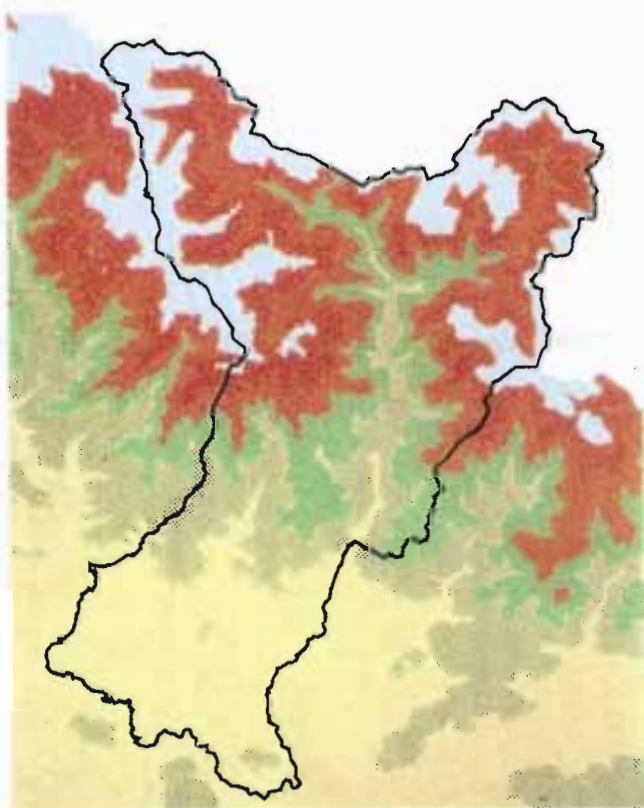


# **MENRIS CASE STUDY SERIES**

## **No. 3**

### **Application of GIS for Planning Agricultural Development in Gorkha District**



**NEPAL**

Mountain Environment and Natural Resources' Information Service (MENRIS)



**INTERNATIONAL CENTRE FOR INTEGRATED MOUNTAIN DEVELOPMENT  
(ICIMOD)**



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Administrative Map of Nepal (Source: HMG Nepal, Survey Department, Topographical  
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Inset Photograph: Winnowing at Lamagaon, Chhekampar VDC, Shyar *Khola* valley,  
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# **Gorkha Development Project (GDP)**

## **HMG/GTZ**

Application of GIS for Planning Agricultural  
Development in Gorkha District, Western Region of  
Nepal

prepared by  
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Kathmandu, Nepal  
December 1995



# Foreword

One of the main reasons why mountain areas have been left behind in the development process is the lack of adequate information about their limitations to and potential for development. Geographic Information Systems (GIS) and remote sensing technology are powerful tools that can increase the information base essential for sustainable mountain development. The strength of GIS lies in its ability to integrate data and information on different subjects and from different sources using a common geographical reference.

Through remote sensing, new mechanisms for obtaining information on remote and inaccessible areas have become available. Since 1989 ICIMOD has developed a strong capacity in the fields of GIS and remote sensing through its Mountain Environment and Natural Resources' Information Service (MENRIS). The present study provides a good example of the applications of GIS and remote sensing technology for regional development planning.

It is the result of a joint effort of the Gorkha Development Project (implemented by His Majesty's Government of Nepal and the German Technical Assistance [GTZ]), and ICIMOD. It is primarily intended to meet the needs of development planners and extension agencies in the fields of agricultural planning and natural resources' management. Its contents will also be of interest to donor agencies of agricultural/natural resources' development projects/programmes, NGOs working in this field, researchers, and GIS experts. The paper is meant to stimulate the readers' interest in GIS applications and also help them to reorient development planning at district level so as to contribute to sustainable forms of mountain agriculture.

Prior to this case study, ICIMOD published 'Applications of GIS for Natural Resource Management in Dhading District, Nepal' in 1992. It illustrated basic concepts and the use of GIS to demonstrate how data integration enables decision-makers and development planners to improve the management of natural resources. The second case study series was published in 1994, 'Applications of GIS to Rural Development Planning in Nepal'. The illustrations presented both basic and advanced usage of GIS and remote sensing applications in several districts of Nepal.

The five case studies recorded in the present publication cover agricultural planning and natural resources' management in Gorkha District: Agroclimatic Zones; Analysis of the Feed Situation and Livestock Carrying Capacity; Horticultural Development Zones; Correlation of Land Use with Climatic Factors; and Potato Production. The studies have been undertaken by Mr. Hubert Trapp, ICIMOD/MENRIS specialist in GIS, in collaboration with professionals of the Gorkha Development Project: Mr. Binod Shrestha, Mr. Dhruba Pant, and Dr. Lakshman Pun. Other MENRIS staff members in the team who have assisted with the case studies include Mr. Basanta Shrestha, Mr. Anirudra Shrestha, Mr. Govinda Joshi, Ms. Mona Thapa, Ms. Mona Lacol, and Ms. Sabina Pradhan. On behalf of ICIMOD we would like to thank them all for their contributions and through GTZ the Government of Germany for the financial support it provided to undertake this study.

Pramod Pradhan  
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MENRIS/ICIMOD

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Director General  
ICIMOD



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## ABBREVIATIONS/ACRONYMS

AAT	Arc Attribute Table
AIX™	Advanced Interactive Executive
APROSC	Agricultural Project Services Centre
C	Agricultural land on sloping terraces
DEM	Digital Elevation Model
DM	Dry Matter
F	Agricultural land on footslopes/tars
FAO	Food and Agriculture Organisation of the United Nations
DGP	Gorkha Development Project
GIS	Geographic Information System
GTZ	<i>Deutsche Gesellschaft für Technische Zusammenarbeit</i> (German Technical Agency)
ha	hectare
HKH	Hindu Kush-Himalayas
HMG	His Majesty's Government
HMR	High Mountain Region
IBM™	International Business Machines Corporation
ICIMOD	International Centre for Integrated Mountain Development
LRMP	Land Resource Mapping Project
LU	Livestock Unit
masl	metre above sea-level
MENRIS	Mountain Environment and Natural Resources' Information Service
MMR	Middle Mountain Region
mt	metric tonne
NGO	Non-government Organisation
NPDP	National Potato Development Programme
PAT	Polygon/Point Attribute Table
PC	Personal Computer
PET	Potential Evapotranspiration
PLBP	Promotion of Livestock Breeding Project
RISC™	Reduced Instruction Set Computer
RS	Remote Sensing
SBD	Suspension Bridge Division
T	Agricultural land on level terraces
TDN	Total Digestable Nutrients
UNDP	United Nations Development Programme
UTM	Universal Transfer Mercator
V	Agricultural land on valley floors
VDC	Village Development Committee



## 1. INTRODUCTION

### 1.1 The MENRIS Programme at ICIMOD

The Hindu Kush-Himalayan (HKH) Region presents a formidable range of both ecological and development problems that have physical as well as socioeconomic dimensions. Isolated solutions have proved to be counter-productive, since most of the problems are interconnected. Development interventions must, therefore, be formulated and implemented in an integrated manner. An integrated approach to solving the problems needs a strong database. Advances in satellite image processing and computer analysis have made it possible to evolve a realistic, accurate, and uniform database. Geographic Information Systems' (GIS) technology is regarded as a good tool for adapting and disseminating knowledge and experiences from the region, as well as from various other mountain areas, and can be used as an integrated approach to development and environmental management in mountainous regions.

In 1990, the International Centre for Integrated Mountain Development (ICIMOD) established the Mountain Environment and Natural Resources' Information Service (MENRIS) as a resource centre for the HKH Region for the study and application of GIS technology. The objectives of MENRIS are (1) to improve environment and natural resource management and promote sustainable economic growth in mountainous countries, through facilitating the solution of common problems and ensuring the communication of results on a compatible GIS platform; (2) to assist in the promotion of information exchange between interested participating countries of the HKH Region using GIS technology; and (3) to act as a clearing house for existing knowledge of mountain resource management for agencies involved in mountain development.

MENRIS has placed a major emphasis on (1) the establishment of an in-house GIS and remote-sensing (RS) facility; (2) training and capacity building for application of GIS/RS in natural resources' management in each of the regional member countries, including the establishment of national GIS facilities; (3) the build-up of a digital HKH database; (4) networking among member countries, within the region and the sub-region; and (5) computer applications and development.

### 1.2 The Five Case Studies

MENRIS/ICIMOD, in cooperation with the Gorkha Development Project (GDP) in Nepal, a collaborative project of His Majesty's Government of Nepal and the Federal Republic of Germany, is establishing a Geographic Information System (GIS) for Gorkha District. The scope of the project is to build up a decision support system based on a GIS database with baseline data of the Gorkha District. This will enable decision-makers in Gorkha District as well as the GTZ-supported GDP to (1) better visualise existing natural resources and infrastructure, (2) integrate natural science and socioeconomic data, and (3) use the information thus gained for improved area-specific planning and programme monitoring. A database with baseline data of the Gorkha District had previously been established by MENRIS and was handed over to the GDP (Trapp 1993).

Gorkha District lies in the Western Development Region of Nepal and covers an area of about 3,642sq.km. From south to north the district stretches over a distance of about 100km; in the east-west direction, the length amounts to 60km in the northern part and to approximately 35km in the south (Map 1). The district is divided into 69 Village Development Committees (VDC) — an administrative sub-unit (Map 2). The study area is a land of extremes - the climates range from subtropical to arctic; the physiography includes fertile alluvial plains below 500masl and very rugged, permanently snow-covered peaks. Major Himalayan ranges are part of the district, namely, Manaslu Himal, Sringi Himal, and Ganesh Himal, with altitudes of 8,162m, 7,138m, and 7,424masl respectively. Bedrock and surficial geology, climate, vegetation, and land use were used as differentiating criteria for the three physiographic regions in the district, i.e., Middle Mountains, High Mountains, and High Himalayas, their areas amounting to 28 per cent, 25 per cent, and 47 per cent respectively (LRMP 1986c).



This volume reports on five case studies and is an effort to address development problems and potentials in the agricultural sector by using GIS technology.

- The assessment of agroclimatic zones in the district was conducted in line with the theory that the zonal approach is regarded to be most suitable for planning development interventions in the agricultural sector in mountainous areas.
- Animal husbandry is an integral part of the agricultural system in Nepal, however, there is a shortage of fodder, limiting the animal productivity. The analysis of the feed situation, i.e., feed supply, feed requirements, and livestock carrying capacity in Gorkha District, was conducted to better understand the spatial relations of the feed deficit problem in the district and to identify smaller units for immediate intervention.
- Horticulture is considered to be an effective tool for reducing environmental degradation and improving the economic situation in mountainous areas. There is great potential for the development of various fruit species in Nepal. The case study assessed the potential of horticultural development and particular fruit crops in Gorkha District, taking into account various parameters, i.e., temperature, land use, aspect, and accessibility to marketing infrastructure.
- The suitability of a location for specific plants and crops is influenced by different parameters, such as temperature, moisture, slope gradient, aspect, and cloud formation, and the interaction between these parameters, including the human factor. The case study, 'Correlation of Land Use with Climatic Factors in Gorkha District', tried to assess the spatial relationship between these parameters, to better understand the environmental system and the use of natural resources in the district.
- In the Nepalese mountains, in particular in Gorkha District, potato cultivation has a high socioeconomic value, either as a staple crop in the high mountain areas or as an important vegetable crop in the mid-hills. Furthermore, marketing and bartering of seed potatoes contribute to household incomes and diversification of diets. In general, potatoes can be grown on all cultivated land. The case study applied GIS technology to the analysis of appropriate locations for potato production during optimal growing periods.

### 1.3 Mountain Areas and the GIS Concept

Mountain areas present a great challenge for the application of GIS technology due to their diversity, marginality, and strategic importance, as well as their different physical, biological, and societal systems. When compared with the plains in the lowlands, the physical characteristics of the mountain environment are more complex and need to be analysed using a three-dimensional approach/methodology, in order to arrive at an approximate representation of the aspect, slope, and topography of the mountains (Heywood et al. 1994). GIS and Digital Elevation Models (DEM) are used for different types of applications in mountain environments, e.g., regional resource inventory; planning and management; hazard assessment; modelling of the ecology, climate, or hydrology; and geomorphology (sources quoted in Stocks and Heywood 1994).

Data on resources and environment are available. However, these data are often dispersed among many agencies and cannot be quickly compiled for multisectoral, problem-oriented analyses. Thus the ability to respond to the information needs of planners and decision-makers is limited. The strength of GIS technology is its ability to integrate data from various resource disciplines, using a common geographical boundary of reference.

A Geographic Information System (GIS) is a computer-based system capable of holding and using data describing places on the earth's surface. The system is characterised by two forms of data; i.e., attribute data, either statistical or textual, contained in tables, lists, catalogues, etc and geographic information, either spatial or locational, contained in various kinds of maps. Computer technology, for quite some time, has made it possible to manipulate and analyse statistical information. Recent development has facilitated the automation of maps into digital databases and allowed the simultaneous manipulation of both the geo-reference planners



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to produce a combination of maps and tables that show 'where' and 'what', and to answer many questions that remained open. This computerised system, known as GIS, can store, manipulate, display, and produce geographic (spatial) information integrated with statistical and textual data; it is becoming one of the most useful and powerful analytical tools for resource planners and managers (FAO 1988).

### *Database and Techniques*

The Geographic Information System software Arc/Info was used to establish the database. The software was used based on an IBM compatible PC platform for data input and digitising. The geographic analysis was carried out on an IBM RISC System/6000<sup>TM</sup> and AIX<sup>TM</sup> Operation System; the data are now available on a PC platform. The universal transfer mercator (UTM) system was used for map projection. Gorkha District lies in UTM zone 45 and is based on the Everest spheroid.

The established database of Gorkha District is based mainly on secondary data. The population figures were extracted from the 1991 Census, and all other socioeconomic figures were retrieved from a ward-level baseline survey conducted by GDP. The main references for natural resources and land use were the data and maps published by the Land Resource Mapping Project (LRMP) from 1984 to 1986 (Table 1)

**Table 1: Digital Database of Gorkha District**

Description	Feature Type	Map scale	Source
Land utilisation	polygon	1:50,000	LRMP 1986
Land system	polygon	1:50,000	LRMP 1986
Land capacity	polygon	1:50,000	LRMP 1986
Elevation contours in 500 feet intervals and spotheights	line and point	1:63,360	ONE INCH maps 1950s
Drainage system	line	1:125,000	SBD 1989
VDC boundaries	polygon	1:25,000 - 1:50,000	HMG 1986
Settlements	point	1:125,000	SBD 1989
Roads and trails	line	1:125,000	SBD 1989
Bridges and fords	point	1:125,000	SBD 1989
Meteorological data	point		HMG
Socioeconomic data	-		HMG, Census 1991 and GDP field survey 1992

Different GIS modules were applied for the spatial analysis. The Arc/Info TIN module was used to create a digital elevation model using embedded on elevation contours of 500 foot intervals and spot heights on a scale of 1:63,360. The analyses of aspect and slope gradient were carried out with the GRID raster GIS method using a 100m x 100m pixel size. Similar agroclimatic zones, horticultural development, correlation of land use with climatic factors, and potato production were assessed using the raster GIS method for technical reasons and an overlay technique for the combination of several spatial data layers (coverages). The GRID module PATHDISTANCE was tested to estimate the accessibility of road infrastructure, cultivated areas, and pasture land.

The data of the study area have been stored in the form of thematic layers (coverages) and related attribute tables, using Arc/Info software. This allows one to retrieve, overlay, and present them in map or tabular form or display them as a three-dimensional view. The data can also be retrieved in spatial format with



WINDOWS-driven Arc/View software on PCs. The data are compiled in subdirectories, or coverages. These coverages include different features such as polygons, lines/arcs and points, as well as the database. The database is either stored in <coverage name>\PAT.DBF files (i.e., polygon or point attribute tables) or <coverage name>\AAT.DBF files (i.e., arc attribute tables). All data related to areas (e.g., socioeconomic data of VDCs and land use data) are stored in polygon attribute tables; data related to lines (e.g., villages, settlements, and bridges) are stored in point attribute tables. The \PAT.DBF and \AAT.DBF database files can be retrieved and updated in dBASE software (Annex 1).

### *Data Problems and Limitations*

- The data used for the assessment of natural resources were almost 15 years old. The LRMP had already conducted its surveys in the late seventies. Since then land use could have changed, deforestation and degradation of forests could have continued, the conversion of forests into other land use classes could have occurred, agricultural lands on sloping terrain and in valleys could have been lost through natural and man-made causes, and so on. Still, these data are a good base for conducting GIS applications, since the database can be updated using other less labour-intensive technologies, such as remote sensing (RS).
- The data accuracy was limited by the fact that the major features of the database were digitised from maps on different scales and/or maps which were out of date. Natural resource data of the LRMP were retrieved from maps with scales of 1:50,000; contour lines were taken from the ONE INCH maps (scale 1:63,360). Other features, such as roads/trails, rivers, villages/ settlements, and bridges, were extracted from the SBD maps with scales of 1:125,000. The latest updated VDC boundary maps were not available. The maps used were prepared in 1989 without proper reference points; thus, the line features were delineated manually on the topographical sheets of the Indian Survey and only then were they digitised.
- While there are limitations to and lack of data, it is essential that we make the best use of what is available, knowing fully the limitations and responding to needs as we proceed.

### **1.4 Conclusions**

The application of Geographic Information Systems has proved to be a useful and effective tool in the frame of area planning for agricultural development at the district level.

A big advantage of GIS technology is its flexibility. GIS analysis can be carried out by applying different sets of indicators based on adjusted parameters. The system is easy to update, in particular the socioeconomic part. In general, the database can be used for the assessment of different problems and for their solutions. Once a methodology as such is developed, it can be expanded and transferred to other regions with much less effort.

A GIS model tries to describe the reality based on a selected number of parameters. The quality of the model, i.e., the deviation from the reality, needs to be either tested in the field or compared with available secondary sources or other existing models. For Gorkha District, the quality of the model could only be tested in two cases, potato cultivation and agroclimatic zones. Only for potato cultivation do the available sources cover the whole district. The results of the model proved to closely reflect the reality. With regard to agroclimatic zones, a model was developed and compared to an already existing pattern elaborated by the LRMP through non-GIS methodology. The GIS results were different since additional information was used and the methodology used to delineate the zones was also different.

The management and use of the database are now the primary tasks for the future. The first step in this direction was a GIS orientation workshop in Gorkha bazaar in April 1995 in which representatives of the local government, various line agencies, and NGOs working in the district participated and results of the case studies were presented. During discussions it was agreed, in general, that the district database should be installed and managed by the local government of Gorkha District. It was envisaged that all agencies should



## Introduction

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contribute to the information system and have access to it. At present, the district bodies do not have the capability to undertake this task independently. The Gorkha Development Project aims to have staff trained on the subject, and it is planned to establish basic computer facilities for the District Development Committee to manage the database. For proper utilisation of the system, data networking with other agencies, updating of databases, and so on, the local government body needs support to upgrade its institutional skills and knowledge.

It is hoped that these initial exercises using GIS will strengthen local-level planning capacities in the future, as the potentials for more sound decentralised decision-making in local development have been substantially improved through the careful use of GIS technology and available data.



# **PART I**

## **AGROCLIMATIC ZONES**

### **IN GORKHA DISTRICT**



### 1. INTRODUCTION

Land use planning is seen as an appropriate way to implement agricultural development programmes in the Himalayan areas of Nepal, although to some extent the diversity of the mountain environment restricts the efficiency of such a technique. Since 1952, many efforts have been undertaken to represent the mountain landscape in three dimensions (Troll 1988:39). During this time, it was found that a zonal planning approach that characterises different agro-ecological systems, should be based on a mountain perspective framework and mountain specificities, and consider the whole ecosystem, including human beings (Partap et al. 1992). Besides biophysical factors, other information should also be considered for characterising agro-ecological systems in mountainous areas, e.g., cropping systems, culture, technology, market options, and information linkages (Lundberg 1992).

Different studies have been undertaken in the past to define agroclimatic or agro-ecological zones for Nepal as a whole or for particular districts<sup>1</sup>. A comprehensive model was developed for classifying agroclimatic homogeneous geographic areas, using several factors that are instrumental in creating mountain specificities (Partap et al. 1990, 1992). A geographic information system (using the IDRISI and Arc/Info™ softwares) was used for that case study; Sindhupalchowk District of Nepal was used as a representative mountain area. Agroclimatic zones of Nepal were mapped on a scale of 1:500,000 using temperature and rainfall data (APROSC 1990). Within the framework of the Master Plan for Horticultural Development, an agro-ecological classification (on a scale of 1:250,000) was developed, describing natural resources of Nepal that are significant to horticultural development, i.e., physiography, soils, climate, vegetation, land use, and people (Carson 1990, 1992). Later, a less complex framework for an ecological classification system was proposed for planning in Nepal, one potentially relevant to different sectors, e.g., agriculture, forestry, and natural resource management (Carson and Sharma 1992). Recently, a project conducted a case study on agro-ecological zonation in the Nuwakot District and used a complex strategy, developed by FAO, for agricultural planning using GIS technology (PCArc/Info™) (Sharma and Antoine 1994).

### 2. METHODOLOGY

This case study was conducted within the wider framework of establishing a database for Gorkha District. The objective of the study was to analyse 'agroclimatic' conditions in Gorkha District using GIS technology and, more particularly, to delineate zones based on climatic parameters. Other parameters, e.g., soils, slope gradients, land use, and aspect, were considered for the purpose of planning in particular developing areas. This is referred to in Part III (Horticultural Development in the Gorkha District) and Part IV (Correlation of Land Use with Climatic Factors) of this report, both of which deal with other aspects of the zonation approach.

This analysis of the agroclimatic zones was based on different sets of information, namely,

- temperature,
- precipitation,
- evapotranspiration, and
- altitude.

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<sup>1</sup> Carson and Sharma (1992:2) used the terms 'agroclimatic' and 'agro-ecological' interchangeably because edaphic influences are not important for many planning purposes.



Map sheets of the Indian Survey (on a scale of 1:63,360) and meteorological data were used as the main sources for the study. Classification systems and equations were taken from secondary data. The contour lines in the district were digitised at 500-foot (about 152m) intervals. A meteorological database was established. In Gorkha District itself there are only four meteorological stations where precipitation data are recorded, i.e., Gorkha Bazaar (1,097masl), Arughat Bazaar (518masl), Jagat (Setibas) (1,334masl), and Larke Samdo (3,650masl); and only one station, Gorkha Bazaar, at the district headquarters, provides temperature data as well. There are two other stations which are near the district boundary, Bandipur (965masl), in Tanahu District; and Gharedunga (1,120masl), in Lamjung, located in the south and west. Apart from Gorkha Bazaar, all stations are established on valley floors where precipitation is lower than on the adjacent slopes. Therefore, the overall precipitation in the area may be higher than calculated. Climatic conditions of a specific area can be analysed by referring to the overall situation in the region. This method provides a general overview at the macro-level; however, it is not suitable for the analysis of micro-ecosystems. To fill the data gap in the Gorkha District, the climatic conditions of central Nepal were assessed by processing data from 55 stations in the Central and Western development regions of Nepal<sup>2</sup>. The different stations recorded data for periods of from four to 32 years (HMG Nepal). In 28 meteorological stations, air temperature data were recorded (Annex 2) (Map 3). The results achieved were compared to the data provided by the Land Resource Mapping Project of Nepal (on a scale of 1:50,000), including temperature and moisture regimes.

## 2.1 Analysis of Temperature Regimes

The model to compute the mean annual air temperature zones of the area used by this study is basically defined through the altitudinal trend of temperature. This means that, in general, for the same altitude the same temperature is calculated. However, meteorological stations, even if they are located at the same altitude, may have different positions - either on a valley floor, on top of a ridge, or on southern/northern slopes - which has a considerable influence on the temperature value. The data available for each station, and used for the analysis, do not include the position of the station, and thus this will influence the result of the model. Other parameters that affect temperature, e.g., latitude and longitude, were not taken into consideration. For the very north-east of the district, data were not available.

The calculation of mean annual temperature zones in the district was based on the linear equation given by Sthapit and Bhattarai (1989):

$$(1) \text{ temperature } (^{\circ}\text{C}) = 25.3822 - 0.0054397 \times \text{altitude (m)}.$$

The mean annual temperature data of 28 meteorological stations where air temperature was recorded were interpolated on to the area using raster GIS modules and a Digital Elevation Model (DEM). First the influence of altitude on the meteorological stations' measurements was removed by calculating 0masl-altitude-equivalent temperatures at each station, according to the equation:

$$(2) \text{ temperature } 0 (^{\circ}\text{C}) = \text{temperature } (^{\circ}\text{C}) + 0.0054397 \times \text{altitude (m)}.$$

The 0m-altitude-equivalent temperature data were then interpolated on to the area and the influence of the altitude added to the interpolated temperature using the DEM.

The temperature regimes were reclassified based on LRMP (1986) temperature ranges (Table 2).

<sup>2</sup> No climatological data are available from the Tibetan Plateau north of Gorkha (compare Domrös and Gongbing 1988).



## Part I: Agroclimatic Zones in Gorkha District

**Table 2: Classification of Temperature Regimes**

Temperature regime	Mean annual air temperature (°C)
Arctic	$\leq 3$
Alpine	$3 < \leq 10$
Cool temperate	$10 < \leq 15$
Warm temperate	$15 < \leq 20$
Subtropical	$> 20$

### 2.2 Analysis of Moisture Regimes

The classification of rainfall patterns and moisture regimes for the region is subject to severe limitations. There is no clear altitudinal trend of precipitation as there is with air temperature (Alford 1992). Only recently, Hormann (1994) presented the results of a spatial regression model for precipitation distribution in high mountainous areas of the Hindu Kush-Himalayan Region which captures the interdependence between meteorological values and mountain topography; however, the methodology is not yet available. Here, the analysis is based on the relationship between altitude, temperature, and potential evapotranspiration (PET). The higher the altitude, the cooler the temperature and, consequently, the lower the PET. Recorded values of mean monthly precipitation of the 55 meteorological stations and potential evapotranspiration data were used to delineate the moisture regime zones in the area. The moisture regime was based upon the number of wet months, defined as precipitation exceeding potential evapotranspiration.

Carson and Sharma (1992) mentioned that (1) wet months during the vegetation period indicate a surplus of moisture for crop production; (2) during moist months there are slight limitations on available moisture and the moisture is sufficient for the production of crops with low water requirements, but irrigation facilities are still necessary during these months to obtain high yields; and (3) during dry months, crop production is only possible with irrigation.

For each month and meteorological station the potential evapotranspiration was calculated incorporating average monthly rainfall data, the altitude, and an equation given by Lambert and Chitrakar (1989) who adapted the Penman equation for Nepal (Table 3).

**Table 3: Parameters for the Calculation of Potential Evapotranspiration (PET) in Nepal; Linear Equation:  $PET = A - B(Z)$ , for computing PET (in mm/day) from Elevation, Z (in km)**

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
A	1.60	2.63	4.04	5.27	5.70	5.06	4.35	4.32	3.80	3.30	2.27	1.52
B	0.26	0.37	0.54	0.75	0.90	0.91	0.81	0.78	0.76	0.55	0.44	0.27

Each month was classified as either wet or dry, and the number of wet months was used as the criterion to distinguish between different moisture regimes (Table 4). In a different approach, Carson and Sharma (1992) have used the number of dry months as the differentiating criterion. Their method was also tested for this study and compared with the other approach. To distinguish between wet, moist, and dry months the definition of Carson and Sharma (1992) was applied:

wet: precipitation  $>$  PET  
moist:  $0.5 \text{ PET} < \text{precipitation} < \text{PET}$   
dry: precipitation  $< 0.5 \text{ PET}$



Table 4: Classification of Moisture Regimes

Moisture regime	Number of wet months per year
Arid	< 2
Semi-arid	2 - 3
Subhumid	4 - 5
Humid	6 - 8
Perhumid	> 8

Source: Lawson 1979, in Müller-Sämann 1986

### 3. RESULTS

#### 3.1 Temperature Regime

The mean annual air temperature in the region ranges from 5.9°C in Mustang (Lomangthang) District (3,705masl) in the alpine temperature zone to 22.7°C at Chapkot (460masl) and Khaireni Tar (500masl) in the subtropical zone. The station at Gorkha Bazaar (1,097masl), with a temperature mean of 20.2°C, is located between the subtropics and the warm temperate zone. The meteorological stations for which air temperature data were available are distributed almost equally throughout the subtropical (11), warm temperate (9), and cool temperate (7) zones. Only one station is located in the alpine zone and none in the arctic zone. Due to the different positions of the stations, isolines of air temperature do not match the contour lines.

*The temperature regime in Gorkha covers five major zones, dominated by the subtropics in the south and the arctic zone in the north. The subtropical zone, covering about 22.8 per cent of total area, reaches far north into the Budhigandaki Valley, and also along the Daroundi and Chepe rivers. The warm temperate zone (11.9 %) is mainly located along or above these rivers up to Rana (Bihi VDC) in the Budhigandaki Valley; there are also some patches on top of the middle mountains in the south. The cool temperate zone (12.3 %) follows a similar pattern high above the rivers and reaches up to Lho and Chumchet VDCs in the north. Alpine and arctic zones cover more than 50 per cent of the area in the northern part of the district (Table 5) (Map 4).*

Table 5: Area of Temperature Zones in Gorkha District

Temperature zone	Area in sq.km.		Percentage of total	
	MENRIS	LRMP	MENRIS	LRMP
Subtropical	829.7	721.6	22.7	19.8
Warm temperate	432.8	534.8	11.9	14.7
Cool temperate	447.7	529.9	12.3	14.5
Alpine	721.7	968.8	19.8	26.6
Arctic	1,210.7	891.1	33.2	24.4
No data	3.6		0.1	
Total	3,646.6	3,646.2		

The analyses carried out by this study and the LRMP show a similar pattern for temperature regimes in Gorkha. However, both the subtropical and the arctic zones are larger in this current analysis, whereas the alpine, warm temperate, and cool temperate zones are smaller (Map 5). The LRMP delineated the



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mean annual temperature lines along the altitude contours, e.g., setting the upper limit of the subtropical zone at 1,000m or the lower boundary of the arctic zone at 4,500m. Furthermore, the project mentioned that the values could vary about 300m. This study, however, assigned the calculated 20°C mean annual temperature isoline to the upper limit of the subtropics, with the result that the zone, to some extent, lies above 1,000m. A similar explanation is given for the arctic zone; however, there it was assumed that a larger area is found below 3°C mean annual temperature.

### 3.2 Moisture Regime

There is limited precipitation from November to February throughout the region. About 80 per cent of the annual precipitation occurs during the months from June to September. In the study area, precipitation varies from 1,800mm in the south to 1,100mm in the north. The heavy pre-monsoon rainfalls in spring have the highest deterioration effect in the area since, at that time, the soils are still bare, or crops are too meagre to protect soil from erosion.

The analysed precipitation data of the meteorological stations covered range from a low of approximately 180mm at the station in Mustang (Lomangthang), north of the Great Himalayan Range at an altitude of 3,705masl, to about 5,200mm at the Lumle station, south of the range at 1,642masl. This decrease in precipitation is caused by (1) lee effects north of the Dhaulagiri and Annapurna Himalayan ranges; (2) special effects in the upper Kali Gandaki Valley (Thak Khola), producing increased precipitation at higher altitudes but dryness in the valley bottom; and (3) the 'nozzle effect' in which the valley enlarges in the upper part and consequently affects the air current from the south so that it becomes divergent north of the narrowest part and produces additional dryness (Hormann 1994: 7). For the area of the upper Marsyangdi Valley, east of the Kali Gandaki Valley, Hormann describes similar effects for items (1) and (2) caused by the Annapurna Himal, although in Manang Bhot (3,420masl) higher mean annual precipitation values were recorded (472mm). As for the Larke Samdo station, at an altitude of 3,650masl, these effects seem to be invalid for the upper Budhigandaki Valley in Gorkha District, east of Manang. There, a mean annual precipitation of 1,121mm was recorded during eight consecutive years from 1978 to 1985. One reason for the higher value might be that, unlike the Dhaulagiri and Annapurna ranges, Manaslu Himal stretches from southeast to northwest and, subsequently, does not cause such a tremendous lee effect in the north.

The analysis of the moisture regimes showed that the stations in Gorkha are either located in a subhumid moisture regime, i.e., Gorkha Bazaar, Arughat, and Jagat (Setibas), or in a perhumid moisture regime, i.e., Larke Samdo. The 55 stations used for analysing the distribution of precipitation are mainly located in subhumid (23) and humid (22) moisture regimes. Three stations each were found under arid, semi-arid, and perhumid conditions. Most of the stations used for the analysis, where temperature and precipitation data were available, were located in the subtropics (11) or in either of the warm (9) and cool temperate (7) zones and in either subhumid (14) or humid (11) moisture regimes. Three stations in the upper Thak Khola Valley, i.e., Thakmarpha, Jomsom, and Lomangthang, were classified as arid or semi-arid.

The methods of Carson and Sharma (1992) were also tested. These two used the number of dry months as the differentiating criterion for moisture regimes. Applying the equation of Lambert and Chitrakar (1989) for the calculation of PET results, all arid and semi-arid stations, i.e., Jomsom, Thakmarpha, Ghami (Mustang), and Lomangthang, were classified as subhumid or humid, and the station of Manang Bhot, unexpectedly, as perhumid. This is due to the fact that many more months in stations at higher altitudes, as well as in areas with low precipitation, were classified as moist, given their low potential evapotranspiration.

*There are three major moisture regimes in the district, i.e., subhumid, humid, and perhumid. The arctic temperature zone, which was not included in the moisture analysis, was added on. In the extreme north-eastern part of Gorkha, about 74sq.km. were not analysed due to lack of rainfall data. Along with the*



arctic temperature zone, the areas of the subhumid and humid zones cover the major part of the district, with 27.3 per cent and 24.8 per cent respectively. The perhumid zone amounts to 12.7 per cent only (Table 6) (Map 6).

**Table 6: Area of Moisture Zones in the Gorkha District**

Moisture zone	Area in sq.km.		Percentage of total	
	MENRIS	LRMP	MENRIS	LRMP
Subhumid	995.0	1,134.5	27.3	31.1
Humid	905.7	928.5	24.8	25.5
Perhumid	460.9	692.1	12.7	19.0
Arctic	1,210.7	891.1	33.2	24.4
No data	73.9	-	2.0	-
Total	3,646.2	3,646.2		

The results for the moisture regime of this study differ from LRMP figures (Map 7). The moisture regimes of LRMP were based on mean annual precipitation in combination with mean annual air temperature (LRMP 1986b: 20); and it seems that the project delineated the moisture zone boundaries also according to temperature zones. In this study, potential evapotranspiration, precipitation, and altitude were taken as parameters for the analysis of the moisture regime, and these are included in the equation of Lambert and Chitrakar (1989). Different results occur, in particular in the perhumid zone. This moisture regime was basically found in the north, in contrast to LRMP, and is based on the precipitation and altitude data of Larke Samdo (Samagaun VDC). Only a limited perhumid area was calculated for the south of Manaslu Himal where a high amount of precipitation is expected. The comparably low calculated precipitation values are probably due to the locations of the stations, which are mainly concentrated in valley areas and are not evenly dispersed in the district.

### 3.3 Agroclimatic Zones

The agroclimatic zones in Gorkha District are characterised by different cropping patterns and different crop productivity levels as well as by different levels of fodder yields from sources other than agricultural land. The district area is split into about nine different zones.<sup>3</sup> The huge subtropical area in the south, below approximately 1,000masl and along the Budhigandaki Valley up to Machha Khola, was classified as subhumid. Some subtropical areas along the upper valleys of the Daroundi and Chepe rivers were classified as humid. Further north, there is a similar pattern for the warm temperate zone up to about 2,000masl along and above the two western valleys south of Manaslu Himal, the moisture regime was defined as humid; the deep valley of the Budhigandaki river lies in a subhumid zone. Some patches of the warm temperate/subhumid zone are located on the southeastern hills of the district. The cool temperate zone is mainly characterised by humid conditions, but some areas high above the Budhigandaki River were classified as subhumid. The alpine zone, from about 3,000m to 4,500m, is, in general, perhumid; nevertheless, in the lower part of this zone, the moisture regime was found to be humid (Table 7) (Map 8).

<sup>3</sup> This does not include the alpine area for which no moisture data were available.



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The results of this study and LRMP figures differ in many agroclimatic zones. Overall it can be stated that, in contrast to this analysis, LRMP expected the warm temperate zone to be more humid and the cool

**Table 7: Area of Agroclimatic Zones in Gorkha District**

Agroclimatic zone	Area in sq.km.		Percentage of total	
	MENRIS	LRMP	MENRIS	LRMP
Subtropical/subhumid	705.4	721.6	19.4	19.8
Subtropical/humid	122.7	-	3.4	-
Warm temperate/subhumid	210.2	17.1	5.8	0.5
Warm temperate/humid	222.5	517.7	6.1	14.2
Cool temperate/subhumid	79.4	78.1	2.2	2.1
Cool temperate/humid	367.5	65.3	10.1	1.8
Cool temperate/perhumid	-	386.5	-	10.6
Alpine/subhumid	-	323.5	-	8.9
Alpine/humid	193.0	339.8	5.3	9.3
Alpine/perhumid	460.9	305.6	12.7	8.4
Alpine/no data	69.0	-	1.9	-
Arctic	1,210.7	891.1	33.2	24.4
No data	4.9	-	0.1	-
<b>Total</b>	<b>3,646.2</b>	<b>3,646.2</b>		

temperate zone to be, in general, more perhumid. As already mentioned above (see Chapter 3.1), the analysis of this study resulted in larger subtropical and arctic areas than the LRMP figures due to the application of the mean annual temperature rates rather than the altitudinal contour lines applied by LRMP. Accordingly, the areas of warm and cool temperate zones, as well as the alpine zone, were found to be smaller in this study than in LRMP results. Although the total area sizes of the moisture zones do not differ very much, apart from the arctic zone, the distribution of these zones varies considerably (Map 9).

The major differences in this study, with respect to LRMP figures, are (1) the occurrence of an area under a subhumid moisture regime along the Budhigandaki Valley in the warm temperate zone, which is mainly based on data from the meteorological stations at Jagat (Setibas) and Arughat Bazaar where precipitation has been recorded for 26 and 28 years respectively; (2) the existence of an extensive humid area in the cool temperate zone, which was classified in a similar distribution area as perhumid by LRMP, (these results are based on data from two stations located in Lamjung District, i.e., Gharedhunga and Kunchha); and (3) the alpine zone in the upper Budhigandaki Valley which was classified as perhumid in this study, in contrast to the LRMP which held this area to be subhumid. As already discussed in Chapter 3.2, the data from the meteorological station at Larke Samdo validate the perhumid moisture regime in that area.

In general, the application of different methodologies to the analysis of moisture regime zones affects the results. The LRMP based the analysis of moisture regimes on mean annual precipitation in combination with mean annual temperature, whereas this study, in addition to precipitation, used potential evapotranspiration. This study also used the number of wet months to distinguish between different moisture regimes, whereas LRMP used the number of dry months in its classification. This means that, in this study, the meteorological station at Gorkha Bazaar is located in a subhumid moisture regime, whereas the LRMP classified it as humid.



### 4. CONCLUSIONS

The application of GIS is an appropriate tool for the assessment of agroclimatic zones in an area planning and development framework at a macro- or district-level. In view of the small map scale (1:50,000) used to establish the database and the extensive variability of the mountain ecosystem, its application is limited at the micro-level. Major constraints to the analysis were data availability and data quality. These aspects need to be improved for better assessment of the climatic conditions in the area. Still, the system developed showed its flexibility and can be updated or extended at any time when further data are available or a methodology is developed for the use of GIS technology to assess the mountain perspective holistically.



**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.<sup>4</sup> 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

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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.<sup>5</sup> 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.<sup>6</sup> Yak (*Bos grunniens*) and *chauri*<sup>7</sup> herds stay in the high mountain area all through the year.<sup>8</sup>

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:

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

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5 The most detailed description of the migratory system of sheep rearing in the 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 Digestible 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 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



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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)<sup>9</sup>.

**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		Feed Demand mt DM/year	LU sheep	
		mt DM/year	Per cent		Total	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

<sup>9</sup> 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<sup>10</sup>.

#### 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.

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<sup>10</sup> 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.



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### 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.

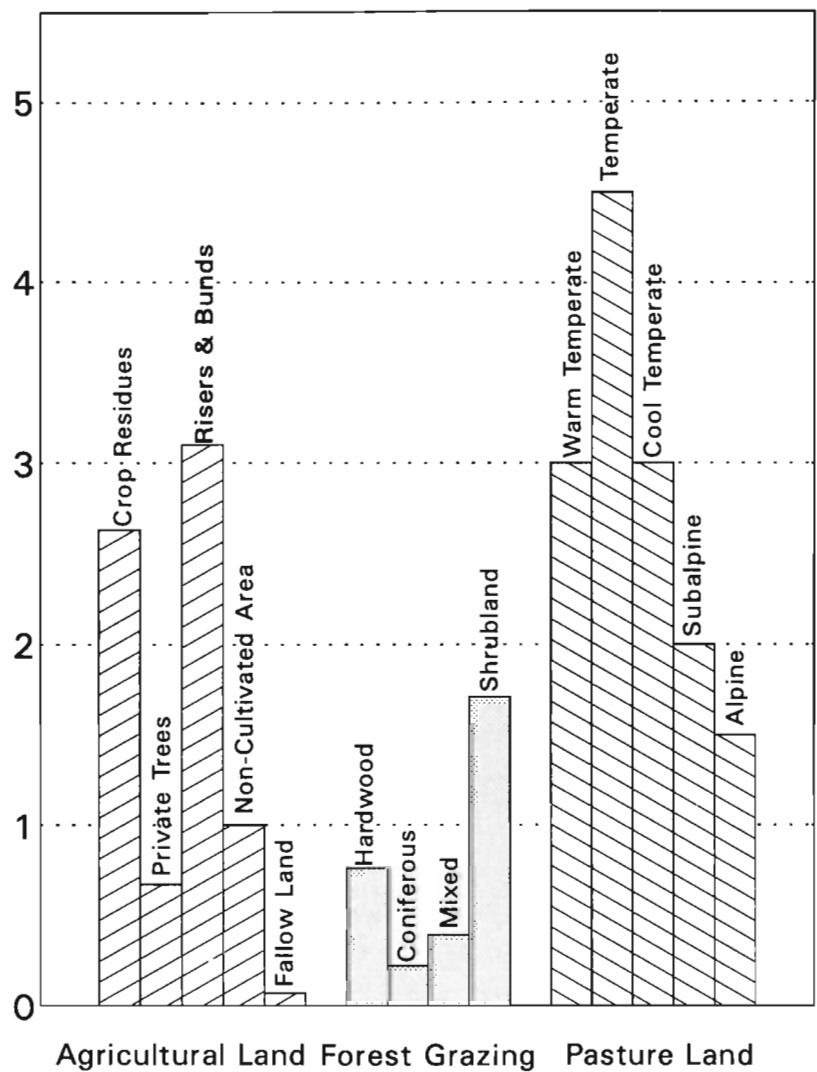
Table 10: Fodder Productivity of Different Sources

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  
mt DM/ha/year



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<sup>11</sup>. 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).

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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<sup>2</sup>. The southwestern part is the most densely populated area in the district. In 13 VDCs, the density is more than 300/km<sup>2</sup>. 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<sup>2</sup>, 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.



