given by LRMP (1986a) for the Middle Mountain and High Mountain Region in the Western Development Region (Table 9).

The actual area covered with crops was determined on the basis of LRMP methodology (LRMP 1986a: 37ff.) and the land-use maps (LRMP 1986). LRMP distinguished between (1) agricultural land, (2) gross cultivated area, (3) net cultivated area, and (4) actual area covered with crops.

10 The calculation of feed concentrates differs from all the other feed sources since it is not related to an area but to the number of livestock kept by the farm households. Also, imported concentrates should not be included in the carrying capacity analysis of an area.

Calculation of Agricultural Land, Gross Cultivated Area, Net Cultivated Area, and Cropped Area

Agricultural land covers the cultivation areas on hill slopes and valley areas. Hill slope cultivation is practised on two types of cultivated terraces, level (T) and sloping (C). Valley cultivation is divided into two types, valley floors (V) and tars/foot slopes (F).

Table 9: Feed Derived from Crop Residues

Crop	Crop yield mt/ha		Feed	Feed/mt of crop yield	% Feed utilised	Residues/Cropped area mt DM/ha	
	MMR	HMR				MMR	HMR
Paddy	1.94	1.43	Straw	1.56	90	2.98	2.19
			Bran	0.13	100		
Wheat	1.04	0.86	Straw	1.65	30	0.60	0.49
			Bran	0.08	100		
Maize	1.18	1.00	Stalk	1.87	30	0.80	0.68
			Cob	0.13	90		
Millet	1.16	1.10	residue	1.95	65	1.47	1.39
Mustard	0.28	-	residue	1.50	60	0.25	-
Pulses	0.43	0.75	residue	0.90	75	0.29	0.51
Potatoes	6.58	4.53	residue	1.50	60	5.92	4.08

MMR: Middle Mountain Region; HMR: High Mountain Region
Source: LRMP 1986a:Table 32 & 39

Agricultural land, on either sloping terraces or level terraces, is associated with forests, shrublands, grazing lands, etc., i.e., non-cultivated inclusions. Therefore, the LRMP grouped the agricultural land into three cultivation intensities:

- intense (3) where more than 75 per cent of the mapped unit is used as agricultural land (=gross cultivated area),
- medium (2) where 50 - 75 per cent is cultivated, and
- light (1) where 25 - 50 per cent is cultivated.

The LRMP defined net cultivated area as gross cultivated area minus the area of risers and bunds. Thus, for Gorkha District in the Western Development Region, a figure of 82.6 per cent for net cultivated area was estimated (LRMP 1986d: 43). This means 17.4 per cent of the gross cultivated area was under risers and bunds, which also contribute to the fodder supply (see Chapter 2.2.5).

The cropped area (actual area under crops) was seen as part of the net cultivated area. For the Middle Mountains in the Western Development Region, LRMP (1986a: 49, Table 22) estimated a reduction of 9.0 per cent of the net cultivated area by farmstead area.

Calculation of Feed Supply by Crop Residues

To calculate the amount of feed derived from crop residues, the areas cropped with paddy, maize, wheat, millet, potato, and mustard were selected and multiplied by the amount of feed expected from residues of these crops (Table 9).

2.2.2 *Fodder from Forests and Shrubland*

There are a number of different methods for estimating the amount of fodder available in forests and shrubland. Most of them yield pure estimates and do not quote their sources.

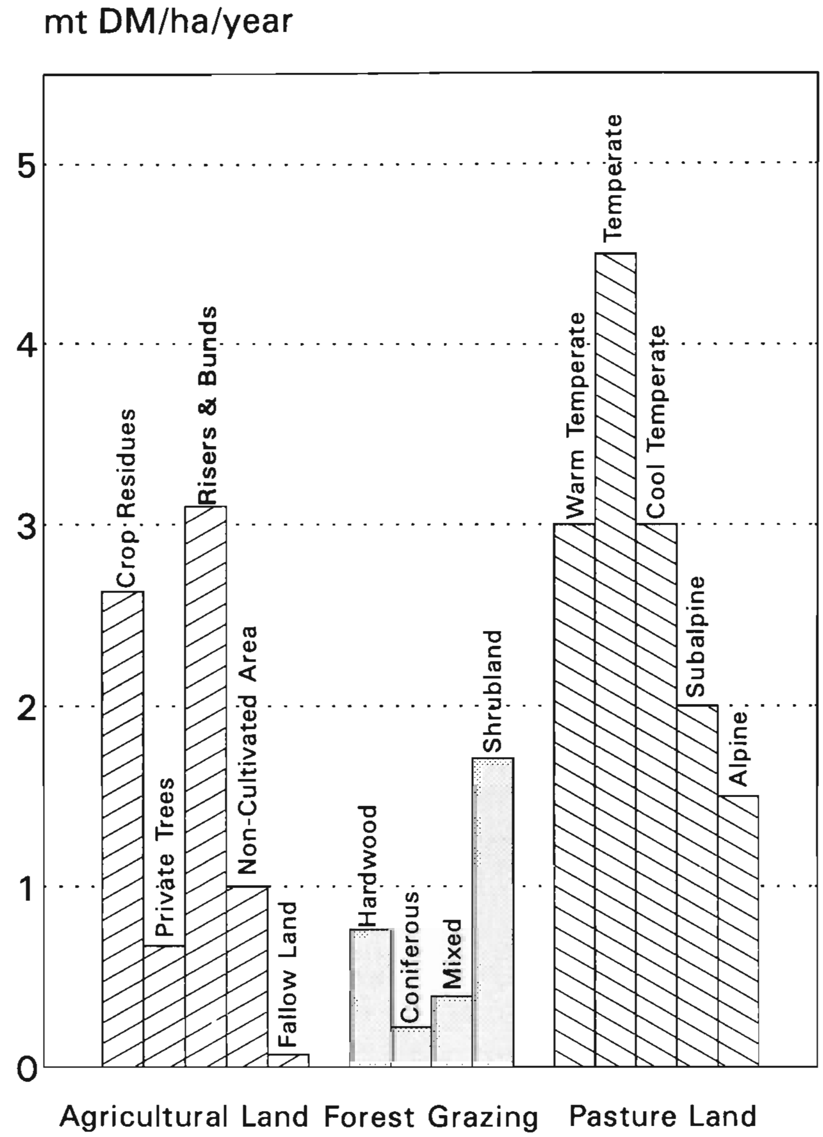
Heuch (1986), for example, gave an overview of sources referring to forest productivity in Nepal in terms of tree fodder and leaf material. He concluded that, in areas with good stocking and a high proportion of fodder species, no more than 3.0mt DM of harvestable fodder can be expected and, in other areas, much less. Panday (1982: 33) estimated 2.0mt DM/ha/year, including 1.5mt from tree leaves and 0.5mt from soilage fodder. Parde (1980) estimated a leaf biomass production of 2.0-3.0mt DM in deciduous forests and 7.0-11.0mt DM in evergreen forests. Among the authors, Singh and Singh (1992) present more detailed data about biomass and net primary productivity of undergrowth in the Indian Central Himalayan forests. Like LRMP (1986a), they differentiate between forest types. In addition to data about herbs/grasses, they also give figures for fodder from shrubs. In this study, fodder productivity of forests and shrubland was calculated, as shown in Table 10, referring to LRMP (1986a: 66). Their findings showed far less available fodder from forests than that of other authors. This approach considered that not all biomass produced by forest areas can be used by grazing systems. LRMP listed the figures in total digestible nutrients (TDN). These were converted to dry matter (DM) units using the factor 2.22 (Figure 1). The classification of forest types is closely related to altitude and climatic zones. Subsequently, these items were not considered separately while selecting productivity levels.

Table 10: Fodder Productivity of Different Sources

Feed type	Yield mt DM/ha/year	Source
1. Forest		LRMP 1986
- Hardwood forest grazing	0.76	
- Coniferous forest grazing	0.22	
- Mixed forest grazing	0.39	
- Shrubland grazing	1.71	
2. Grazing land/pasture		Archer 1990 and LRMP 1986
- Warm temperate zone	3.0	
- Temperate zone	4.5	
- Cool temperate zone	3.0	
- Subalpine zone	2.0	
- Alpine zone	1.5	
3. Private trees on gross cultivated land in the Middle Mountain Region	0.67	Gilmour 1988 and Panday 1982
4. Soilage fodder from risers and bunds	3.1	LRMP 1986
5. Non-cultivated area within agricultural land	1.0	Panday 1982
6. Grazing on fallow land in the Middle Mountain Region	0.068	LRMP 1986

Access to fodder from forests or shrubland is limited by distances from the farmstead. LRMP (1986a:66 & 73) estimated that only inside a two-to-four kilometre zone around agricultural land is fodder within reach. In this study, fodder from forests and shrubland was considered only if the area was within an hour's walk from the cultivated area. The accessibility was defined as the minimum walking time for a person from forests and shrublands to the cultivated area. The analysis was based on a Digital Elevation Model (DEM) produced of the contour coverage. The walking time was calculated under the following assumptions: (1) the walking speed on flat land is 4,000m/h, (2) during one hour it is possible to ascend an elevation of 400m or to descend 800m, and (3) only slopes with less than, 40 degrees can be passed. The major rivers were included as natural boundaries only to be crossed by bridges or fords.

Figure 1: Feed Sources and Productivity Levels in the Western Region of Nepal



Note: The value for crop residues is an average of different crops; the productivity of private trees refers to the gross cultivated area only.