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**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

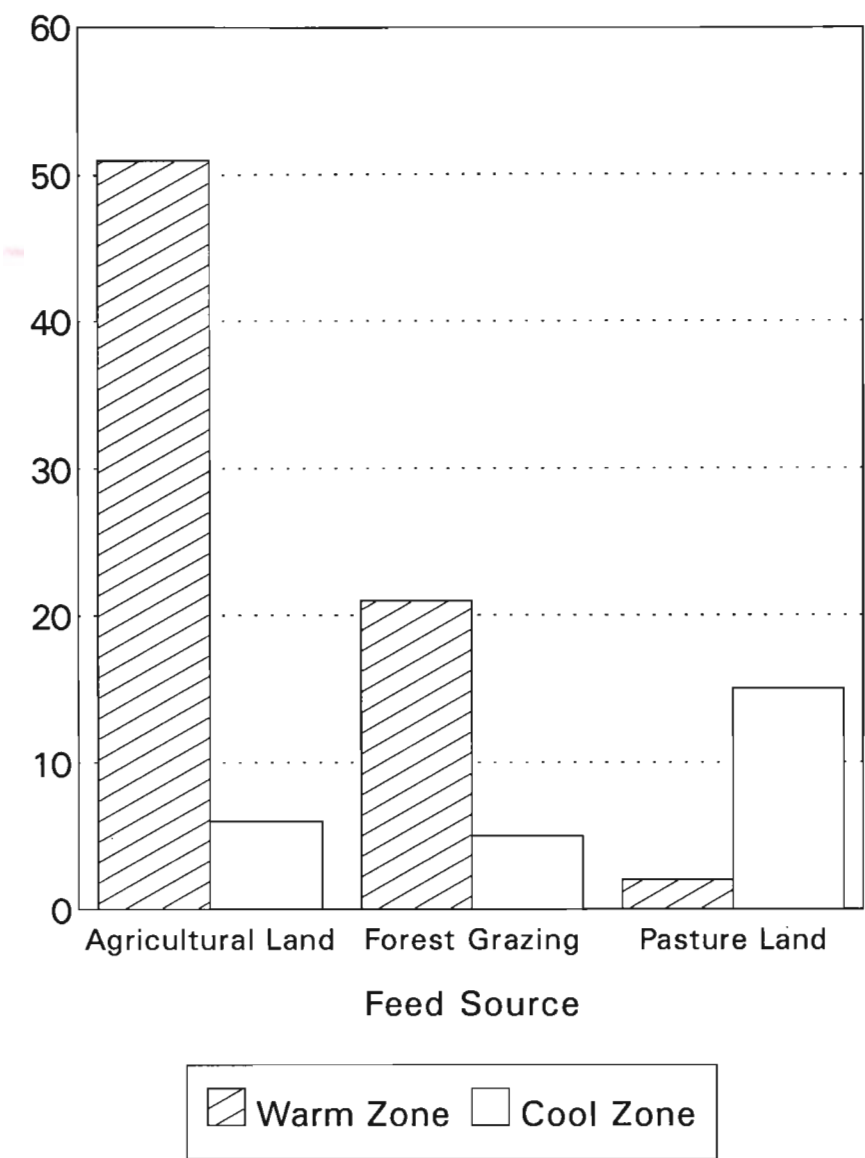
( ) percentage of total feed supply in the district

**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  
per cent of total



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.



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

**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/ <i>chauri</i>	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
<b>Total</b>		<b>157,846</b>		<b>495,532</b>	<b>100.0</b>	<b>3.14</b>

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



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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/ <i>chauri</i>	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 neighbouring 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.



**PART III**  
**HORTICULTURAL DEVELOPMENT**  
**IN GORKHA DISTRICT**



### 1. INTRODUCTION

In the 1960s, His Majesty's Government of Nepal (HMG/N) launched horticultural development programmes all over the country to improve the economic and nutritional status of the people (Gurung 1993). Horticultural farms were established in different locations, reflecting various agroclimatic conditions, within three altitudinal ranges: the *terai* (below 1,000m) the hills (1,000 to 1,800m) and the high hills (above 1,800m). Suitable areas for growing fruits within these zones were defined in the seventh Five-Year Plan (1985-90) by the National Planning Commission (NPC) of HMG/N. Some districts were selected to intensify the commercialisation of different prioritised fruit varieties, i.e., citrus, apples, walnuts, pears, grapes, mangoes, bananas, and pineapples. Citrus, mangoes, and apples were seen as the economically most feasible fruits. None of these fruits farms is located in Gorkha District; still, in addition to other districts, Gorkha was chosen for the implementation of a citrus development programme, including mandarin oranges (*suntala*), sweet oranges (*junar*), limes (*kagati*), and lemons (*nibuwa*).

#### 1.1 Master Plan for Horticultural Development

Horticulture is regarded as an effective means of reducing environmental degradation and improving the economic situation in the hills. In 1990, a Master Plan for Horticultural Development in Nepal, covering the following 20 years, was developed for HMG Nepal. A major concern of the Master Plan is to reverse the environmental degradation processes. The priority for horticultural development is focussed on those areas where degradation is the most severe (Carson 1990:86-94). Horticultural development is further seen as one option for increasing the cash income of poor households, thus at the same time reducing pressure on common resources and decreasing exploitation of forest land.

There is potential for the development of different fruit varieties in Nepal, and twelve fruits were selected by the Master Plan as priority crops. The selection was based on a fruit crop screening methodology, incorporating ecological and subsistence suitabilities and market capacity. Other criteria were the profitability of production and the competitive position of Nepal.

### 2. CRITERIA FOR HORTICULTURAL DEVELOPMENT ZONES IN GORKHA

MENRIS based its analysis of horticultural development zones in Gorkha, in general, on data/information gathered and compiled by the Master Plan for Horticultural Development (Carson 1990; Ranjit 1990); in particular, requirements for different fruit crops, in terms of climate (altitude, temperature), soils, and soil drainage, were extracted from this plan. Furthermore, information about crop requirements was taken from Rehm and Espig (1991). This information was then linked to the MENRIS/GDP database for Gorkha, i.e., the

- land system data of LRMP,
- land-use data 1979 of LRMP,
- agroclimatic zones,
- altitude (DEM),
- aspect, and
- accessibility of road infrastructure.

The Master Plan identified several constraints to horticultural development on village lands, which could not be included in this study because of its complexity and due to lack of data. Soil fertility may be the major constraint in hill agricultural production. If the soil fertility is too low, the crop yield may not justify investment in horticultural crops. Livestock management practices, e.g., free grazing, hamper horticultural development to a great extent. Stall feeding is necessary, since protection or fencing is too costly.



Microclimatic factors, such as frequency of hailstorms, fog, local winds, air drainage, and low winter night temperatures, may affect horticultural crops considerably (Carson and Sharma 1992:16; Carson 1990:52). Socioeconomic factors were not considered (such as land tenure and its implications on perennial/cash crop production; the economic status of the farm household, including all gender-related issues and changes due to cash crop production; profitability and sustainability of the farming system, e.g., high expenditure on plant protection, degradation of the environment caused by horticultural monocultures or utilisation of pesticides, and new diseases [Partap 1993:352]); and there is a lack of spatial data on local traditional fruit tree production as well as on the distribution of present horticultural pocket areas.

### 2.1 Land System Requirements

To obtain the greatest benefits in the form of high fruit crop yields (provided accessibility and marketing are not major problems), pressing soil requirements, including soil drainage and slope gradients, must be met. Extreme soil landscapes are not very favourable for fruit production. Further, each fruit species has its particular demand on soil and drainage in the optimum production range (Ranjit 1990). On the other hand, certain land systems (according to LRMP) require different land management practices. Horticultural crops have direct positive effects on the reduction of topsoil erosion and the improvement of soil fertility when horticulture is developed in an overall farming systems' approach. However, orchards/trees alone do not protect the soil from erosion; soil protection is achieved through long-term implemented management practices, e.g., protection of topsoil by applying different systems, intercropping, sowing of grasses, and coverage with litter, stones, etc. This is particularly valid for land system units in which the slope is steep, the infiltration rate of soil is low, and the rainfall intensities are high (Carson 1990:89) (Map 20).

The land system data and maps of LRMP still constitute the best source for describing the soil landscapes of Nepal. There are five physiographic regions: the *terai*, the Siwaliks, Middle Mountains, High Mountains, and High Himalayas, where geology, climate, landform patterns, and thus land-use practices and management options are different. Within these regions, land systems and land units were categorised, based on properties significant for land management such as slope gradient, soil depth, and water drainage (Carson 1990:2).

Gorkha lies in three physiographic regions:

- Middle Mountains (Annex 8),
- High Mountains (Annex 9), and
- High Himalayas (Annex 10).

The Master Plan recommends the encouragement of horticultural development within the Middle Mountain Region as a profitable and environmentally appropriate agricultural system. This region, covering the southern part of Gorkha, includes a great variety of soil types and slope gradients, depending on bedrock materials and climate. Most of the cultivated land is located on sloping mountainous terrain with a tendency towards topsoil erosion on sloping terraces. Agriculture is mainly practised on level terraces; nevertheless, in this region, about 19 per cent of the cultivated area is located on sloping terraces, either on slopes with a gradient of less than 30° (13.3%) or on steeper slopes (5.7%).

Three of four land units were classified as having a high agricultural land-use index, i.e., alluvial plains and fans (land unit 9) covering 36sq.km., or 6.6 per cent, of the agricultural land in the Middle Mountain Region of Gorkha; ancient lake and river terraces (*tars*) (10) covering 50sq.km., or 9.2 per cent; and moderately to steeply sloping mountainous terrain (11) having a slope gradient of less than 30° covering 355sq.km., or 65.4 per cent. If these land units, especially units 10 and 11, are well managed, they are expected to undergo only slight topsoil erosion (Carson 1990:90). Steep to very steep mountainous terrain



### Part III: Horticultural Development in Gorkha District

(12) which covers 102sq.km., or 19 per cent (Table 15), has a low land-use index and is not a logical priority area for horticultural development.

**Table 15: Agricultural Land and Land System Categories in Gorkha District**

Land systems category	Agricultural land types				
	Area in hectares (percentage of land system category)				
	Sloping terraces	Level terraces	Valley floors	Tars	Total
<u>Middle Mountain Region:</u>					
Alluvial plains and fans	133	653	545	2,266	3,597
0 - 5°	(1.1)	(1.5)	(57.7)	(24.9)	(5.4)
Ancient lake and river terraces	406	384	78	4,115	4,983
0 - 5°	(3.2)	(0.9)	(8.3)	(45.2)	(7.5)
Moderately to steeply	7,470	26,668	167	1,220	35,525
Sloping terrain < 30°	(59.4)	(61.4)	(17.7)	(13.4)	(53.8)
Steeply to very steeply	3,206	5,991	95	935	10,227
Sloping terrain > 30°	(25.5)	(13.8)	(10.1)	(10.3)	(15.5)
<u>High Mountain Region:</u>					
Alluvial plains and fans	90	53	47	-	190
0 - 10°	(0.7)	(0.1)	(5.0)		(0.3)
Past glaciated mountainous terrain below the altitudinal limit of arable agriculture					
a) Moderate to steep < 30°	767	5,763	3	-	6,533
	(6.1)	(13.3)			(9.9)
b) Steep to very steep > 30°	146	3,158	8	-	3,312
	(1.2)	(7.3)			(5.0)
Past glaciated mountainous terrain above the altitudinal limit of arable agriculture	254	738	-	-	992
	(2.0)	(1.7)			(1.5)
<u>High Himalayan Region:</u>					
Alluvial, colluvial and morainal depositional, surfaces	84	-	-	544	628
	(0.7)			(6.0)	(1.0)
Steeply to very steeply	10	-	-	12	22
Sloping terrain	(0.1)			(0.1)	(0.1)
Total	12,566	43,408	943	9,092	66,009

Agricultural land in the High Mountain Region of Gorkha is found mainly along and above the three valleys of the Budhigandaki River and the Daroundi and Chepe *kholas*. Most of the area in this region is not suited for horticultural production because of low temperatures and high slope gradients. Only two of the five land units in this region have a high/medium use index, i.e., alluvial plain and fan complexes (13) which cover 1.9sq.km., or about three per cent, of the agricultural land in this region; and past glaciated mountainous terrain below the upper limit of arable agriculture, with moderate to steep slopes (14a), covering 64.2sq.km., or 59 per cent of the land area.



There is hardly any agricultural land in the High Himalayan Region of Gorkha, apart from 870ha of land along the upper Budhigandaki River in Prok, Lho, and Samagaun VDCs and Shyar *Khola* in Chhekampar VDC. According to the Master Plan these land units, in general, have a low use index, if irrigation is not made available.

### 2.2 Horticultural Development Areas

The Master Plan for Horticultural Development defined that the basic area units for horticultural development are (1) the farmstead, with kitchen gardens where horticulture is practised traditionally; (2) privately owned rainfed agricultural land; (3) irrigated land; and (4) the area of community and private forests (Carson 1990:75).

At least in the southern part of Gorkha, most of the area would fall into one of these categories, and it was decided to analyse and delineate the horticultural areas for agricultural land only, which could be expected to be privately owned. The land tenure system could not be considered. Agricultural land includes not only the cultivated area, but also the areas of farmstead, risers and bunds, and non-cultivated land between the fields, e.g., small sections of grassland, shrubland, and forest. There are doubts about whether the farm households are willing to use or to convert intensely cultivated irrigated terraces for horticultural production, even if these crops are more profitable than grain crops, since intense cultivation areas, on both level and sloping terraces (terms used according to the LRMP), are assumed to be the most productive farmland for staple crops in the Middle Mountain Region. These fields are, in particular, located in the valley bottoms, on flat plains or *tars*, and also on steep slopes where the climate, soils, aspect, etc are favourable for cultivation.

Thus, these areas were also excluded from the analysis, and low- and medium-density cultivated agricultural land on sloping and level terraces were regarded as the potential horticultural development areas. In this study a detailed classification was conducted for these areas, applying parameters of the LRMP land use data of 1979, classes C1/T1 and C2/T2. Agricultural land in the High Mountain Region is scarce, and people rely on it for staple crop production even more than in the mid-hills. Still, the land is not cultivated intensively due to the harsh climatic conditions. To show the potential of horticultural development in this region, it was decided to include all agricultural land delineated by LRMP in the analysis (Maps 21 and 22).

### 2.3 Temperature Regimes and Altitude/Agroclimatic Zones

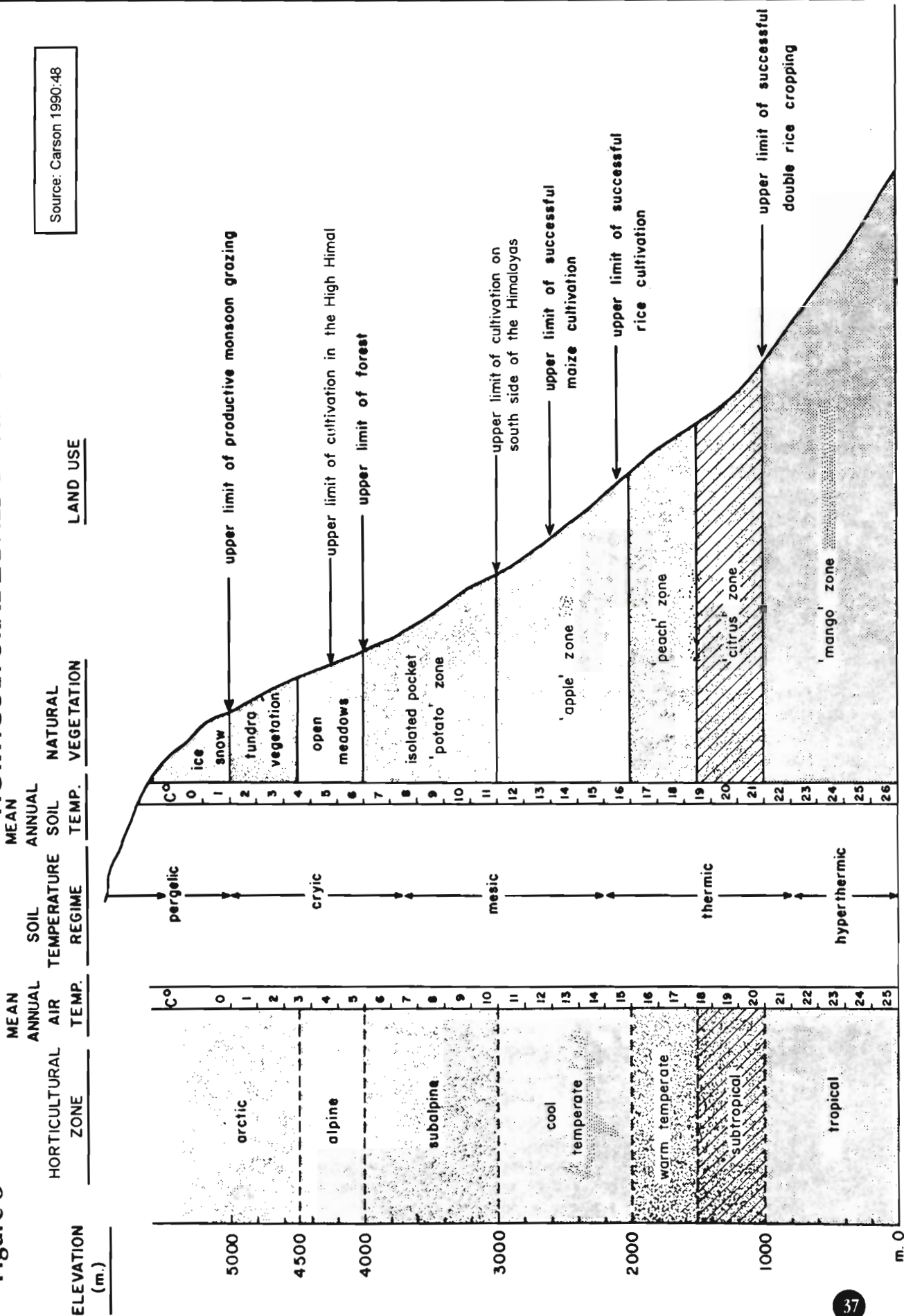
Temperature is given by most authors as the primary indicator/parameter for horticultural production. The Master Plan for Horticultural Development, for example, describes horticultural (climatic) zones as primarily based on the mean annual air temperature and its relation to the altitude (Carson 1990:47). The Master Plan mainly differentiates between five horticultural zones: tropical (< 1,000m); subtropical (1,000 - 1,500m); warm temperate (1,500 - 2,000m); cool temperate (2,000 - 3,000m); and the subalpine zone (3,000 - 4,000m), with isolated pocket areas and potato-growing agricultural systems. Furthermore, each fruit crop is related to certain temperature requirements. However, the optimum production ranges of various fruit crops, according to temperatures and elevations, do not match the given horticultural zones and the agroclimatic zones (compare Part I). Therefore, the delineated agroclimatic zones could not be used directly for the assessment of horticultural development areas for particular fruit crops in Gorkha. Also, the Master Plan does not refer to the particular temperature requirements of individual fruits, but it provides altitudinal ranges. (It was not made clear which criteria were selected first, the elevation ranges, based on field experience, or the temperature values.) Nevertheless, the optimal elevation ranges for all fruit crops, as given by the Master Plan, were converted to mean annual temperature values (Ranjit 1990:36a) (Figure 3) (Map 23).



Figure 3

HORTICULTURAL ZONES OF NEPAL

Source: Carson 1990:48





There is a great variability in precipitation in the area in relation to seasonal and altitudinal distribution and the orientation of the relief/slopes. In Part I of this report, it was assumed that the precipitation, in general, is one limiting factor to horticultural production, especially on south-facing slopes. However, the database of the moisture regime is not detailed enough to draw area-specific spatial or quantitative conclusions. Still, in accordance with the aspect, qualitative recommendations are given by this study.

### 2.4 Aspect

There is no doubt that in mountainous areas the aspect has an important influence on the ecosystem. The aspect directly affects the climate, e.g., south-sloping areas receive more radiation than slopes on northern aspects; this is additionally influenced by the slope gradient. Carson (1990) referred to Whiteman (1980) who had reported from the Jumla area that maximum fall temperatures on northern slopes are at least 3°C cooler than on southern aspects. Thus the upper limit of specific crops, including horticultural crops, may vary by 200m. As shown in Part IV of this report, the aspect directly affects the land cover or land-use practices above the subtropical zone. Of course, these practices are also induced by other natural parameters, or the farm households.

Less evapotranspiration and higher soil moisture content on northern slopes create different micro-ecosystems; different soil types may derive from the same parent material on southern and northern slopes, since in the long term the dominant factor of soil genesis is the climate (soil climax). In general, south-facing slopes are drier and have less reproductive strength, which may, in the case of overutilisation of vegetation, e.g., forest and grassland, become critical factors and lead to higher human-induced topsoil erosion (due to a higher soil erodibility; the K-factor of the Universal Soil Loss Equation (USLE). In the subtropical and warm temperate zones, moisture is the limiting climatic factor, and irrigation becomes necessary in horticultural development areas located on south-facing slopes (Map 24).

### 2.5 Accessibility and Marketing

The Master Plan for Horticulture indicates that horticultural development should incorporate marketing of the products as well as accessibility to markets and road infrastructure. Harston (1993) pointed out that the Master Plan is following a demand-driven approach along with the marketing of fruits at different levels, such as community markets, *haat bazaar*, district headquarters, and city markets. The lack of road infrastructure is recognised as a major hindrance for the economic development of rural areas, in general, and the availability of agricultural inputs as well as marketing of farm surplus products (cash crops), including horticultural products, in particular (Onta 1990:3).

This study can only give recommendations at the production level. For the marketing of fruits, e.g., demand for kinds of fruits, consumers' consumption habits, and changes and analyses of prices, the reader should refer to the Master Plan. At this stage, the GIS database can provide some information about transportation of fruits to markets or the road network in Gorkha and the adjoining districts. GDP has initiated a District Road Master Plan which is still under consideration by the District Development Council/Committee (DDC). Presently, in terms of access to the road network, the southern part of Gorkha can be split into four corridors, according to the main drainage system. The very southern area, located along the Trishuli Ganga and Marsyangdi rivers, has good access to the Prithivi Highway where there are bridges across the streams. The case is similar in the west, along the Marsyangdi River, where an earthen feeder road links Besisahar, the Lamjung district headquarters, to the national highway. People from the Chepe *Khola* Valley use this road as a linkage as well. The central southern part, along the Daroundi *Khola*, has been opened up through a bitumen road to the district headquarters, Gorkha Bazaar, through an earthen motorable road from Gorkha Bazaar to Nareswar. Additionally, on the western river bank of Daroundi *Khola*, there is an earthen road under construction which will be linked to the bitumen road.



## Part III: Horticultural Development in Gorkha District

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Only in the east, next to Dhading District, along the Budhigandaki River, is access by road limited, although in Dhading local roads have been constructed or are in the process of being constructed. Only further up the valley at Arughat do the people of Gorkha benefit from these roads. Recent studies have shown (Rapp 1994) that the major commodity flow to Arughat, which previously was by porter and on mules via Gorkha Bazaar, has been shifted to motor vehicles operating on the earthen road from Dhadingbesi to Salyantar. This road is still under construction, and it takes about three to four hours to reach Arughat from the present roadhead (Maps 25,26, and 27).

Horticultural development has to be seen from the mountain perspective, which means that specific mountain conditions have to be considered while planning and implementing activities. Especially the northern, but also the central, part of Gorkha, can be characterised by dimensions of mountain specificities: inaccessibility, fragility, marginality, diversity, comparative advantages, and adaptation (Jodha 1992). Inaccessibility is accompanied socially by the isolation of mountain communities; economically by subsistence agriculture and poverty; biologically by underexplored resources; and physically by remoteness and transportation problems. This implies that the focus of horticultural development in remote areas has to be on crops which help to make the areas self-sufficient in food needs and increase nutrition levels. However, agricultural land is scarce in these areas and is needed for the cultivation of staple crops. Also, it is only feasible to promote products of high value and low volume and those that yield non-perishable substances (Partap 1990:362).

### 3. APPLIED METHODOLOGY

As already mentioned above, the Master Plan differentiates between four horticultural (climatic) zones, according to elevation and temperature, where particular fruits should be promoted (Ranjit 1990:32,35). The fruits recommended by the Master Plan were included in the analysis of horticultural development in Gorkha.

- tropical (mango) zone: mango, banana, pineapple
- subtropical (citrus) zone: mandarin (*suntala*), sweet orange (*junar*), lime, lemon
- warm temperate (peach) zone: peach, plum
- cool temperate (apple) zone: apple, pear, walnut

The analysis was conducted using overlay modules of the GIS software; due to the size of the database, a raster GIS method was applied. The unit size for the assessment was one hectare (100m resolution); the total agricultural land in Gorkha amounted totally to about 66,000 units.

As already mentioned above, some preconditions were set, i.e., potential horticultural development areas were classified only as medium- and low-density cultivated agricultural land of sloping and level terraces in the Middle Mountain Region and all cultivated land in the High Mountain Region. For each fruit crop, suitability classes were defined, including the parameters of temperature and soil conditions, which were used according to the land units of the LRMP (Annex 13). Finally, the suitabilities were clustered into four categories, making the result less complex and better understandable and including the aspect as well.

#### (1) Suitable Areas

- 1.1 Northwestern to eastern aspect (NW, N, NE, E)
- 1.2 Southeastern to western aspect and level land (SE, S, SW, W)

Besides the fact that only agricultural land was considered for horticultural development, the main criteria for suitable areas for each fruit crop were the optimal temperature ranges defined by Ranjit (1990) and



Rehm and Espig (1991); land units, incorporating dominant soils, defined by LRMP; and soil requirements extracted from the Master Plan.

Suitable soils for horticultural development were mainly found on alluvial plains and fans (land units 9a and 9c); ancient lake and river terraces (10a and 10b); and on moderately to steeply sloping mountainous terrain (11).

Aspects were differentiated mainly to reflect the scarcity of water for fruit production on south-facing slopes and level ground areas, which were expected to be more dry than north-facing slopes and, thus, possibly to require irrigation facilities for successful fruit growing.

### (2) Moderately Suitable Areas

#### 2.1 Northwestern to eastern aspect

#### 2.2 Southeastern to western aspect and level land

Moderately suitable areas were classified mainly as being steeply to very steeply mountainous terrain (land unit 12) in temperature ranges below and above the optimum level, where fruit crops would survive but would have lower productivity.

Precipitation was not used as a main parameter in the first place, but it was considered in the analysis, as was accessibility to roads and marketplaces.

## 4. RESULTS

### 4.1 Potential Horticultural Development Areas

There seems to be a considerable potential for horticultural development in the district, within the focus of the agricultural area, which, in terms of density, is under low or medium cultivation. Level terraces under medium cultivation cover the largest part of the agricultural area and amount to more than 50 per cent of the potential horticultural development areas (Map 22).

Apart from humidity, which may affect fruit production in Gorkha, no other climatic restrictions, such as the threat of hail or poor air drainage, are indicated by the Master Plan for the district; this is, in part, due to the poor climatic data available (PACMAR 1990:13).

### 4.2 Tropical Fruits

In terms of temperature and soil requirements, mangoes, bananas, and pineapples are seen as the most suitable fruit crops for horticultural development in Gorkha District. Mangoes, bananas, and pineapples have similar needs in terms of soil conditions and can be planted in the same areas. The agricultural area suitable for banana production is larger due to the fact that banana trees grow better than mangoes or pineapples and also grow in cooler climates.

Mangoes (*Mangifera indica*) and pineapples (*Ananas comosus*) are well suited for the southern part of Gorkha District, especially the southwest. About 35 per cent of the potential horticultural development could be met by both fruits, considering temperature and soil requirements; approximately 40 per cent of the area is moderately suitable for cultivation (Figure 4) (Map 28). The mango grows best in tropical summer rainfall regions; a dry period of several months encourages flowering and fruit setting (Rehm and

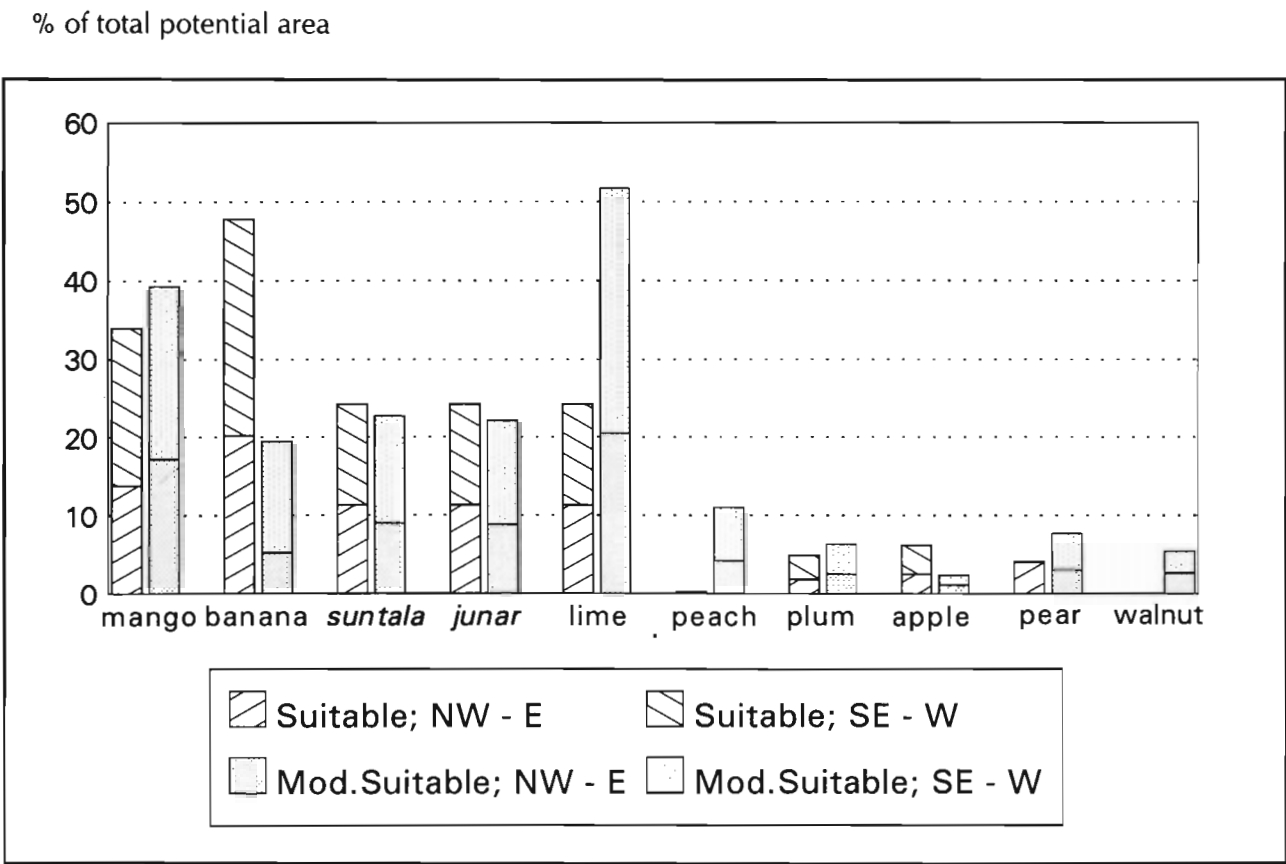


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Espig 1991:186). This indicates that the mango is adaptable to the summer monsoon climate in the area. Pineapples grow well with precipitations of 1,000 - 1,500mm/year, which can be expected in the area. In contrast to mangoes, however, pineapples may need additional sprinkler irrigation in the dry season.

Almost 50 per cent of the potential horticultural development area is well suited for banana (*Musa spp*) production, considering temperature and soil conditions; approximately 20 per cent of the area might be moderately suitable for these fruits (Figure 4) (Map 29). Bananas need evenly spread rainfall of about 2,500mm/year and cannot tolerate waterlogged conditions (Rehm and Espig 1991:183, Ranjit 1990). This implies that, in general, bananas could be grown commercially in Gorkha under humid conditions only, though, on south-facing slopes, irrigation facilities might be necessary. On level terraces, which are used for paddy production, only the risers are suitable for banana growing, due to the compaction of soils which results in waterlogging. Only about 20 per cent of the potential area for banana plantation lies in the humid zone, and approximately 70 per cent is located on level terraces where medium and low densities of cultivation occur; this might restrict the total potential area considerably and make irrigation necessary on a very large scale on southeastern to western aspects and on level ground areas (Table 16).

Figure 4: Suitable Areas for Fruit Crop Production in Gorkha



Note: Junar : sweet orange; Suntala: mandarin



**Table 16: Potential Development Area for Banana Crops**

Suitability category	Total area	Humid area sq.km.	Area of level terraces
Suitable area			
NW - E	94.3	15.9	64.6
SE - W & level ground	128.7	17.5	89.9
Moderately suitable area			
NW - E	24.1	3.2	14.4
SE - W & level ground	66.7	25.0	46.4

### 4.3 Citrus Fruits

In addition to tropical fruit crops, citrus species, i.e., *suntala* (*Citrus reticula*), *junar* (*Citrus sinensis*), and lime (*Citrus aurantiifolia*), are the most suitable crops for the district. All three species have similar requirements for temperature and soils in the suitable categories. Almost 25 per cent of the potential horticultural development area might be well suited to citrus fruits. *Suntala* and *junar* could be grown in an additional 22 per cent of the area, whereas the area moderately suitable for lime cultivation is much larger due to its resistance to tropical temperatures (Figure 4) (Map 30). Citrus crops may not grow successfully in a subhumid moisture regime without irrigation, especially on south-facing slopes and in areas where the dry period is more than two months before fruit ripening (Rehm and Espig 1991:178). Only about 38 per cent of the suitable and moderately suitable citrus areas are located in the humid area, providing enough moisture for appropriate fruit cultivation (Table 17).

**Table 17: Potential Development Area for *Suntala* and *Junar* Crops**

Suitability category	Total area	Humid area
	Sq.km.	
Suitable area		
NW - E	52.9	25.4
SE - W & level ground	60.2	25.1
Moderately suitable area		
NW - E	41.0	12.2
SE - W & level ground	63.0	19.9

### 4.4 Warm Temperate Fruits

The warm temperate fruit crops mentioned by the Master Plan for Horticultural Development, such as peaches (*Prunus persica*) and plums (*Prunus salicina/Prunus domestica*), are less suitable for Gorkha. There is only a limited area of agricultural land in the temperature zone suited for both crops; and the soil conditions are also not favourable since warm temperate fruit trees prefer deep soils (Figure 4) (Map 31).

Especially in spring, though also in winter, water supplies for warm temperate fruit crops must be guaranteed to grow quality fruits. Therefore, in summer monsoon areas, the trees must be irrigated before the beginning of the rains and after the monsoon (Rehm and Espig 1990:202). Nevertheless, more than



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70 per cent of the area, suitable or moderately suitable for plum fruit trees, lies in the humid zone, thus securing enough moisture during the year (Table 18).

**Table 18: Potentials Development Area for Plum Crops**

Suitability category	Total area sq.km.	Humid area
Suitable area		
NW - E	8.5	7.4
SE - W & level ground	14.3	11.1
Moderately suitable area		
NW - E	11.5	7.9
SE - W & level ground	17.9	10.6

#### 4.5 Temperate Fruits

According to the Master Plan, humidity affects the production of fruit crops in the cool temperate/humid zone. High cloud cover and wet conditions have undesirable effects, e.g., diseases and poor fruit quality, particularly on horticultural crops. Only proper selection of varieties can overcome this problem (PACMAR 1990:13).

Like warm temperate fruits, the development of temperate fruits is not very relevant in Gorkha District. Temperate fruits, such as apples (*Malus domestica*), pears (*Pyrus pyrifolia*/*P. communis*), and walnuts (*Juglans regia*), are suited for less than 10 per cent of the potential horticultural development area. Among the temperate fruits, nevertheless, apple production has the greatest scope due to its hardiness in winter (Figure 4) (Map 32). The main potential growing areas for apples are located in the VDCs of Kerauja, Uhiya, Laprak, Barpak, and Kharibot. Water availability is the biggest constraint to temperate fruit cultivation. Apples do well in areas with dry summers and wet winters (Ranjit 1990:38). However, the situation in the mid-hills of Nepal is just the opposite, with heavy monsoon rains in summer and, usually, rather dry winters. The Master Plan recommends irrigation for both apple and pear fruit trees in the subhumid moisture regime and in the humid areas at least during the establishment phase (PACMAR 1990:8). About 40 per cent of the potential apple-growing areas are located in the subhumid zone and need irrigation facilities, and the other 60 per cent are possibly too wet for apple growing (Table 19).

**Table 19: Potential Development Area for Apple Crops**

Suitability category	Total area sq.km.	Humid area
Suitable area		
NW - E	11.7	3.4
SE - W & level ground	17.2	11.0
Moderately suitable area		
NW - E	5.1	4.9
SE - W & level ground	5.9	5.7



### 4.6 Accessibility and Marketing

Harston (1990:67) has pointed out that the fruit consumption by urban households in Nepal (expenditure in NRs) is mainly of bananas (29%) and oranges (20%), followed by apples (17%), mangoes (13%), and guavas (7.5%). This information may be important in considering the marketing aspect.

The Master Plan indicates that marketability, e.g., cost of transportation, should be considered before commercial production of horticultural crops is started (PACMAR 1990:16). It was added that the further the production area is from the existing road network, the greater will be the difficulties in transporting and marketing fruits. The Master Plan distinguishes between (1) areas within a day's walk to road collection centres and (2) remote areas. For the first category it was found feasible to produce and market perishable fruits of high weight and low value. The horticultural production in the second category should emphasise (i) local consumption only to meet the basic requirements of the people, (ii) producing fruits/crops of low weight and high value, and (iii) processing fruits locally in order to produce a high-value product for the market (PACMAR 1990:16).

The accessibility analysis of roads and bazaars in Gorkha shows that the main potential areas for tropical fruits – mangoes, pineapples, and bananas – lie within only four hours' walking distance of, or one day to and from, the existing road infrastructure and roads that are under construction. Development areas for subtropical, citrus fruits are located within one day's walk to the road network. Also, almost all areas with a potential for warm temperate fruits – peaches and plums – are found within one day's walk from the roads, and transportation should not be a major constraint. The main potential area for apple and pear production lies within two days' walk of Gorkha Bazaar and Arughat. At least the marketing and transportation of apples could be economically feasible, due to their storage capabilities and the fact that, in Gorkha Bazaar and Arughat, private wholesalers are already dealing with agricultural products. Also, transportation facilities are available on the three road corridors to the north, which are by now mainly used for importing goods.

## 5. CONCLUSIONS

There is a considerable potential for horticultural development in southern Gorkha District. Temperature and soil conditions are favourable for tropical and citrus fruits in this part of the district. Water availability might be a problem locally, especially on south-facing slopes, where irrigation becomes necessary. Road infrastructure is going to be fairly well developed compared to other parts of the mid-hills in Nepal; also, mule trails are currently being improved. Still, the cost of transportation of fruits to markets and roads is a major constraint, although villagers may have access to the road network within a one-day walk. Besides cultivation and transportation aspects, marketing of fruits is the crucial point in the commercialisation process. As indicated by the Master Plan, horticultural development should be demand-driven; horticultural programmes need to support fruits for marketing that people want to consume and are willing to pay a reasonable price for. Considering this, there seems to be good scope only for banana, citrus, and mango production on a larger scale. Horticultural development in the middle part of the district has to be seen from a different angle. There, the potential fruit-growing area is rather small. Furthermore, accessibility and transportation are the major constraints. Nevertheless, there is some potential for apple growing in these areas, since apples are storable fruits. A two days' walk - as is necessary from these areas - seems to be economically feasible, especially since apples are a high-value cash crop. The High Mountains, i.e., the upper valley of the Budhigandaki and the valley of the Shyar Kholā, are remote areas and development of horticultural cash crops is rather limited. However, the promotion of fruit cultivation for local consumption and improvement of the diet is recommended.



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



### 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).



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**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	
<b>Total</b>	<b>364,620.1</b>		<b>66,009.0</b>		<b>31,680.0</b>		<b>89,740.0</b>		<b>24,300.0</b>		<b>58,490.0</b>	

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 subtropical 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.



Part IV: Correlation of Land Use with Climatic Factors in Gorkha District

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

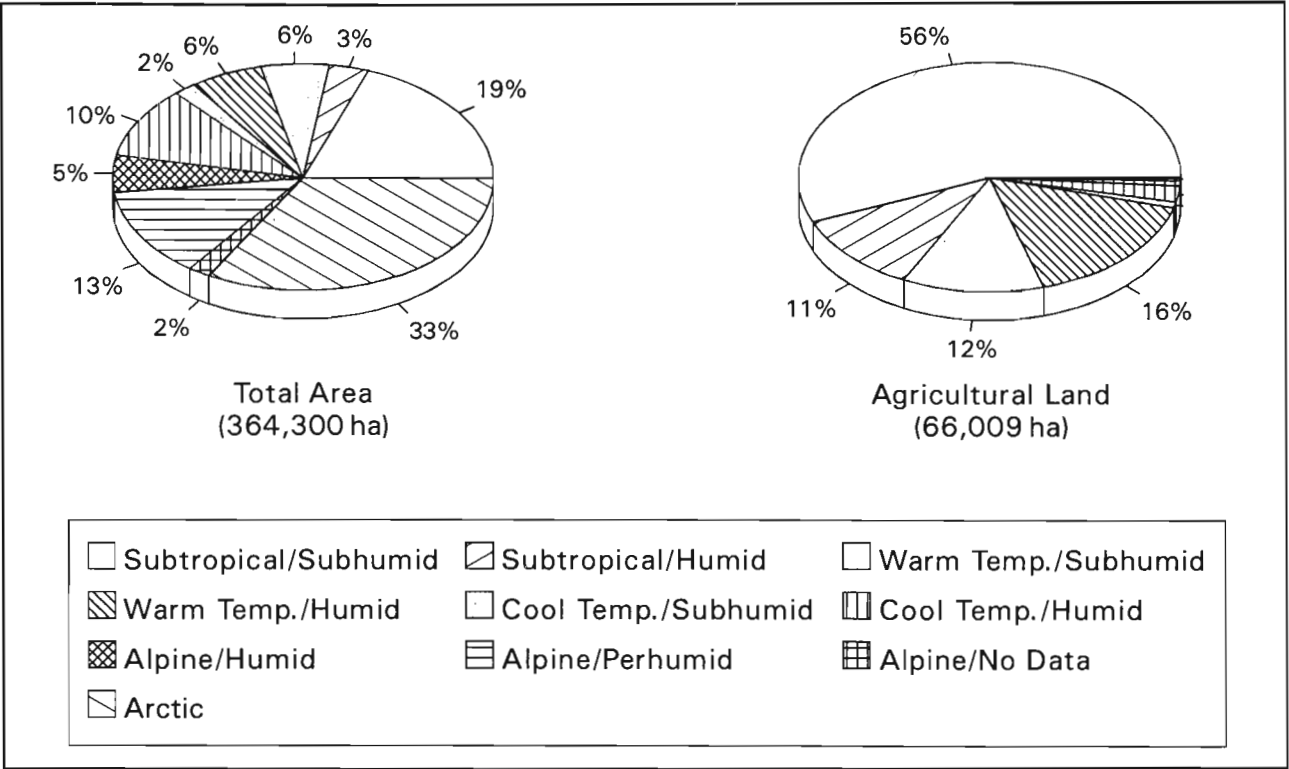
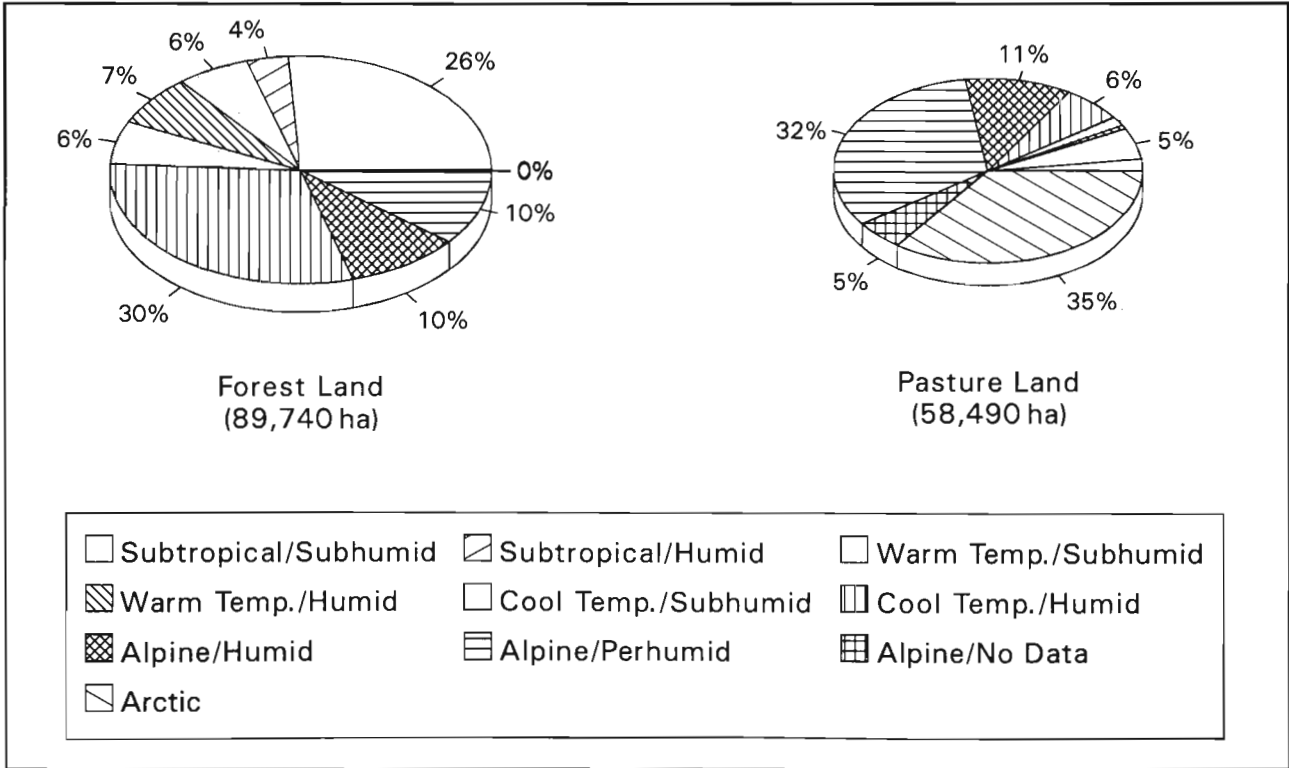


Figure 6: Agroclimatic Zones in Gorkha: Forest and Pasture Land





**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
<b>Total</b>	<b>66,009.0</b>		<b>31,680.0</b>	

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-density 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*



## Part IV: Correlation of Land Use with Climatic Factors in Gorkha District

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

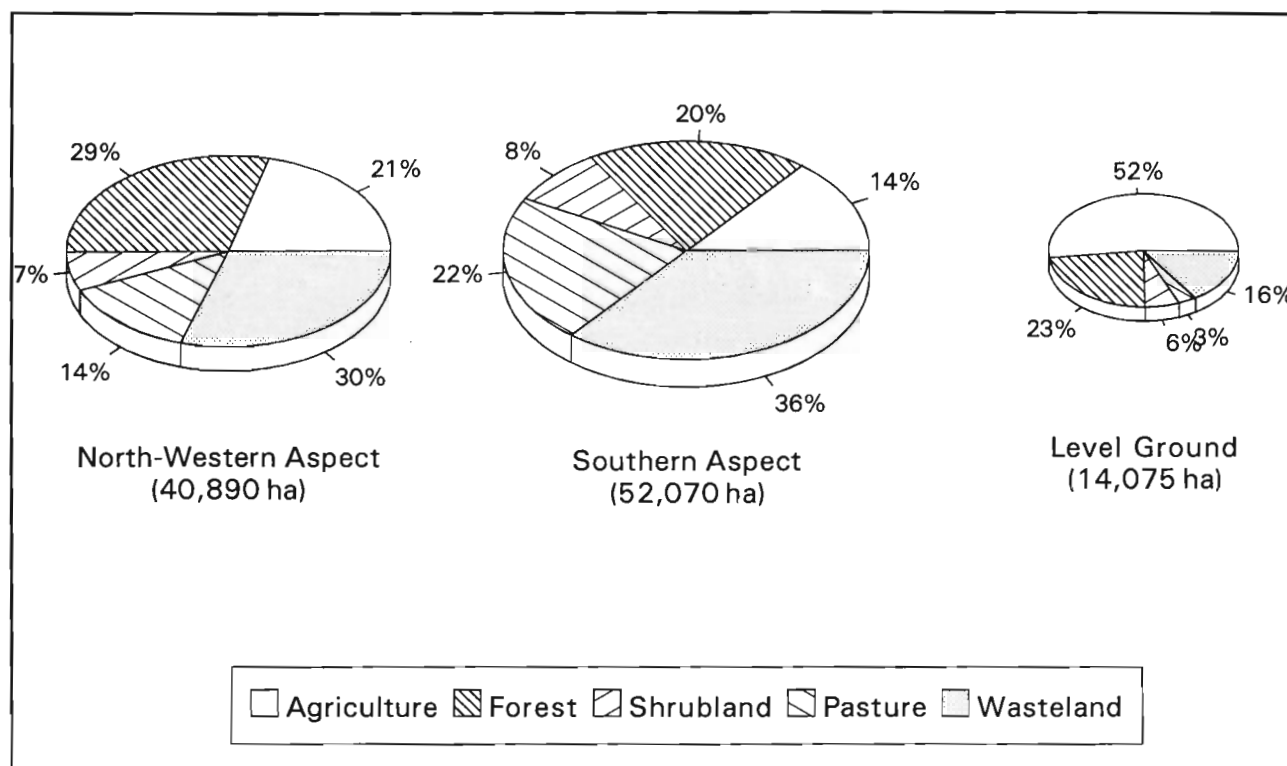
Further, the land-use classes and their coverage areas were analysed in relation to aspects (Table 22). There are more areas with south-facing than north-facing aspects in Gorkha District. This is due to the delineation of the district boundary in the south along the valleys of the Marsyangdi and Trishuli 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
<b>Total</b>	<b>66,009.1</b>		<b>31,679.9</b>	



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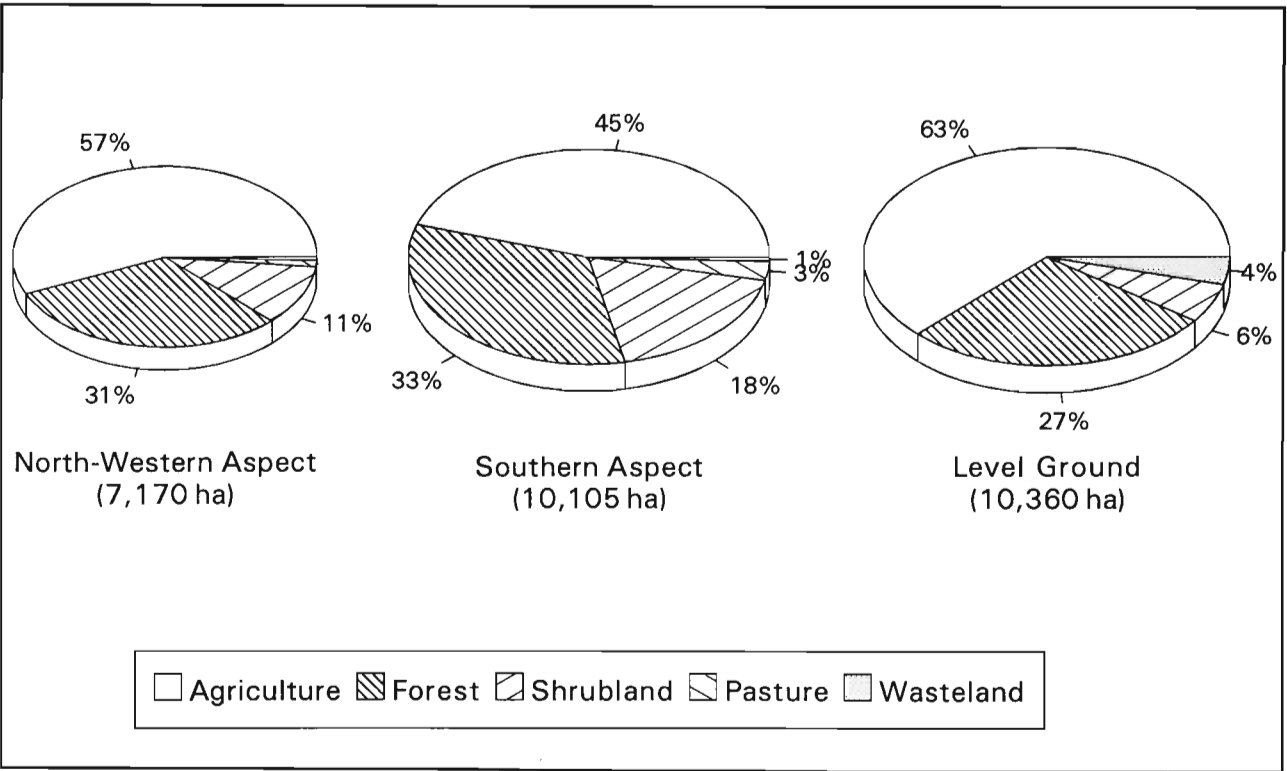
For about 22 per cent of the forest area there were no data available on crown coverage and maturity classes. Therefore the analysis of forest area in relation to aspect had some limitations. Still, a general trend was visible. The portion of shrubland was largest on southern, i.e., southern, southeastern, 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



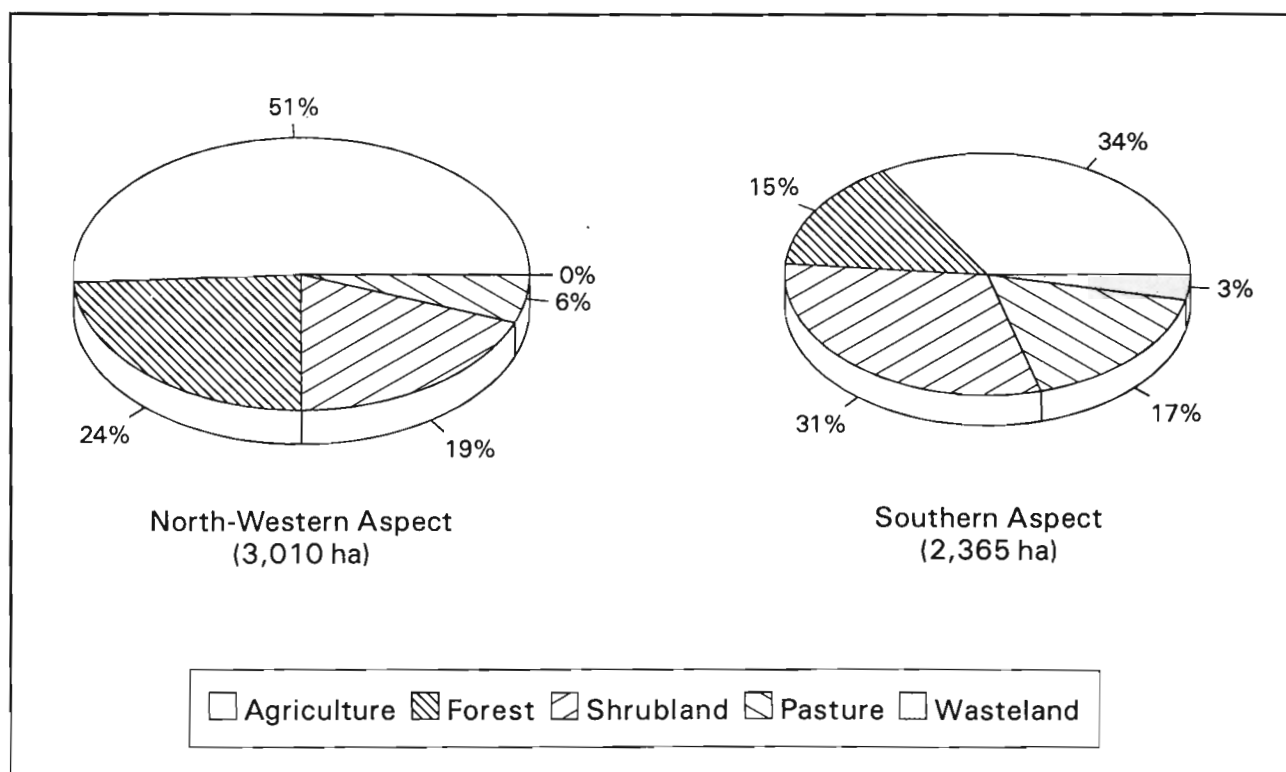


The analysis of cropped land shows that cultivation on level ground covered more than 20 per cent of the area under these agroclimatic conditions and that the intensity of cultivating was highest, i.e., more than 56 per cent of the agricultural land. In this zone, level ground is among the most fertile 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**

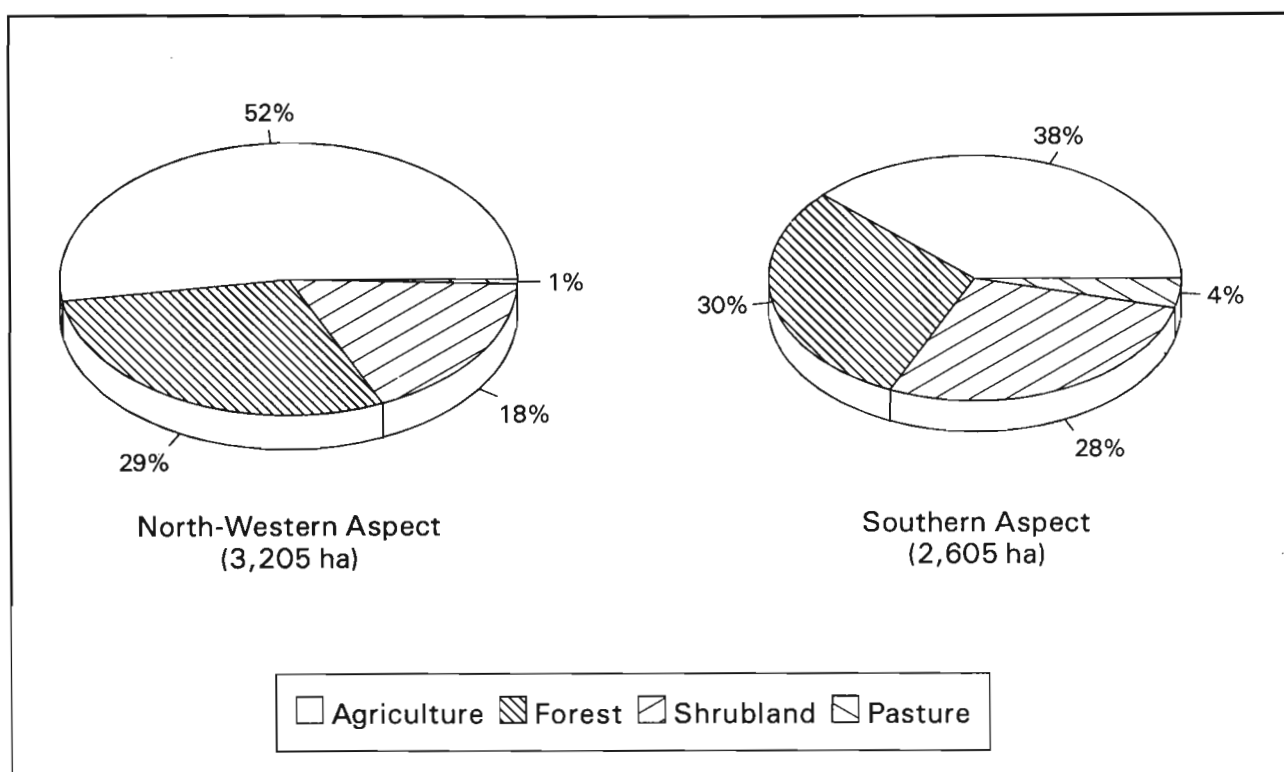




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The warm temperate/humid zone is about the same size as the subhumid zone. It covers the area above the two valleys of the Chepe and Daroundi *Khola*(s). Unlike in the other zones, the south-exposed slopes were less used for crop production (less than 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

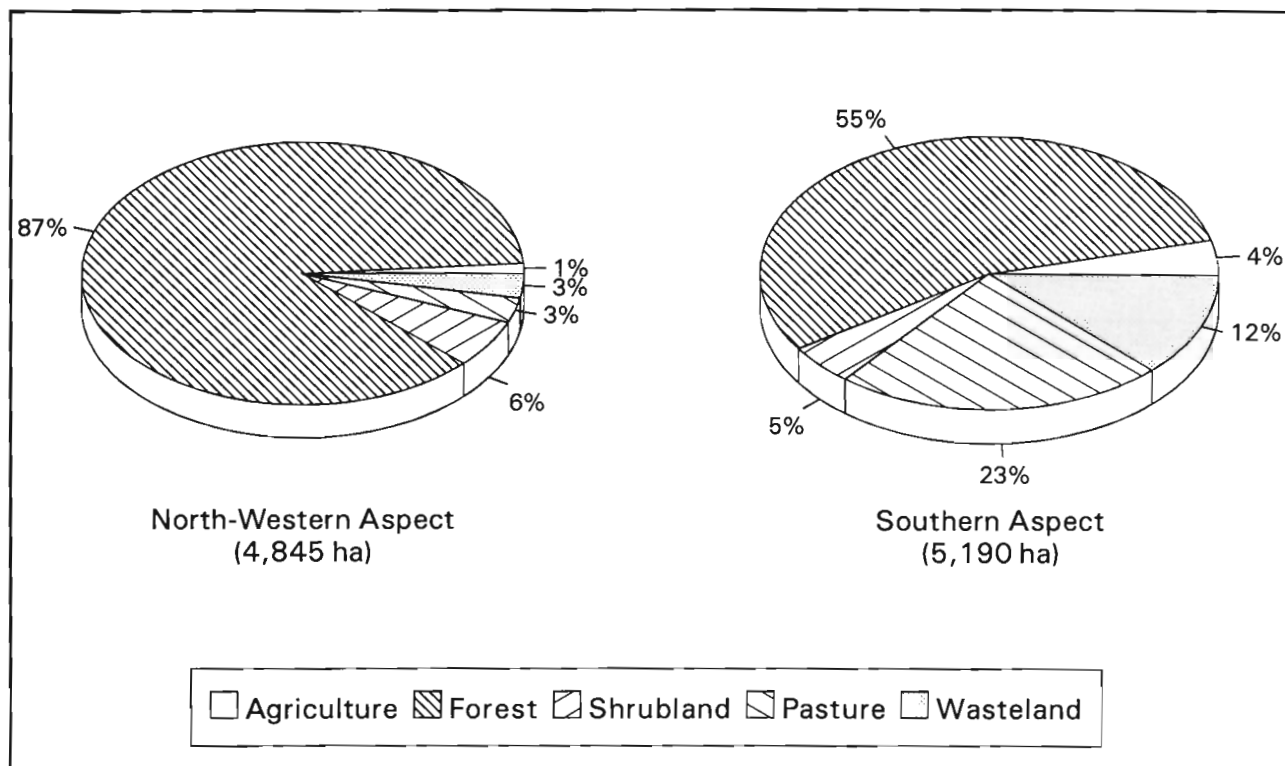
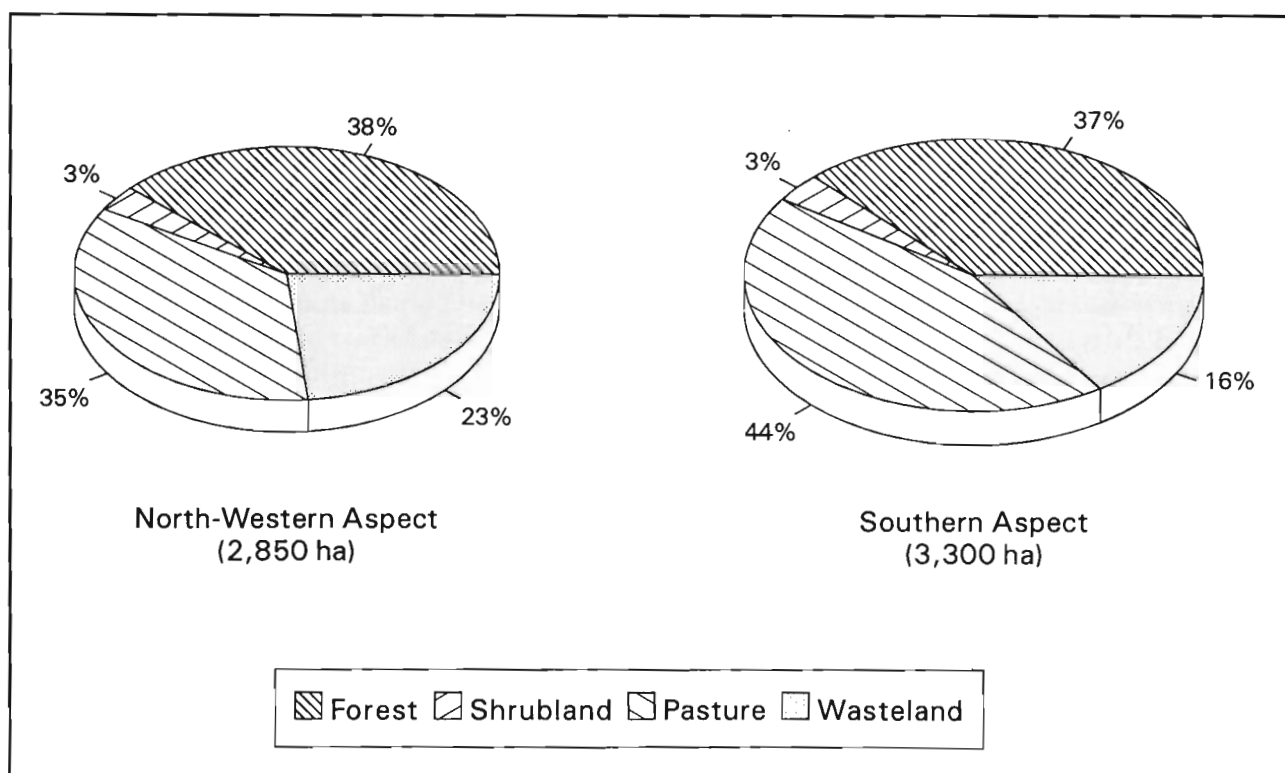


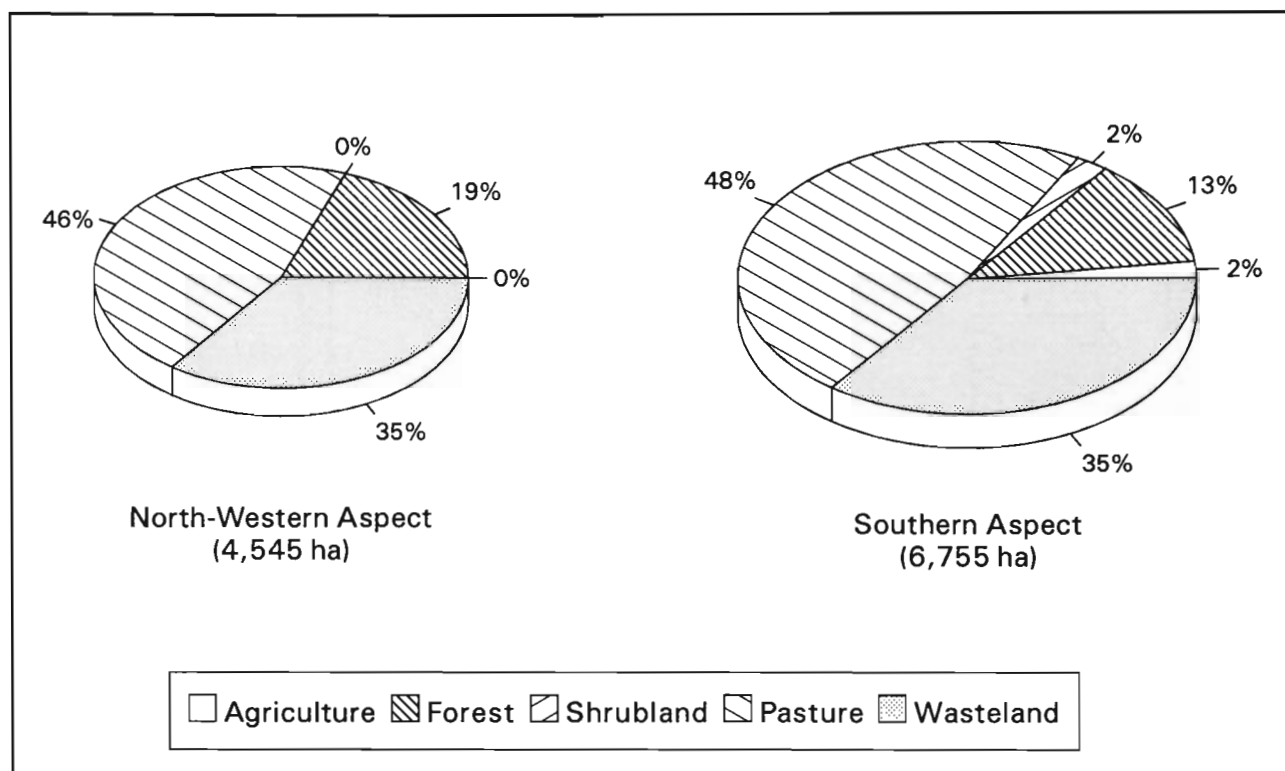
Figure 12: Distribution of Land-use Classes: Alpine/Humid Zone





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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

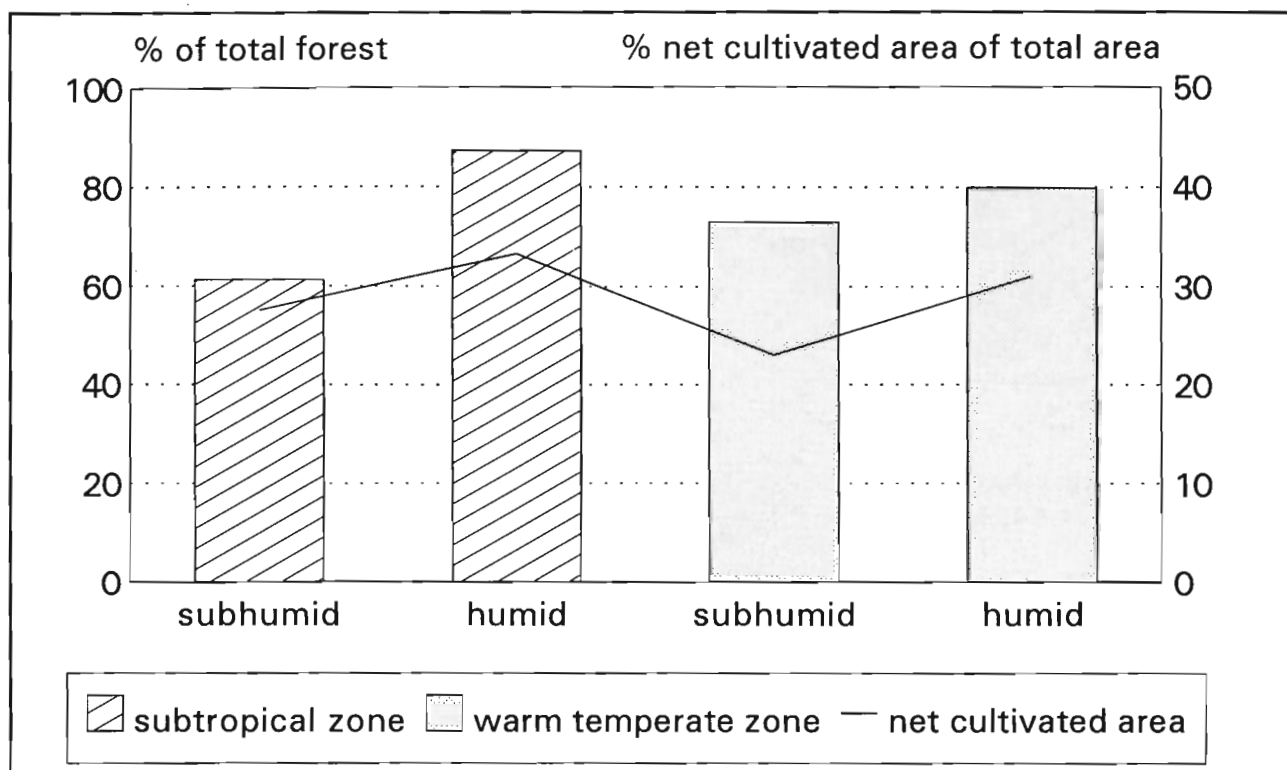
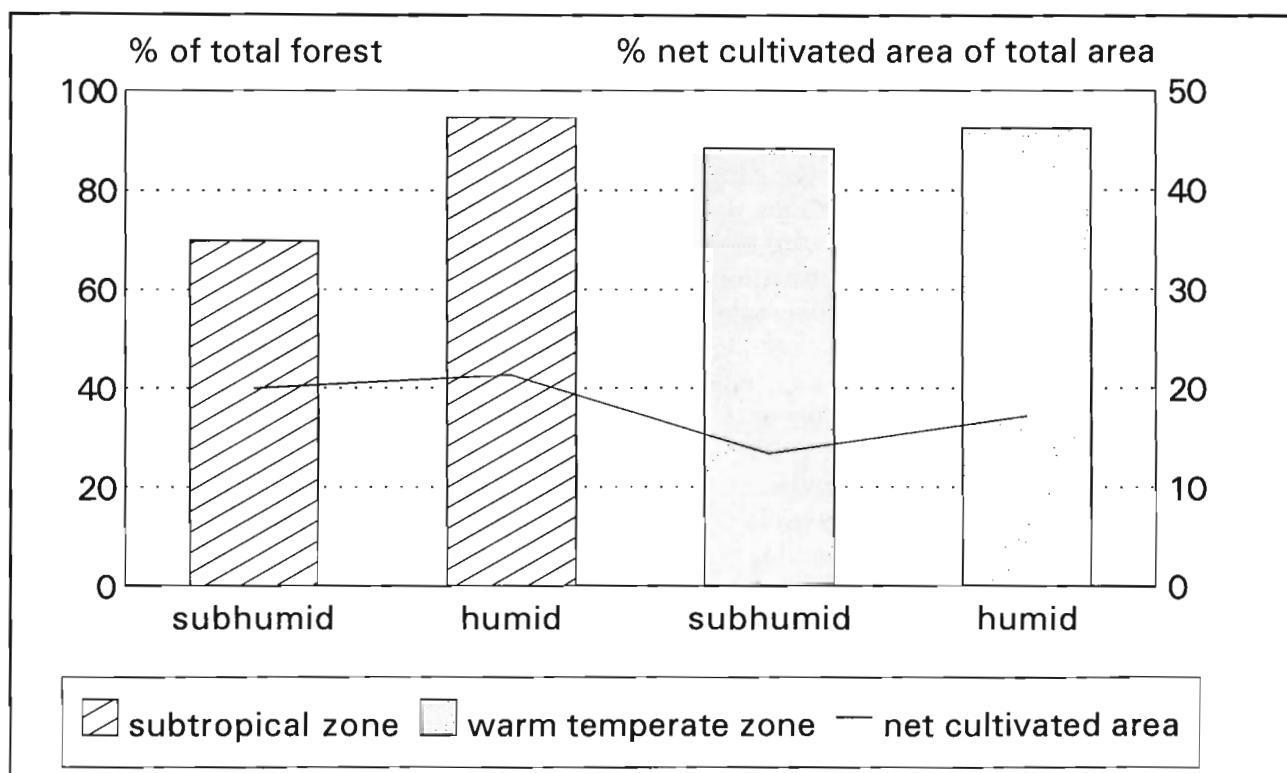


Figure 15: Distribution of Low Density Forest and Net Cultivated Area on the Southern Aspects





## Part IV: Correlation of Land Use with Climatic Factors in Gorkha District

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*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).

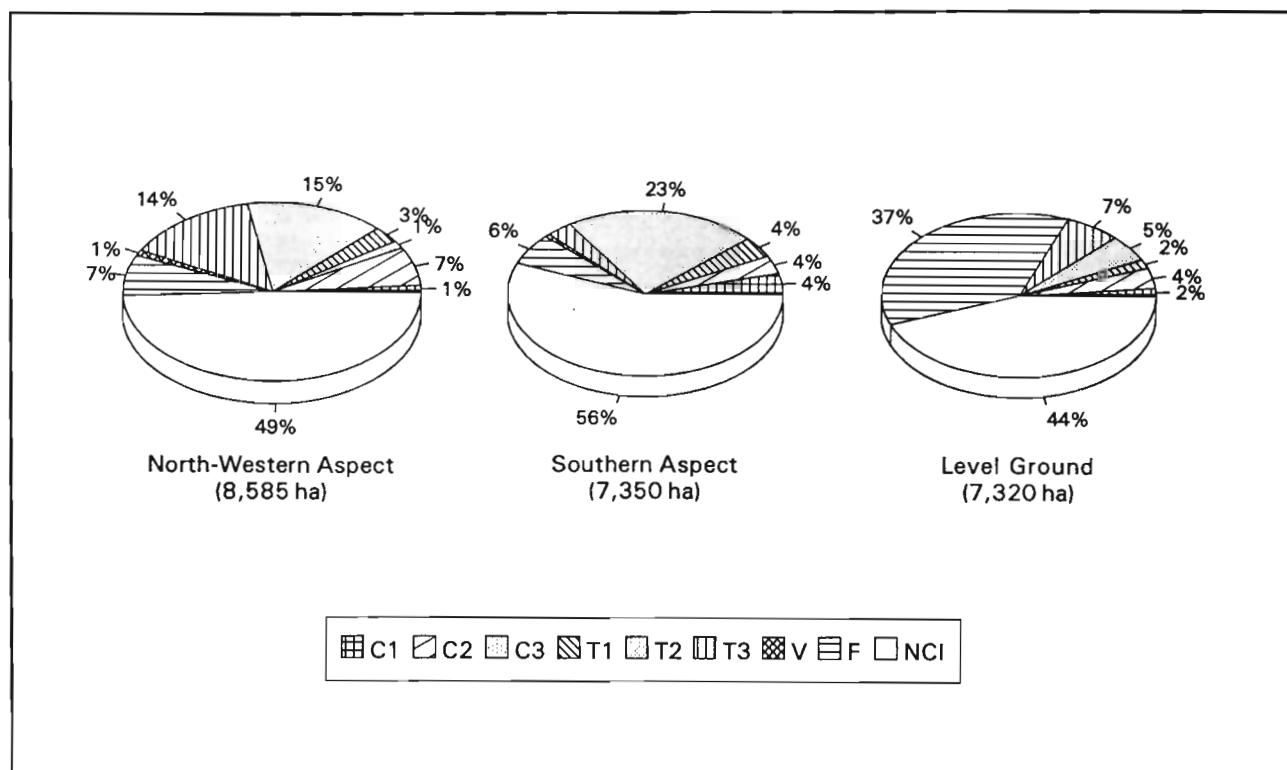
### 3.5 Cropping Systems in Relation to Agroclimatic Zones and Aspects

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 similar in size to the figure for level ground (Figure 19).



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Figure 17: Distribution of Cropping Systems in the Subtropical Zone

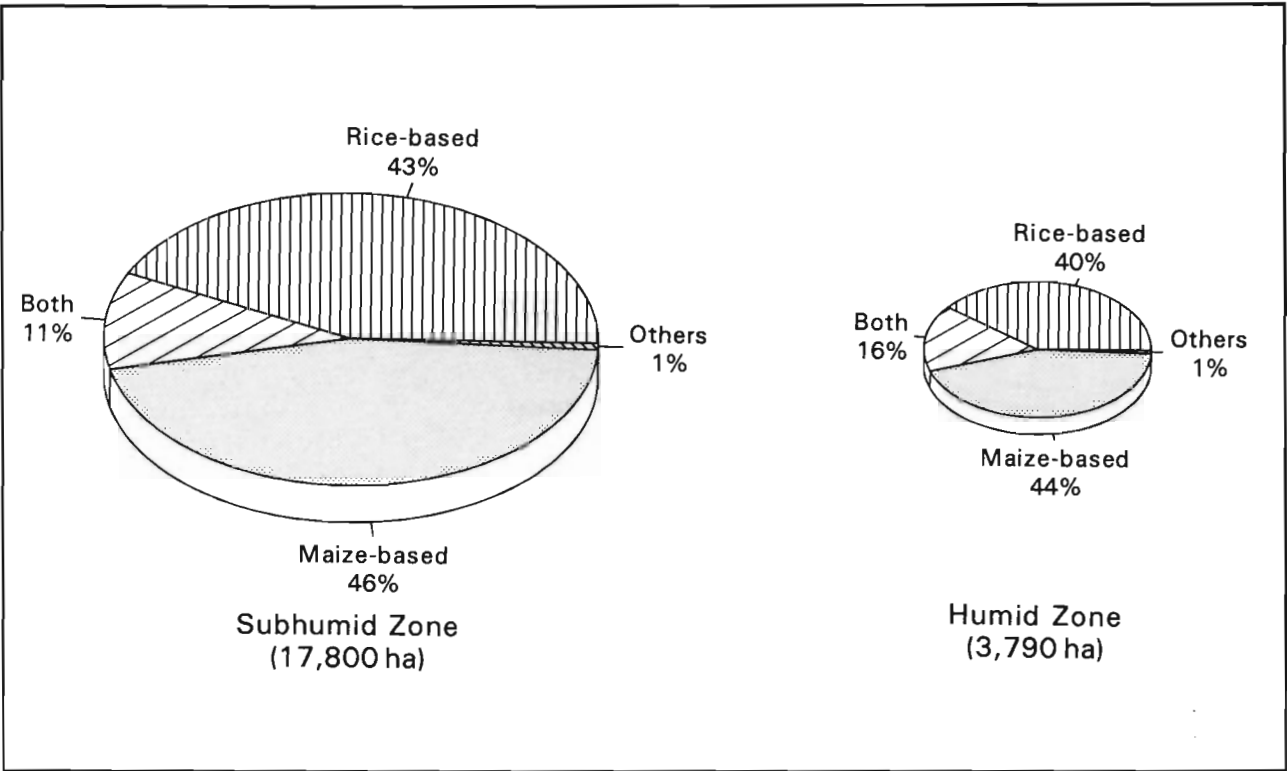
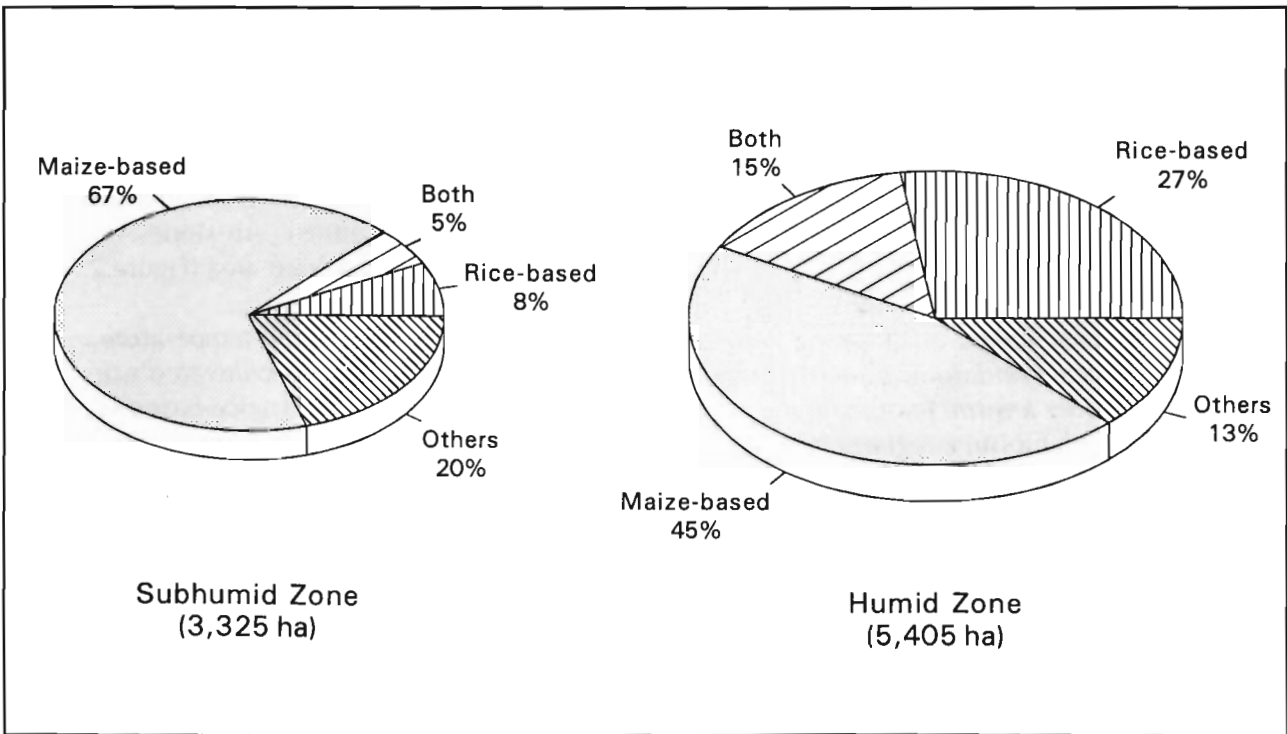
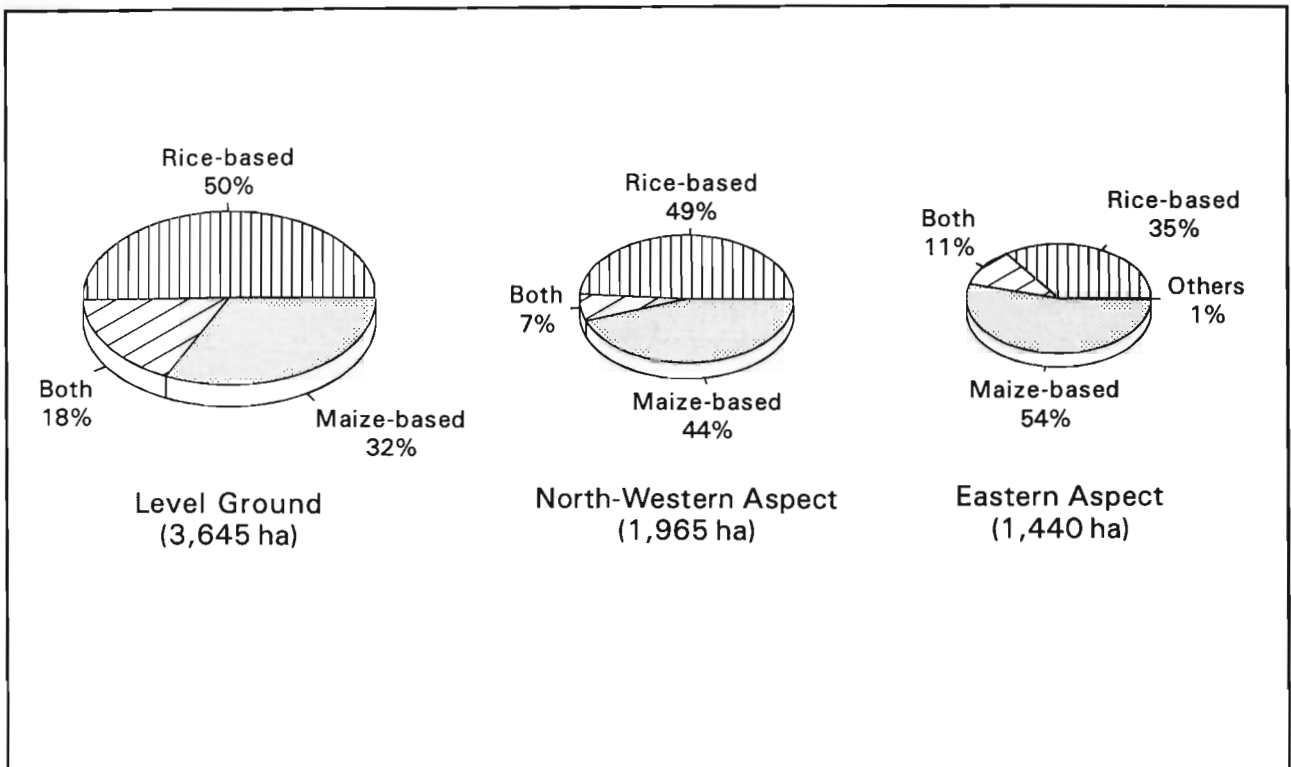


Figure 18: Distribution of Cropping Systems in the Warm Temperate Zone





**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).

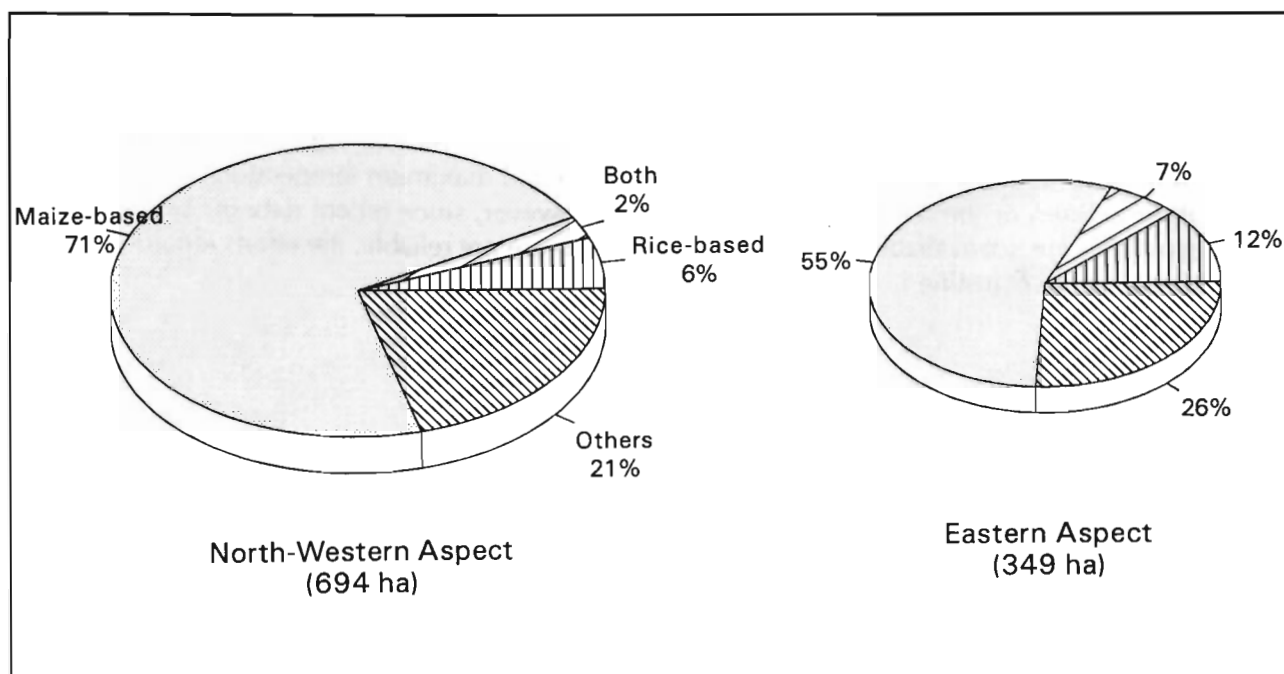
*The distribution of rice-based cropping systems is, in the first place, related to the temperature regime. Under subtropical conditions, a higher proportion of the agricultural land was cultivated using these systems than under a warm temperate regime. The percentage of area devoted to rice-based systems 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.*

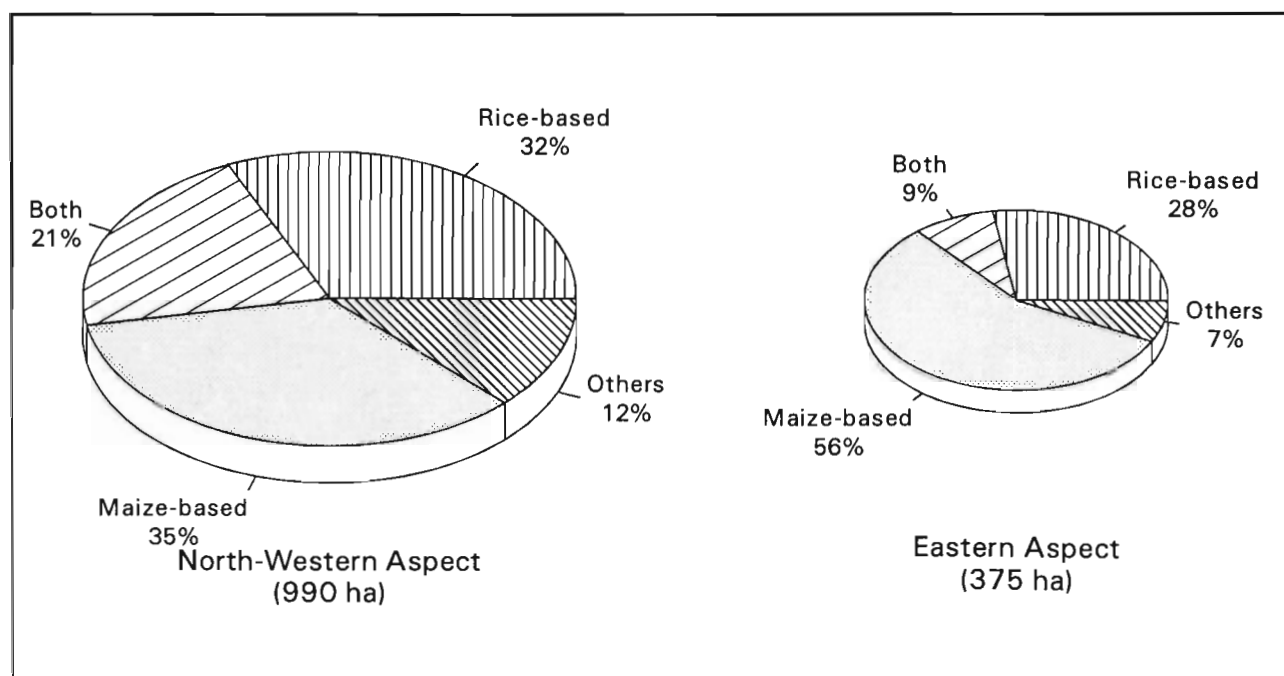


## Part IV: Correlation of Land Use with Climatic Factors in Gorkha District

**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.



**PART V**  
**POTATO PRODUCTION IN**  
**GORKHA DISTRICT**



### 1. INTRODUCTION

Potatoes have been grown as food crops in Nepal for more than two centuries. Presently, about 86,000ha are under potato cultivation in Nepal, including 60,000ha in the hills and 26,000ha in the *terai* (NPDP 1994). Potatoes are cultivated in different regions, defined according to altitude; in the *terai*, potatoes are grown in winter after paddy; similarly, in the Middle Mountains (800 - 1,500masl), potatoes are cropped after paddy on irrigated terraces; above 1,500m, there are mixed cropping systems with maize and potatoes; and, above 2,500m, potatoes are cultivated in monocropping systems during the summer season. In the northern High Mountain Region, the growing period lasts six months, and potatoes are grown as the predominant crop from April to September (Rhoades 1985:9).