2.2.3 *Fodder from Grazing Land/Public Grasslands/Pastures*

The area of grazing land was calculated based on the LRMP land use maps. LRMP (1986d) classified areas of non-cultivated public land which do not have sufficient tree cover to be included in the forest or shrubland classes as 'grazing land'. The six grazing classes, according to altitude, given by LRMP, were adjusted to the agroclimatic zonation of our GIS project. For example, some areas of grazing land, classified as 'temperate' by LRMP, ended up being located in the warm temperate zone.

Specific productivity levels for grasslands were not given by the LRMP. The project expected a yield of 0.24mt TDN from wasteland grazing. Schmidt (1992) proposed application of different productivity levels depending on the climatic zones or altitudinal ranges. In the case study presented here, the calculation was carried out based on data provided by the Pasture and Fodder Development in the High Altitude Zone Project, Nepal, which conducted studies on fodder production in several districts of the High

Mountain Region (Archer 1990); however, Gorkha District itself was not included in that study. Therefore, for this report, Sindhupalchowk and Dolakha districts were chosen as reference areas. Also, grazing land in the altitudinal range below 2,000masl was not covered by the pasture project. For this study, the productivity level for that zone was estimated by referring to LRMP figures for other fodder sources.

Rai and Thapa (1993:11 & 13), citing the Master Plan for Livestock Development, assumed that only approximately 45 per cent of alpine pasture land was accessible for grazing. The remaining area was inaccessible to livestock due to difficult terrain, lack of access tracks, and unavailability of drinking water for animals. In addition, the authors mentioned that, in Nepal, only 37 per cent of the forage produced from all types of pasture land was actually available. Accordingly, in this study, it was assumed that about 40 per cent of all pasture fodder was available in Gorkha District.

2.2.4 *Fodder from Private Trees*

There seems to be considerable variation in the importance of fodder trees in feeding livestock in the Middle Mountains of Nepal. Many studies have been conducted on fodder trees, with different results. Heuch (1986), Robinson (1986), and Robinson et al. (1989) gave an overview of the literature on fodder trees in Nepal and about fodder tree research. All authors relate the number of privately owned fodder trees either to the number of livestock units or to the number of households or both. In none of the quoted sources were linkages made to the size of area.

On the other hand, the Nepal-Australia Forestry Project presented results in relation to coverage area. In their studies on the increase in tree cover on private farmland in the Kavrepalanchowk and Sindhupalchowk districts, the project assumed a coverage varying from 138 to 298 trees per hectare of farmland (Gilmour 1988, Carter and Gilmour 1989, Gilmour 1991). For this study, therefore, an average number of 200 trees per hectare of 90 per cent of the gross cultivated land was assumed[11]. It was estimated that about 50 per cent was used for fodder supply. The agricultural land in the High Mountain Region was excluded from the analysis.

The quantity of fodder available from private trees amounts to 37kg of fresh matter per tree, per year (Panday 1982: 28 and Panday 1992:53). To convert the fresh matter from fodder trees into dry matter, PLBP recommended the use of a factor of 0.2 resulting in 7.4kg DM/tree/year.

2.2.5 *Soilage Fodder from Risers and Bunds*

According to LRMP (1986d:43), about 17.4 per cent of the gross cultivated area in Kavrepalanchowk District is under risers and bunds. The fodder survey conducted by the PLBP on the Livestock Activity Records (LAR) farms in Kavrepalanchowk showed yields of 1.2mt DM/ha/year from these areas. Panday (1982:31) assumed a fodder yield of 1.5mt DM/ha/year from these areas. For this study, LRMP (1986a:68) data were used. The project estimated that the fodder yield from risers and bunds was 1.4 mt TDN/ha/year, which amounts to 3.1mt DM/ha/year.

2.2.6 *Fodder from Non-Cultivated Areas within Agricultural Land*

The areas covered with forests, shrublands, grazing lands, etc but mapped by LRMP within agricultural land are called non-cultivated areas or non-cultivated inclusions (compare Chapter 2.2.1). It is estimated that the productivity of this area is about 1.0mt DM/ha/year, comparable to that of grassland or bush land (Panday 1982:34).

11 The fodder resources from the non-cultivated areas are included in the fodder calculation in chapter 2.2.6: fodder from non-cultivated areas within the agricultural land.

2.2.7 *Fodder from Grazing on Fallow Land*

The calculation of the fallow area in Gorkha District was based on the methodology presented in Chapter 2.2.1. The cropping pattern with the mapping symbols a, u, and j was taken for calculation.

From grazing on fallow land, the LRMP (1986a:68) projected a fodder yield of 60kg TDN/ha/year. Taking a conversion factor of 2.22, about 133kg DM are available per hectare and annum.