IIDS (1993) distinguished between four categories of potato-growing areas in Gorkha: (1) mountain and snowfall areas (i.e., High Mountain Region), covering the VDCs of Samagaun, Lho, Prok, Bihi, Chumchet, and Chhekampar, where potatoes are the main staple crop; (2) high hill areas (above 2,000masl), where the VDCs of Laprak, Gumda, Uhiya, Sirdibas, Lapu, Kerauja, Kashigaun, Manbu, Barpak, Kharibot, and Simjung are the main traditional potato-growing areas and potatoes are cultivated alongside maize, wheat, and millet; (3) low hill areas (700 - 2,000masl), where potatoes are grown for home consumption and small quantities marketed; and (4) valley bottom areas where potatoes are cultivated in the winter season.

This study applied GIS technology to the analysis of appropriate locations for potato cultivation in Gorkha District. Since potatoes can be grown on all cultivated land during different seasons, the major focus of this study was to define the appropriate growing period for particular locations.

### 2. POTATO PRODUCTION IN THE MOUNTAINS OF NEPAL

In the mountains of Nepal, potato cultivation has a high socioeconomic value and is practised in a broad sociocultural context. Noteworthy features include (1) the importance of potatoes as a food crop, (2) the demand for seed potatoes for the next growing period, and (3) the marketing and bartering of seed potatoes. Potatoes are eaten as a staple food in the High Mountains and as a vegetable in the Middle Mountains.<sup>12</sup> Rhoades (1990) reported that, in 1985, the potato economy in eastern Nepal was still a non-monetarised, altitudinal, exchange and barter system for lower zone cereals, namely, paddy, finger millet, and maize. About 25 to 50 per cent of the potatoes cultivated in the main growing areas of Gorkha and Lamjung are either sold, exchanged, or marketed on a credit basis<sup>13</sup> in the hills (Pradhanang and Lorenzen 1990). Bartering is the most common marketing system for seed potatoes in Gorkha. The exchange rate of seed potatoes to cereal grain is generally 1:1 by volume, but, depending on the season, potato farmers may get more cereal grain.<sup>14</sup>

#### 2.1 Seed Potato Flow in Gorkha

In Nepal, seed potatoes are never replanted on the plot where they are produced; and seed potatoes are never taken from downhill sites. Farmers in a community exchange seed potatoes, and, every three years, renewal from higher altitudes takes place (Rhoades 1990). In Gorkha District, the main seed potato pockets are in Laprak, Gumda, Sirandanda (Simjung), and Barpak (Pradhanang and Lorenzen 1990:13),

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12 The Master Plan for Horticultural Development indicates that potatoes are the main vegetable in urban households; about 28 per cent of the expenditure for vegetables is spent on potatoes (Horton 1990:67).

13 There is a credit system between the farmers of Sirandanda and low-hill growers in the vicinity of the village: seed potatoes are supplied by the up-hill farmers on credit, and they receive rice only after the harvest in winter.

14 Rhoades (1990) observed barter systems of seed potatoes also in the Andes; there the exchange rate for potatoes seems to be based rather on a symbolic than on an economic value.



followed by Lapu, Sirdibas (Philim, Sarsyu, Anga), and Kerauja (IIDS 1993). According to IIDS, the seed potato flow is from Gumda and Laprak to the southern parts of the district and to areas outside the district; while the areas of Sirdibas, east of the Marsyangdi River, supply the south-east of Gorkha with seed potatoes. Pradhanang and Lorenzen provided a more detailed seed flow chart for Laprak, Gumda, and Sirandanda. According to them, high-hill seed pockets<sup>15</sup> and areas in Bhot Kholā<sup>16</sup> are occasionally<sup>17</sup> used for renewal of seed stocks in Laprak and Gumda. From these areas there is a seed flow to cool and warm areas, i.e., to Barpak, in the west, and Taranagar and Ranishwara, south of Gorkha District Headquarters; Laprak also provides seed potatoes to other cool areas, i.e., Sirandanda (Simjung VDC), Kharibot, Saurpani, and the warmly located Nareshwar; and, from Gumda, further seed potatoes flow, mainly to warm places, i.e., Gaikhur, Masel, Asrang, Arughat (Aru Chanaute VDC), Okhle (Tandrung VDC), and also to the distant village of Ghanpokhara in central Lamjung. Sirandanda (Simjung VDC), which receives seed potatoes from Laprak, itself is a main seed pocket in Gorkha and supplies places in the southwestern district, i.e., Aampipal, Simpani, Chhoprak, Gaikhur, Changli, Bhirsing, and Neupane in Kerabari VDC. In Gorkha, middlemen are not involved in the potato marketing system. IIDS (1993) reported that farmers in the southern subtropical areas of Gorkha received seed potatoes from the *terai* region.

## 2.2 Traditional Potato Cultivation Practices

In contrast to modern technology and development efforts for Himalayan potatoes, farmers prefer to plant very small tubers as seed for specific reasons, mainly, (1) to cater to the consumption preferences of the people for these small potatoes; (2) to minimise the risks of production; (3) to secure food; and (4) to decrease the packing volume of seeds for trading. There is always a shortage of food after the winter, and farmers have a strategy of holding back the amount needed for seeds, consuming them if there is a shortage of food.<sup>18</sup> Also, more land can be planted with small seed potatoes, even if the amount (weight) is less than recommended. Furthermore, farmers plant seed potatoes more densely for a greater density of sprouting and thus a higher survival rate. Farmers harvest the tubers at a premature stage (and of small size) before the late blight hits them (Rhoades 1990:300). Experiences of the National Potato Development Programme (NPDP) all over Nepal show that the small tuber size of the local varieties reflects the low soil fertility and the disease infestation of the seed material. Improved varieties and appropriate cultivation technologies could double the potato yield and thus help to sustain the system and make it more flexible for soil fertility measures (personal communication, S. Schulz, NPDP)

In Nepal, about 25-35 potato cultivars are grown. Potato growers maintain potato diversity. They are aware of the agro-ecological zones suitable for particular cultivars; utilise resistances to diseases, pests, frost, and drought; and adapt the varieties to different zones to minimise the risks of production (Rhoades 1990:296). Nevertheless, Pradhanang and Lorenzen (1990:7 & 17) reported that many farmers in Gorkha are not aware of plant selection techniques for seed purposes. Mainly traditional potato varieties are cultivated in Gorkha; their names are based on tuber colour and shape, e.g., local black (*kalo aalu*), local white (*seto aalu*), and local red (*rato aalu*).<sup>19</sup> The Agricultural Development Office in Gorkha introduced an improved variety, *Kufri Jyoti*, in Gumda more than 10 years ago, but due to preferences in taste and

15 IIDS (1993) mentioned that Sarsyu and Anga (Sirdibas VDC) are the main pockets for the renewal of potato seed sources in Gumda and Laprak.

16 The location is not described in detail; however, since it takes 10-12 days for a round trip, the areas are probably the upper valleys of the Budhigandaki River and the Shyar Kholā.

17 According to the experiences of the NPDP (1994), the potato seed degenerates after six years in the hills of Nepal.

18 Also, multiple potato harvesting is practised due to acute food shortages, in April/May (Pradhanang and Lorenzen 1990:18).

19 In Gumda/Laprak, seed purchasers from below prefer the black variety because of its taste, small tuber size, and yield performance. Customers refuse to buy white varieties of seed; therefore these varieties are only used for local consumption and cover a much smaller area; whereas in Sirandanda, farmers have no problem in marketing the local white variety (Pradhanang and Lorenzen 1990).



## Part V: Potato Production in Gorkha District

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problems in marketing, the cultivation of these potatoes is insignificant<sup>20</sup> (Pradhanang and Lorenzen 1990:4).

According to the LRMP, in Gorkha the cropping pattern, including potatoes, is mainly potato - fallow (z); maize - relayed potato (x); maize + potato - winter crop (y), and the total cropped area per year covers about 755ha (Trapp 1993:17). For Gumda and Laprak, the main potato pockets in Gorkha, no potato cropping patterns were recorded. Pradhanang and Lorenzen (1990:4) indicated that potato cultivation and potato-based cropping patterns were much more diverse locally than the LRMP had presented. In Laprak, Gumda, and Barpak, various two-year rotations are applied, in particular on *bari* (rain fed agricultural land), i.e.,

- potato - fallow - potato,
- potato - wheat - *silam* (*Amaranthus spp*),
- potato - barley - *silam*,
- potato - barley - millet,
- potato - *silam* - maize,
- potato - barley - soybean, and
- potato - *silam* - potato.

Planting and harvesting times vary considerably depending on location, year, and individual needs, e.g., the availability of labour in the household. In general, the planting time in Laprak, Gumda, Barpak, and Sirandanda starts from November/December and continues until February/March, and the harvesting of potatoes usually is in July but may last until October/November.

### 3. REQUIREMENTS FOR POTATOES

There are several physical factors which influence the growth of potatoes: weather and climate, soils and relief, and pests and diseases (Horton 1987:36).

Weather and climate. Day length and temperature affect the growth of potatoes. In general, the daily bulking rate of potatoes is related to the hours of daylight; there is a great variety of subspecies cultivated under different day-length regimes. Different aspects of temperature are important for potato production. Due to the potato's physiology, the most favourable soil temperature is between 15 to 18°C for common potato varieties; daytime air temperatures below 25°C are preferable; and the night temperature should remain below 20°C. Potatoes are well adapted to cool climates, but frost can damage potato plants and decrease yields. Hail can also damage the plants. The potato plant is sensitive to moisture, and any drought period during the growth cycle may harm the plant as well.

Soils and relief. Potatoes grow best on deep soils with good water drainage. Compacted soils or dense soil layers limit water availability during dry periods, become wet after heavy rainfall or irrigation, and damage the potato plant. In general, potatoes should be planted on level land rather than on slopes, to reduce soil erosion. Still, due to the scarcity of flat land, farmers are forced to cultivate potatoes on sloping land in the mountainous area of Gorkha. Compared to valley floors, slopes are less endangered by night frost.

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20 *Kufri Jyoti* is an early seed potato variety and may be an option for food deficit areas where farmers give priority to earliness and food security rather than taste. Other recommended potato varieties for the Western Region are *Desiree* and *Achirana Inta*. All recommended varieties are resistant to wart disease and are at least tolerant to late blight (NPDP 1994).



**Pests and diseases.** The potato is exposed to several pests and diseases that lead to extensive losses in yield. In the mountainous areas of Gorkha in particular, fungal diseases, i.e., late blight (*Phytophthora infestans*), to some extent black scurf (*Rhizoctonia solani*), and also viral diseases have been observed. Fungal disease wart (*Synchytrium endobioticum*) and bacterial wilt (*Pseudomonas solanacearum*) may become serious problems in the future. Various insects are damaging potato plants in the area but seem to be a minor problem.

Besides diseases and pests, other factors are seen as major problems for cultivating potatoes in the high mountain area of Gorkha, i.e., lack of soil fertility, small seed size, high plant density, curing and drying after harvest, planting time, desprouting/pre-sprouting, and multiple harvests. Pradhanang and Lorenzen (1990) recommend potato planting in December in the high mountains in case desprouting has been practised before; otherwise March/April may be the appropriate planting time. Irrigation is not feasible in the high mountains, but monsoon rains seem to be sufficient if there is no long drought during the spring season. In lowland, subtropical areas, potatoes are grown during the winter season. Soils must be well drained, and enough moisture should be secured during the growing period through irrigation (Horton 1987:124).

#### 4. APPLIED METHODOLOGY

To define the appropriate growing period for particular locations in Gorkha, agronomical parameters and requirements of potatoes were considered. Socioeconomic factors and values were not included in the analysis; however, an attempt was made to gather data on seed flow and, thus, the location of commercial potato production. Temperature was taken as the main indicator for potential potato growing areas. Mean annual maximum temperature data of Gorkha District were extracted from the available climatic database of Nepal. A mean maximum temperature range of 14°C<sup>21</sup> to 25°C was selected as the most favourable temperature for potato cultivation, and for each month the areas suitable for potato growing were identified using the Arc/Info raster GIS method (unit size 150 x 150m). Secondly, all agricultural land was taken into consideration except sloping terrace areas (C) on very steep slopes where potato cultivation would cause heavy soil erosion (see Annexes 8 & 9: land units 12; 142; 152).

Water availability was not considered in the analysis at all, although moisture is one of the most restricting factors during the winter cultivation of potatoes. Irrigation facilities are necessary, at least in lowland areas where soil moisture is more in deficit. There are no data available yet about irrigation systems in the district. Nevertheless, the moisture regime data of the area may provide some information on water availability.

Since the main potato growing areas in Gorkha were known (Pradhanang and Lorenzen 1990; IIDS 1993), the data on agricultural land use and cropping patterns, gathered by the LRMP, were evaluated using the overlay technique.

#### 5. RESULTS

The potential potato growing area in Gorkha was fairly large. Most of the agricultural land in the district could be used for potato cultivation. Still, there were constraints in terms of water availability which could hamper development considerably. Only about 5.5 per cent of the total potential area located in the High Mountains was cultivated during the summer season. Also, there was a considerable potential for the cultivation of early potato varieties in the upper valleys of the Chepe and Daroundi *Khola(s)* and the Budhigandaki up to Philim (Sirdibas VDC). Regardless of other main cropping patterns in the district,

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21 Soil temperature in topsoils is usually expected to be 1°C higher than air temperature.



## Part V: Potato Production in Gorkha District

winter potato production could eventually play a bigger role in southern Gorkha if water becomes available through irrigation (Tables 24 and 25) (Map 33). The analysis showed that the major summer potato growing areas were located in the VDCs of Laprak, Barpak, Kharibot, Lapu, and Uhiya, west of the Budhigandaki, and in the VDCs of Manbu, Kashigaun, Kerauja, Sirdibas (Philim, Sarsyu), and Chumchet (Lokwa), east of the river. The agricultural land in Gumda VDC and the ridge at Sirandanda were shown to be particularly suitable for early potato varieties.

The cropped area of the two main seed pockets, Gumda and Laprak, covered an area of about 890ha. Assuming the cropping patterns mentioned in Chapter 2.2 to be applied on all cultivated land, the actual potato growing area per year amounted to approximately 570ha. Assuming an average productivity of 10mt/ha<sup>22</sup>, the potato production would be 5,700mt per year in these two VDCs. IIDS (1993) mentioned that farmers from Gumda and Laprak sold about 50 per cent of their potato harvest. The estimated seed flow of 2,850mt to various VDCs in the cool and warm zones of Gorkha resulted in a potential potato cultivated area of approximately 1,900ha, considering a seed requirement of 1.5mt/ha in the middle mountain areas of Nepal.

**Table 24: Potential Agricultural Land and Potential Cropped Area in Gorkha Suitable for Potato Cultivation during Various Potato Growing Periods**

Optimal growing period	Agricultural land (ha)	Cropped area (ha)
<u>Winter growing areas</u>		
September - April/May	2,920	1,340
October - March/April	7,930	3,690
November - February/March	28,380	13,350
December - February	19,480	10,220
Sub-total	58,710	28,600
<u>Summer growing areas</u>		
February - December	1,460	650
March - November	1,470	600
April - October	150	60
May - September/October	390	230
June - September	200	120
Sub-total	3,670	1,660
<u>Area with no potential</u>	3,629	1,420
Total	66,009	31,680

22 Rhoades (1995:23) estimated an average yield of 6.6mt/ha in Ilam District, Eastern Region. Whereas Pradhanang and Lorenzen (1990:8), in general, found it difficult to get accurate yield data due to multiple harvesting practices; but they estimated an average yield of 22.3mt/ha in Sirandanda. NPDP (1994) monitors potato yields in Nepal on a yearly basis; for local varieties and non-potato programme areas, the yield varied from 8.5 to 11.4 mt/ha in hill areas of the Western Region in 1994.



Table 25: Potential Agricultural Land and Potential Cropped Area in Gorkha Suitable for Potato Cultivation during One Year

Month	Agricultural land (ha)	Cropped area	
		(ha)	% of total
January	58,710	28,600	90.2
February	60,170	29,250	92.3
March	42,160	19,360	62.0
April	12,930	6,360	20.1
May	6,390	2,880	9.0
June	3,670	1,660	5.2
July	3,670	1,660	5.2
August	3,670	1,660	5.2
September	6,590	3,000	9.5
October	14,320	6,570	20.7
November	42,160	19,630	62.0
December	60,170	29,250	92.3

## 6. CONCLUSIONS

The cultivation and bartering of potatoes in the High Mountain Region of Gorkha are based on indigenous knowledge systems. The influence of modern practices in cultivating this crop, e.g., use of improved varieties and application of recent agronomical technologies, is very limited. As has been pointed out, there are many constraints in these traditional systems, such as low yields due to lack of soil fertility and inappropriate cropping patterns, which may cause or increase problems with diseases and pests and, in the longer term, lead to unsustainability of the farming system. Therefore, for selected aspects of cultivation, intervention or guidance is necessary – offering options to farmers, e.g., improved varieties and appropriate cultivation technologies. This is regarded as an economically viable system, although one should keep Horton's (1987:57) comment in mind that in developing countries, *"where potatoes are already a low-cost staple food because they grow well in the local environment with minimal use of purchased inputs, economic development is likely to erode their competitive position relative to higher value crops."*

The potato analysis confirmed the relevance and usefulness of GIS technology and its application in the agricultural production fields. The results obtained, showing the locations of particular potato seed pockets for summer cultivation in Gorkha, corresponded to the information gathered by different survey teams. Linking the available knowledge and data with an information system could save time and effort and, if applied to a larger area, zone, region, or the whole country, could be a useful tool and database for planning, implementing, and monitoring particular area-based programmes and projects like the National Potato Development Programme at the Nepal Agricultural Research Council (NARC).



# ANNEXES



## Annex 1: Database Structure

Geographic Information System for District Level Planning in Gorkha District, Western Development Region of Nepal

### Annex 1.1 Temperature Regime Based on Analysis

The temperature regime data, which are based on the raster GIS analysis (unit size 100 x 100m), are stored in a polygon coverage.

ICIMOD/MENRIS 1994				
Coverage name: temp			Storage capacity: 0.2 MByte	
Attribute table: temp.pat				
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
TEMP_	11	N	-	internal no. of polygons/temp (used by system)
TEMP_ID	11	N	-	no. given by user
T_CODE	11	N	-	temperature regime 1: arctic 2: alpine 3: cool temperate 4: warm temperate 5: subtropical

### Annex 1.2 Moisture Regime Based on Analysis

The moisture regime data, which are based on the raster GIS analysis (unit size 100 x 100m), are stored in a polygon coverage.

ICIMOD/MENRIS 1994				
Coverage name: moist			Storage capacity: 0.2 MByte	
Attribute table: moist.pat				
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
MOIST_	11	N	-	internal no. of polygons/moist (used by system)
MOIST_ID	11	N	-	no. given by user
M_CODE	11	N	-	moisture regime 1: subhumid 2: humid 3: perhumid 4: arctic 5: no data



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### Annex 1.3 Temperature and Moisture Regime Based on Analysis

The overlay of the coverages 'temp' and 'moist' is compiled in the coverage 'tempmois'.

ICIMOD/MENRIS 1994				
Coverage name: tempmois			Storage capacity: 1.0 MByte	
Attribute table: tempmois.pat				
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
TEMPOIS_	11	N	-	internal no. of polygons/tempmois (used by system)
TEMPOIS_ID	11	N	-	no. given by user
T_CODE	11	N	-	temperature regime 1: arctic 2: alpine 3: cool temperate 4: warm temperate 5: subtropical
M_CODE	11	N	-	moisture regime 1: subhumid 2: humid 3: perhumid 4: arctic 5: no data
TM_CODE	11	N	-	agroclimatic zone 1: subtropical/subhumid 2: subtropical/humid 3: warm temperate/subhumid 4: warm temperate/humid 5: cool temperate/subhumid 6: cool temperate/humid 9: alpine/humid 10: alpine/perhumid 11: alpine/no data 12: arctic



## Annexes

### Annex 1.4 Mean Annual Temperature Based on Analysis

The mean annual temperature data are based on the raster GIS analysis (unit size 100 x 100m) and are stored in a polygon coverage.

ICIMOD/MENRIS 1994				
Coverage name: temp2_			Storage capacity: 0.3 MByte	
Attribute table: temp2_.pat				
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
TEMP2__	11	N	-	internal no. of polygons/temp2_ (used by system)
TEMP2__ID	11	N	-	no. given by user
GRID_CODE	11	N	-	mean annual temperature 1: < -3°C 2: -3 - 0°C 3: 0 - 3°C 4: 3 - 6°C 5: 6 - 9°C 6: 9 - 12°C 7: 12 - 15°C 8: 15 - 18°C 9: 18 - 21°C 10: 21 - 24°C 11: > 24°C



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### Annex 1.5 Land Capability

The land capability data are stored in a polygon coverage. They are based on the land capability maps of the LRMP, published in 1984 at a scale of 1:50,000: 71D8, 71D10, 71D11, 71D12, 71D14, 71D15, 71D16, 71H2, 71H3, 72A5, 72A9, 72A13. These single sheets are combined into one land capability map and clipped with the Gorkha District boundary (coverage: goutline). The land capability database includes information about the temperature and moisture regimes and provides an irrigation classification (Annex 11).

ICIMOD/MENRIS 1994				
Coverage name: landcap			Storage capacity: 0.9 MByte	
Attribute table: landcap.pat				
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
LANDCAP_	11	N	-	internal no. of polygons/landcap (used by system)
LANDCAP_ID	11	N	-	no. given by user
CLASSES	10	C	-	LRMP land capability legend (see Annex 11)
CAP	11	N	-	land capability classes (see Annex 11)
T_CODE	11	N	-	temperature regime 1: arctic 2: alpine 3: cool temperate 4: warm temperate 5: subtropical
M_CODE	11	N	-	moisture regime 1: subhumid 2: humid 3: perhumid 4: arctic
TM_CODE	11	N	-	temperature and moisture regimes 1: subtropical/subhumid 3: warm temperate/subhumid 4: warm temperate/humid 5: cool temperate/subhumid 6: cool temperate/humid 7: cool temperate/perhumid 8: alpine/subhumid 9: alpine/humid 10: alpine/perhumid 12: arctic
IR_CODE	11	N	-	irrigation suitability classes 1: suitable 2: moderately suitable 3: tentative



## Annexes

### Annex 1.6 Contour Lines

The contour line data are stored in a line coverage. The contour lines were digitised at 500-foot intervals from the Indian Survey Topographical Maps, published in the 1960s at a scale of 1:63,360: 71D8, 71D10, 71D11, 71D12, 71D14, 71D15, 71D16, 71H2, 71H3, 72A5, 72A9, 72A13. These single sheets are combined into one contour map and clipped with the Gorkha District boundary (coverage: goutline).

ICIMOD/MENRIS 1994				
Coverage name: contour			Storage capacity: 2.3 MByte	
Attribute table: contour.aat				
Item name	Width	Type	Dec.	Explanation
LENGTH	13	N	6	length of contour-lines in metres
CONTOUR_	11	N	-	internal no. of arc/contour (used by system)
CONTOUR_ID	11	N	-	contour lines in feet above sea-level (500 feet interval)

### Annex 1.7 Drainage System (rivers)

The data on drainage systems are stored in a line coverage. They are based on the 'Central Service Map - Gorkha District', published in 1989 at a scale of 1:125,000.

ICIMOD/MENRIS 1994				
Coverage name: river			Storage capacity: 265 KByte	
Attribute table: river.aat				
Item name	Width	Type	Dec.	Explanation
LENGTH	13	N	6	length of river in metres
RIVER_	11	N	-	internal no. of line/river (used by system)
RIVER_ID	11	N	-	no. given by user 1: Budhigandaki River 2: Trisuli River 3: Marsyangdi River 4: Daroundi <i>Khola</i> 5: Chepe <i>Khola</i> 6: Shyar <i>Khola</i> 10: other rivers
NAME	20	C	-	name of river



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### Annex 1.8 Road and Trail Network

The road and trail network data are stored in a line coverage. They are based on the 'Central Service Map - Gorkha District', published in 1989 at a scale of 1:125,000.

ICIMOD/MENRIS 1994				
Coverage name: road			Storage capacity: 34 KByte	
Attribute table: road.aat				
Item name	Width	Type	Dec.	Explanation
LENGTH	13	N	6	length of road in metres
ROAD	11	N	-	internal no. of line/road (used by system)
ROAD_ID	11	N	-	no. of road type 2: bitumen road 5: local trail 7: main trail

### Annex 1.9 Bridges

The data on bridges are stored in a point coverage. They are based on the 'Central Service Map - Gorkha District' of the Suspension Bridge Division (HMG), published in 1989 at a scale of 1:125,000.

ICIMOD/MENRIS 1994				
Coverage name: bridge			Storage capacity: 10 KByte	
Attribute table: bridge.pat				
Item name	Width	Type	Dec.	Explanation
BRIDGE_	11	N	-	internal no. of point/bridge (used by system)
BRIDGE_ID	11	N	-	no. of point given by user
REG NO	9	C	-	serial no. of central bridge register



## Annexes

### Annex 1.10 Land Utilisation in 1979

The land utilisation data are stored in a polygon coverage. They are based on the land use maps of the LRMP, published in 1984 at a scale of 1:50,000: 71D8, 71D10, 71D11, 71D12, 71D14, 71D15, 71D16, 71H2, 71A5, 71A9, 71A13. These single sheets are combined into one land utilisation map and clipped with the Gorkha District boundary (coverage: goutline). The land-use database includes information about the main land-use classes, agricultural cropping patterns, forest types and forest density, etc.

ICIMOD/MENRIS 1994				
Coverage name: landuse			Storage capacity: 1.3 Mbyte	
Attribute table: landuse.pat			(page 1)	
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
LANDUSE_	11	N	-	internal no. of polygon/landuse (used by system)
LANDUSE_ID	11	N	-	no. of polygon given by user
AREA_GROSS	13	N	6	gross cultivated area in hectares
AREA_NCI	13	N	6	area of non-cultivated inclusions in hectares
AREA_NET	13	N	6	net cultivated area in hectares
AREA_BUND	13	N	6	area of risers and bunds in hectares
AREA_CROP	13	N	6	area covered with crops in hectares
CLASSES	11	C	-	LRMP land use legend (see Annex 7)
LUT	11	N	-	aggregation of LRMP-defined land-use classes
				1: sloping terraces
				2: valley floors
				3: grazing land
				4: rocks, sand & boulders
				5: snow & ice
				6: foot slopes & tars
				7: forest
				12: level terraces
				14: shrubland
CROPS	11	N	-	cultivation type of agricultural land sloping terraces
				1: C1; low intensity cultivated
				2: C2; medium intensity cultivated
				3: C3; intensity cultivated
				level terraces
				4: T1; low intensity cultivated
				5: T2; medium intensity cultivated
				6: T3; intensity cultivated
				7: V; valley floors
				8: F; foot slopes & tars
PADDY	11	N	-	agricultural land cover with paddy
PADDY_UP	11	N	-	agricultural land cover with upland paddy
MAIZE	11	N	-	agricultural land cover with maize
WHEAT	11	N	-	agricultural land cover with wheat
MILLET	11	N	-	agricultural land cover with millet
POTATO	11	N	-	agricultural land cover with potatoes
PULSES	11	N	-	agricultural land cover with pulses
OILSEED	11	N	-	agricultural land cover with oil seeds



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Annex 1.10: continued

ICIMOD/MENRIS 1994				
Coverage name: landuse				(page 2)
Attribute table: landuse.pat				
Item name	Width	Type	Dec.	Explanation
MIXED	11	N	-	agricultural land cover with mixed crops
SUGAR	11	N	-	agricultural land cover with sugarcane
LUT3	11	N	-	pasture zones according to altitude 1: subtropical (< 1,000masl) 2: warm temperate (1,000 - 2,000masl) 3: temperate (2,000 - 2,600masl) 4: cool temperate (2,600-3,000masl) 5: subalpine (3,000 - 4,000masl) 6: alpine (> 4,000masl)
LUT7	11	N	-	forest types 1: mixed forest 2: hardwood forest 3: coniferous forest 4: protected forest 5: shrubland
LUT7_2	11	N	-	forest density & maturity classes 3: no density data 4: 10-40%; small timber 5: 40-70%; small timber 6: >70%; small timber 7: 10-40%; mature 8: 40-70%; mature 9: shrubland



## Annexes

### Annex 1.11 Aspect Based on Analysis

The aspect data are based on analysis using DEM and raster GIS. The data are stored in a polygon coverage.

ICIMOD/MENRIS 1994				
Coverage name: aspect			Storage capacity: 3.8 MByte	
Attribute table: aspect.pat				
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
ASPECT_	11	N	-	internal no. of polygons/aspect (used by system)
ASPECT_ID	11	N	-	no. given by user
GRID_CODE	11	N	-	aspect code
				1: level ground
				2: north            337.5 - 22.5°
				3: northeast      22.5 - 67.5°
				4: east            67.5 - 112.5°
				5: southeast      112.5 - 157.5°
				6: south           157.5 - 202.5°
				7: southwest      202.5 - 247.5°
				8: west            247.5 - 292.5°
				9: northwest      292.5 - 337.5°



## Annex 1.12 Land Systems

The land system data are stored in a polygon coverage. They are based on the land system of the LRMP, published in 1984 at a scale of 1:50,000: 71D8, 71D11, 71D12, 71D15, 71D16, 71H3, 72A5, 72A9, 72A13; and three map sheets from northern Gorkha at a scale of 1:125,000 : 71D10, 71D14, 71H2. These single sheets are combined into one land system map and clipped with the Gorkha District boundary (coverage: gridline). The land-system database includes information about the landform, land units, dominant soils, slopes and textures, seasonal variations in the water table, and drainage (Annexes 8 - 10).

ICIMOD/MENRIS 1994				
Coverage name: landsys			Storage capacity: 0.8 MByte	
Attribute table: landsys.pat				
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
LANDSYS_	11	N	-	internal no. of polygons/landsys (used by system)
LANDSYS_ID	11	N	-	no. given by user, based on LRMP land-system legend (see Annexes 8 - 10) 99: glacier 500: riverbed/lake
CODE	11	N	-	LRMP land-system legend (see Annexes 8 - 10)

## Annex 1.13 Land Utilisation and Land Systems

The overlay of the coverages 'landuti' and 'landsys' is compiled in the coverage 'utisys'. The database of this coverage was used to identify the location of agricultural land and forest area in relation to categories of land systems.

ICIMOD/MENRIS 1994				
Coverage name: utisys			Storage capacity: 3.5 Mbyte	
Attribute table: utisys.pat				
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
UTISYS_	11	N	-	internal no. of polygons/utisys (used by system)
UTISYS_ID	11	N	-	no. of polygon given by user
CLASSES	11	C	-	LRMP land utilisation legend (see Annex 7)



## Annexes

### Annex 1.13: continued

ICIMOD/MENRIS 1994				
Coverage name: utisys				(page 2)
Attribute table: utisys.pat				
Item name	Width	Type	Dec.	Explanation
LUT	11	N	-	aggregation of LRMP-defined land use classes 1: sloping terraces 2: valley floors 3: grazing land 4: rocks, sand, & boulders 5: snow & ice 6: foot slopes & tars 7: forest 12: level terraces 14: shrubland (shrubland = LRMP defined)
LUT1	11	N	-	agricultural land related to land systems 1: no data available Middle Mountain Region 9: alluvial plains and fans 10: ancient lakes and river terraces 11: moderately to steeply sloping terrain 12: steeply to very steeply sloping terrain High Mountain Region 13: alluvial plains and fans 14: past glaciated mountainous terrain below limit of arable agriculture 15: past glaciated mountainous terrain above limit of arable agriculture High Himalayan Region 16: alluvial, colluvial, and morainal depositional surfaces 17: steeply to very steeply sloping terrain
LUT7	11	N	-	forest area related to land systems (see LUT1)
LSCODE	11	N	-	LRMP land systems and land units (see Annexes 8 - 10)
LRMP_SYS	11	N	-	LRMP land systems (see Annexes 9 - 10)



## MENRIS Case Study, Series No. 3

### Annex 1.14 VDC Database

The VDC data are stored in a polygon coverage. It is based on the VDC boundary maps published by the HMG/Topographical Survey Branch in 2046 B.S. (1986) at a scale of 1:50,000 or 1:25,000 for each VDC. These single sheets did not have proper reference points; thus the line features were delineated manually on the topographical sheets of the Indian Survey and only then were they digitised.

ICIMOD/MENRIS 1994				
Coverage name: vdc_gdp			Storage capacity: 0.2 Mbyte	
Attribute table: vdc_gdp.pat			(page 1)	
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
VDC_GDP_	11	N	-	internal no. of polygons/vdc_gdp (used by system)
VDC_GDP_ID	11	N	-	no. given by user
VDCNO	5	N	-	no. of VDC used on maps
NAME	20	C	-	name of VDC
VDCAREA	13	N	6	total area in hectares
AREA_AGRI	13	N	6	agriculture area in hectares
AREA_GROSS	13	N	6	gross cultivated area in hectares
AREA_NCI	13	N	6	non-cultivated inclusions in hectares
AREA_NET	13	N	6	net cultivated area in hectares
AREA_BUND	13	N	6	area of bunds & risers in hectares
AREA_CROP	13	N	6	cropped area in hectares
AREA_GRAZ	13	N	6	area of grazing land in hectares
TOT_HH	4	N	-	total no. of households 1991
TOT_POP	6	N	-	total no. of population 1991
TOT_MALE	6	N	-	total no. of males 1991
TOT_FEMALE	6	N	0	total no. of females 1991
POP_DENS	7	N	1	population density relative to total area
POP_DENS2	7	N	1	population density relative to agri. area
AGE16	6	N	-	no. of children under 16 years
BOY16	6	N	-	no. of boys under 16 years
GIRL16	6	N	-	no. of girls under 16 years
SGO	6	N	-	no. of school-going children
SGO_PER	6	N	1	% of children going to school
GSGO	6	N	-	no. of school-going girls
GSGO_PER	6	N	1	% of girls going to school
PSBOY	6	N	-	no. of primary school boys
PSGIRL	6	N	-	no. of primary school girls
SSBOY	6	N	-	no. of secondary school boys
SSGIRL	6	N	-	no. of secondary school girls
HSSBOY	6	N	-	higher secondary school boys
HSSGIRL	6	N	-	higher secondary school girls



## Annexes

Annex 1.14: continued

ICIMOD/MENRIS 1994				
Coverage name: vdc_gdp				(page 2)
Attribute table: vdc_gdp.pat				
Item name	Width	Type	Dec.	Explanation
PSDIST	5	N	1	distance factor to primary school
SSDIST	5	N	1	to secondary school
HSSDIST	5	N	1	to higher secondary school
H_DIST	5	N	1	to health post
M_DIST	5	N	1	to monsoon water
W_DIST	5	N	1	to winter water
ROAD_DIST	5	N	1	to road-head
MARDIST	5	N	1	to market
WOODDIST	5	N	1	to firewood source
ASCDIST	5	N	1	to agricultural service centre
VETDIST	5	N	1	to veterinary service centre
POSTDIST	5	N	1	to post office
SIXLESS1	4	N	-	food sufficiency < 6 months (number of households, HH)
SIXL1PER	6	N	1	food sufficiency < 6 months (% of HH)
NINE1	4	N	-	for 9 months (HH)
YEAR1	4	N	-	for whole year (HH)
SALE1	4	N	-	surplus for sale (HH)
YEAR3	4	N	-	employment out of ward in a year (number of households, HH)
YEAR3PER	6	N	1	whole year (% of HH)
SIX3	4	N	1	up to 6 months (HH)
THREE3	4	N	-	up to 3 months (HH)
THREELESS3	4	N	-	< 3 months (HH)
WOODTOTAL	5	N	-	required firewood/house/year
BURY_PER	3	N	-	buried by landslides: persons
BURY_CAT	3	N	-	cattle
BURY_HOU	3	N	-	houses



## MENRIS Case Study, Series No. 3

### Annex 1.15 Database of Livestock and Feed Situation

The data on livestock and the feed situation in Gorkha District are stored in a polygon coverage. They are based on the VDC boundary maps published by the HMG/Topographical Survey Branch in 2046 B.S. (1986) at a scale of 1:50,000 or 1:25,000 for each VDC.

ICIMOD/MENRIS 1994				
Coverage name: vdc_feed			Storage capacity: 0.2 Mbyte	
Attribute table: vdc_feed.pat			page 1	
Item name	Width	Type	Dec.	Explanation
AREA	18	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
VDC_FEED_	11	N	-	internal no. of polygons/vdc_feed (used by system)
VDC_FEED_ID	11	N	-	no. given by user
VDCNO	5	N	-	no. of VDC used on maps
NAME	20	C	-	name of VDC
VDCAREA	13	N	6	total area in hectares
TOT_HH	4	N	-	total no. of households 1991
TOT_POP	6	N	-	total no. of population 1991
TOT_MALE	6	N	-	total no. of males 1991
TOT_FEMALE	6	N	0	total no. of females 1991
POP_DENS	7	N	1	population density relative to total area
POP_DENS2	7	N	1	population density relative to agri. area
COWOX	5	N	-	number of cows/oxen
BUFF	5	N	-	number of buffaloes
YAK	5	N	-	number of yaks and <i>chauris</i>
SHEEP	5	N	-	number of sheep
PIG	5	N	-	number of pigs
HENDUCK	5	N	-	number of hens/ducks
LU	8	N	1	no. of livestock units
COOL	11	N	-	location of VDC in terms of temperature zone 1: VDC located in cool zone 2: VDC located in both zones 3: VDC located in warm zone
LU_MODEL	8	N	2	no. of livestock units as calculated with grazing model
LU_COOL	8	N	2	no. of livestock units in cool zone
LU_WARM	8	N	2	no. of livestock units in warm zone
LUDENS	8	N	2	livestock density relative to total area
LUDENS_M	8	N	2	livestock density under the grazing model
FODETOT	8	N	1	annual feed requirements of all livestock in metric tonnes dry matter (mt DM) (first set of indicators)
FODETOT2	8	N	1	annual feed requirements of all livestock (mt DM) (second set of indicators)
FODEFOSU	8	N	1	feed supply in relation to feed requirements (first set of indicators)
FODEFOS2	8	N	1	feed supply in relation to feed requirements (first set of indicators and in access to pastures)



# Annexes

Annex 1.15: continued

ICIMOD/MENRIS 1994 Coverage name: vdc_feed Attribute table: vdc_feed.pat (page 2)				
Item name	Width	Type	Dec.	Explanation
FODEFOS3	8	N	1	feed supply in relation to feed requirements (second set of indicators)
FODEFOS4	8	N	1	feed supply in relation to feed requirements (second set of indicators and in access to pastures)
LU_CARRY	8	N	2	livestock carrying capacity relative to total area excluding wasteland
LU_CARRYB	8	N	2	livestock carrying capacity relative to total area excluding wasteland under livestock distribution model)
LU_CARRY2	8	N	2	livestock carrying capacity relative to total area excluding wasteland and 60% of pastures
LU_CARRY2B	8	N	2	livestock carrying capacity relative to total area excluding wasteland and 60% of pastures under livestock distribution model)
FODEHA	8	N	1	annual feed requirements of all livestock related to the VDC area excluding wasteland (mt DM/ha) (first set of indicators)
FODEHA2	8	N	1	annual feed requirements of all livestock related to the VDC area excluding wasteland and 60% of pasture land (mt DM/ha) (first set of indicators)
FODEHA3	8	N	1	annual feed requirements of all livestock relative to the VDC area excluding wasteland (mt DM/ha) (second set of indicators)
FODEHA4	8	N	1	annual feed requirements of all livestock related to the VDC area excluding wasteland and 60% of pastures (mt DM/ha) (second set of indicators)
FOSUTOT	8	N	1	annual amount of feed supply (mt DM)
FOSUTOT2	8	N	1	annual amount of feed supply excluding 60% pasture land (mt DM)
FOSUTOTC	8	N	1	annual amount of feed supply in cool zone (mt DM)
FOSUTOTW	8	N	1	annual amount of feed supply in warm zone (mt DM)
FOSUFOR	8	N	1	annual amount of feed supply from forest resources (mt DM)
FOSUFORC	8	N	1	annual amount of feed supply from forest resources in cool zone (mt DM)
FOSUFORW	8	N	1	annual amount of feed supply from forest resources in warm zone (mt DM)
FOSUGRA	8	N	1	annual amount of feed supply from pastures (mt DM)



# MENRIS Case Study, Series No. 3

Annex 1.15: continued

ICIMOD/MENRIS 1994				
Coverage name: vdc_feed				(page 3)
Attribute table: vdc_feed.pat				
Item name	Width	Type	Dec.	Explanation
FOSUGRAC	8	N	1	annual amount of feed supply from pastures in cool zone (mt DM)
FOSUGRAW	8	N	1	annual amount of feed supply from pastures in warm zone (mt DM)
FOSUAGR	8	N	1	annual amount of feed supply from agricultural land (mt DM)
FOSUAGRC	8	N	1	annual amount of feed supply from agricultural land in cool zone (mt DM)
FOSUAGRW	8	N	1	annual amount of feed supply from agricultural land in warm zone (mt DM)
FOSUNCI	8	N	1	annual amount of feed supply from non-cultivated area within agricultural land (mt DM)
FOSUBUND	8	N	1	annual amount of feed supply from risers and bunds (mt DM)
FOSUTREE	8	N	1	annual amount of feed supply from fodder trees (mt DM)
FOSUSHR	8	N	1	annual amount of feed supply from shrubland (mt DM)
FOSUSHRC	8	N	1	annual amount of feed supply from shrubland in cool zone (mt DM)
FOSUSHRW	8	N	1	annual amount of feed supply from shrubland in warm zone (mt DM)



## Annexes

### Annex 1.16 Accessibility of Road Infrastructure

The data on the walking distance to road infrastructure are based on the raster GIS analysis (unit size 200 x 200m) and are stored in a polygon coverage.

ICIMOD/MENRIS 1994				
Coverage name: acc1_			Storage capacity: 0.6 MByte	
Attribute table: acc1_.pat				
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
ACC1__	11	N	-	internal no. of polygons/acc1_ (used by system)
ACC1__ID	11	N	-	no. given by user
GRID_CODE	11	N	-	walking distance to roads in hours

### Annex 1.17 Accessibility of Road Infrastructure Including Proposed Road to Arkhet

The data on walking distance to road infrastructure, including the proposed road to Arkhet, are based on the raster GIS analysis (unit size 200 x 200m) and are stored in a polygon coverage.

ICIMOD/MENRIS 1994				
Coverage name: acc2_			Storage capacity: 0.6 MByte	
Attribute table: acc2_.pat				
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
ACC2__	11	N	-	internal no. of polygons/acc2_ (used by system)
ACC2__ID	11	N	-	no. given by user
GRID_CODE	11	N	-	walking distance to roads in hours

### Annex 1.18 Accessibility of Bazaar(s)

The data on walking distance to *bazaar(s)* are based on the raster GIS analysis (unit size 200 x 200m) and are stored in a polygon coverage.

ICIMOD/MENRIS 1994				
Coverage name: acc3_			Storage capacity: 0.4 MByte	
Attribute table: acc3_.pat				
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
ACC3__	11	N	-	internal no. of polygons/acc3_ (used by system)
ACC3__ID	11	N	-	no. given by user
GRID CODE	11	N	-	walking distance to <i>bazaar(s)</i> in hours



## MENRIS Case Study, Series No. 3

### Annex 1.19 Horticultural Development Areas

The data on potential horticultural development areas in Gorkha are based on the raster GIS analysis (unit size 100 x 100m) and are stored in a polygon coverage.

ICIMOD/MENRIS 1994				
Coverage name: horti_			Storage capacity: 7.7 Mbyte	
Attribute table: horti_.pat			(page 1)	
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
HORTI_	11	N	-	internal no. of polygons/horti_ (used by system)
HORTI_ID	11	N	-	no. given by user
LUT	11	N	-	agricultural land-use classes
				sloping terraces
				1: C1 low-intensity cultivated
				2: C2 medium-intensity cultivated
				3: C3 intensly cultivated
				level terraces
				4: T1 low-intensity cultivated
				5: T2 medium-intensity cultivated
				6: T3 intensly cultivated
				7: V valley floors
				8: F foot slopes & tars
TEMP	11	N	-	mean annual temperature
				1: < -3°
				2: -3 - 0°
				3: 0 - 3°
				4: 3 - 6°
				5: 6 - 9°
				6: 9 - 12°
				7: 12 - 15°
				8: 15 - 18°
				9: 18 - 21°
				10: 21 - 24°
				11: > 24°
LANDUNIT	11	N	-	LRMP land-system legend (see Annexes 8 - 10)
ASPECT	11	N	-	aspect code
				1: level ground
				2: north 337.5 - 22.5°
				3: northeast 22.5 - 67.5°
				4: east 67.5 - 112.5°
				5: southeast 112.5 - 157.5°
				6: south 157.5 - 202.5°
				7: southwest 202.5 - 247.5°
				8: west 247.5 - 292.5°
				9: northwest 292.5 - 337.5°



## Annexes

Annex 1.19: continued

ICIMOD/MENRIS 1994				
Coverage name: horti_				(page 2)
Attribute table: horti_.pat				
Item name	Width	Type	Dec.	Explanation
TM_CODE	11	N	-	agroclimatic zone 1: subtropical/subhumid 2: subtropical/humid 3: warm temperate/subhumid 4: warm temperate/humid 5: cool temperate/subhumid 6: cool temperate/humid 9: alpine/humid 10: alpine/perhumid 11: alpine/no data 12: arctic
APPLE	11	N	-	suitable areas for apples 1: suitable; NW - E 2: suitable; SE - W & level ground 3: moderately suitable; NW - E 4: moderately suitable; SE - W & level
PEAR	11	N	-	suitable areas for pears
WALNUT	11	N	-	suitable areas for walnuts
PEACH	11	N	-	suitable areas for peaches
PLUM	11	N	-	suitable areas for plums
SUNTALA	11	N	-	suitable areas for <i>suntala</i> (s)
JUNAR	11	N	-	suitable areas for <i>junar</i> (s)
LIME	11	N	-	suitable areas for limes
MANGO	11	N	-	suitable areas for mangoes
BANANA	11	N	-	suitable areas for bananas



## MENRIS Case Study, Series No. 3

### Annex 1.20 Potential Potato-growing Areas

The data on potential potato growing areas in Gorkha are based on the raster GIS analysis (unit size 150 x 150m) and are stored in a polygon coverage.

ICIMOD/MENRIS 1994				
Coverage name: potato_			Storage capacity: 1.65 Mbyte	
Attribute table: potato_.pat			(page 1)	
Item name	Width	Type	Dec.	Explanation
AREA	13	N	6	area in square metres
PERIMETER	13	N	6	perimeter in metres
POTATO_	11	N	-	internal no. of polygons/potato_ (used by system)
POTATO_ID	11	N	-	no. given by user
AREA_GROSS	13	N	6	gross cultivated area in hectares
AREA_NCI	13	N	6	non-cultivated inclusions in hectares
AREA_NET	13	N	6	net cultivated area in hectares
AREA_BUND	13	N	6	area of bunds & risers in hectares
AREA_CROP	13	N	6	cropped area in hectares
POT_CODE	11	N	-	potential potato-growing area and optimal growing period 1: September - April/May 2: October - March/April 3: November - February/March 4: December - February 5: February - December 6: March - November 7: April - October 8: May - September/October 9: June - September
LU_CODE	11	N	-	10: other agricultural land agricultural land-use classes sloping terraces 1: C1 low-intensity cultivated 2: C2 medium-intensity cultivated 3: C3 intensly cultivated level terraces 4: T1 low-intensity cultivated 5: T2 medium-intensity cultivated 6: T3 intensly cultivated
LANDUNIT	11	N	-	7: V valley floors 8: F foot slopes & tars LRMP land-system legend (see Annexes 8 - 10)



## Annexes

Annex 1.20: continued

ICIMOD/MENRIS 1994				
Coverage name: potato_				(page 2)
Attribute table: potato_.pat				
Item name	Width	Type	Dec.	Explanation
TM_CODE	11	N	-	agroclimatic zone 1: subtropical/subhumid 2: subtropical/humid 3: warm temperate/subhumid 4: warm temperate/humid 5: cool temperate/subhumid 6: cool temperate/humid 9: alpine/humid 10: alpine/perhumid 11: alpine/no data 12: arctic
M_CODE	11	N	-	moisture regime 1: subhumid 2: humid 3: perhumid 4: arctic 5: no data



Annex 2: Location, mean annual air temperature, annual precipitation, and moisture regime recorded at meteorological stations in western and central Nepal

No.	Location	Longitude	Latitude	Altitude masl	Mean annual air temperature		Temperature regime	Mean annual precipitation		No. of months			Moisture regime
					°C	years		mm	years	wet	moist	dry	
601	Jomsom	83°43'	28°47'	2,744	11.4	11	cool temperate	256	18	0	5	7	arid
604	Thakmarpha	83°42'	28°45'	2,566	11.1	11	cool temperate	386	16	1	4	7	arid
605	Baglung	83°36'	28°16'	984	21.2	4	subtropical	1,891	16	5	2	5	subhumid
606	Tatopani	83°39'	28°29'	1,243		-		1,504	15	4	3	5	subhumid
607	Lete	83°36'	28°38'	2,343		-		1,099	16	7	3	2	humid
608	Muktinath	83°53'	28°49'	3,500		-		380	11	3	3	6	semi-arid
609	Beni Bazaar	83°34'	28°21'	835		-		1,454	25	4	3	5	subhumid
610	Ghami (Mustang)	83°53'	29°03'	3,465		-		221	9	0	6	6	arid
612	Mustang (Lomangtang)	83°58'	29°11'	3,705	5.9	8	alpine	177	9	2	2	8	semi-arid
614	Kushma	83°42'	28°13'	891		-		2,320	16	6	2	4	humid
619	Ghorapani	83°44'	28°24'	2,742		-		2,692	10	6	4	2	humid
801	Jagat (Setibas)	84°54'	28°20'	1,334		-		1,299	26	4	5	3	subhumid
802	Khudi Bazaar	84°22'	28°17'	823	19.9	18	warm temperate	3,306	20	6	5	1	humid
803	Pokhara (Hospital)	84°00'	28°14'	918	20.8	8	subtropical	3,849	8	6	3	3	humid
804	Pokhara (Airport)	84°00'	28°13'	827	20.7	25	subtropical	3,709	26	6	3	3	humid
805	Syangja	83°53'	28°06'	860	20.1	3	subtropical	2,926	12	6	2	4	humid
806	Larke Samdo	84°37'	28°40'	3,650		-		1,121	5	11	1	0	perhumid
807	Kunchha	84°21'	28°08'	855		-		2,508	29	6	2	4	humid
808	Bandipur	84°25'	27°56'	965		-		1,900	29	5	3	4	subhumid
809	Gorkha	84°37'	28°00'	1,097	20.2	23	subtropical	1,800	24	5	3	4	subhumid
810	Chapkot	83°49'	27°53'	460	22.7	4	subtropical	1,793	26	4	3	5	subhumid
811	Malepatan (Pokhara)	83°57'	28°13'	856	19.9	10	warm temperate	3,531	13	6	1	5	humid
813	Bhadaure Deurali	83°49'	28°16'	1,600		-		(4,293)	2	7	3	2	
814	Lumle	83°48'	28°18'	1,642	15.6	16	warm temperate	5,224	17	6	5	1	humid
815	Khairani Tar	84°06'	28°02'	500	22.7	8	subtropical	2,249	12	5	2	5	subhumid
816	Chame	84°14'	28°33'	2,680	10.4	4	cool temperate	953	9	7	2	3	humid
817	Damauli	84°17'	27°58'	358	19.7	2	warm temperate	1,878	7	5	3	4	subhumid
818	Lamachaur	83°59'	28°16'	1,070		-		4,476	13	7	4	1	humid
820	Manang Bhot	84°01'	28°40'	3,420		-		471	11	3	6	3	semi-arid



Annex 2: continued

No.	Location	Longitude	Latitude	Altitude masl	Mean annual air temperature		Temperature regime	Mean annual precipitation		No. of months			Moisture regime
					°C	years		mm	years	wet	moist	dry	
821	Ghandruk	83°48'	28°23'	1,960		-		3,388	9	8	3	1	humid
822	Khuldi	83°50'	28°26'	2,440		-		(3,123)	1	8	2	2	
823	Charedhunga	84°37'	28°12'	1,120		-		2,802	10	6	3	3	humid
824	Siklesh	84°06'	28°22'	1,820		-		3,761	9	12	0	0	perhumid
905	Daman	85°05'	27°36'	2,314	12.8	12	cool temperate	1,856	15	6	3	3	humid
1001	Timure	85°23'	28°17'	1,900	16.7	9	warm temperate	853	26	4	2	6	subhumid
1002	Arughat Bazaar	84°49'	28°03'	518		-		2,548	28	4	4	4	subhumid
1003	Trishuli (closed)	85°09'	27°55'	595	22.1	7	subtropical	1,769	7	5	1	6	subhumid
1004	Nuwakot	85°10'	27°55'	1,003	21.0	8	subtropical	1,884	24	4	2	6	subhumid
1005	Dhading	84°56'	27°52'	1,420		-		2,301	28	5	4	3	subhumid
1007	Kakani	85°15'	27°48'	2,064	14.8	15	cool temperate	2,751	17	6	2	4	humid
1015	Thankot	85°12'	27°41'	1,630		-		2,051	17	6	2	4	humid
1016	Sarmathang	85°36'	27°57'	2,625	10.9	3	cool temperate	4,005	14	6	5	1	humid
1017	Dubachaur	85°34'	27°52'	1,550		-		2,391	15	6	1	5	humid
1018	Baunepati	85°34'	27°47'	845		-		1,815	15	4	3	5	subhumid
1022	Godavari	85°24'	27°35'	1,400	16.2	15	warm temperate	1,888	26	4	3	5	subhumid
1024	Dhulikhel	85°33'	27°37'	1,552		-		1,547	32	4	3	5	subhumid
1029	Khumaltar	85°20'	27°40'	1,350	17.3	16	warm temperate	1,281	17	4	2	6	subhumid
1030	Kathmandu Airport	85°22'	27°42'	1,336	17.9	17	warm temperate	1,423	18	4	2	6	subhumid
1036	Panchkhal	85°38'	27°41'	865	21.2	7	subtropical	1,201	12	4	2	6	subhumid
1038	Dhunibesi	85°11'	27°43'	1,085	20.9	10	subtropical	1,571	12	4	3	5	subhumid
1039	Panipokhari (Kathmandu)	85°21'	27°44'	1,335	18.0	10	warm temperate	1,549	12	4	3	5	subhumid
1043	Nagarkot	85°31'	27°42'	2,150	14.3	8	cool temperate	1,852	15	6	0	6	humid
1054	Thamachit	85°19'	28°10'	1,847		-		1,408	12	5	6	1	subhumid
1055	Dhunchhe	85°18'	28°06'	1,982		-		1,860	15	9	3	0	perhumid
1057	Pansayakhola	85°07'	28°01'	1,235	(14.1)	10		3,093	10	6	1	5	humid
1068	Tarke Ghyang	85°33'	28°00'	2,480		-		3,360	8	6	5	1	humid

() data not utilised for analysis

wet : precipitation &gt; PET

moist : 0.5 PET &lt; precipitation &lt; PET

dry : precipitation &lt; = 0.5 PET



Annex 3: Number of livestock units and the feed situation relative to VDCs (first set of indicators)

VDC No.	Name	Number of livestock units		Feed requirements		Feed supply mt DM/year (FOSUTOT)	Carrying capacity		Feed situation per cent (FODEFOSU)
		(LU) (LU_MODEL)	per ha (LUDENS_M)	mt DM/ year (FODETOT)	mt DM/ ha/yr (FODEHA)		(LU_CARRY)	(LU_CARRYB)	
VDCs of category 1 (cool zone)									
10	Bihi	811	1,121	.19	3,635	3,242	.18	.23	89.2
13	Chekampar	304	1,625	.18	6,523	12,945	.44	.80	198.4
15	Chumchet	1,024	1,301	.22	4,363	5,082	.27	.33	116.5
37	Laprak	7,062	2,124	.40	6,979	6,095	.37		87.3
39	Lho	1,450	2,092	.44	6,895	5,972	.40	.52	86.6
50	Prok	803	1,382	.23	4,750	5,438	.29	.41	114.5
52	Samagaun	1,436	2,773	.32	9,778	12,479	.45	.67	127.6
Sub-total					42,923	51,253			119.4
VDCs of category 2 (cool and warm zone)									
2	Aru Arbang	2,135	2,059	.83	6,126	4,257	.55		69.5
28	Gumda	1,596	1,921	.31	6,432	6,862	.35	.41	106.7
32	Kashigaun	773	965	.18	3,201	4,963	.30	.36	155.0
34	Kerauja	1,936	3,712	.19	13,866	23,274	.37	.55	167.8
35	Kharibot	4,611	4,474	.93	14,443	6,986	.46		48.4
38	Lapu	993	976	.30	3,033	3,047	.30		100.5
42	Manbu	1,225	1,219	.23	3,826	4,540	.27		118.7
53	Saurpani	2,897	2,761	.80	8,310	5,478	.51		65.9
55	Simjung	2,400	2,637	.42	8,430	7,189	.37	.40	85.3
56	Sirdibas	4,260	5,552	.31	20,195	23,943	.42	.52	118.6
57	Swara	2,159	2,109	.69	6,341	4,075	.43		64.3
66	Thumi	1,623	1,589	.50	5,018	5,036	.50		100.3
67	Uhiya	2,079	2,719	.24	9,365	11,535	.32	.40	123.2
68	Barpak	1,589	1,852	.22	6,142	8,179	.31	.35	133.2
69	Ghyachok	1,157	1,114	.50	3,370	1,939	.28		57.5
Sub-total					118,098	121,303			102.7



Annex 3: continued

VDC No.	Name	Number of livestock units			Feed requirements		Feed supply mt DM/year (FOSUTOT)	Carrying capacity		Feed situation per cent (FODEFOSU)
		(LU)	(LU_MODEL)	per ha (LUDEN_M)	mt DM/ha/yr (FODEHA)	(LU_CARRY)		(LU_CARRYB)		
VDCs of category 3 (warm zone)										
1	Aampipal	3,331	3,098	1.69	9,359	5.09	4,184	.73		44.7
3	Aru Chanaute	1,874	1,782	2.23	5,362	6.70	1,637	.65		30.5
4	Aru Pokhari	2,901	2,753	1.15	8,182	3.43	4,615	.62		56.4
5	Asrang	2,673	2,522	1.40	7,578	4.20	3,398	.60		44.8
6	Baguwa	1,319	1,249	2.31	3,701	6.83	1,200	.71		32.4
7	Bakrang	1,589	1,508	.58	4,540	1.75	4,308	.53		94.9
8	Mirkot	2,200	1,991	.77	6,118	2.35	4,700	.58		76.8
9	Bhumlichok	2,152	2,030	.72	6,130	2.18	4,555	.52		74.3
11	Borlang	2,636	2,497	.87	7,473	2.59	4,356	.48		58.3
12	Bungkot	3,718	3,517	1.25	10,527	3.75	4,773	.54		45.3
14	Choprak	3,270	3,088	1.41	9,258	4.23	4,440	.65		48.0
16	Changli	3,068	2,933	.97	8,873	2.94	6,465	.68		72.9
17	Darbung	1,855	1,758	1.00	5,292	3.02	3,006	.55		56.8
18	Deurali	3,425	3,231	1.07	9,765	3.23	3,887	.41		39.8
19	Dhawa	2,158	2,039	1.29	6,092	3.86	2,634	.53		43.2
20	Dhuwakot	2,357	2,230	1.04	6,744	3.15	3,351	.50		49.7
21	Phinam	2,546	2,394	2.00	7,263	6.07	2,625	.70		36.1
22	Phujel	3,090	2,929	2.06	8,718	6.12	3,281	.73		37.6
23	Gaikhur	2,873	2,697	1.78	8,209	5.43	2,516	.53		30.7
24	Gakhu	1,667	1,578	1.16	4,752	3.48	2,591	.60		54.5
25	Gairung	2,315	2,202	1.07	6,601	3.19	4,355	.67		66.0
26	Ghyalchok	1,300	1,203	.41	3,642	1.25	4,398	.48		120.8
27	Gorakhkali	2,583	2,392	1.20	7,444	3.73	3,520	.56		47.3
29	Hanspur	3,807	3,633	1.98	10,788	5.89	5,034	.88		46.7
30	Harmi	1,726	1,621	1.33	4,897	4.02	3,263	.85		66.6
31	Jaubari	3,816	3,385	1.64	10,649	5.17	3,802	.59		35.7
33	Kerabari	1,561	1,418	.96	4,321	2.93	2,873	.62		66.5
36	Koplang	3,008	2,819	1.22	8,486	3.68	4,542	.63		53.5
40	Makaising	1,355	1,272	1.34	3,840	4.05	1,736	.58		45.2



## Annex 3: continued

VDC No.	Name	Number of livestock units		Feed requirements		Feed supply		Carrying capacity		Feed situation per cent (FODEFOSU)
		(LU)	(LU MODEL)	per ha (LU DEN. M)	mt DM/yr (FODETOT)	mt DM/ha/yr (FODEHA)	mt DM/yr (FOSUTOT)	(LU CARRY)	(LU CARRYB)	
41	Manakamana	2,952	2,830	.89	8,528	2.68	5,442	.55		63.8
43	Masel	2,297	2,272	1.69	6,626	4.92	3,316	.78		50.0
44	Muchok	1,356	1,189	.69	3,693	2.15	2,980	.55		80.7
45	Namjung	2,708	2,562	1.60	7,635	4.75	2,457	.49		32.2
46	Nareshwar	977	888	.65	2,726	1.99	2,937	.68		107.8
47	Palungtar	3,358	3,197	1.46	9,586	4.37	5,333	.77		55.6
48	Panchkhawadeurali	1,482	1,375	1.64	4,154	4.95	1,489	.57		35.8
49	Pandrung	1,898	1,792	1.30	5,342	3.88	2,293	.53		42.9
51	Ranishwara	2,943	2,724	1.53	8,463	4.75	2,939	.53		34.7
54	Shreenathkot	2,895	2,693	1.34	8,067	4.02	3,544	.56		43.9
58	Taklung	3,181	3,031	1.23	9,181	3.72	5,132	.66		55.9
59	Takukot	2,098	1,986	1.36	5,983	4.08	2,935	.64		49.1
60	Takumajhlakuri	1,021	967	.86	2,881	2.56	2,431	.69		84.4
61	Tandrung	2,504	2,370	1.45	7,036	4.30	3,645	.71		51.8
62	Tanglichok	3,373	3,218	1.43	9,629	4.28	4,225	.60		43.9
63	Taple	2,423	2,286	1.34	6,845	4.00	3,454	.64		50.5
64	Taranagar	1,720	1,666	.87	5,030	2.63	3,791	.63		75.4
65	Thalajung	2,168	2,047	1.09	6,121	3.26	3,789	.64		61.9
Sub-total					332,128		168,180			52.2
Total					483,149		340,736			70.5

() item names used in VDC\_FEED.PAT



Annex 4: Number of livestock units and the feed situation relative to VDCs (first set of indicators); considering limited access to pasture land

VDC No.	Name	Number of livestock units			Feed requirements		Feed supply mt DM/year (FOSUTOT2)	Carrying capacity		Feed situation per cent (FODEFOS2)
		(LU)	(LU_MODEL)	per ha (LUDENS_M)	mt DM/year (FODETOT)	mt DM/ha/yr (FODEHA2)		(LU_CARRY2)	(LU_CARRY2B)	
VDCs of category 1 (cool zone)										
10	Bihi	811	1,121	.19	3,635	.71	1,923	.12	.15	52.9
13	Chekampar	304	1,625	.18	6,523	1.35	5,610	.37	.67	86.0
15	Chumchet	1,024	1,301	.22	4,363	.85	2,875	.18	.22	65.9
37	Laprak	7,062	2,124	.40	6,979	1.67	3,618	.28		51.8
39	Lho	1,450	2,092	.44	6,895	2.49	2,674	.31	.41	38.8
50	Prok	803	1,382	.23	4,750	1.11	2,403	.18	.26	50.6
52	Samagaun	1,436	2,773	.32	9,778	2.08	5,821	.40	.59	59.5
Sub-total		42,923			24,923				58.1	
VDCs of category 2 (cool and warm zone)										
2	Aru Arbang	2,135	2,059	.83	6,126	2.47	4,255	.55		69.4
28	Gumda	1,596	1,921	.31	6,432	1.20	4,345	.26	.30	67.6
32	Kashigaun	773	965	.18	3,201	.66	3,834	.25	.30	119.8
34	Kerauja	1,936	3,712	.19	13,866	1.00	11,767	.27	.40	84.9
35	Kharibot	4,611	4,474	.93	14,443	3.64	5,204	.42		36.0
38	Lapu	993	976	.30	3,033	.97	2,813	.29		92.8
42	Manbu	1,225	1,219	.23	3,826	.71	4,497	.26		117.5
53	Saurpani	2,897	2,761	.80	8,310	2.40	5,438	.50		65.4
55	Simjung	2,400	2,637	.42	8,430	1.62	5,114	.31	.34	60.7
56	Sirdibas	4,260	5,552	.31	20,195	1.78	10,558	.30	.37	52.3
57	Swara	2,159	2,109	.69	6,341	2.08	4,065	.42		64.1
66	Thumi	1,623	1,589	.50	5,018	1.60	4,719	.48		94.0
67	Uhiya	2,079	2,719	.24	9,365	1.01	6,736	.23	.28	71.9
68	Barpak	1,589	1,852	.22	6,142	.79	7,018	.29	.33	114.3
69	Ghyachok	1,157	1,114	.50	3,370	1.53	1,796	.26		53.3
Sub-total		118,098			82,160				69.6	



## Annex 4: continued

VDC No.	Name	Number of livestock units		Feed requirements		Feed supply mt DM/year (FOSUTOT2)	Carrying capacity		Feed situation per cent (FODEFOS2)
		(LU)	(LU_MODEL)	per ha (LUDENS_M)	mt DM/year (FODETOT)		mt DM/ ha/yr (FODEHA2)	(LU_CARRY2)	
VDCs of category 3 (warm zone)									
1	Aampipal	3,331	3,098	1.69	9,359	5.09	4,151	.72	44.4
3	Aru Chanaute	1,874	1,782	2.23	5,362	6.70	1,637	.65	30.5
4	Aru Pokhari	2,901	2,753	1.15	8,182	3.44	4,579	.61	56.0
5	Asrang	2,673	2,522	1.40	7,578	4.26	3,313	.59	43.7
6	Baguwa	1,319	1,249	2.31	3,701	6.83	1,197	.70	32.3
7	Bakrang	1,589	1,508	.58	4,540	1.75	4,291	.53	94.5
8	Mirkot	2,200	1,991	.77	6,118	2.35	4,669	.57	76.3
9	Bhumlichok	2,152	2,030	.72	6,130	2.26	4,254	.50	69.4
11	Borlang	2,636	2,497	.87	7,473	2.59	4,342	.48	58.1
12	Bungkot	3,718	3,517	1.25	10,527	3.75	4,758	.54	45.2
14	Choprak	3,270	3,088	1.41	9,258	4.23	4,426	.64	47.8
16	Changli	3,068	2,933	.97	8,873	2.94	6,393	.68	72.1
17	Darbung	1,855	1,758	1.00	5,292	3.04	2,956	.54	55.9
18	Deurali	3,425	3,231	1.07	9,765	3.23	3,879	.41	39.7
19	Dhawa	2,158	2,039	1.29	6,092	3.86	2,628	.53	43.1
20	Dhuwakot	2,357	2,230	1.04	6,744	3.15	3,333	.50	49.4
21	Phinam	2,546	2,394	2.00	7,263	6.07	2,606	.69	35.9
22	Phujel	3,090	2,929	2.06	8,718	6.25	3,179	.73	36.5
23	Gaikhur	2,873	2,697	1.78	8,209	5.43	2,512	.53	30.6
24	Gakhu	1,667	1,578	1.16	4,752	3.48	2,571	.60	54.1
25	Gairung	2,315	2,202	1.07	6,601	3.74	3,431	.62	52.0
26	Ghyalchok	1,300	1,203	.41	3,642	1.25	4,390	.48	120.5
27	Gorakhkali	2,583	2,392	1.20	7,444	3.73	3,503	.56	47.1
29	Hanspur	3,807	3,633	1.98	10,788	5.89	5,000	.87	46.3
30	Harmi	1,726	1,621	1.33	4,897	4.02	3,252	.85	66.4
31	Jaubari	3,816	3,385	1.64	10,649	5.17	3,786	.59	35.5
33	Kerabari	1,561	1,418	.96	4,321	2.93	2,843	.61	65.8
36	Koplang	3,008	2,819	1.22	8,486	3.68	4,542	.62	53.5
40	Makaising	1,355	1,272	1.34	3,840	4.05	1,731	.58	45.1



Annex 4: continued

VDC No.	Name	Number of livestock units		Feed requirements		Feed supply mt DM/year (FOSUTOT)	Carrying capacity		Feed situation per cent (FODEFOS2)
		(LU)	(LU_MODEL)	per ha (LUDENS_M)	mt DM/year (FODETOT)		(LU_CARRY2)	(LU_CARRYB2)	
41	Manakamana	2,952	2,830	.89	8,528	4,984	.52		58.4
43	Masel	2,297	2,272	1.69	6,626	3,284	.78		49.6
44	Muchok	1,356	1,189	.69	3,693	2,965	.55		80.3
45	Namjung	2,708	2,562	1.60	7,635	2,449	.49		32.1
46	Nareshwar	977	888	.65	2,726	2,905	.68		106.6
47	Palungtar	3,358	3,197	1.46	9,586	5,317	.77		55.5
48	Panchkhuwadeurali	1,482	1,375	1.64	4,154	1,419	.55		34.2
49	Pandrung	1,898	1,792	1.30	5,342	2,083	.51		39.0
51	Ranishwara	2,943	2,724	1.53	8,463	2,930	.52		34.6
54	Shreenathkot	2,895	2,693	1.34	8,067	3,524	.56		43.7
58	Taklung	3,181	3,031	1.23	9,181	4,275	.62		46.6
59	Takukot	2,098	1,986	1.36	5,983	2,910	.63		48.6
60	Takumajhlakuri	1,021	967	.86	2,881	2,425	.69		84.1
61	Tandrung	2,504	2,370	1.45	7,036	3,632	.71		51.6
62	Tanglichok	3,373	3,218	1.43	9,629	4,080	.59		42.4
63	Taple	2,423	2,286	1.34	6,845	3,440	.64		50.3
64	Taranagar	1,720	1,666	.87	5,030	3,769	.63		74.9
65	Thalajung	2,168	2,047	1.09	6,121	3,751	.64		61.3
Sub-total				332,128		164,277			51.0
Total				483,149		271,359			56.2



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**Annex 5: Number of livestock units and the feed situation relative to VDCs (second set of indicators)**

VDC No.	Name	Number of livestock units	Feed requirements	Feed supply	Feed situation	mt DM/year (FOSUTOT)	per cent (FODEFOS3)
		(LU)	(LU MODEL)	mt DM/year (FODETOT2)	mt DM/ha/yr (FODEHA3)		
VDCs of category 1 (cool zone)							
10	Bihi	811	1,121	3,635	.63	3,242	89.2
13	Chekampar	304	1,625	6,523	.70	12,945	198.4
15	Chumchet	1,024	1,301	4,363	.72	5,082	116.5
37	Laprak	7,062	2,124	5,235	.99	6,095	116.4
39	Lho	1,450	2,092	6,895	1.46	5,972	86.6
50	Prok	803	1,382	4,750	.78	5,438	114.5
52	Samagaun	1,436	2,773	9,778	1.12	12,479	127.6
Sub-total				41,178		51,253	124.5
VDCs of category 2 (cool and warm zone)							
2	Aru Arbang	2,135	2,059	4,031	1.62	4,257	105.6
28	Gumda	1,596	1,921	4,956	.79	6,862	138.5
32	Kashigaun	773	965	2,452	.47	4,963	202.4
34	Kerauja	1,936	3,712	12,219	.62	23,274	190.5
35	Kharibot	4,611	4,474	10,690	2.21	6,986	65.4
38	Lapu	993	976	2,110	.66	3,047	144.4
42	Manbu	1,225	1,219	2,735	.50	4,540	166.0
53	Saurpani	2,897	2,761	5,503	1.59	5,478	99.5
55	Simjung	2,400	2,637	6,145	.99	7,189	117.0
56	Sirdibas	4,260	5,552	20,195	1.11	23,943	118.6
57	Swara	2,159	2,109	4,174	1.37	4,075	97.6
66	Thumi	1,623	1,589	3,581	1.12	5,036	140.6
67	Uhiya	2,079	2,719	7,494	.65	11,535	153.9
68	Barpak	1,589	1,852	4,713	.56	8,179	173.5
69	Ghyachok	1,157	1,114	2,256	1.01	1,939	86.0
Sub-total				93,255		121,303	130.1
VDCs of category 3 (warm zone)							
1	Aampipal	3,331	3,098	6,290	3.42	4,184	66.5
3	Aru Chanaute	1,874	1,782	3,552	4.44	1,637	46.1
4	Aru Pokhari	2,901	2,753	5,382	2.25	4,615	85.7
5	Asrang	2,673	2,522	5,039	2.80	3,398	67.4
6	Baguwa	1,319	1,249	2,446	4.52	1,200	49.1
7	Bakrang	1,589	1,508	3,007	1.16	4,308	143.3
8	Mirkot	2,200	1,991	4,230	1.63	4,700	111.1
9	Bhumlichok	2,152	2,030	4,102	1.46	4,555	111.1
11	Borlang	2,636	2,497	4,954	1.72	4,356	87.9
12	Bungkot	3,718	3,517	6,970	2.49	4,773	68.5
14	Choprak	3,270	3,088	6,123	2.80	4,440	72.5
16	Changli	3,068	2,933	5,889	1.95	6,465	109.8
17	Darbung	1,855	1,758	3,520	2.01	3,006	85.4
18	Deurali	3,425	3,231	6,493	2.14	3,887	59.9
19	Dhawa	2,158	2,039	4,025	2.55	2,634	65.4
20	Dhuwakot	2,357	2,230	4,483	2.09	3,351	74.8
21	Phinam	2,546	2,394	4,865	4.07	2,625	54.0
22	Phujel	3,090	2,929	5,738	4.03	3,281	57.2
23	Gaikhur	2,873	2,697	5,517	3.65	2,516	45.6
24	Gakhu	1,667	1,578	3,142	2.30	2,591	82.4
25	Gairung	2,315	2,202	4,377	2.12	4,355	99.5
26	Ghyalchok	1,300	1,203	2,443	.84	4,398	180.0
27	Gorakhhali	2,583	2,392	5,176	2.60	3,520	68.0
29	Hanspur	3,807	3,633	7,057	3.85	5,034	71.3
30	Harmi	1,726	1,621	3,264	2.68	3,263	100.0
31	Jaubari	3,816	3,385	7,597	3.69	3,802	50.1
33	Kerabari	1,561	1,418	2,945	2.00	2,873	97.6
36	Koplang	3,008	2,819	5,647	2.45	4,542	80.4



## Annexes

VDC No.	Name	Number of livestock units	Feed requirements	Feed supply	Feed situation	mt DM/year (FOSUTOT1)	per cent (FODEFOS3)
		(LU)	(LU MODEL)	mt DM/year (FODETOT2)	mt DM/ha/yr (FODEHA3)		
40	Makaising	1,355	1,272	2,566	2.70	1,736	67.7
41	Manakamana	2,952	2,830	5,652	1.78	5,442	96.3
43	Masel	2,297	2,272	4,192	3.11	3,316	79.1
44	Muchok	1,356	1,189	2,593	1.51	2,980	114.9
45	Namjung	2,708	2,562	5,027	3.13	2,457	48.9
46	Nareswar	977	888	1,876	1.37	2,937	156.6
47	Palungtar	3,358	3,197	6,324	2.88	5,333	84.3
48	Panchkhawadeurali	1,482	1,375	2,788	3.32	1,489	53.4
49	Pandrung	1,898	1,792	3,528	2.56	2,293	65.0
51	Ranishwara	2,943	2,724	5,829	3.27	2,939	50.4
54	Shreenathkot	2,895	2,693	5,389	2.68	3,544	65.8
58	Taklung	3,181	3,031	6,137	2.49	5,132	83.6
59	Takukot	2,098	1,986	3,981	2.72	2,935	73.7
60	Takumajhlakuri	1,021	967	1,898	1.69	2,431	128.1
61	Tandrung	2,504	2,370	4,629	2.83	3,645	78.7
62	Tanglichok	3,373	3,218	6,339	2.82	4,225	66.6
63	Taple	2,423	2,286	4,542	2.65	3,454	76.1
64	Taranagar	1,720	1,666	3,321	1.74	3,791	114.2
65	Thalajung	2,168	2,047	4,047	2.15	3,789	93.6
Sub-total				214,931		168,180	78.2
Total				349,364		340,736	97.5



## MENRIS Case Study, Series No. 3

**Annex 6: Number of livestock units and the feed situation relative to VDCs (second set of indicators); considering limited access to pasture land**

VDC No.	Name	Number of livestock units		Feed requirements		Feed supply	Feed situation
		(LU)	(LU MODEL)	mt DM/year (FODETOT2)	mt DM/ha/yr (FODEHA4)	mt DM/year (FOSUTOT2)	per cent (FODEFOS4)
VDCs of category 1 (cool zone)							
10	Bihi	811	1,121	3,635	.71	1,923	52.9
13	Chekampar	304	1,625	6,523	1.35	5,610	86.0
15	Chumchet	1,024	1,301	4,363	.85	2,875	65.9
37	Laprak	7,062	2,124	5,235	1.26	3,618	69.1
39	Lho	1,450	2,092	6,895	2.49	2,674	38.8
50	Prok	803	1,382	4,750	1.11	2,403	50.6
52	Samagaun	1,436	2,773	9,778	2.08	5,821	59.5
Sub-total				41,178		24,923	60.5
VDCs of category 2 (cool and warm zone)							
2	Aru Arbang	2,135	2,059	4,031	1.62	4,255	105.5
28	Gumda	1,596	1,921	4,956	.92	4,345	87.7
32	Kashigaun	773	965	2,452	.51	3,834	156.3
34	Kerauja	1,936	3,712	12,219	.88	11,767	96.3
35	Kharibot	4,611	4,474	10,690	2.69	5,204	48.7
38	Lapu	993	976	2,110	.67	2,813	133.3
42	Manbu	1,225	1,219	2,735	.50	4,497	164.4
53	Saurpani	2,897	2,761	5,503	1.59	5,438	98.8
55	Simjung	2,400	2,637	6,145	1.18	5,114	83.2
56	Sirdibas	4,260	5,552	20,195	1.78	10,558	52.3
57	Sawara	2,159	2,109	4,174	1.37	4,065	97.4
66	Thumi	1,623	1,589	3,581	1.14	4,719	131.8
67	Uhiya	2,079	2,719	7,494	.81	6,736	89.9
68	Barpak	1,589	1,852	4,713	.60	7,018	148.9
69	Ghyachok	1,157	1,114	2,256	1.03	1,796	79.6
Sub-total				93,255		118,098	88.1
VDCs of category 3 (warm zone)							
1	Aampipal	3,331	3,098	6,290	3.42	4,151	66.0
3	Aru Chanaute	1,874	1,782	3,552	4.44	1,637	46.1
4	Aru Pokhari	2,901	2,753	5,382	2.26	4,579	85.1
5	Asrang	2,673	2,522	5,039	2.83	3,313	65.7
6	Baguwa	1,319	1,249	2,446	4.52	1,197	48.9
7	Bakrang	1,589	1,508	3,007	1.16	4,291	142.7
8	Mirkot	2,200	1,991	4,230	1.63	4,669	110.4
9	Bhumlichok	2,152	2,030	4,102	1.51	4,254	103.7
11	Borlang	2,636	2,497	4,954	1.72	4,342	87.6
12	Bungkot	3,718	3,517	6,970	2.49	4,758	68.3
14	Choprak	3,270	3,088	6,123	2.80	4,426	72.3
16	Changli	3,068	2,933	5,889	1.95	6,393	108.6
17	Darbung	1,855	1,758	3,520	2.02	2,956	84.0
18	Deurali	3,425	3,231	6,493	2.14	3,879	59.7
19	Dhawa	2,158	2,039	4,025	2.55	2,628	65.3
20	Dhuwakot	2,357	2,230	4,483	2.09	3,333	74.3
21	Phinam	2,546	2,394	4,865	4.07	2,606	53.6
22	Phujel	3,090	2,929	5,738	4.11	3,179	55.4
23	Gaikhur	2,873	2,697	5,517	3.65	2,512	45.5
24	Gakhu	1,667	1,578	3,142	2.30	2,571	81.8
25	Gairung	2,315	2,202	4,377	2.48	3,431	78.4
26	Ghyalchok	1,300	1,203	2,443	.84	4,390	179.7
27	Gorakhkali	2,583	2,392	5,176	2.60	3,503	67.7
29	Hanspur	3,807	3,633	7,057	3.85	5,000	70.9
30	Harmi	1,726	1,621	3,264	2.68	3,252	99.6
31	Jaubari	3,816	3,385	7,597	3.69	3,786	49.8
33	Kerabari	1,561	1,418	2,945	2.00	2,843	96.5
36	Koplang	3,008	2,819	5,647	2.45	4,527	80.2



## Annexes

VDC No.	Name	Number of livestock units		Feed requirements		Feed supply	Feed situation
		(LU)	(LU_MODEL)	mt DM/year (FODETOT2)	mt DM/ha/yr (FODEHA4)	mt DM/year (FOSUTOT2)	per cent (FODEFOS4)
40	Makaising	1,355	1,272	2,566	2.70	1,731	67.5
41	Manakamana	2,952	2,830	5,652	1.87	4,984	88.2
43	Masel	2,297	2,272	4,192	3.11	3,284	78.3
44	Muchok	1,356	1,189	2,593	1.51	2,965	114.4
45	Namjung	2,708	2,562	5,027	3.13	2,449	48.7
46	Nareshwar	977	888	1,876	1.37	2,905	154.8
47	Palungtar	3,358	3,197	6,324	2.88	5,317	84.1
48	Panchkhuwadeurali	1,482	1,375	2,788	3.41	1,419	50.9
49	Pandrung	1,898	1,792	3,528	2.70	2,083	59.1
51	Ranishwara	2,943	2,724	5,829	3.27	2,930	50.3
54	Shreenathkot	2,895	2,693	5,389	2.68	3,524	65.4
58	Taklung	3,181	3,031	6,137	2.81	4,275	69.7
59	Takukot	2,098	1,986	3,981	2.73	2,910	73.1
60	Takumajhlakuri	1,021	967	1,898	1.69	2,425	127.7
61	Tandrung	2,504	2,370	4,629	2.83	3,632	78.5
62	Tanglichok	3,373	3,218	6,339	2.87	4,080	64.4
63	Taple	2,423	2,286	4,542	2.65	3,440	75.8
64	Taranagar	1,720	1,666	3,321	1.74	3,769	113.5
65	Thalajung	2,168	2,047	4,047	2.15	3,751	92.7
Sub-total				214,931		164,277	76.4
Total				349,364		271,359	77.7



## Annex 7

## LAND-USE LEGEND

## TERAI CULTIVATION

Wet Lands	W
Upper Wetlands	W
Dry Lands	D
Mixed Lands	X

## HILLSLOPE CULTIVATION

Level Terraces	T
Sloping Terraces	C
Intense 75% - 100% cultivated	3
Medium 50% - 75% cultivated	2
Light 25% - 50% cultivated	1
Abandoned	A