2.3 Limitations of the Database

(1) Only limited information was available on the productivity of specific feed and fodder resources in the Middle Mountain Region of Nepal. Due to this, estimates of fodder yields had to be used to assess the amount of feed supply in the district.

(2) The analyses of livestock carrying capacity and the feed situation were restricted by the fact that the VDC was seen as a closed system without interlinkages, although a model was developed which simulated the distribution of sheep, cattle, and buffaloes in the summer.

(3) Fodder availability was only assessed in terms of resources but not in relation to social aspects. For example, the access of a household to fodder resources depends heavily on the amount of agricultural land, but there is also a linkage between farm size, the number and type of livestock kept, and the amount of fodder received through grazing activities on common land (Rapp et al. 1992); also, the surplus of food production, e.g., maize, millet, might be used for feeding livestock.

(4) The analysis does not include the aspect of fodder/feed quality, and the variation in feed availability/scarcity in different seasons was also not assessed.

3. RESULTS

3.1 Population and Livestock

Sharma and Banskota (1992) pointed out that over 90 per cent of the economically active population in Nepal are engaged in the primary sector. Crop-dominated farming systems are, in general, found in the Middle Mountain areas. These systems include livestock raising as an integral part. Livestock-dominated systems are found in the high mountains (Sharma and Jodha 1992). In Gorkha, both systems are practised. In the south, in general, crop-dominated systems with a predominance of cereals are found with maize-based cropping patterns predominating hillslope cultivation and rice-based cropping patterns the lowlands. Livestock are highly diversified, with a predominance of cattle and buffaloes in the Middle Mountains and yak and *chauri* in the High Mountain Region.

The human population of Gorkha is approximately 291,690, with an average density of 80/km^2. The southwestern part is the most densely populated area in the district. In 13 VDCs, the density is more than 300/km^2. The northern VDCs are less densely populated. In analysing the population density in relation to agricultural land, however, the situation is different, especially in the northern part. From this perspective, five VDCs in the High Mountain and High Himalayan Region belong to the most densely populated areas, with more than 600/km^2, which highlights the dependency of the human population on livestock (Map 11).

Livestock production is an essential part of the farming system in the study area. The total number of livestock aggregated from VDC figures amounts to 157,000 livestock units (LU), incorporating 112,000 cattle, 63,000 buffaloes, 11,000 yaks and *chauri*, 208,000 sheep, 12,000 pigs, and 250,000 poultry. The average livestock density of the total area, excluding wasteland, ranges from 0.17 to 2.31 LU/ha in the different VDCs. In the southern part of the district in particular, the livestock population is quite high. In the north, the livestock density does not exceed one LU/ha of total area, not including wasteland (Map 12).

3.2 Total Feed Supply

Forests directly and indirectly affect crop production. They provide compost materials and supply fodder for livestock which deliver the manure needed for crop production. Also, forests protect cultivated land from landslides and erosion (Yadav 1992). Both the degradation of forest resources and the consequent decline in crop production affect feed supply drastically.

Three major feed sources were seen to be contributing to livestock nutrition. These were feed from (1) agricultural land, i.e., crop residues, fodder trees, the non-cultivated area within agricultural land, and risers and bunds; (2) forests and shrubland; and (3) grasslands and pastures (Map 13).

A potential amount of more than 340,000mt DM feed was calculated to be available to livestock within Gorkha District in one year. Considering the inaccessibility of pasture land, only 270,000mt DM of feed was actually available for livestock (Table 11). Agricultural land turned out to be the major feed source in the district, contributing about 57 per cent of the total feed supply. Fodder from grazing in forests and shrublands was the second largest source in the district, amounting to approximately 26 per cent of total feed supply. Fodder from grazing on public grassland was another important feed source and provided about 17 per cent of the total feed supply.

On agricultural land, crop residues of paddy, millet, and maize were the major single feed source, providing about 28 per cent of the total feed supply (Table 12). Fodder trees on private land, soilage fodder from risers and bunds, and fodder from non-cultivated areas within the agricultural land each contributed approximately seven to nine per cent of total feed supply. Fodder from forest grazing was used mainly in shrubland and hardwood forests; the portion of total feed supply amounted to about 10 per cent each from both categories. Grazing in mixed or coniferous forests was not a main feed source in the district, also due to inaccessibility. The largest fodder sources from grazing on pasture land were the subalpine and alpine agroclimatic zones, contributing seven per cent and six per cent respectively to the total feed supply in the district.

In the warm climatic zone below the 15°C mean annual temperature isoline or at approximately 2,000masl, feed from agricultural land was regarded as the major fodder source, contributing 68 per cent of the total feed supply in this zone or 51 per cent of the total feed supply in the district. Fodder from forests and shrublands amounted to 29 per cent of the total supply in this zone. Grasslands and pastures provided about three per cent of the total feed supply. In contrast, pasture land provided approximately 56 per cent of the fodder in the cool climatic zone. There, agricultural land produced a small portion of fodder only (24 per cent) (Figure 2).