## GRAZING LANDS

	amsl	
Sub-Tropical Zone	< 1000m	1
Warm Temperate Zone	1000m - 2000m	2
Temperate Zone	2000m - 2600m	3
Cool Temperate Zone	2600m - 3000m	4
Sub-Alpine Zone	3000m - 4000m	5
Alpine Zone	> 4000m	6

## VALLEY CULTIVATION

Valley Floors, Including Tars, Footslopes and/or Alluvial Fans which are too small to map	V
Tars, Alluvial Fans and/or Lower Footslopes	F

## NON AGRICULTURAL LANDS

Perpetual Snow and ice	I
Rock	R
Sand/Gravel/Boulders	B
Lake	L
Urban	U

## DOMINANT CROPPING PATTERNS

## MONSOON SEASON

Rice
Rice
Rice
Rice
Rice
Jute — Rice
Jute — Rice
Rice Maize
Rice seedlings
Maize or Millet
Maize
Maize
Cereal

## WINTER / DRY SEASON

Fallow	a
Oilseed	b
Mixed Winter crop	c
Pulses	d
Cereal	e
Fallow	f
Winter crop	g
Winter crop	h
Mustard	i
Fallow	j
Mustard	k
Cereal	l
Fallow	n

## MONSOON SEASON

Maize
Cereal — Fallow
Maize — Rice
Tobacco
Maize — Rice
Maize
Maize
Maize + Potato
Potato
Mixed
Pigeon Pea
Sugar Cane
Other

## WINTER / DRY SEASON

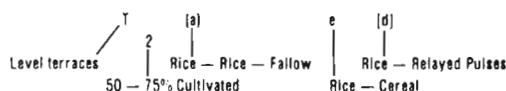
Tobacco	o
Fallow — Fallow	q
Winter crop	r
Fallow	t
Fallow	u
Pulses	w
Potato	x
Winter crop	y
Fallow	z
	m
	p
	s
	v

Upland rice-underlined ... e

Double monsoon crop in brackets (-)

Relayed winter crop in square brackets (•)

## TYPE LEGEND SAMPLE



## FORESTRY LEGEND

## COVER TYPE

C	Coniferous — 75% or more of tree species are coniferous
H	Hardwood — 75% or more of tree species are hardwoods
M	All other combinations of tree species
S	Shrub: shrub vegetation which may include hardwood regeneration

## SPECIES TYPE

Tropical types	Temperate and Alpine Types
Sal — Shorea robusta	DMB — Deciduous mixed broad leaved
KS — Acacia catechu and Dalbergia sissoo	Q — Quercus (Oak) all species
Pr — Pinus roxburghii (Chir Pine)	Bu — Betula utilis (Birch)
TMH — Tropical mixed hardwoods	A — Abies spectabilis and Abies pindrow (Fir)
	Pw — Pinus wallichiana (Blue Pine)
	Td — Tsuga dumosa (Hemlock)

Species of interest which may form a minor or infrequent component within a major type will be shown

by subscripts in lower case species abbreviation. Severe degradation is shown by the subscript d.

c — Conifers present in hardwood mix	jw — Juniperus wallichiana (Juniper)
ce — Cedrus deodara (Cedar)	lg — Larix griffithiana (Larch)
ct — Cupressus torulosa (Cypress)	pw — Pinus wallichiana (Blue Pine)
d — Degraded, caused by heavy lopping of trees for fodder and/or fuel	sp — Picea smithiana (Spruce)
	td — Tsuga dumosa (Hemlock)

Major species are noted. When feasible more than one species group is given, if possible in order of predominance, e.g. APw for an Abies stand with Pinus wallichiana

## CONDITION TYPES

R	Rock or rock outcrop with scattered trees
	Slide and slips — arrow indicates downslope direction
Br	Burn — area of burn leaving little or no residual stand
PI	Plantation
PF	Protection Forest — forests with management problems due to site fragility

## CROWN DENSITY

Expressed as a percentage of the area covered by tree crowns

1	< 10% (Non — forest type)
2	10 — 40%
3	40 — 70%
4	> 70%

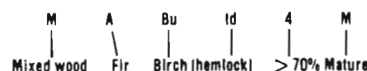
## MATURITY CLASS

M	Mature to overmature — trees have reached at estimated rotation age or saw timber size
I	Immature or small timber size material
R	Reproduction — new regeneration to pole size

Land Use Boundary

Forest Boundary

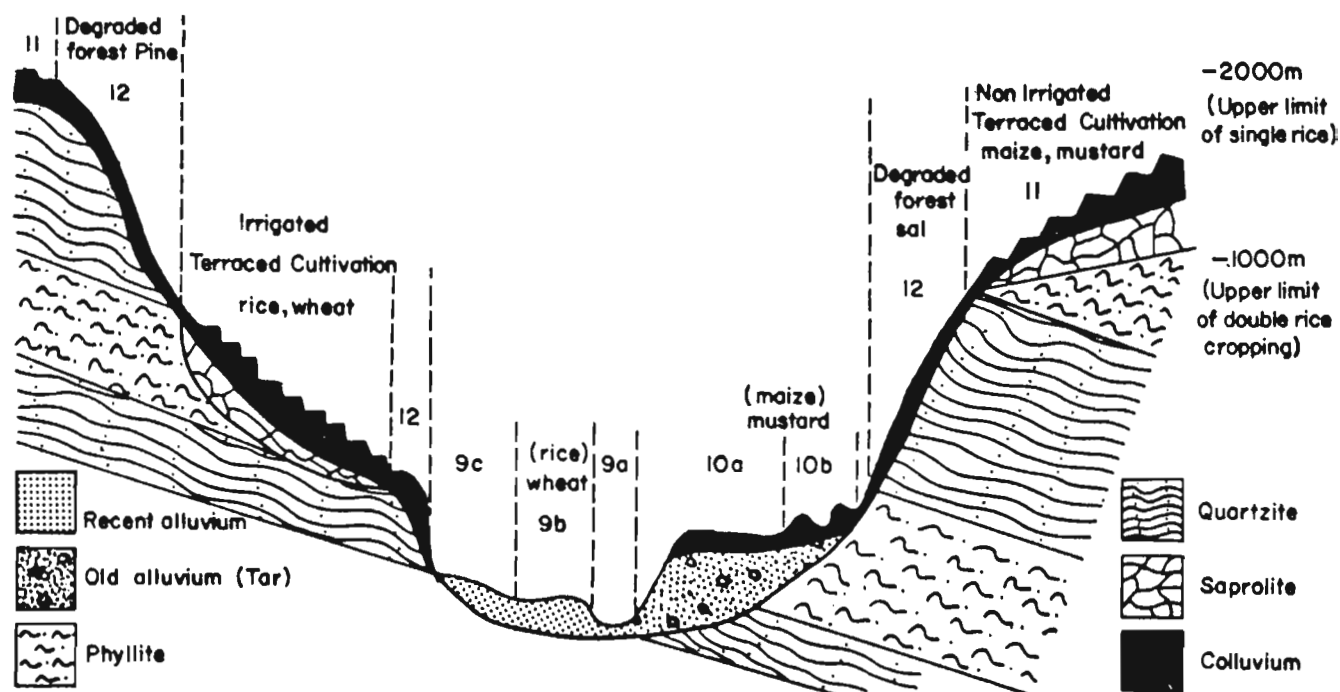
## TYPE LEGEND SAMPLE



Source: LRMP 1986d



## Annex 8: Schematic Cross Section of Land Systems in the Middle Mountain Region



### MIDDLE MOUNTAIN REGION

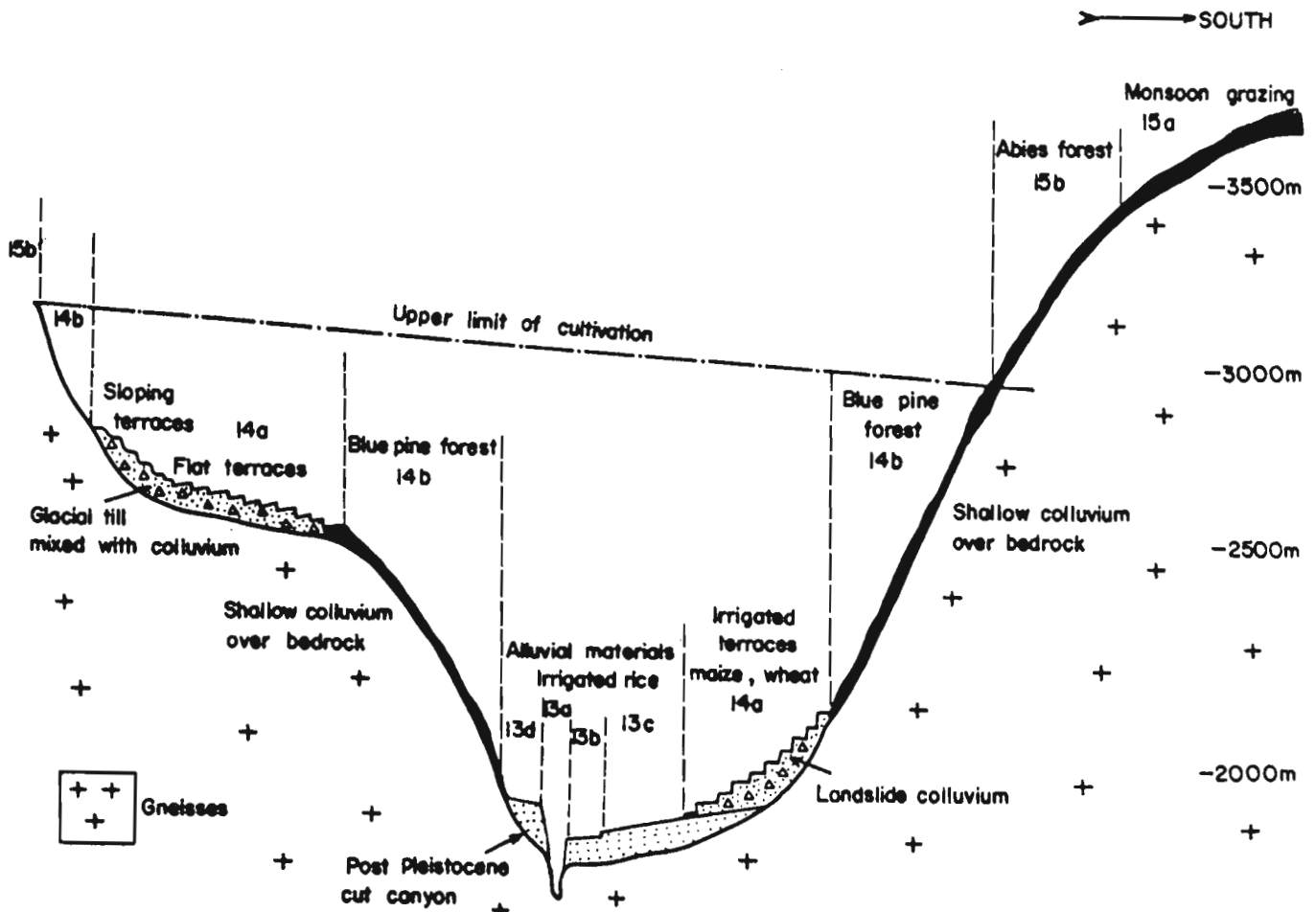
Precambrian to Eocene phyllites, quartzites, schists, limestones and gneisses, generally deeply weathered, Subtropical to Warm Temperate.

Land System	Landform	Land Unit	Dominant Soils	Dominant Slopes	Dominant Texture	Seasonal Range of Depth to Water Table	Drainage
9	Alluvial Plains and Fans (depositional)	9a river channel	Psamment Ustorthents	<1°	Fragmental Sandy	0 - 2m	variable
		9b alluvial plains	Ustifluvents Fluvaquents Ustochrepts	<1°	Loamy/ Bouldery	0 - 2m	well
		9c alluvial fans	Ustochrepts Haplustalfs	1 - 5°	Loamy/ Bouldery	1 - 15m	well
10	Ancient Lake and River Terraces (Tars) (erosional)	10a non-dissected	Typic & Rhodic Haplustalfs Ustochrepts	0 - 5°	Loamy	> 2m	well
		10b dissected	"	0 - 5°	Loamy	> 2m	well
11	Moderately to Steeply Sloping Mountainous Terrain		Typic, Rhodic, Udic, Anthropic Subgroups of Ustochrepts Dystrochrepts Haplobrepts	< 30°	Loamy Skeletal	> 50cm to bedrock	moderately well to well
12	Steeply to Very Steeply Sloping Mountainous Terrain		Lithic Subgroups of H and Ustorthents	> 30°	Loamy Skeletal	< 50cm to bedrock	well

Source: Carson 1990:19



Annex 9: Schematic Cross Section of Land Systems in the High Mountain Region



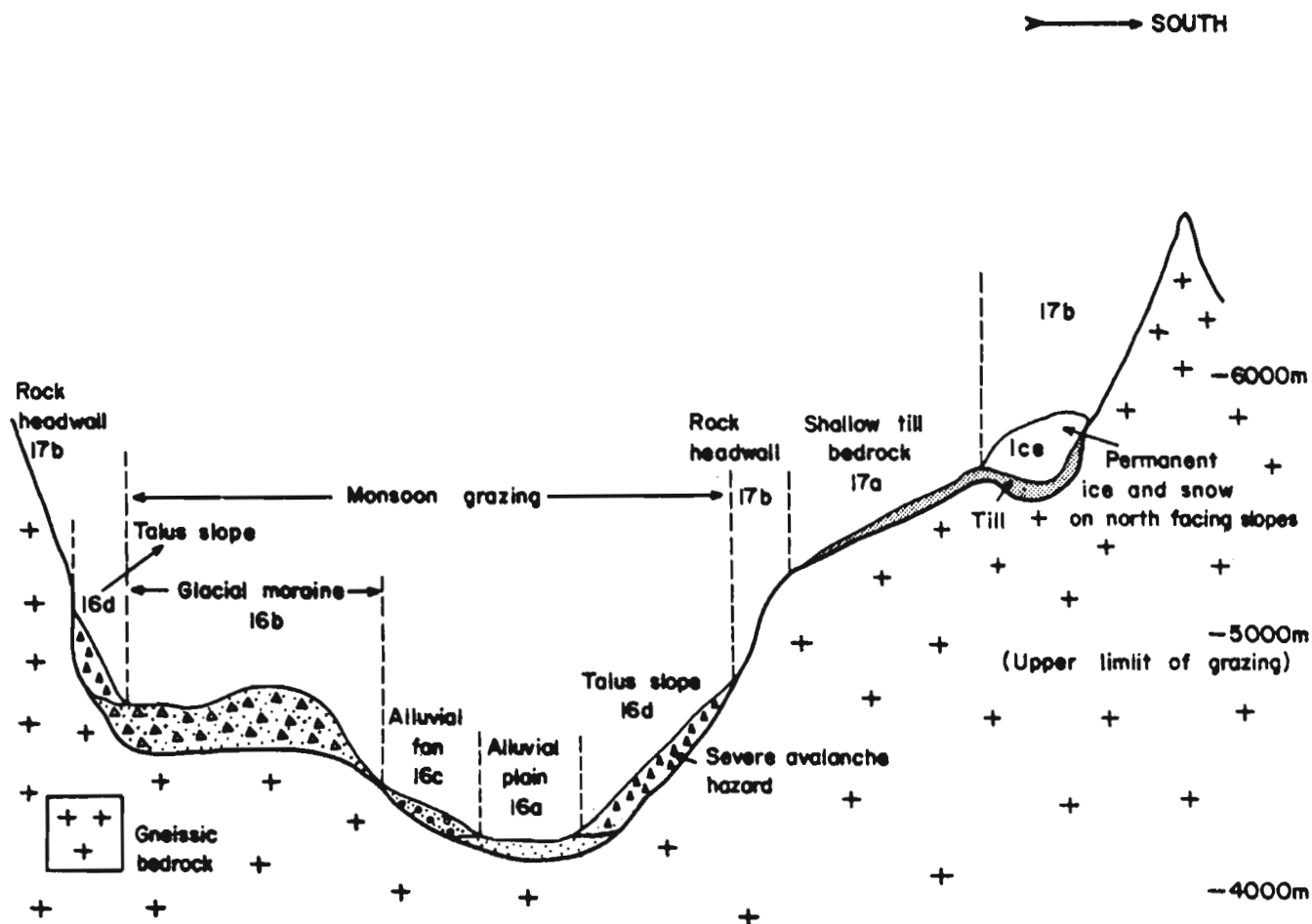
# **HIGH MOUNTAIN REGION**

Precambrian to Eocene gneisses, quartzites, schists, phyllites and limestones, generally not deeply weathered; Glaciated; Warm Temperate to Alpine.

13	Alluvial Plains Fans	13a active alluvial plain	Ustifluvents	<1°	Loamy	0-2m	variable
		13b recent alluvial plain	Eutrochrepts Dystrochrepts	<2°	Loamy/ Bouldery	0-2m	moderately well
		13c fans	"	1-10°	Loamy/ Bouldery	> 2m	well
		13d ancient alluvial terraces	"	<5°	Loamy/ Bouldery	> 2m	moderately well
14	Past Glaciated Mountainous Terrain below Upper Altitudinal Limit of Arable Agriculture	14a moderate to steep slopes	Anthropic and Typical Eutrochrepts Dystrochrepts Haplumbrepts	< 30°	Loamy Skeletal	> 50cm to bedrock	moderately well to well
		14b steep to very steep slopes	Lithic Subgroups of 14a and Ustorthents	> 30°	Loamy Skeletal	< 50cm to bedrock	well
15	Past Glaciated Mountainous Terrain above Upper Altitudinal Limit of Arable Agriculture	15a moderate to steep slopes	Typic and Lithic Haplumbrepts Cryumbrepts	< 40°	Loamy Skeletal	> 20cm to bedrock	moderately well
		15b very steep slopes	Lithic Subgroups of 15a and Cryorthents	> 40°	Loamy Skeletal	< 20cm to bedrock	moderately well



## Annex 10: Schematic Cross Section of Land Systems in the High Himalayan Region

**HIGH HIMALAYAN REGION**

Precambrian to Eocene gneisses, limestones, schists and granites;  
active glaciation; Subalpine to Arctic

<b>16</b>	Alluvial, Colluvial and Morainal Depositional Surfaces	<b>16a</b> glacio-alluvial plains	Cryumbrepts Cryorthents	< 20°	Loamy Skeletal	soil frozen > 4 months per year	poor
		<b>16b</b> morainal deposits	Cryumbrepts Cryorthents	< 40°	Loamy Skeletal	"	imperfect
		<b>16c</b> alluvial colluvial fans	Cryumbrepts Cryorthents	2 - 15°	Loamy Skeletal	"	moderately well
		<b>16d</b> colluvial slopes (talus)	Cryumbrepts Cryorthents	10-35°	Fragmental Loamy	"	well
<b>17</b>	Steeply to Very Steeply Sloping Mountainous Terrain	<b>17a</b> shallow till or colluvium over bedrock	Lithic Cryumbrepts Cryorthents	< 40°	Fragmental Loamy	< 50cm to bedrock	well
		<b>17b</b> rock headwalls	Rock	> 40°	—	bedrock at surface	rapid

Source: Carson 1990:27



Annex 11

## LAND CAPABILITY LEGEND

### CLASSES

- Class I** Lands are nearly level (slopes  $< 1^\circ$ ) and soils are deep. There are few limitations for arable agriculture or forestry
- Class II** Lands are gently sloping (slopes  $1-5^\circ$ ) and soils are deep and well drained. Terracing or contouring is necessary to control erosion when used for arable agriculture, and maintenance of ground cover is required for forestry related useage
- Class III** Lands are moderately to strongly sloping (slopes  $5-30^\circ$ ) and soils are 50 to 100cm deep and well drained. There are few limitations to traditional forest use provided adequate ground cover is maintained. Terracing is mandatory to control erosion when used for arable agriculture. Under the existing agricultural system a large portion of class III land is required for fodder production and grazing in order to maintain the productivity of the cultivated lands [see report].
- Class IV** Lands are either too steep to be terraced and cultivated ( $>30^\circ$  slope), or lie above the altitudinal limit of arable agriculture. Soils are more than 20cm deep and well to imperfectly drained. These lands are suitable for fuelwood, fodder and timber production provided a good, permanent vegetative cover is maintained to minimize erosion.
- Class V** Soils are more than 20cm deep and slopes are less than  $30^\circ$  on lands which are alpine (above treeline), or are river terraces that are frequently flooded. These lands will not support tree growth but have few limitations when used for fodder collection or grazing.
- Class VI** This class includes areas with slopes of  $40$  to  $50^\circ$ , or gentler slopes with soils less than 20cm deep. These lands are considered fragile because of extreme erosion hazard and/or poor regeneration potential.
- Class VII** This class consists of rock and ice.

### SUBCLASSES (Temperature regimes)

A	Sub-tropical	( $< 1000\text{m}$ )	( $> 20^\circ\text{C}$ )
B	Warm temperate	( $1000-2000\text{m}$ )	( $15-20^\circ\text{C}$ )
C	Cool temperate	( $2000-3000\text{m}$ )	( $10-15^\circ\text{C}$ )
D	Alpine	( $3000-4500\text{m}$ )	( $3-10^\circ\text{C}$ )
E	Arctic	( $> 4500\text{m}$ )	( $< 3^\circ\text{C}$ )

### SUBDIVISIONS (Moisture regimes)

s	semiarid
u	subhumid
h	humid
p	perhumid

## IRRIGATION CLASSIFICATION LEGEND

The USBR Land Classification is used in part to identify the arable lands according to their suitability for irrigation agriculture. In mountainous areas only class I and II are given irrigation ratings.

Two classes for both diversified croplands and wetland ricelands represent lands with progressively less favourable physical characteristics. Two classes identify nonarable lands.

The subclasses used indicate deficiencies in soils, topography or drainage.

### CLASSES

- 1 Diversified crops — arable (suitable)
- 2 Diversified crops — arable (moderately suitable)
- 1R Wetland rice — arable (suitable)
- 2R Wetland rice — arable (moderately suitable)
- 5 Nonarable — tentative
- 6 Nonarable

### SUBCLASSES

- s Soil deficiency
- t Topography deficiency
- d Drainage deficiency

### MAP SYMBOL EXPLANATION

- IVBCU Dominant Subclasses, Warm temperate and cool temperate
- IVBCU Dominant Subdivision, subhumid
- IVBCU Dominant Capability Class IV

#### Denominator

- Irrigation Suitability (USBR) Class 2 for
- Diversified Crops, arable with a
- topographic deficiency

II A h

2T

#### Numerator

- Dominant Capability Class 2
- Dominant Subclass, Subtropical
- Dominant Subdivision, humid

### NOTES

- Map unit designations show dominant capability only.
- These maps are to be used in conjunction with the Land Capability Report.

Source: LRMP 1986b



## Annexes

### Annex 12: Suitability categories for fruit crops

Fruit crops	Suitable areas: requirements			Moderately suitable areas: requirements		
	temperature °C	altitude approx. masl	land unit (LRMP)	temperature °C	altitude approx. masl	land unit (LRMP)
<i>Tropical fruits</i>						
mango	> 21	0 - 800	9b, 9c, 10a, 10b, 11	> 21	0 - 800	12
				18.5 - 21	800 - 1,300	9b, 9c, 10a, 10b, 11, 12
pineapple	> 21	0 - 800	9b, 9c, 10a, 10b, 11	> 21	0 - 800	12
				18.5 - 21	800 - 1,300	9b, 9c, 10a, 10b, 11, 12
banana	> 20	0 - 1,000	9b, 9c, 10a, 10b, 11	> 20	0 - 1,000	12
				17.5 - 20	1,000 - 1,500	9b, 9c, 10a, 10b, 11, 12
<i>Citrus fruits</i>						
<i>suntala</i>	18 - 21	800 - 1,400	9c, 10a, 10b, 11	18 - 21	800 - 1,400	9, 9b, 12
				21.0 - 21.5 16.5 - 18.0	700 - 800 1,400 - 1,700	9, 9b, 9c, 10a, 10b, 11, 12
<i>junar</i>	18 - 21	800 - 1,400	9c, 10a, 10b, 11	18 - 21	800 - 1,400	9, 9b, 12
				21.0 - 21.5 17.0 - 18.0	700 - 800 1,400 - 1,600	9, 9b, 9c, 10a, 10b, 11, 12
lime	18 - 21	800 - 1,400	9c, 10a, 10b, 11	18 - 21	800 - 1,400	9, 9b, 12
				21.0 - 23.5 17.0 - 18.0	300 - 800 1,400 - 1,600	9, 9b, 9c, 10a, 10b, 11, 12



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## Annex 12: continued

Fruit crops	Suitable areas: requirements			Moderately suitable areas: requirements		
	temperature °C	altitude approx. masl	land unit (LRMP)	temperature °C	altitude approx. masl	land unit (LRMP)
Warm temperate fruits						
peach	15 - 19	1,200 - 2,000	9c, 10a, 10b, 13c	15 - 19	1,200 - 2,000	9, 9b, 11, 12, 13b, 13d
				19.0 - 19.5 13.5 - 15.0	1,100 - 1,200 2,000 - 2,300	9, 9b, 9c, 10a, 10b, 11, 12*, 13b, 13c, 13d
plum	15 - 19	1,200 - 2,000	9, 9b, 9c 10a, 10b, 11, 13c	15 - 19	1,200 - 2,000	12, 13b, 13d
				19.0 - 19.5 13.5 - 15.0	1,100 - 1,200 2,000 - 2,300	9, 9b, 9c, 10a, 10b, 11, 12 13b, 13c, 13d
Temperate fruits						
apple	11 - 16	1,800 - 2,800	9b, 9c, 10a, 10b, 11, 12, 13c 14a, 14b	11 - 16	1,800 - 2,800	9, 13b, 13d 15a, 16c
				16.0 - 18.0 9.5 - 11.0	1,500 - 1,800 2,800 - 3,100	9, 9b, 9c, 10a, 10b, 11, 12 13b, 13c, 13d, 14a, 14b 15a, 16c
pear	12.5 - 18	1,400 - 2,500	9c, 10a, 10b, 11, 13c, 13d, 14a	12.5 - 18	1,400 - 2,500	9, 9b 12, 13b 14b, 15a
				18.0 - 18.5 11.0 - 12.5	1,300 - 1,400 2,500 - 2,800	9, 9b, 9c, 10a, 10b, 11, 12 13b, 13c, 13d, 14a, 14b 15a
walnut	11 - 16	1,800 - 2,800	9c, 10a, 10b, 13c	11 - 16	1,800 - 2,800	9, 9b, 11 13b, 13d 14a
				16.0 - 16.5 10.0 - 11.0	1,700 - 1,800 2,800 - 3,000	9, 9b, 9c, 10a, 10b, 11 13b, 13c, 13d, 14a



## Annexes

**Annex 13: Area size of forest density classes in relation to agroclimatic zones**

Forest density; maturity	Agroclimatic zone	Area (ha)	% of total per agroclimatic zone	
			% of total	% of forest
shrubland (< 10%)	subtropical/subhumid	7806.3	11.1	25.0
	subtropical/humid	1565.2	12.8	33.0
	warm temperate/subhumid	4076.5	19.4	42.6
	warm temperate/humid	4810.5	21.6	42.8
	cool temperate/subhumid	809.1	10.2	12.9
	cool temperate/humid	1927.4	5.3	6.6
	cool temperate/perhumid	114.7	24.8	42.4
	alpine/humid	575.1	3.0	6.2
	alpine/perhumid	1628.8	3.5	14.8
	alpine/no data	645.8	9.4	67.3
	arctic	327.3	0.3	86.8
low (10-40%); small timber	subtropical/subhumid	11851.2	16.8	38.0
	subtropical/humid	2544.8	20.7	53.6
	warm temperate/subhumid	2816.4	13.4	29.4
	warm temperate/humid	4405.7	19.8	39.2
	cool temperate/subhumid	1260.0	15.9	20.1
	cool temperate/humid	6074.2	16.7	20.9
	alpine/humid	1558.4	8.1	16.7
	alpine/perhumid	606.6	1.3	5.5
	alpine/no data	0.1	0.0	0.0
	arctic	41.7	0.0	11.1
medium (40-70%); small timber	subtropical/subhumid	11287.6	16.0	36.2
	subtropical/humid	640.0	5.2	13.5
	warm temperate/subhumid	1285.8	6.1	13.4
	warm temperate/humid	1232.5	5.5	11.0
	cool temperate/subhumid	949.4	12.0	15.2
	cool temperate/humid	3376.6	9.3	11.6
	alpine/humid	780.8	4.1	8.4
	alpine/perhumid	354.9	0.8	3.2
	alpine/no data	4.0	0.1	0.4
high (> 70%); small timber	subtropical/subhumid	213.0	0.3	0.7
low (10-40%); mature trees	warm temperate/subhumid	23.3	0.1	0.2
	cool temperate/subhumid	759.1	9.6	12.1
	cool temperate/humid	1587.7	4.4	5.5
	alpine/humid	1186.9	6.2	12.7
	alpine/perhumid	455.9	1.0	4.1
	alpine/no data	5.7	0.1	0.6



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Forest density; maturity	Agroclimatic zone	Area (ha)	% of total	% of forest
			per agroclimatic zone	
mature trees	warm temperate/subhumid	680.0	3.2	7.1
	warm temperate/humid	660.5	3.0	5.9
	cool temperate/subhumid	1818.0	22.9	29.1
	cool temperate/humid	8372.9	23.1	28.8
	cool temperate/perhumid	0.7	0.1	0.2
	alpine/humid	2137.1	11.1	23.0
	alpine/perhumid	1147.9	2.5	10.4
	alpine/no data	4.1	0.1	0.4
no density data	subtropical/subhumid	0.8	0.0	0.0
	warm temperate/subhumid	695.8	3.3	7.3
	warm temperate/humid	132.6	0.6	1.2
	cool temperate/subhumid	662.3	8.3	10.6
	cool temperate/humid	7701.8	21.2	26.5
	cool temperate/perhumid	155.1	33.6	57.4
	alpine/subhumid	40.0	96.6	100.0
	alpine/humid	3071.5	15.9	33.0
	alpine/perhumid	6795.3	14.7	61.8
	alpine/no data	300.4	4.4	31.3
	arctic	7.9	0.0	2.1
	subtropical/humid	7516.1	61.3	
non-forest area	subtropical/subhumid	39368.2	55.8	
	warm temperate/subhumid	11440.3	54.4	
	warm temperate/humid	11009.6	49.5	
	cool temperate/subhumid	1680.9	21.2	
	cool temperate/humid	7242.8	20.0	
	cool temperate/perhumid	191.3	41.4	
	alpine/subhumid	1.4	3.4	
	alpine/humid	9948.7	51.7	
	alpine/perhumid	35095.3	76.2	
	alpine/no data	5939.7	86.1	
	arctic	121048.7	99.7	
total		364461.7		



Annex 14: Area size of forest density classes in relation to aspect

Forest density; maturity	Aspect	Area (ha)	% of total	% of forest
			per aspect	
shrubland (< 10%)	level	816.9	5.7	19.9
	N	1,582.1	3.7	11.2
	NE	1,207.6	3.0	9.8
	E	1,825.8	4.6	17.0
	SE	3,824.3	8.4	28.9
	S	4,361.6	8.4	29.9
	SW	3,934.2	8.7	27.3
	W	4,012.1	9.6	25.5
	NW	2,725.9	6.6	18.7
low (10-40%); small timber	level	1,326.7	9.2	32.4
	N	3,591.4	8.3	25.3
	NE	3,122.5	7.7	25.3
	E	3,499.6	8.7	32.6
	SE	4,125.0	9.0	31.2
	S	4,494.6	8.6	30.8
	SW	3,552.5	7.8	24.7
	W	3,683.8	8.8	23.4
	NW	3,727.8	9.1	25.6
medium (40-70%); small timber	level	1,761.1	12.2	43.0
	N	2,129.7	4.9	15.0
	NE	1,569.8	3.9	12.7
	E	1,498.2	3.7	14.0
	SE	2,211.9	4.8	16.7
	S	2,064.9	4.0	14.1
	SW	3,062.0	6.7	21.3
	W	2,903.2	6.9	18.4
	NW	2,703.5	6.6	18.6
high (> 70%); small timber	level	10.9	.1	.3
	SE	4.0	.0	.0
	S	92.0	.2	.6
	SW	83.8	.2	.6
	W	22.3	.1	.1
low (10-40%); mature trees	level	18.2	.1	.4
	N	528.6	1.2	3.7
	NE	414.3	1.0	3.4
	E	356.3	.9	3.3
	SE	150.3	.3	1.1
	S	498.9	1.0	3.4
	SW	636.4	1.4	4.4
	W	747.3	1.8	4.7
	NW	651.5	1.6	4.5



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Forest density; maturity	Aspect	Area (ha)	% of total	% of forest
			per aspect	
medium (40-70%); mature trees	level	28.0	.2	.7
	N	2,531.4	5.9	17.8
	NE	2,516.6	6.2	20.4
	E	2,040.4	5.1	19.0
	SE	1,271.3	2.8	9.6
	S	1,026.8	2.0	7.0
	SW	1,388.2	3.1	9.6
	W	1,888.4	4.5	12.0
	NW	2,122.0	5.2	14.6
no density data	level	136.8	.9	3.3
	N	3,825.8	8.9	27.0
	NE	3,511.8	8.7	28.5
	E	1,515.9	3.8	14.1
	SE	1,635.3	3.6	12.4
	S	2,060.7	4.0	14.1
	SW	1,750.5	3.9	12.1
	W	2,497.9	6.0	15.9
	NW	2,629.5	6.4	18.1
non-forest area	level	10,354.4	71.6	
	N	28,970.0	67.1	
	NE	28,116.8	69.5	
	E	29,380.9	73.2	
	SE	32,497.1	71.1	
	S	37,565.2	72.0	
	SW	30,983.2	68.3	
	W	26,183.5	62.4	
	NW	26,446.2	64.5	
total		364,408.0		



Annex 15: Total area, agricultural and cultivated land, forest and shrubland, and grazing land in relation to agroclimatic zones and aspect

Agroclimatic zone	Total area		Agricultural land		Net cultivated land		Forest land		Shrubland		Grazing land	
Aspect	ha	% of total area	ha	% of agri.	ha	% of agri.	ha	% of total area	ha	% of total area	ha	% of total area
subtropical/subhumid level	10,371.7	62.5	6,480.6	56.4	3,651.9	56.4	2,839.9	27.4	604.0	5.8	12.1	.1
	N	6,837.3	3,899.6	47.5	1,850.7	47.5	2,390.6	35.0	459.1	6.7	44.2	.6
	NE	6,081.4	3,292.3	43.6	1,434.7	43.6	2,505.5	41.2	232.5	3.8	39.9	.7
	E	5,685.6	3,029.6	47.5	1,438.5	47.5	2,143.5	37.7	355.9	6.3	109.7	1.9
	SE	9,085.1	4,327.3	47.6	2,104.2	48.6	3,054.8	33.6	1,161.4	12.8	334.1	3.7
	S	10,103.8	4,554.5	45.1	2,024.4	44.4	3,353.4	33.2	1,838.5	18.2	287.5	2.8
	SW	8,867.6	4,173.0	47.1	1,858.3	44.5	3,073.1	34.7	1,298.6	14.6	261.2	2.9
	W	6,094.0	3,199.5	52.5	1,465.2	45.8	1,755.8	28.8	1,089.6	17.9	30.2	.5
	NW	7,170.6	4,067.4	56.7	1,971.1	48.5	2,202.5	30.7	763.9	10.7	80.4	1.1
subtropical/humid level	654.7	65.7	430.3	50.5	217.1	50.5	195.2	29.8	26.8	4.1		
	N	1,357.6	1,058.6	55.4	586.3	55.4	273.2	20.1	25.9	1.9		
	NE	1,113.6	958.0	54.5	521.9	54.5	104.9	9.4	50.8	4.6		
	E	1,031.5	586.3	46.3	271.4	46.3	319.8	31.0	125.4	12.2		
	SE	1,659.0	943.0	51.4	484.3	51.4	399.1	24.1	316.2	19.1	.1	.1
	S	1,213.6	563.7	45.8	258.0	45.8	345.8	28.5	298.6	24.6		
	SW	1,594.9	900.0	48.5	436.8	48.5	369.2	23.2	322.6	20.2	2.7	.2
	W	1,808.2	905.6	46.7	422.8	46.7	617.7	34.2	278.7	15.4	6.2	.3
	NW	1,766.6	1,102.2	53.4	589.1	53.4	544.1	30.8	120.1	6.8	.2	.2
warm temperate/subhumid level	172.0	57.4	98.7	49.8	49.1	49.8	12.3	7.1	45.6	26.5	9.8	5.7
	N	2,542.9	1,080.7	43.7	472.5	43.7	1,055.0	41.5	313.8	12.3	93.5	3.7
	NE	1,944.5	660.8	41.0	270.7	41.0	804.6	41.4	246.9	12.7	221.8	11.4
	E	2,805.6	891.4	39.1	348.4	39.1	761.2	27.1	345.0	12.3	783.2	27.9
	SE	2,834.6	1,147.2	40.5	458.0	39.9	485.6	17.1	665.4	23.5	463.0	16.3
	S	2,366.4	797.7	33.7	317.1	39.7	351.9	14.9	725.4	30.7	408.6	17.3
	SW	2,221.7	615.1	27.7	258.3	42.0	485.1	21.8	446.1	20.1	614.0	27.6
	W	3,113.2	1,093.4	35.1	458.2	41.9	822.3	26.4	710.5	22.8	413.3	13.3
	NW	3,016.8	1,536.2	50.9	694.2	45.2	723.4	24.0	577.5	19.1	173.8	5.8



Agroclimatic zone	Total area		Agricultural land		Net cultivated land		Forest land		Shrubland		Grazing land	
Aspect	ha	% of total area	ha	% of agri.	ha	% of agri.	ha	% of total area	ha	% of total area	ha	% of total area
warm temperate/humid												
level	261.1	61.7	161.2	55.5	89.4	55.5	32.8	12.6	58.0	22.2	9.1	3.5
N	2,146.1	50.9	1,092.4	55.8	609.7	55.8	768.9	35.8	269.1	12.5	15.7	.7
NE	1,872.6	53.6	1,003.2	44.7	447.9	44.7	683.0	36.5	174.7	9.3	11.8	.6
E	1,906.7	45.7	871.8	42.9	373.8	42.9	598.0	31.4	420.8	22.1	15.7	.8
SE	2,735.6	36.5	999.0	44.2	441.6	44.2	666.5	24.4	974.4	35.6	95.5	3.5
S	2,607.9	38.1	994.6	45.0	447.8	45.0	783.9	30.1	726.8	27.9	102.1	3.9
SW	3,526.9	50.1	1,765.4	49.5	874.7	49.5	931.6	26.4	786.6	22.3	42.8	1.2
W	3,974.0	51.5	2,047.7	55.0	1,125.2	55.0	1,027.8	25.9	828.9	20.9	69.5	1.7
NW	3,206.1	52.5	1,682.2	59.2	995.5	59.2	937.7	29.2	566.5	17.7	19.6	.6
cool temperate/subhumid												
level	24.1	16.9	4.1	47.0	1.9	47.0	20.0	83.1				.5
N	1,201.3	6.9	83.2	46.2	38.5	46.2	971.0	80.8	141.0	11.7	6.1	6.6
NE	748.9	6.8	51.3	45.4	23.3	45.4	589.5	78.7	58.7	7.8	49.5	17.6
E	876.0	11.4	100.0	37.0	37.0	37.0	585.8	66.9	30.5	3.5	154.2	15.1
SE	823.2	7.3	60.2	30.7	18.5	30.7	552.8	67.2	68.3	8.3	124.7	29.0
S	948.2	8.3	78.3	40.0	31.3	40.0	432.5	45.6	81.4	8.6	274.7	25.5
SW	890.3	6.1	54.3	37.9	20.6	37.9	456.8	51.3	104.2	11.7	226.8	7.6
W	1,051.5	3.8	39.5	40.0	15.8	40.0	735.6	70.0	177.8	16.9	79.4	2.6
NW	1,375.4	5.9	81.1	43.9	35.6	43.9	1,105.0	80.3	147.3	10.7	35.2	.2
cool temperate/humid												
level	44.0						37.9	86.1	6.0	13.7	.1	3.9
N	4,653.1	2.1	95.8	46.1	44.2	46.1	4,274.3	91.9	48.9	1.1	179.8	4.4
NE	4,255.8	3.7	155.1	42.2	65.4	42.2	3,759.6	88.3	113.6	2.7	183.6	18.2
E	3,500.4	8.7	303.9	39.2	119.0	39.2	2,271.2	64.9	122.4	3.5	634.8	17.1
SE	3,390.3	7.5	250.7	40.8	102.3	40.8	2,006.8	59.2	253.1	7.5	582.3	23.4
S	5,190.4	4.2	216.5	42.4	91.9	42.4	2,865.0	55.2	251.1	4.8	1,212.3	10.9
SW	5,233.5	5.1	268.9	35.7	96.1	35.7	3,276.0	62.6	504.4	9.6	560.2	4.0
W	5,604.4	2.1	118.2	41.8	49.4	41.8	4,553.0	81.2	455.2	8.1	221.8	3.1
NW	4,843.5	1.3	60.0	52.5	31.5	52.5	4,200.1	86.7	287.2	5.9	148.6	



# Annexes

Agroclimatic zone	Total area		Agricultural land		Net cultivated land		Forest land		Shrubland		Grazing land	
Aspect	ha	% of total area	ha	% of agri.	ha	% of agri.	ha	% of total area	ha	% of total area	ha	% of total area
alpine/humid level	70.4						45.3	64.3			5.1	7.3
N	2,334.8						1,297.2	55.6	23.4	1.0	601.9	25.8
NE	1,827.3						994.9	54.4	16.0	.9	570.6	31.2
E	1,791.2						973.3	54.3	22.1	1.2	521.0	29.1
SE	2,277.7	.7	15.6	32.4	5.1	32.4	944.1	41.5	142.4	6.3	792.4	34.8
S	3,301.5	.1	2.1	47.0	1.0	47.0	1,230.2	37.3	111.9	3.4	1,441.7	43.7
SW	2,349.1	.7	16.8	43.8	7.4	43.8	960.2	40.9	70.2	3.0	923.2	39.7
W	2,472.3	.4	8.7	47.0	4.1	47.0	1,217.7	49.3	95.2	3.9	651.0	26.4
NW	2,851.1						1,090.6	38.3	93.5	3.3	1,000.7	35.1
alpine/perhumid level	726.6						86.7	11.9	76.4	10.5	126.6	17.4
N	5,771.1	.7	41.8	63.1	26.4	63.1	1,525.0	26.4	70.5	1.2	2,748.1	47.6
NE	6,422.2	.8	51.4	52.3	26.9	52.3	1,690.8	26.3	272.2	4.2	2,539.4	39.5
E	5,564.1	.3	15.6	35.4	5.5	35.4	1,249.9	22.5	346.4	6.2	1,995.4	35.9
SE	5,333.8	1.2	61.4	30.3	18.6	30.3	1,241.2	23.3	185.7	3.5	1,758.4	33.0
S	6,755.7	2.0	134.7	51.0	68.7	51.0	855.3	12.7	154.6	2.3	3,240.8	48.0
SW	5,644.5	1.5	86.4	51.7	44.6	51.7	892.0	15.8	235.2	4.2	2,409.9	42.7
W	5,281.8	.1	4.8	47.0	2.3	47.0	941.5	17.8	273.0	5.2	2,100.1	39.8
NW	4,545.1						876.3	19.3	12.3	.3	2,072.3	45.6
alpine/no data level	152.2						7.0	4.6			37.3	24.5
N	732.4		103.3	63.1	65.2	63.1	47.1	6.4	230.5	31.5	338.5	46.2
NE	359.7		.1				.2		32.1	8.9	137.6	38.3
E	881.0	1.5	13.4	63.1	8.5	63.1	4.0	.4			216.7	24.6
SE	933.0	9.9	92.7	63.1	58.6	63.1	16.1	2.1	30.5	4.0	233.9	25.1
S	755.9	.9	6.6	63.1	4.1	63.1	25.0	3.2	130.7	16.7	452.7	59.9
SW	780.9	5.3	41.6	63.1	26.3	63.1	59.8	4.8	66.9	5.4	383.5	49.1
W	1,247.9	2.3	28.2	63.1	17.8	63.1	151.1	14.4	154.9	14.8	692.6	55.5
NW	1,046.2	5.3	55.6	63.1	35.1	63.1					549.4	52.5