In the warm zone, the productivity in the fodder area was, on an average, about 1.85mt DM/ha, while it was only 1.38mt in the cool zone.

Table 11: Amount of Feed from Different Sources in Two Climatic Zones of Gorkha District

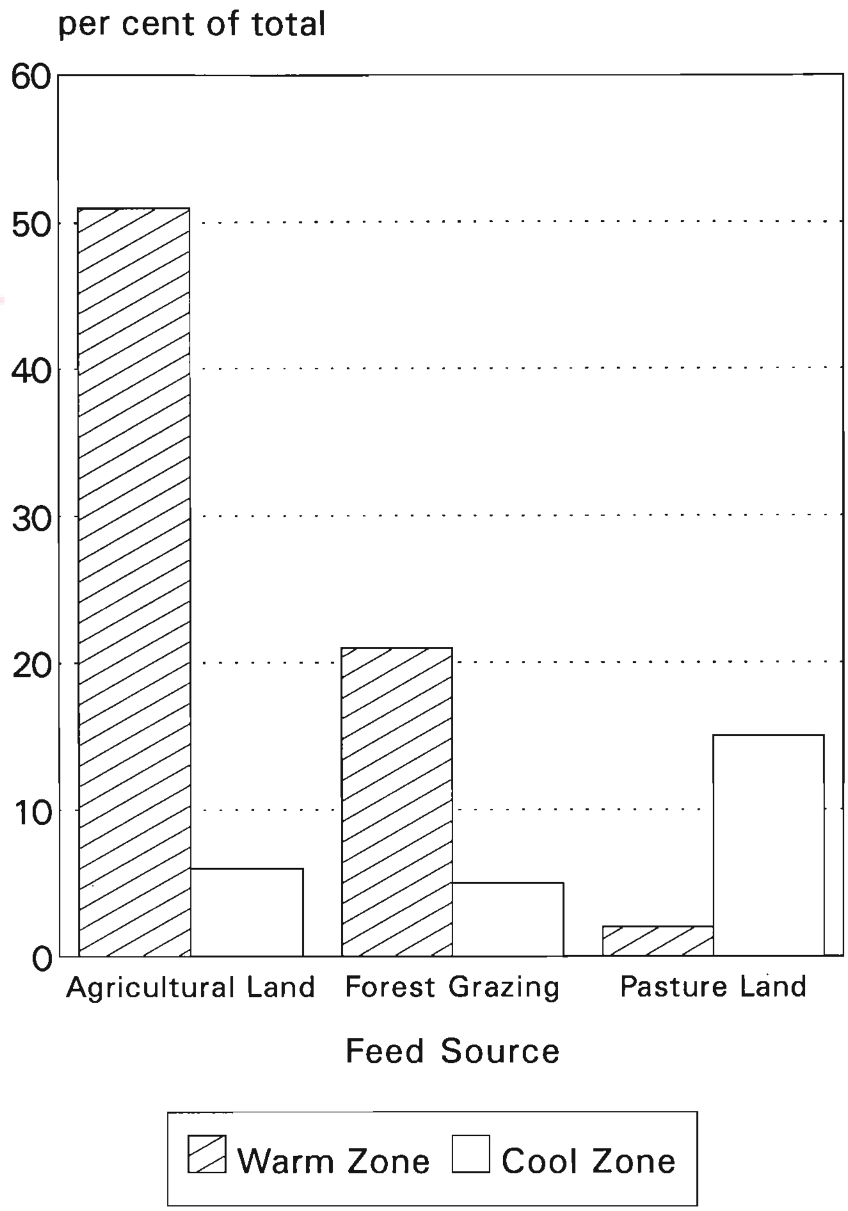
Feed type	Total feed mt DM/year				Area ha	
	Warm zone		Cool zone		Warm zone	Cool zone
1. Forest						
- Hardwood forest grazing	26,770	(10)	5,615	(2)	35,232	7,390
- Coniferous forest grazing	77	(0)	3	(0)	351	14
- Mixed forest grazing	540	(0)	3,360	(1)	1,566	8,422
- Shrubland grazing	31,020	(11)	4,810	(2)	18,140	2,813
Sub-total	58,407	(21)	13,788	(5)	55,289	18,639
2. Grazing land/pasture (access 40%)						
- Warm temperate zone	5,724	(2)	-		1,908	-
- Temperate zone	-		2,052	(1)	-	456
- Cool temperate zone	-		3,046	(1)	-	1,023
- Subalpine zone	-		18,634	(7)	-	9,317
- Alpine zone	-		16,028	(6)	-	10,686
Sub-total	5,724	(2)	39,760	(15)	1,908	21,482
3. Agricultural land						
- Crop residues	74,960	(28)	8,365	(3)	26,749	4,930
- Private fodder trees in Middle Mountains	23,700	(9)	-		-	-
- Soilage fodder from risers and bunds	19,195	(7)	3,537	(1)	6,191	1,141
- Non-cultivated area within agricultural land	18,745	(7)	5,118	(2)	18,745	5,118
- Grazing on fallow land in Middle Mountains	820	(0)	-		-	-
Sub-total	137,420	(51)	17,020	(6)	51,685	11,189
4. Total	201,551	(74)	70,568	(26)	108,882	51,310

( ) percentage of total feed supply in the district

Table 12: Amount of Feed Derived from Crop Residues in Two Climatic Zones of Gorkha District

Crop	Total feed mt DM/year		Cropped area ha	
	Warm zone	Cool zone	Warm zone	Cool zone
Paddy	43,890	286	14,730	131
Wheat	1,620	980	2,705	2,003
Maize	12,290	1,725	15,365	2,435
Millet	14,645	2,740	9,963	1,973
Mustard	640	-	2,562	-
Pulses	1,290	-	4,441	-
Potato	585	2,630	98	645
Total	74,960	8,361	49,864	7,187

Figure 2: Feed Supply in Two Climatic Zones in Gorkha District



3.3 Total Feed Requirements

Two sets of indicators were chosen for analysing the total feed requirements per VDC, one based on an ideal feed situation and the other on a likely present situation.

3.3.1 *Feed Requirements on the Basis of Ideal Feed Supply*

The first set of indicators showed annual feed requirements on the basis of ideal feed supply and well-nourished livestock. It was assumed that feed ratios were equal to those needed for sustaining high productivity of one livestock unit with a body weight of 400kg.

Based on the livestock figures given for each VDC, a total feed requirement of about 495,500mt DM/year or 3.14mt DM/LU/year was calculated for Gorkha District (Table 13). Including the movements of sheep out of the district in winter, this amount decreased by about 12,000mt DM/year.

Table 13: Total Number of Livestock and Number of Livestock Units per Livestock Category and Feed Requirement in an Ideal Feed Situation in Gorkha District

Livestock types	Total No.	No. of LU	Head per LU mt DM/year	Feed requirements		
				total	per cent of total	per LU mt/DM/year
Buffalo	63,309	46,849	0.74	132,817	26.8	2.835
cattle	111,771	76,004	0.68	223,908	45.2	2.946
Yak/*chauri*	10,817	8,005	0.74	22,694	4.6	2.835
Sheep	207,731	24,928	0.12	106,143	21.4	4.258
Pig	11,733	1,467	0.125	6,854	1.4	4.672
Poultry	250,237	593	0.00237	3,116	0.6	5.256
Total		157,846		495,532	100.0	3.14

The livestock density in relation to total area, excluding wasteland, differed in the three VDC categories. The density in the cool zone (category 1) was much lower (less than 0.5 LU/ha) than in the warm zone (category 3) where it reached more than 2.0 LU/ha in four VDCs, Aru Chanaute, Baguwa, Phinam, and Phujel. About 50 per cent of the VDCs in category 2 (cool and warm zone) also had a low livestock density; the others did not exceed one LU/ha. The highest feed requirements per hectare were found in the warm zone (category 3). There, in 35 out of 47 VDCs, the annual dry matter requirements to maintain high productivity exceeded 3.0mt/ha of total area, excluding wasteland. In the four VDCs with the highest livestock densities they amounted to more than 6.0mt/ha. Only one VDC, Ghyalchok, was in that category with a feed demand of less than 1.5mt DM/ha. In the VDCs in the cool zone, the fodder demand did not go beyond 1.5mt DM/ha. Kharibot VDC had the highest requirements per hectare in category 2 (cool and warm zone), about 3.0mt DM (Annex 4) (Map 14).

Sirdibas, in category 2, was the VDC with the highest total feed demand, amounting to more than 20,000mt DM per year. This was due to the large numbers of livestock permanently stationed there and the huge high mountain pasture areas where many sheep from other VDCs grazed during summer. Other VDCs in this category, with feed requirements beyond 10,000mt DM/year, were Kerauja and Kharibot. Nevertheless, the amount of feed required in one VDC was not related to the demand per hectare, due to the different area sizes of the VDCs.

In the cool zone, the biggest fodder demand was calculated for Samagaun VDC. This again reflects the considerable areas of pasture there. In Laprak, the highest value of livestock units was recorded, including the biggest sheep population in the district (45,600). However, the calculated number of livestock units kept in this VDC was much lower, since it was customary practice for the sheep to graze in other districts during winter and on the high mountain pastures of other VDCs in summer.