Agroclimatic zone	Total area		Agricultural land		Net cultivated land		Forest land		Shrubland		Grazing land	
	ha	% of total area	ha	% of agri.	ha	% of total area	ha	% of total area	ha	% of total area	ha	% of total area
arctic level	1,598.8										234.6	14.7
N	15,392.5										3,077.5	20.0
NE	15,725.2						1.1		5.1		2,400.2	15.3
E	16,011.0						6.5		56.7	.4	2,316.1	14.5
SE	16,534.7						38.8	.2	52.3	.3	2,767.9	16.7
S	18,824.4						.8		141.8	.8	4,042.8	21.5
SW	14,137.1						.5		35.5	.3	2,448.8	17.3
W	11,160.8						1.9		35.3	.3	1,675.2	15.0
NW	11,070.8								.1		1,492.3	13.5
no data	1,229.5		159.1		100.3		155.6		24.9		48.8	
total	364,300.0		66,009.0		31,680.0		89,739.9		24,300.0		58,490.0	



# Annexes

**Annex 16: Size of agricultural land in relation to cultivation types and aspect**

Type	Aspect	Agricultural land			Cropped land		
		ha	% of aspect	% of total	ha	% of aspect	% of total
C1	level	417.7	5.7		117.7	2.9	
	N	441.6	6.0		124.5	3.4	
	NE	608.9	9.9		171.6	6.2	
	E	290.2	5.0		81.8	3.1	
	SE	545.2	6.9		153.7	4.2	
	S	1072.0	14.6		302.2	9.3	
	SW	1190.6	15.0		335.6	9.3	
	W	551.8	7.4		155.5	4.4	
C2	NW	396.6	4.6	8.4	111.8	2.6	4.9
	level	620.5	8.5		291.5	7.1	
	N	1097.0	14.9		515.4	14.3	
	NE	576.7	9.3		270.9	9.7	
	E	500.6	8.6		235.2	9.0	
	SE	503.2	6.4		236.4	6.4	
	S	555.8	7.6		261.1	8.0	
	SW	644.6	8.1		302.8	8.4	
C3	W	873.0	11.7		410.1	11.5	
	NW	1264.0	14.7	10.1	593.8	13.6	9.8
	N	45.8	0.6		30.1	0.8	
	NE	11.5	0.2		7.6	0.3	
	E	8.7	0.1		5.7	0.2	
	SE	11.5	0.1		7.6	0.2	
	S	21.8	0.3		14.3	0.4	
	SW	68.2	0.9		44.9	1.2	
T1	W	75.7	1.0		49.8	1.4	
	NW	173.3	2.0	0.6	114.0	2.6	0.9
	level	454.7	6.2		128.2	3.1	
	N	582.2	7.9		164.1	4.5	
	NE	1232.0	20.0		347.3	12.4	
	E	1526.9	26.3		430.4	16.5	
	SE	1498.3	19.0		422.3	11.4	
	S	1046.4	14.2		295.0	9.1	
T2	SW	1019.6	12.9		287.4	7.9	
	W	1097.6	14.7		309.4	8.7	
	NW	922.8	10.7	14.2	260.1	6.0	8.3
	level	824.8	11.3		387.5	9.4	
	N	3307.6	45.0		1553.9	43.0	
	NE	2454.5	39.8		1153.1	41.3	
	E	2270.0	39.1		1066.4	41.0	
	SE	3163.0	40.0		1485.9	40.2	
	S	3540.6	48.2		1663.3	51.3	
	SW	3248.8	41.0		1526.3	42.1	
	W	2819.1	37.9		1324.4	37.2	
	NW	2793.7	32.5	37.0	1312.5	30.1	36.2



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## Annex 16: continued

Type	Aspect	Agricultural land			Cropped land		
		ha	% of aspect	% of total	ha	% of aspect	% of total
T3	level	724.6	9.9		476.6	11.6	
	N	1663.8	22.6		1094.3	30.3	
	NE	1070.1	17.3		703.8	25.2	
	E	782.0	13.5		514.3	19.8	
	SE	920.4	11.6		605.3	16.4	
	S	340.0	4.6		223.6	6.9	
	SW	894.3	11.3		588.2	16.2	
	W	1296.1	17.4		852.4	23.9	
	NW	1882.5	21.9	14.5	1238.1	28.4	19.9
V	level	35.8	0.5		21.3	0.5	
	N	16.5	0.2		9.8	0.3	
	NE	37.9	0.6		22.5	0.8	
	E	148.0	2.5		87.9	3.4	
	SE	342.6	4.3		203.4	5.5	
	S	75.0	1.0		44.5	1.4	
	SW	54.5	0.7		32.3	0.9	
	W	85.3	1.1		50.6	1.4	
	NW	146.9	1.7	1.4	87.2	2.0	1.8
F	level	4251.0	58.0		2684.0	65.4	
	N	195.9	2.7		123.7	3.4	
	NE	180.6	2.9		114.0	4.1	
	E	285.7	4.9		180.4	6.9	
	SE	918.7	11.6		580.0	15.7	
	S	698.9	9.5		441.3	13.6	
	SW	806.1	10.2		509.0	14.0	
	W	648.1	8.7		409.2	11.5	
	NW	1006.8	11.7	13.6	635.7	14.6	17.9
no data		132.2		0.2	83.7		0.3
total		66009.0			31680.0		

C : sloping terrace

T : level terrace

V : valley floor

F : foot slopes/tars



Annex 17: Cropped area under different rice-based cropping systems in relation to agroclimatic zones and aspect

Agroclimatic zone	Aspect	Cropping pattern (area in hectares)										% of cropped area
		a	a2	b	b <sub>-</sub>	d <sub>-</sub>	e	e2	u	u <sub>-</sub>	r	
subtropical/subhumid	level	583.3	197.0		195.3	434.1	307.5	115.7	432.6	6.5	201.8	67.9
	N	228.4	8.2		268.0	223.7	93.9	1.7	102.5	0.8	2.1	50.2
	NE	112.1	18.9		186.5	203.8	49.9	14.9	86.2	4.7	7.0	47.7
	E	97.2	27.4		160.2	143.5	62.9	6.4	145.3	9.8	5.3	45.7
	SE	220.0	57.3		166.3	227.9	122.0	20.5	217.3	15.9	14.1	50.5
	S	151.7	49.3		140.5	280.9	156.1	10.4	180.9	19.3	10.3	49.4
	SW	152.3	52.9		104.5	241.4	123.2	22.8	164.9	18.8	6.6	47.8
	W	151.8	29.9		144.7	224.7	65.3	5.5	114.6	1.4	9.8	51.0
subtropical/humid	NW	240.8	20.9		197.5	421.7	71.5	7.0	120.2		11.5	55.4
	level	36.4			4.7	19.4	55.3		34.8	7.4		72.8
	N	49.2	0.7	0.8	65.0	38.5	19.7		78.3	47.0		51.9
	NE	77.5			107.3	11.2	15.6		23.3	16.4		49.9
	E	50.5	3.5	1.5	26.5	15.9	25.7		23.6	4.8		56.0
	SE	103.5	12.0	0.7	21.2	32.2	59.6		71.1	11.6		65.1
	S	39.8		0.4	19.5	13.3	27.7		28.5	6.2		52.5
	SW	83.0		0.3	23.4	36.2	58.6		27.9	11.7		55.2
warm temperate/subhumid	W	39.9	1.3	0.7	36.8	43.5	35.4		36.8	4.8		47.2
	NW	39.1	2.6		27.0	49.4	32.0		107.8	53.8		54.4
	level	0.1			1.8	2.8			8.6			27.1
	N	0.6			6.4	33.6	2.5		7.9			10.8
	NE	2.1			5.1	11.5	5.5		11.5			13.2
	E	9.6			18.0	12.4	1.5		23.7			18.7
	SE	1.3			9.5	9.8	2.8		60.3			18.2
	S	0.1			11.9	18.1	6.3		24.5			19.2
	SW	0.1			13.1	7.0	0.2		8.5			11.2
	W	1.5			12.3	6.1			18.4			8.3
	NW	8.3			15.8	15.9			17.0			8.2



Annex 17: continued

Agroclimatic zone	Aspect	Cropping pattern (area in hectares)										% of cropped area
		a	a2	b	b <sub>u</sub>	d <sub>u</sub>	e	e2	u	u <sub>u</sub>	r	
warm temperate/humid	level	3.6			7.9	0.1	20.7		13.5	4.2	0.4	56.4
	N	66.7			37.3	11.2	71.4		94.5	8.6		50.2
	NE	76.0		2.6	42.9	5.8	38.7		25.0	4.8		45.2
	E	31.3		7.5	33.4	3.3	27.3		22.5	9.9	0.2	36.2
	SE	23.4		4.6	29.8	4.4	9.9		60.8	25.9	0.2	36.0
	S	17.8		0.7	28.3	3.3	15.4		56.0	22.6	0.4	32.3
	SW	69.4		1.3	34.7	3.1	98.1		63.7	12.8	2.2	32.6
	W	61.9		5.8	29.7	11.9	205.0		137.2	3.3	5.0	40.9
	NW	49.6			20.0	4.5	241.0		199.5	7.4	3.1	52.9
cool temperate/humid	N								0.2			0.3
	NE								0.3			0.3
	E								0.1			0.1
	SE						0.1		0.5		0.1	0.8
	S								0.9		0.4	1.4
	SW										0.2	0.3
	W											
	NW											
total		2879.9	481.7	35.9	2252.8	2825.9	2128.5	205.2	2851.9	340.4	280.8	

Major cropping patterns

- a rice - fallow
- a2 rice - rice - fallow
- b rice - oilseed (b<sub>u</sub> upland rice)
- d rice - pulses (d<sub>u</sub> upland rice)
- e rice - cereal
- e2 rice - rice - cereal
- u maize - rice - fallow (u<sub>u</sub> upland rice)
- r maize - rice - winter crop



Annex 18: Cropped area under different maize-based cropping systems in relation to agroclimatic zones and aspect

Agroclimatic zone	Aspect	Cropping pattern (area in hectares)										% of cropped area
		u	u <sub>+</sub>	r	j	j2	k	l	w	x	y	
subtropical/subhumid	level	432.6	6.5	201.8		621.0	72.3	0.2	477.1			49.7
	N	102.5	0.8	2.1		823.0	19.5		78.6			55.5
	NE	86.2	4.7	7.0	0.7	598.6	0.9	1.7	147.1			59.0
	E	145.3	9.8	5.3	0.2	609.4	7.2	2.3	153.5			64.9
	SE	217.3	15.9	14.1	0.9	755.7	29.4	7.9	240.2			60.9
	S	180.9	19.3	10.3	0.5	847.7	8.0	1.1	142.4			59.8
	SW	164.9	18.8	6.6	3.3	703.2	9.6	2.3	157.2			57.4
	W	114.6	1.4	9.8	9.2	616.4	24.7	9.6	53.1			57.2
subtropical/humid	NW	120.2		11.5		769.3	5.3	15.7	81.6			50.9
	level	34.8	7.4			50.6	4.7		3.2			46.4
	N	78.3	47.0			273.7			2.6			69.7
	NE	23.3	16.4			261.0			0.2			57.7
	E	23.6	4.8			109.4	1.4	0.3	6.6			53.9
	SE	71.1	11.6			136.9	1.6	2.5	24.0			51.7
	S	28.5	6.2			105.7	5.9	3.4	4.0			59.6
	SW	27.9	11.7			173.3	11.7		8.0			53.3
warm temperate/subhumid	W	36.8	4.8			192.4	6.3		14.2			60.2
	NW	107.8	53.8			250.1			3.3			72.4
	level	8.6				29.1						76.8
	N	7.9			47.6	182.8		77.5	0.8			67.0
	NE	11.5			25.5	119.1		7.4	2.8		1.1	61.8
	E	23.7			12.6	159.6		8.5	10.9		1.1	62.1
	SE	60.3			9.1	263.7		40.0	13.5			84.4
	S	24.5			9.3	168.6		11.8	22.9			74.8
	SW	8.5			17.0	139.3		19.7	15.4			77.4
	W	18.4			22.8	223.8		63.4	3.5			72.4
	NW	17.0			41.9	338.1		111.4				73.2



## Annex 18: continued

Agroclimatic zone	Aspect	Cropping pattern (area in hectare)										% of cropped area
		u	u <sub>-</sub>	r	j	j2	k	l	w	x	y	
warm temperate/humid	level	13.5	4.2	0.4		32.4	10.9	0.4		1.2		58.0
	N	94.5	8.6		0.1	228.1	12.7	3.9				59.4
	NE	25.0	4.8			194.6	15.2	13.5			0.1	55.6
	E	22.5	9.9	0.2		181.4	11.0	21.9	0.5	0.5		65.0
	SE	60.8	25.9	0.2		223.6	5.6	20.9	0.6	0.6		78.0
	S	56.0	22.6	0.4		218.8	19.7	20.5	2.2	1.2		73.2
	SW	63.7	12.8	2.2		374.5	11.6	13.6	2.0	6.7		57.4
	W	137.2	3.3	5.0		422.0	9.0	6.5	4.0	15.1		54.4
	NW	199.5	7.4	3.1		318.3			0.5	9.4		55.8
cool temperate/subhumid	level				0.3	1.0						70.0
	N				1.1	9.5		9.2				51.6
	NE				3.9	7.4					0.2	49.3
	E				3.5	9.8		0.8				38.3
	SE				0.7	7.4		4.1				65.5
	S				4.0	15.8						63.2
	SW				2.7	8.4		2.8				67.7
	W				2.0	4.0		2.9				55.9
	NW				0.2	11.4		7.7				54.2
cool temperate/humid	N				3.0	5.3		0.3				19.6
	NE	0.2			9.9	14.2		0.1			4.3	44.0
	E	0.3			16.6	23.9		0.7			0.1	35.0
	SE	0.1			8.9	25.4		13.0				46.4
	S	0.5		0.1	0.1	31.2		4.5		0.4		40.6
	SW	0.9		0.4		33.9		0.7		1.1		38.7
	W			0.2		23.4		1.0		0.5		50.7
	NW				1.4	13.4		2.3				54.5
total		2851.9	340.4	280.8	259.2	11960.8	304.4	537.8	1675.9	36.9	6.9	

u maize - rice - fallow (u<sub>-</sub> upland rice) l maize - cereal k maize - mustard

r maize - rice - winter crop w maize - pulses

j maize or millet - fallow x maize - potato

j2 maize - millet y maize + potato - winter crop



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**MAPS**



Map 1

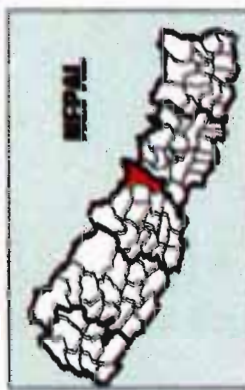
Gorkha District

Western Region of Nepal

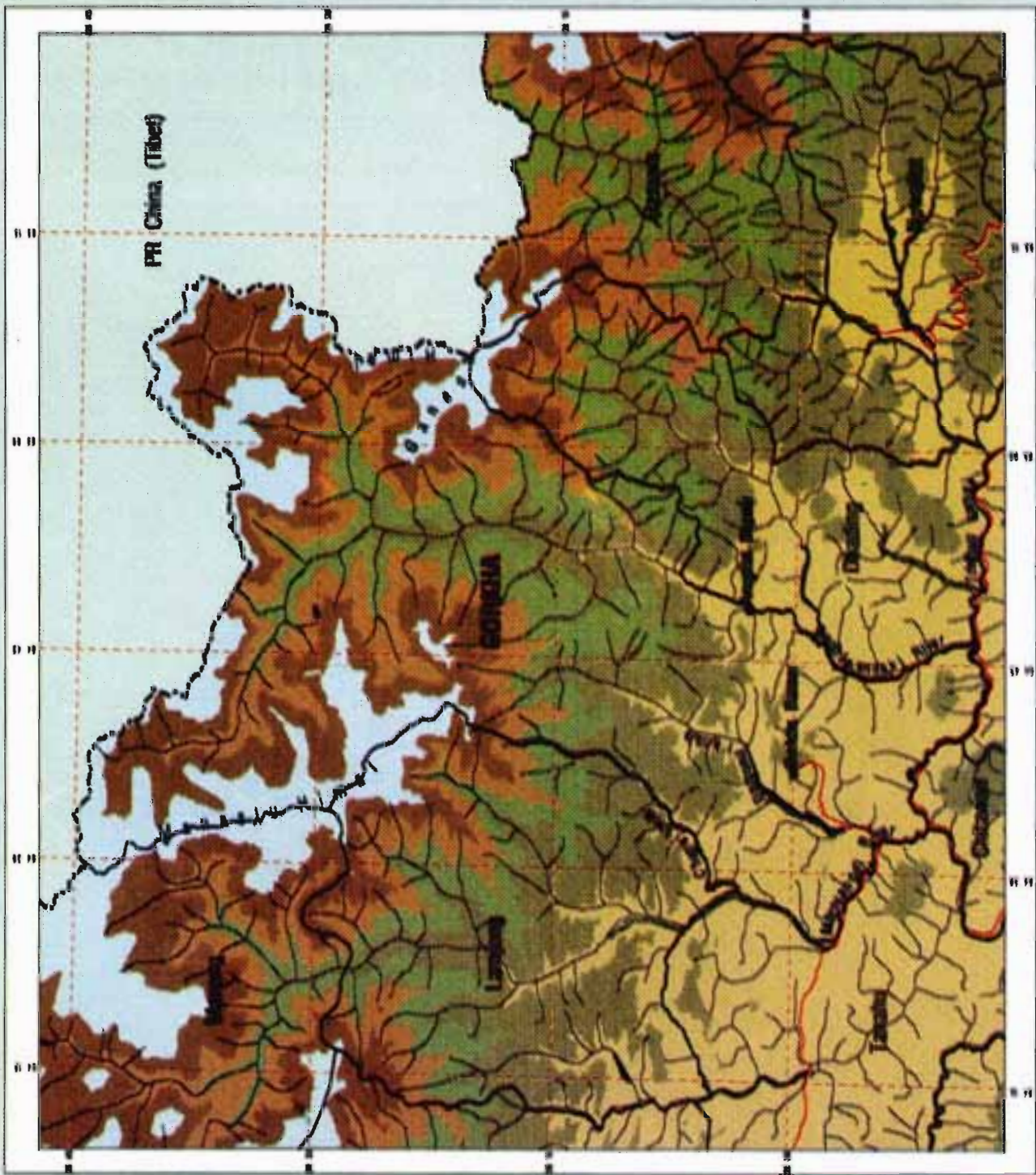
Location

LEGEND

- < 1,000masl.
- 1,000 - 2,000masl.
- 2,000 - 3,000masl.
- 3,000 - 4,000masl.
- 4,000 - 5,000masl.
- > 5,000masl.
- International Boundary
- District Boundary
- Bitumen Road
- Gravelled Road



0 5 10 15 20 km

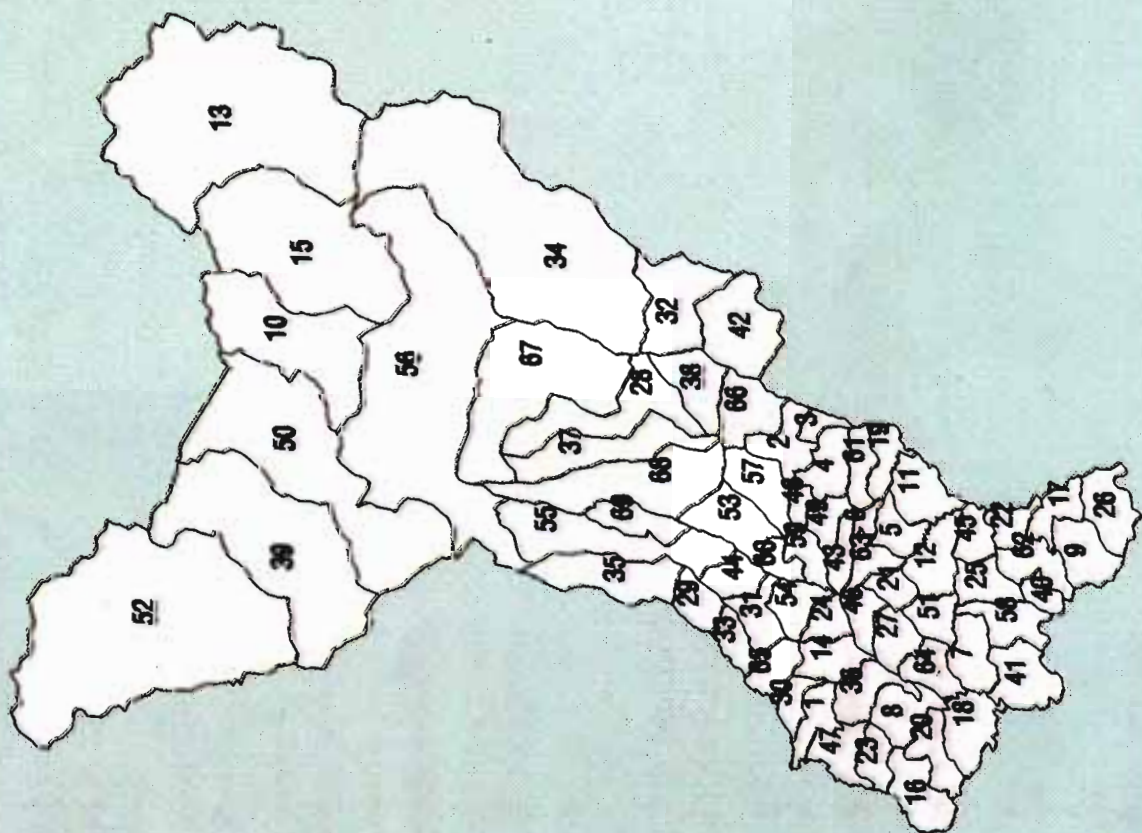




Map 2 VDC Names

Gorkha District

1	Aampipal	36	Koplang
2	AruArbang	37	Laparak
3	AruChanaute	38	Lapu
4	AruPokhari	39	Lho
5	Asrang	40	Makaising
6	Baguwa	41	Manakamana
7	Bakrang	42	Manbu
8	Mirkot	43	Masel
9	Bhumlichok	44	Muchok
10	Bihi	45	Namjung
11	Borlang	46	Nareshwar
12	Bungkot	47	Palungtar
13	Chekampar	48	Panchkhuwadeurali
14	Choprak	49	Pandrung
15	Chumchet	50	Prok
16	Changli	51	Ranishwara
17	Darbung	52	Samagaun
18	Deurali	53	Saurpani
19	Dhawa	54	Shreenathkot
20	Dhuwakot	55	Simjung
21	Phinam	56	Sirdibas
22	Phujel	57	Swara
23	Gaikhur	58	Taklung
24	Gakhu	59	Takukot
25	Gairung	60	Takumajhiakuri
26	Ghyalchok	61	Tandrung
27	Gorakhkali	62	Tanglichok
28	Gumda	63	Taple
29	Hanspur	64	Taranagar
30	Harmi	65	Thalajung
31	Jaubari	66	Thumi
32	Kashigaun	67	Uhiya
33	Kerabari	68	Barpak
34	Kerauja	69	Ghyachok
35	Kharibot		



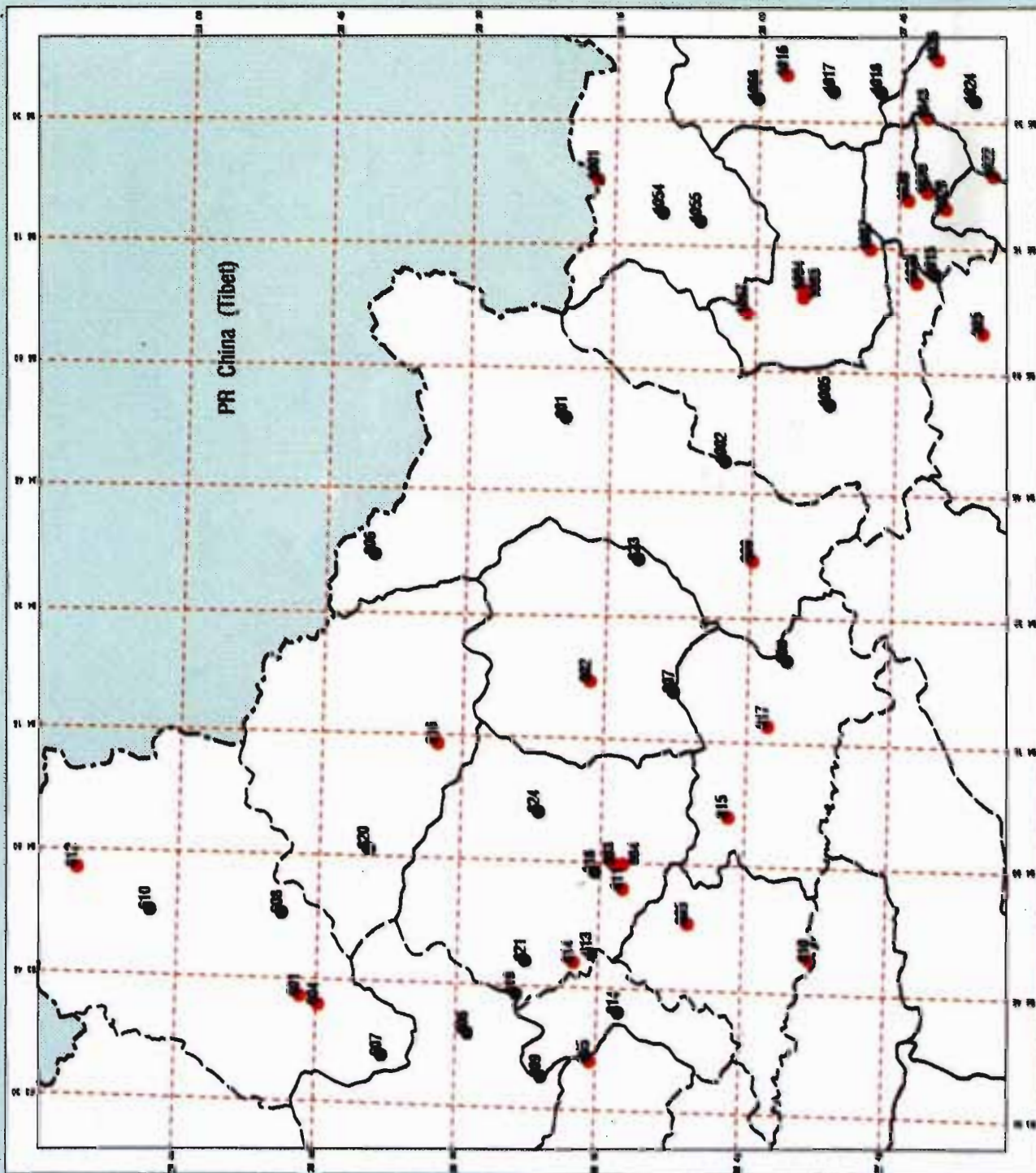


Map 3

# Location of Selected Meteorological Stations in Western and Central Nepal

## LEGEND

- International boundary
- Zonal boundary
- District boundary
- Temperature and precipitation measurement
- Precipitation measurement
- Station-ID no.





Map 4

Gorkha District

Western Region of Nepal

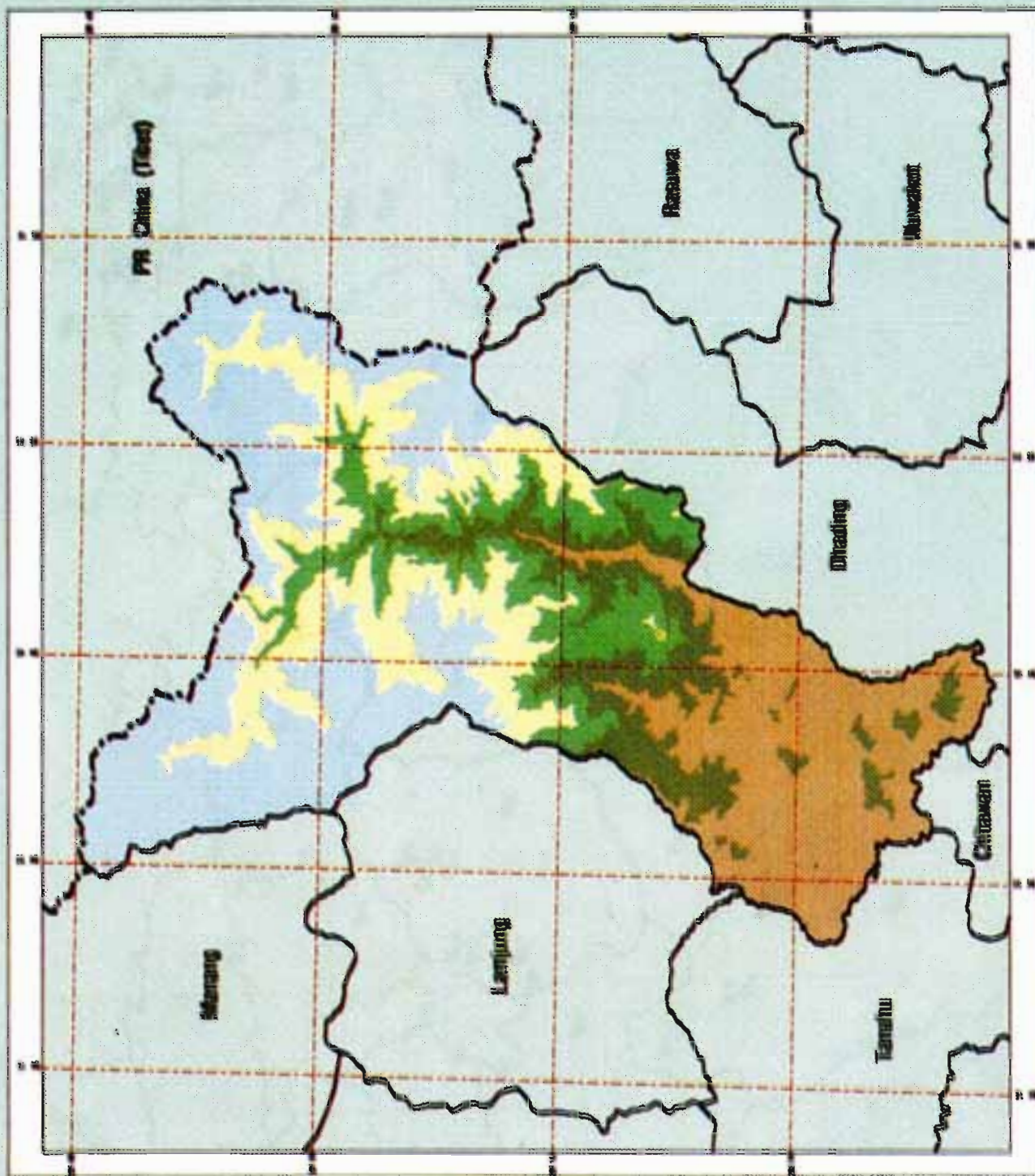
Temperature Regime

(based on analysis)

LEGEND



0 5 10 15 20 km





Map 5

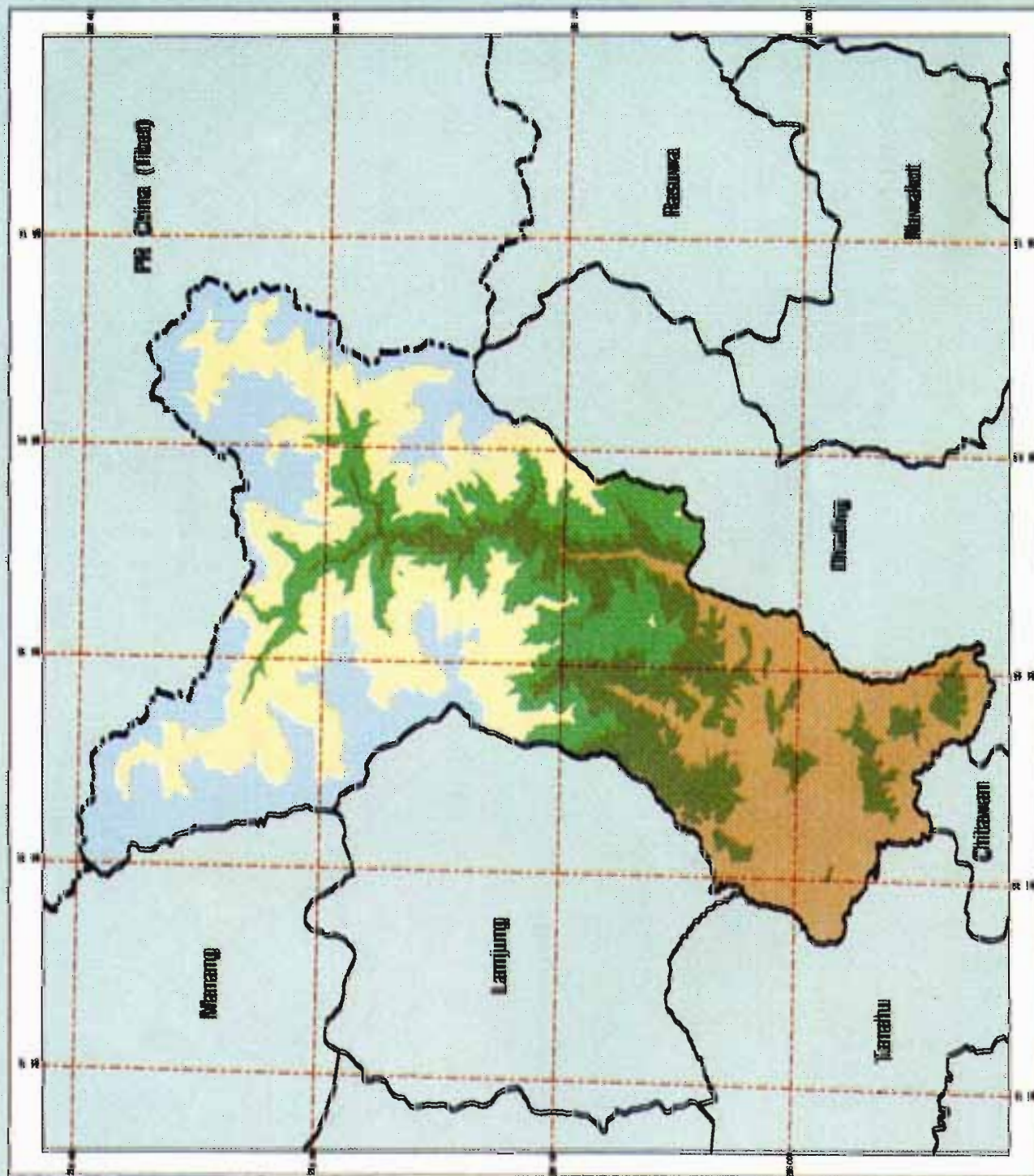
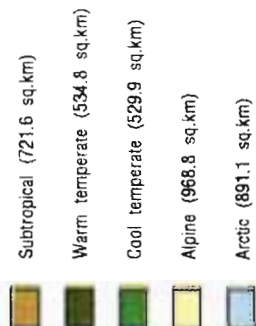
Gorkha District

Western Region of Nepal

Temperature Regime

(based on LRMP data)

LEGEND





Map 6

Gorkha District

Western Region of Nepal

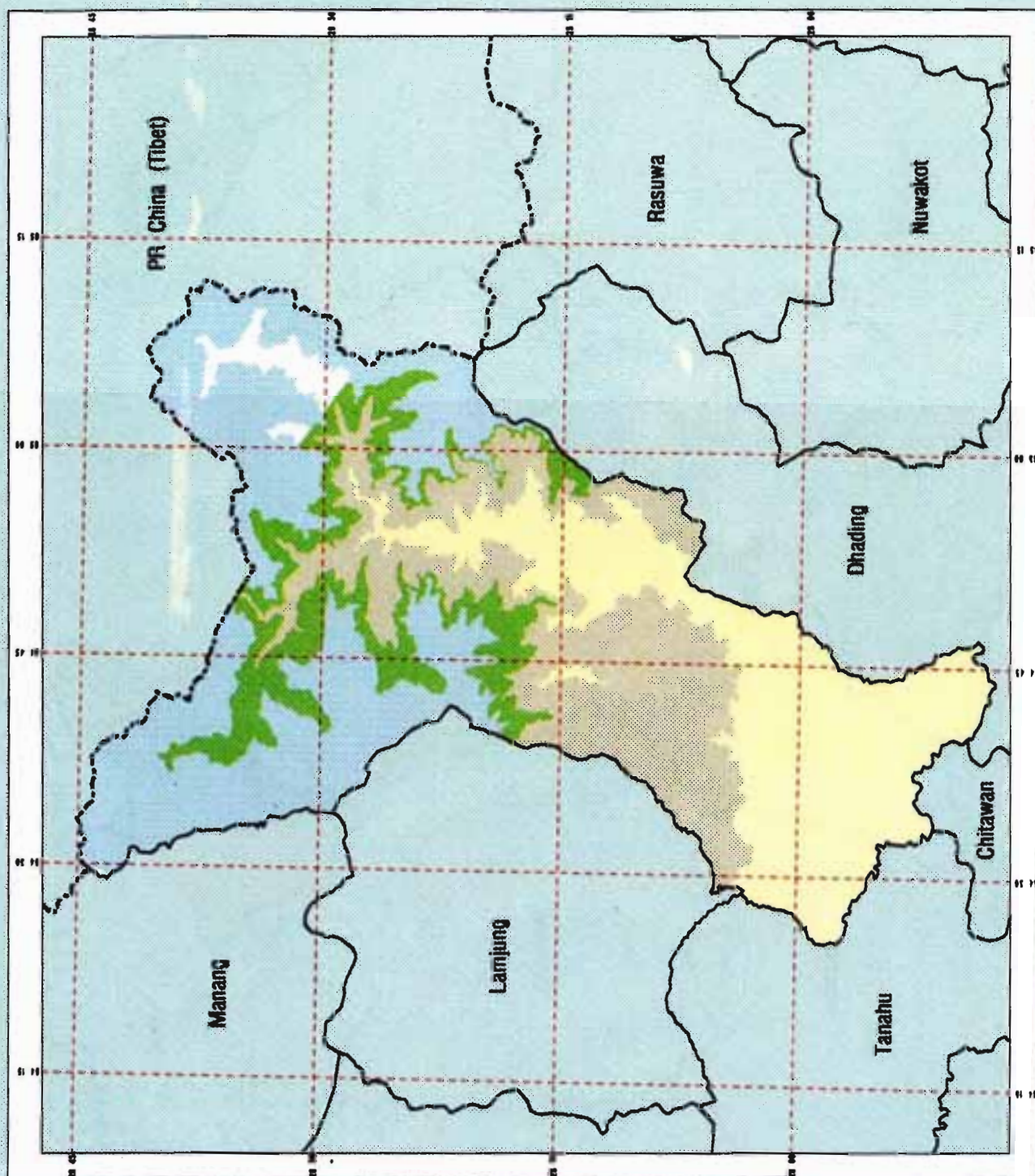
Moisture Regime

(based on analysis)

LEGEND

- Subhumid (995.0 sq.km.)
- Humid (905.7 sq.km.)
- Perhumid (480.9 sq.km.)
- Arctic Temperature Regime (1,210 sq.km.)
- No data (69.0 sq.km.)