In the warm zone, the feed requirements of three VDCs were higher than 10,000mt DM/year, i.e., Bungkot, Hanspur, and Jaubari.

3.3.2 *Feed Requirements on the Basis of Insufficient Feed Supply*

The second set of indicators tried to display the current feed situation in the district. Instead of an ideal feed supply, a smaller amount was considered to be available, and one livestock unit to have an average body weight of 250kg. These considerations led to an annual feed requirement of about 362,000mt DM or 2.29mt DM/ha in the district, which was about 73 per cent of the first scenario (Table 14). Analogous to the first set of indicators, this amount was reduced by about 12,000mt DM, reflecting the movements of sheep out of the district.

Table 14: Total Number of Livestock and Number of Livestock Units per Livestock Category and Feed Requirement in a Likely Present Feed Situation in Gorkha District

Livestock types	Total No.	No. of LU	Head per LU mt DM/year	Feed requirements		
				total	per cent of total	per LU mt/DM/year
Buffalo	63,309	46,849	0.74	83,016	22.9	1.772
Cattle	111,771	76,004	0.68	139,923	37.8	1.841
Yak/*chauri*	10,817	8,005	0.74	22,694	6.3	2.835
Sheep	207,731	24,928	0.12	106,143	29.3	4.258
Pig	11,733	1,467	0.125	6,854	1.9	4.672
Poultry	250,237	593	0.00237	3,116	0.9	5.256
Total		157,846		361,746	100.0	2.29

Since only the body weights of cattle and buffaloes were reduced in this set of indicators, changes in total feed requirements occurred mainly in the VDCs in categories 2 and 3, and also in Laprak VDC. Still, in 12 VDCs in the warm zone the feed requirements per hectare exceeded 3.0mt DM/year, i.e., in Aampipal, Aru Chanaute, Baguwa, Phinam, Phujel, Gaikhur, Hanspur, Jaubari, Masel, Namjung, Panchkhuwa-deurali, and Ranishwara (Annex 5).

3.4 Livestock Carrying Capacity

The analysis of livestock carrying capacity was based on the annual feed supply of the total area, excluding wasteland, and the requirements for well-nourished animals. How many productive and healthy livestock units can be sustained in a defined area with a given fodder production? The calculation indicated that, in Gorkha District, the livestock carrying capacity was between 0.18 LU/ha in Bihi VDC and 0.88 LU/ha in Hanspur VDC (Annex 4) (Map 15). VDCs in the cool zone of the district especially had a low livestock carrying capacity. Also, the carrying capacities of the VDCs in category 2 (cool and warm zone) were much smaller than in the warm zone. The low carrying capacity in the cool zone was a result of the huge pasture areas in the subalpine and alpine zones which had limited fodder production. Further, there was little expectation that the extensive forest areas in categories 1 and 2 of northern Gorkha could provide much fodder for grazing. In contrast, the southern VDCs in the warm zone relied mainly on agricultural land with high feed productivity.

Based on livestock distribution and the model incorporating the livestock movements in the district during the year, the VDCs in the cool zone (apart from Laprak) and also some VDCs in the middle part of the district were seen to have a higher carrying capacity. In these high mountainous VDCs, large numbers of livestock graze for only about six months, leading to a higher number of livestock units in the VDCs according to the livestock distribution model. The fact that feed supply was calculated on a yearly basis, but that sheep grazing is only practised during the summer months on high mountain pastures, increases the rate of livestock carrying capacity relative to the number of additional livestock grazing in these VDC areas. The inaccessibility of pasture land also affects the livestock carrying capacity of the VDCs with large pasture areas, particularly in the northern part of the district. Under the given circumstances, the carrying capacity decreases to a low of 0.12 LU per hectare of potential fodder area in Bihi VDC (Annex 5).

3.5 Feed Situation

3.5.1 *Feed Situation on the Basis of Ideal Feed Supply*

There is no doubt that the feed situation in southern Gorkha is at a critical point. There, in almost all VDCs, livestock are malnourished and have low productivity; in more than two thirds of the VDCs (47), a feed deficit is expected. In order to maintain good nutrition for livestock, the number of LU should be reduced by about 50 per cent in the south. In northern Gorkha, all VDCs have sufficient or surplus fodder production; if the limited access to fodder from pasture grazing, especially in Chhekampar VDC, is not considered there seems to be a big surplus of fodder. In other VDCs in the cool zone, i.e., Bihi, Lho, and Laprak, the fodder seems to be just sufficient. From an overall point of view there is a fodder surplus of approximately 20 per cent in the VDCs in category 1 (cool zone). Most VDCs in middle Gorkha, lying in both the cool and warm zones, seem to have either sufficient fodder supplies or even surplus production; only five VDCs, i.e., Aru Arbang, Kharibot, Saurpani, Swara, and Ghyachok, are fodder deficit areas. In the whole district, a feed deficit of about 30 per cent is expected (Map 16; Annex 4).

Considering that about 60 per cent of the pasture land may be inaccessible to livestock, the feed situation is poor, especially in the VDCs of the cool zone in the north, where only Chhekampar seems to have sufficient fodder. Pastures and other grazing lands are the most important feed sources in the cool zone. Applying the scenario of limited access to these grazing areas, the feed situation drops from a surplus of 20 per cent to a deficit of more than 40 per cent. The feed balance also becomes negative in some VDCs in category 2, located in both temperature zones where pasture land is the major feed source, i.e., Sirdibas, Uhiya, Simjung, and Gumda. The southern VDCs in the warm zone are not much affected by this scenario due to lack of pasture areas. In total, the feed deficit is increasing to about 44 per cent, on account of inaccessibility to pasture land in the district (Map 17; Annex 5).

3.5.2 *Feed Situation on the Basis of Insufficient Feed Supply*

Applying the second set of indicators, which tried to display the current feed situation in the district, in southern Gorkha, the feed supply was still in deficit by 22 per cent. There was inadequate livestock nutrition in 50 per cent of the VDCs. Nutritional demands were either met through feed concentrates, e.g., maize corn; through support from neigbouring VDCs; or through VDCs from outside the district. In northern Gorkha, the number of cattle and buffaloes recorded was fairly small, and only Laprak VDC was positively affected by applying this set of indicators. All six other VDCs showed the same results as for the first set of indicators. In middle Gorkha, one VDC, i.e., Kharibot, remained a feed deficit area (Map 18; Annex 6).

Mainly the VDCs in the north are affected by the lack of access to pasture land. Nevertheless, the results are not much different from the first set of indicators, the feed deficit being about 40 per cent in the cool zone. In middle Gorkha, apart from Kharibot, the area of Sirdibas VDC was expected to have insufficient feed. Again, the southern VDCs were not much affected by this scenario (Map 19; Annex 7).

The most likely current feed situation, assuming insufficient feed for cattle and buffaloes and inaccessibility to pasture, was expected to be best in middle Gorkha where the livestock have access to plenty of fodder from agricultural land as well as from grazing in forests and on pasture areas. There, the feed supply was expected to be sufficient. The worst feed situation seems to be in the cool zone of northern Gorkha, where the inaccessibility of pasture land puts a lot of pressure on the remaining grazing areas. Correlative of livestock with low body weight, and thus not too productive, the feed supply seems to be just sufficient in the southern VDCs. There, inaccessibility to pasture areas has little influence on the feed situation.

4. CONCLUSIONS

The study has shown the potential of GIS technology for an area-based analysis of development problems in mountainous areas by using different sets of indicators.

The livestock system practised in Gorkha and its exploitation of natural resources found in the study area are highly unsustainable. The animal husbandry system cannot maintain a certain defined level of performance over time without damaging the essential ecological integrity of the whole mountain agricultural system (Jodha 1992). By integrating the linkages between agriculture, livestock, and natural resources even worse results emerge. Exploitation of forests and other resources decreases soil fertility and increases soil erosion, thus leading to less crop productivity and fodder availability from cultivated areas.

The analysis of the feed situation shows that there is an overall feed deficit of about 50 per cent in southern Gorkha District. Under both sets of indicators, the worst areas are in such bad condition that calculations, with 400kg and 250kg body weights for one livestock unit, almost show the same results. Efforts should be made to (1) reduce the fodder demand and (2) increase fodder production. Unproductive livestock, in particular cattle, need to be replaced by a smaller number of improved, more productive, breeds using different management options. However, this is difficult to put into practice in the cultural and religious context of Nepal and due to the fact that cattle are often kept for the purpose of providing manure only. There are still options left for increasing fodder production in the middle mountains, e.g., the promotion of traditional fodder tree planting; the sowing of improved varieties of grasses and legumes on non-cultivated farmland; and the support of programmes encouraging users to manage afforestation, plant fodder tree species, and sow grasses between tree saplings. At present, northern Gorkha seems to face major problems with fodder. Large areas of pasture land are not accessible, other pastures have become degraded over the years, and productivity has decreased due to overgrazing caused by the closure of the border to China (Tibet). Improved grazing management practices and pasture development activities need to be promoted. Also, the problems sheep pastoralists have been facing lately during the winter seasons should be addressed. Because of increased cropping during this season, traditional grazing areas are no longer open.

The biggest problem of data quality for analysis of the feed situation is not that the land use data are already 15 years old but that the livestock figures in the district have to become more reliable and information about the productivity levels of different sources, in general, need to be improved for better livestock planning at both the district and VDC levels. An update of land use data, incorporating remote sensing and aerial photographs into the GIS, is essential for other planning and monitoring purposes.