0 5 10 15 20 km





# Map 7

Gorkha District

Western Region of Nepal

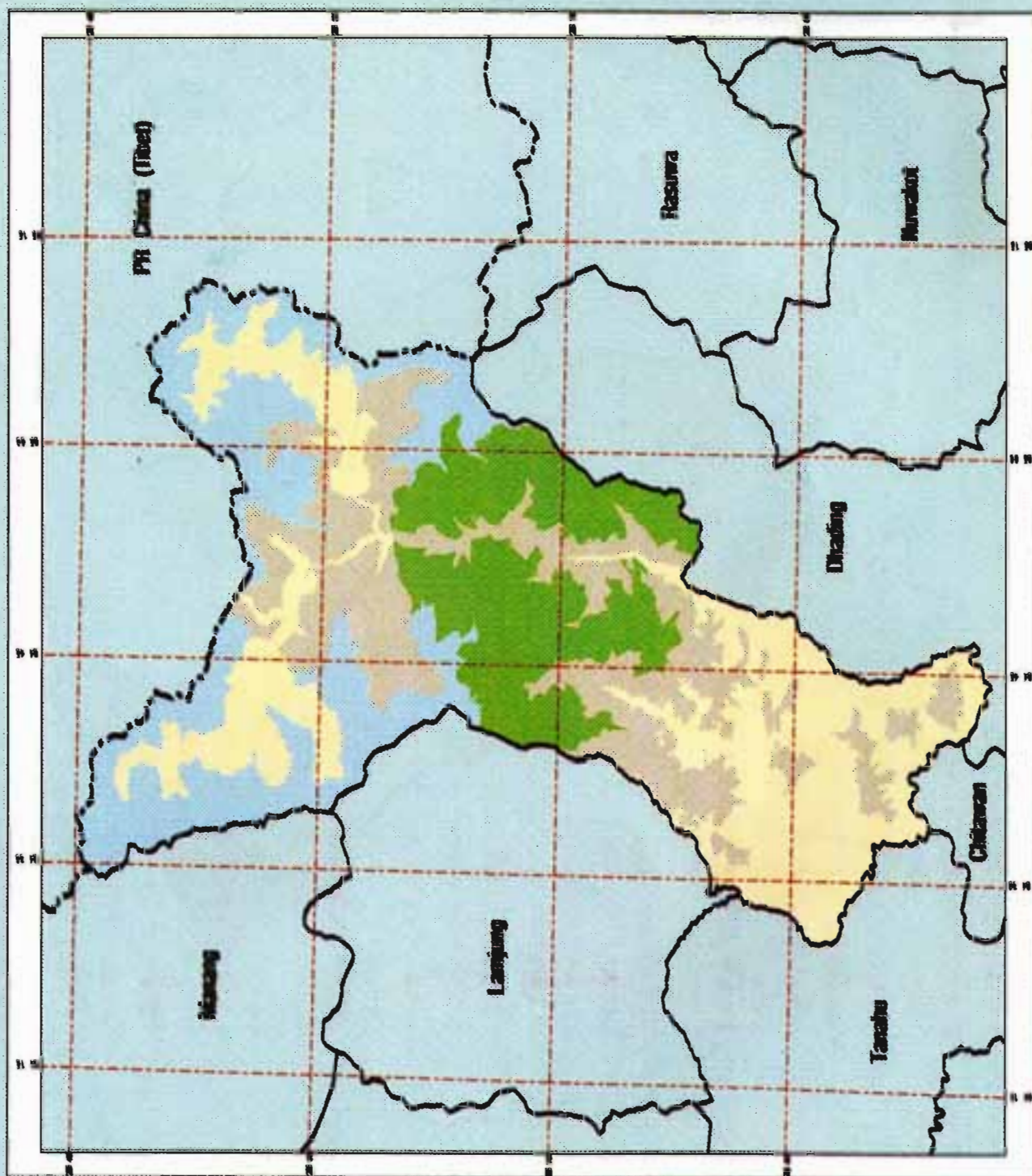
Moisture Regime

(based on LRMP data)

## LEGEND

- Subhumid (1,134.5 sq.km.)
- Humid (928.5 sq.km.)
- Perhumid (692.1 sq.km.)
- No data (891.1 sq.km.)  
(arctic temperature regime)

0 5 10 15 20 km















Map 8

Gorkha District

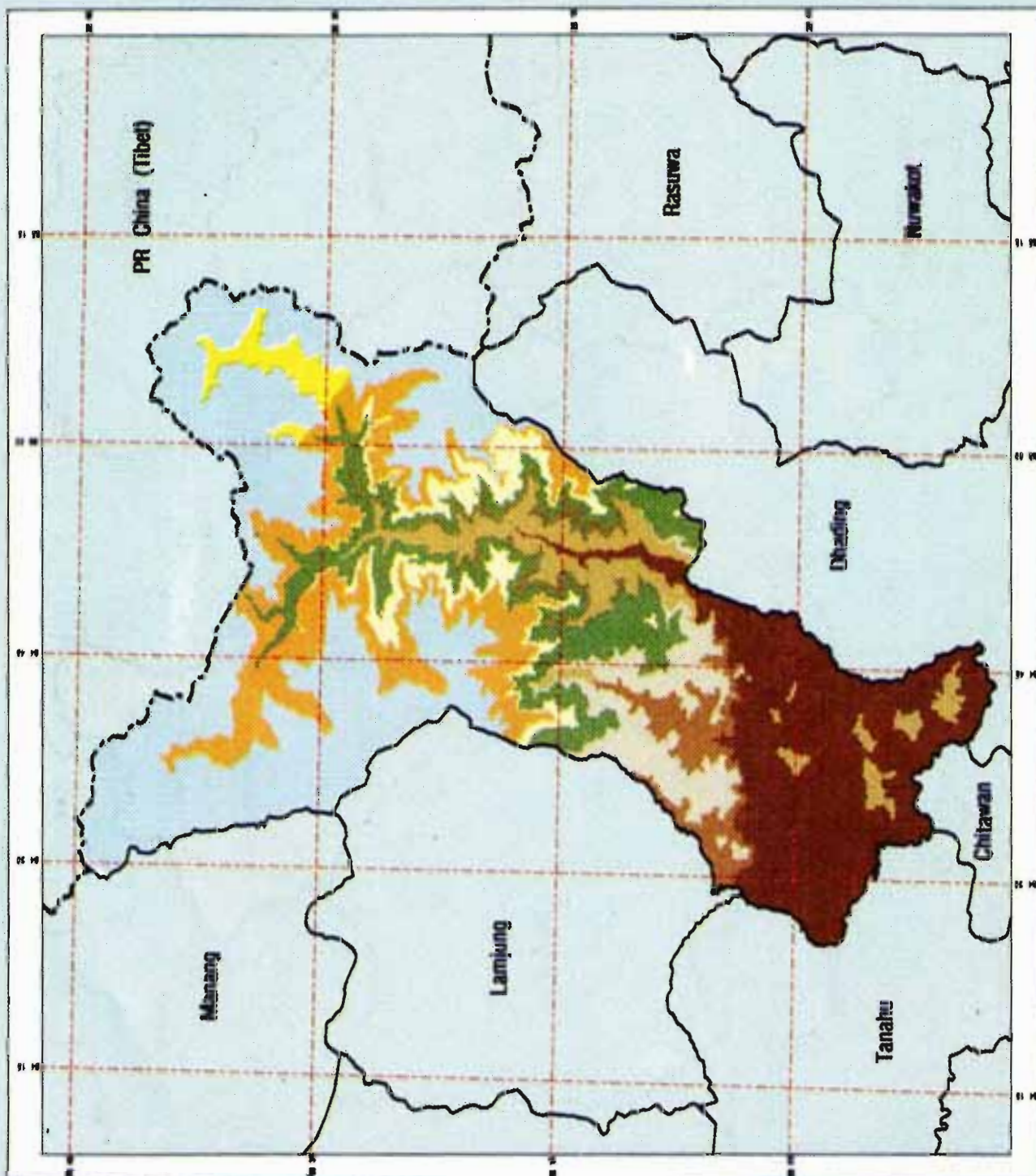
Western Region of Nepal

Agroclimatic Zonation  
(based on analysis)

LEGEND

	Subtropical/subhumid (705.4 sq.km)
	Subtropical/humid (122.7 sq.km)
	Warm temperate/subhumid (210.2 sq.km)
	Warm temperate/humid (222.5 sq.km)
	Cool temperate/subhumid (79.4 sq.km)
	Cool temperate/humid (387.5 sq.km)
	Alpine/humid (193.0 sq.km)
	Alpine/perhumid (480.9 sq.km)
	Alpine/no data (69.0 sq.km)
	Arctic (1,210.0 sq.km)

0 5 10 15 20 km





Map 9

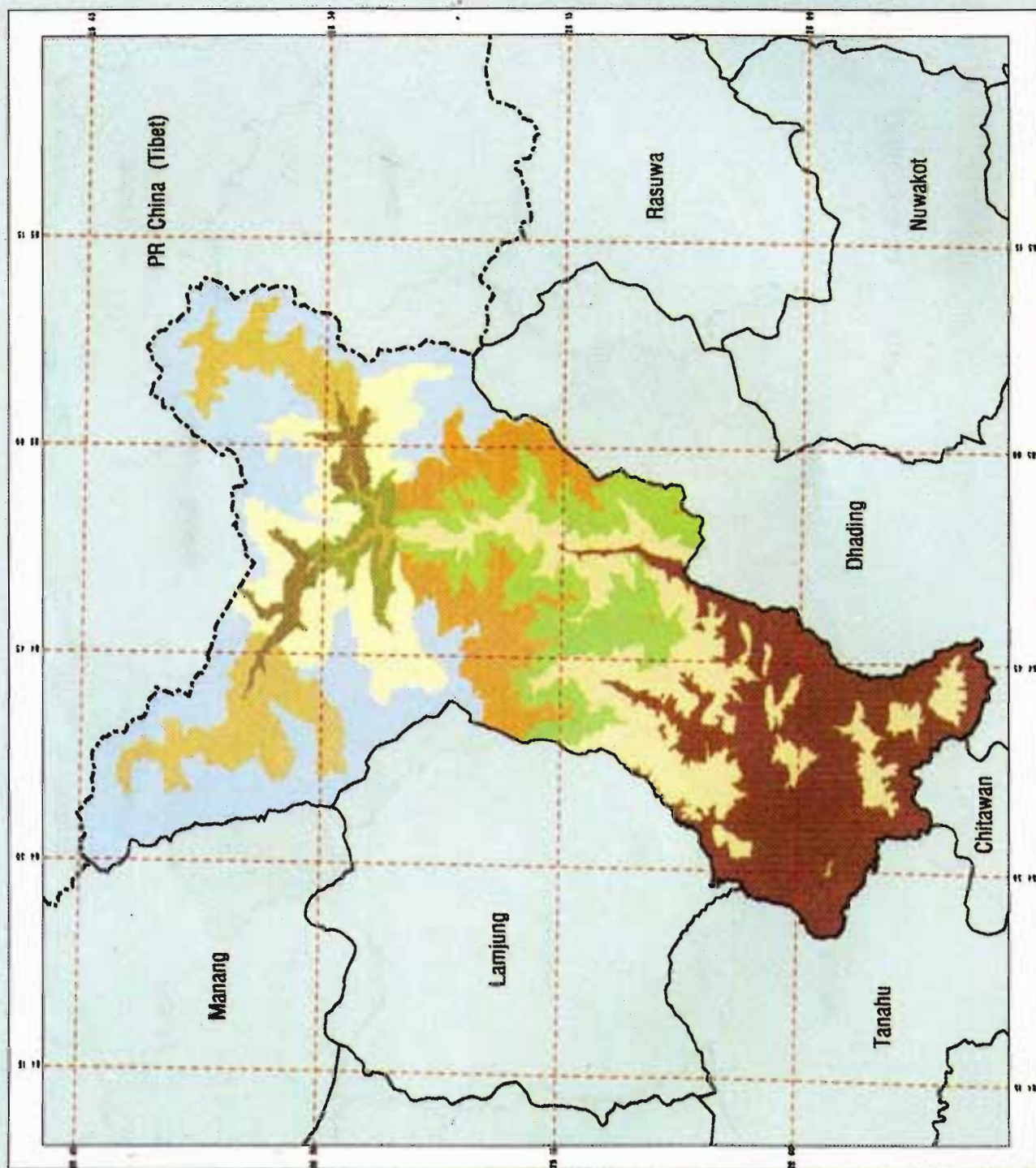
Gorkha District

Western Region of Nepal

Agroclimatic Zonation

(based on LRMP data)

LEGEND





Map 10

Gorkha District

Western Region of Nepal

Distribution of VDCs

According to Climatic Zones

LEGEND

LOCATION OF VDCs



in warm zone [47 no.]



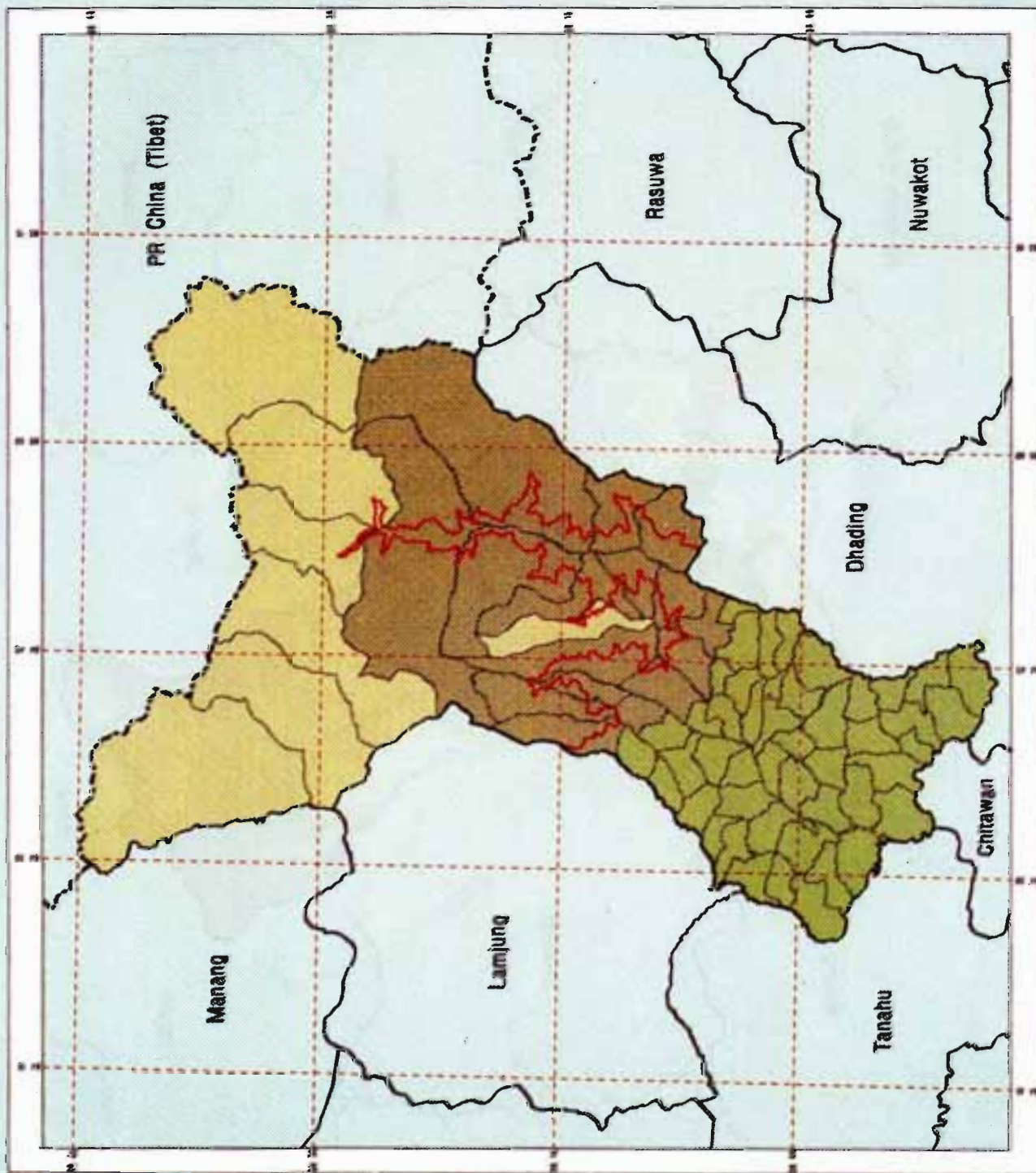
in warm & cool zones [15 no.]



in cool zone [7 no.]



Temperature Isoline  
(15°C approx. 2,000m a.s.l.)





Map 11

Gorkha District

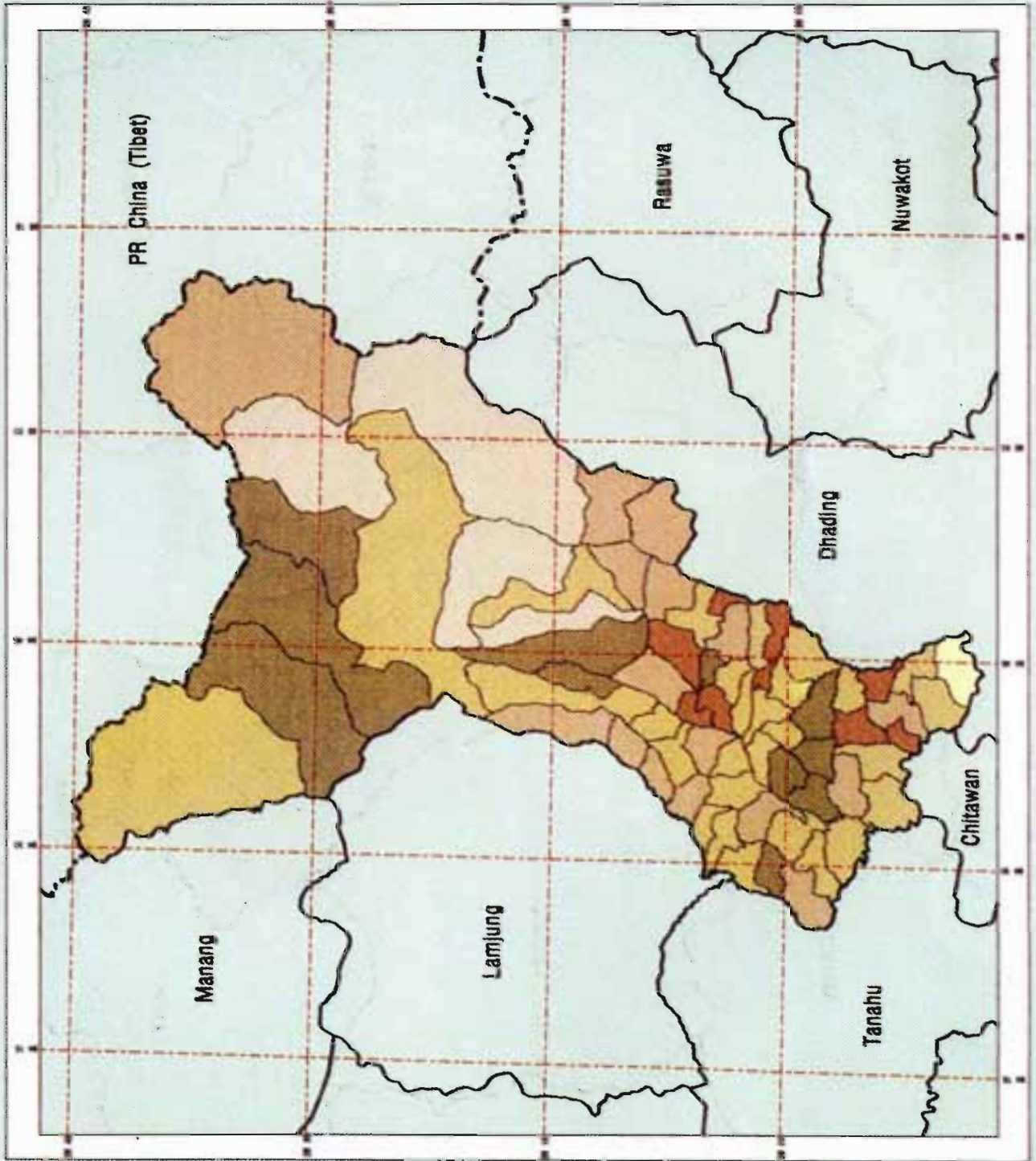
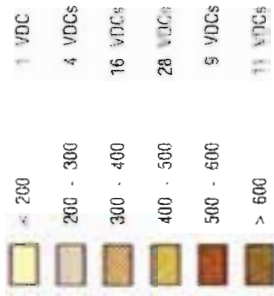
Western Region of Nepal

Population Density

relative to agricultural area

LEGEND

inhabitants per sq.km





# Map 12

Gorkha District

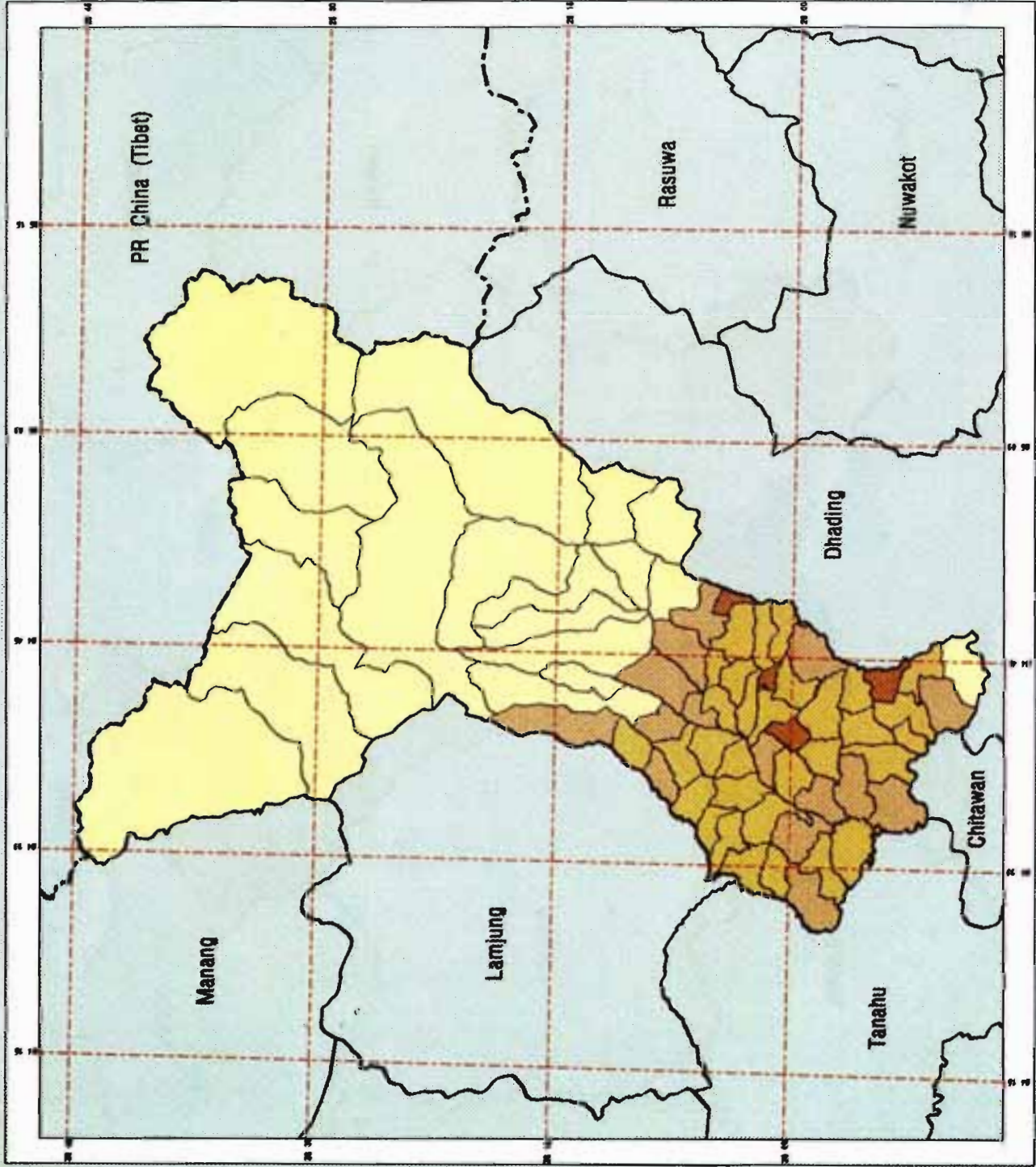
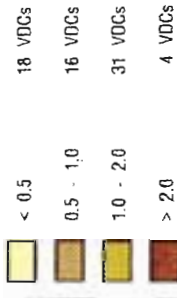
Western Region of Nepal

Livestock Density

relative to total area excluding  
wasteland

## LEGEND

livestock units per hectare





# Map 13

## Gorkha District

### Western Region of Nepal

#### Fodder Sources

##### LEGEND

Warm to Subtropical Temperature Regime

Cultivated Land (631.7 sq.km.)

Forest (369.7 sq.km.)

Shrubland (181.4 sq.km.)

Grazing Land (47.7 sq.km.)

Cool to Alpine Temperature Regime

Cultivated Land (28.4 sq.km.)

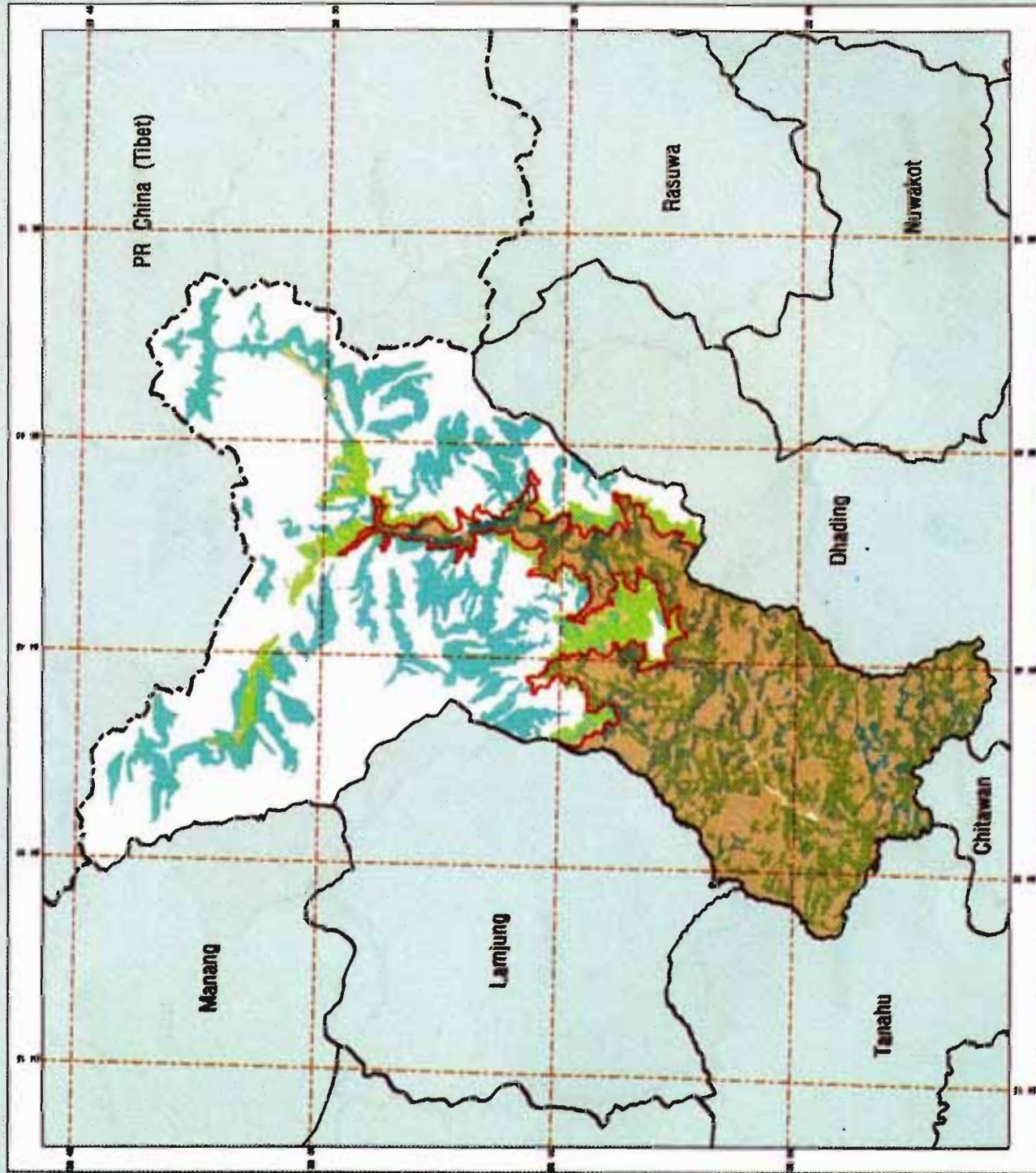
Forest (160.6 sq.km.)

Shrubland (27.6 sq.km.)

Grazing Land (537.2 sq.km.)

Temperature Isoline  
(15 °C; approx. 2,000masl)

0 5 10 15 20km





Map 14

Gorkha District

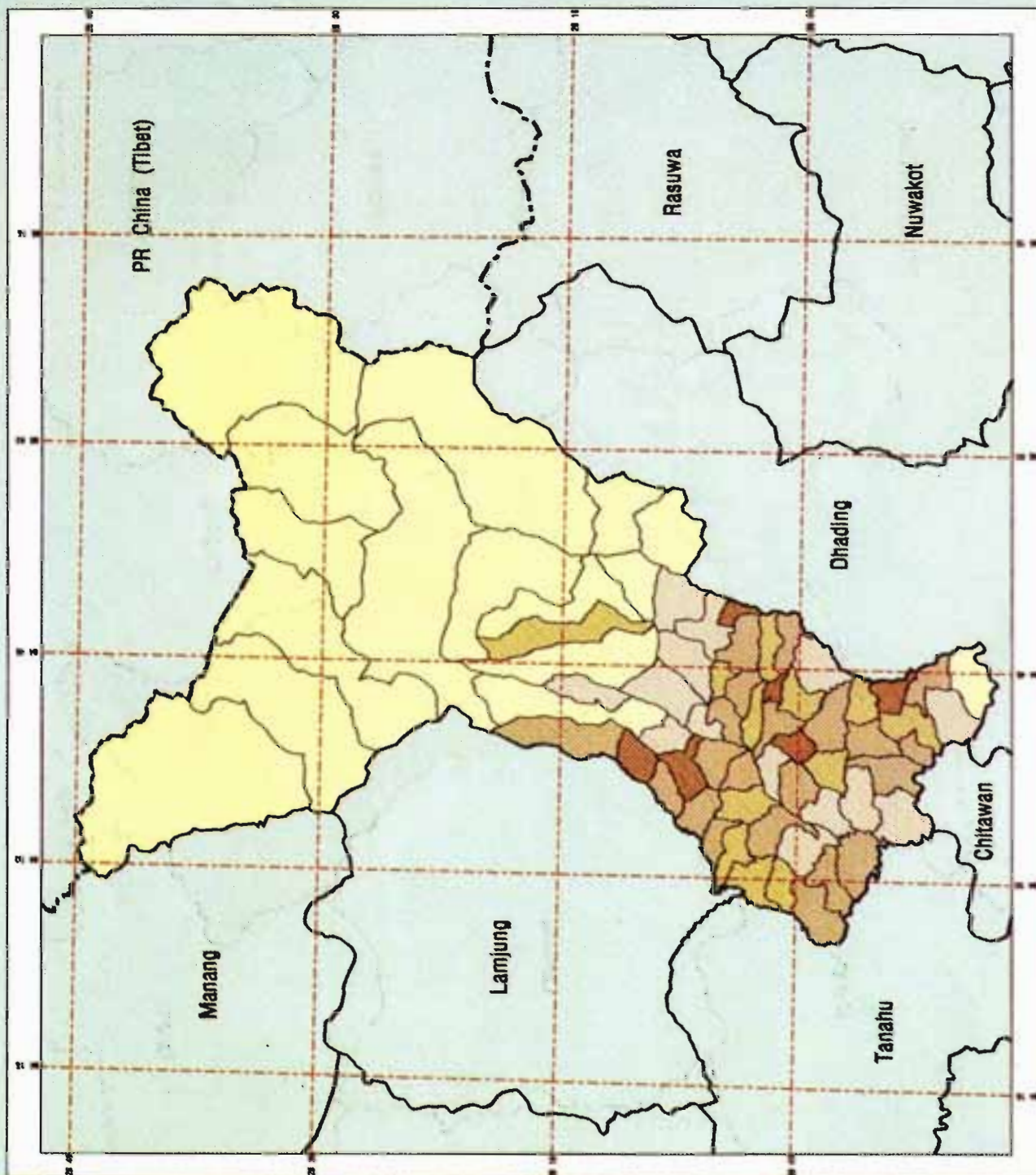
Western Region of Nepal

Feed Requirements

(per hectare of total area  
excluding wasteland)

LEGEND

Metric Tonnes Dry Matter per hectare





Map 15

Gorkha District

Western Region of Nepal

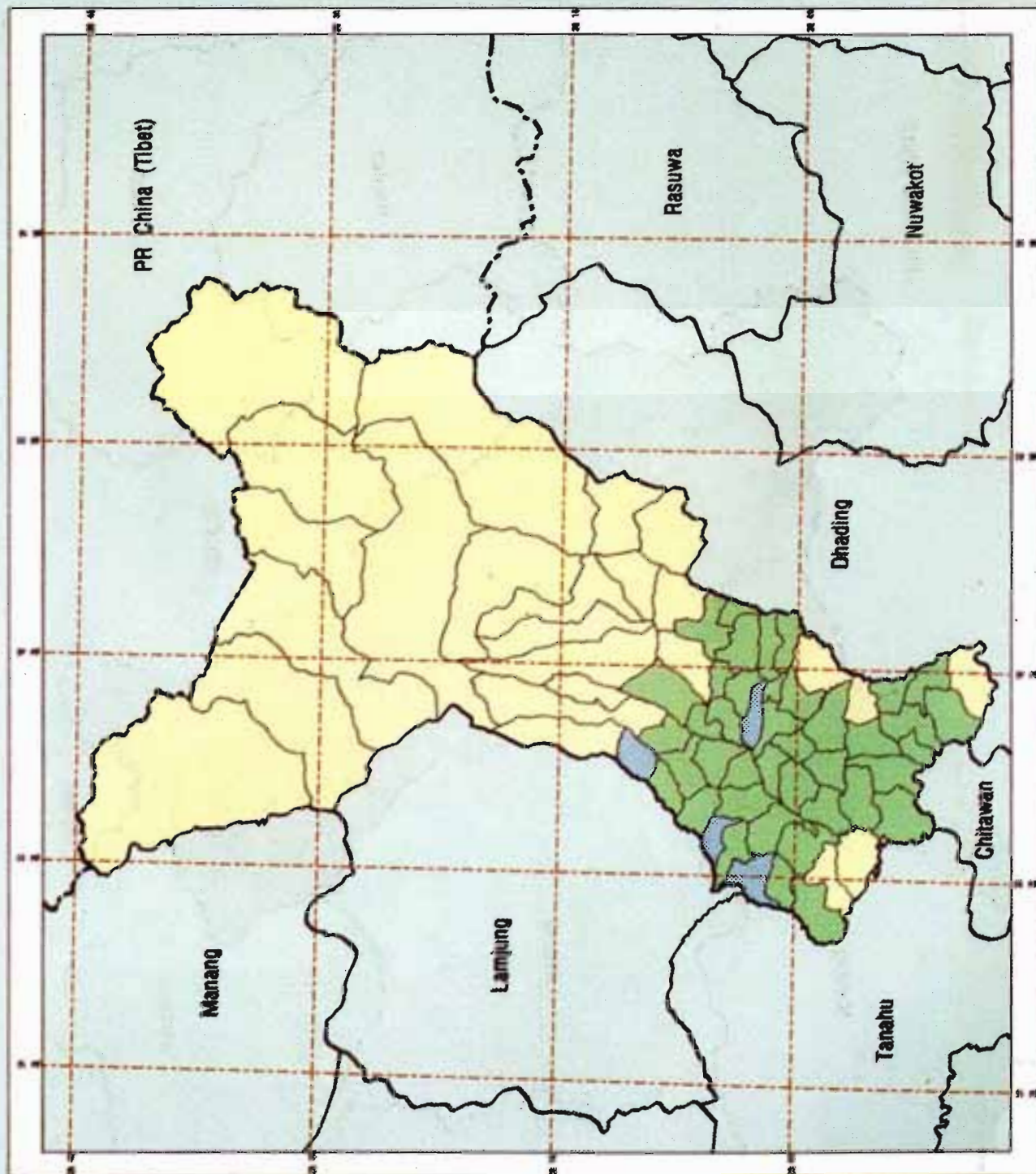
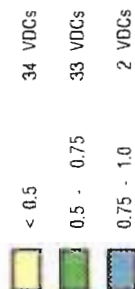
Livestock Carrying Capacity

based on ideal feed supply;

400kg body weight

LEGEND

livestock units per hectare





Map 16

Gorkha District

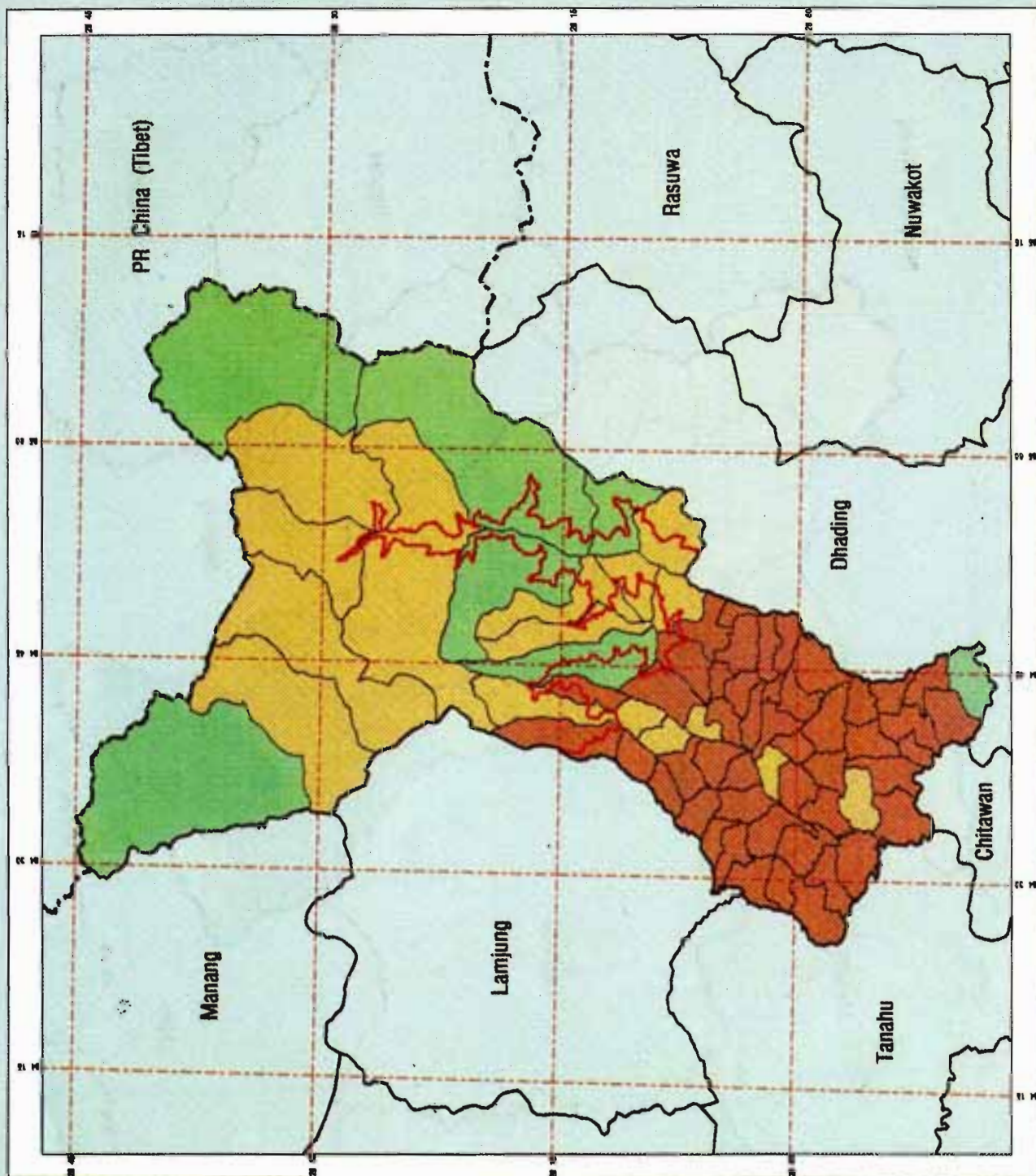
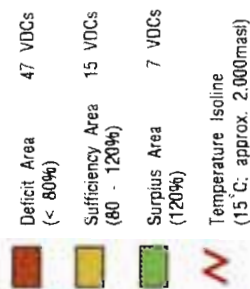
Western Region of Nepal

Feed Situation

based on ideal feed supply;

400kg body weight

LEGEND





Map 17

Gorkha District

Western Region of Nepal

Feed Situation

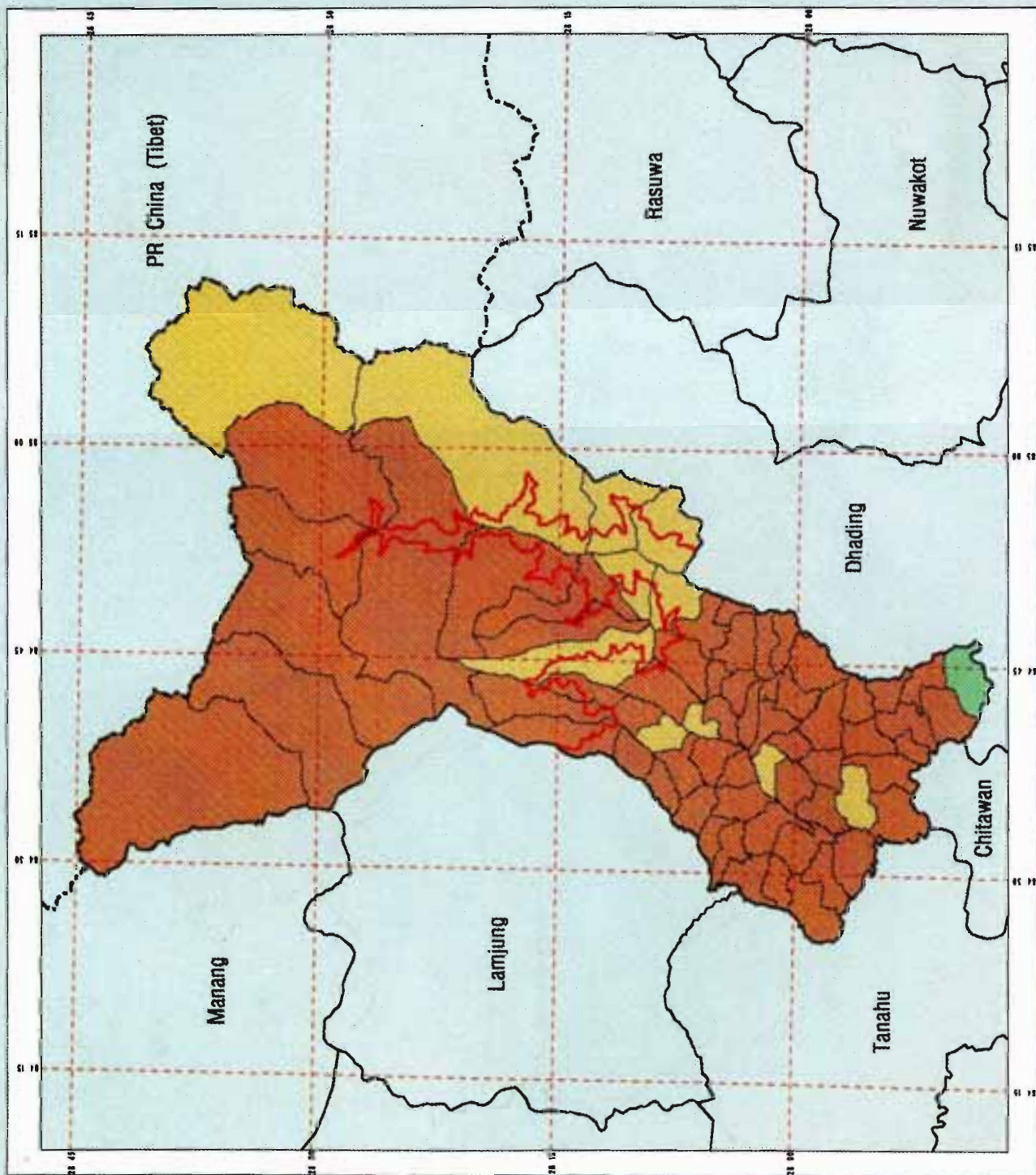
based on ideal feed supply;

& limited access to pastures

LEGEND

- Deficit Area (< 80%) 57 VDCs
- Sufficiency Area (80 - 120%) 11 VDCs
- Surplus Area (120%) 1 VDC
- Temperature Isoline (15°C: approx. 2,000masl)

0 5 10 15 20 km





Map 18

Gorkha District

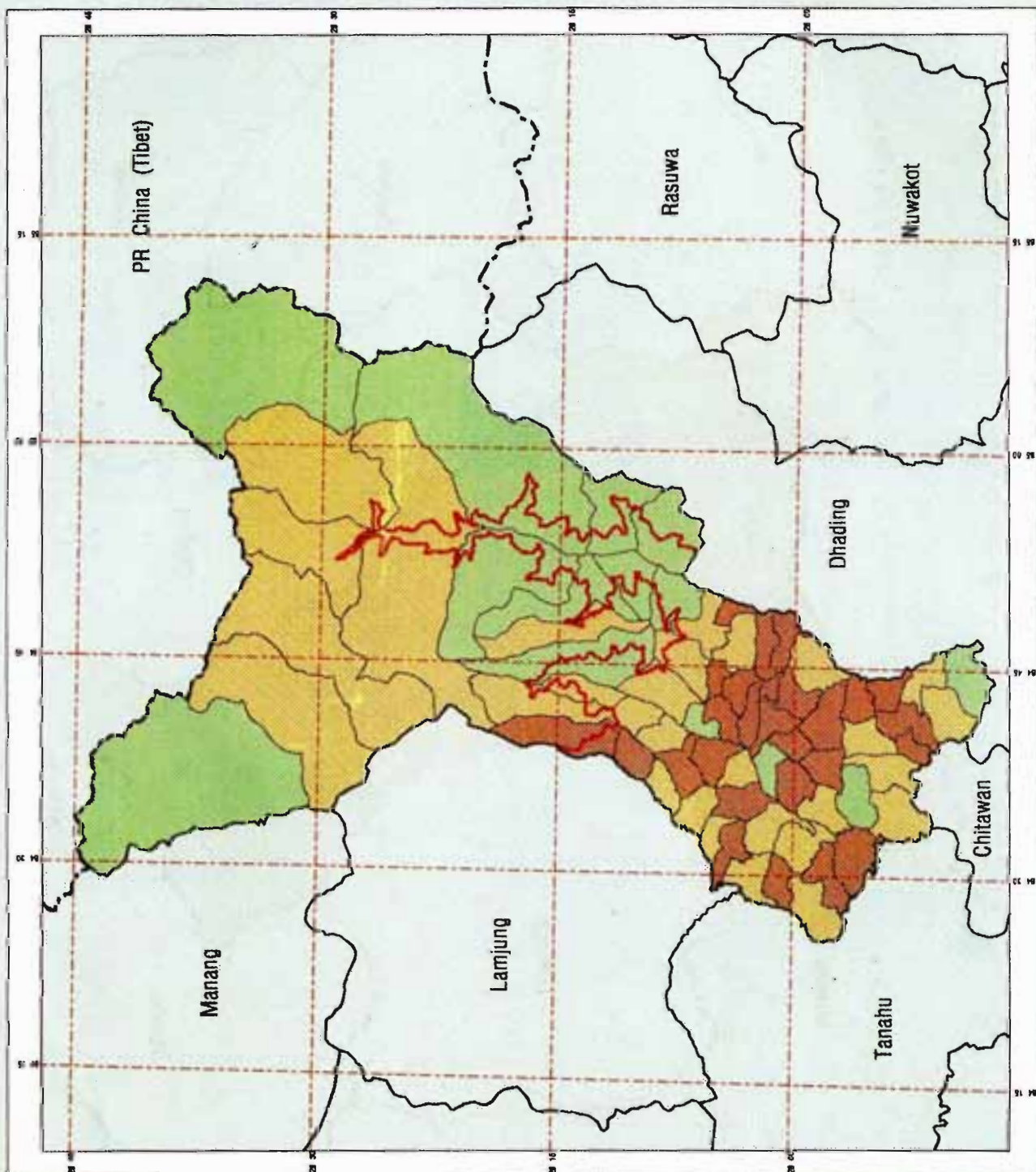
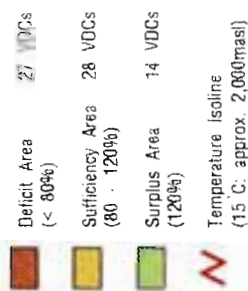
Western Region of Nepal

Feed Situation

based on insufficient feed supply;

250kg body weight

LEGEND





# Map 19

Gorkha District

Western Region of Nepal

Feed Situation

based on insufficient feed supply;

& limited access to pastures

## LEGEND

Deficit Area  
( $< 80\%$ )

37 VDCs

Sufficiency Area  
( $80 - 120\%$ )

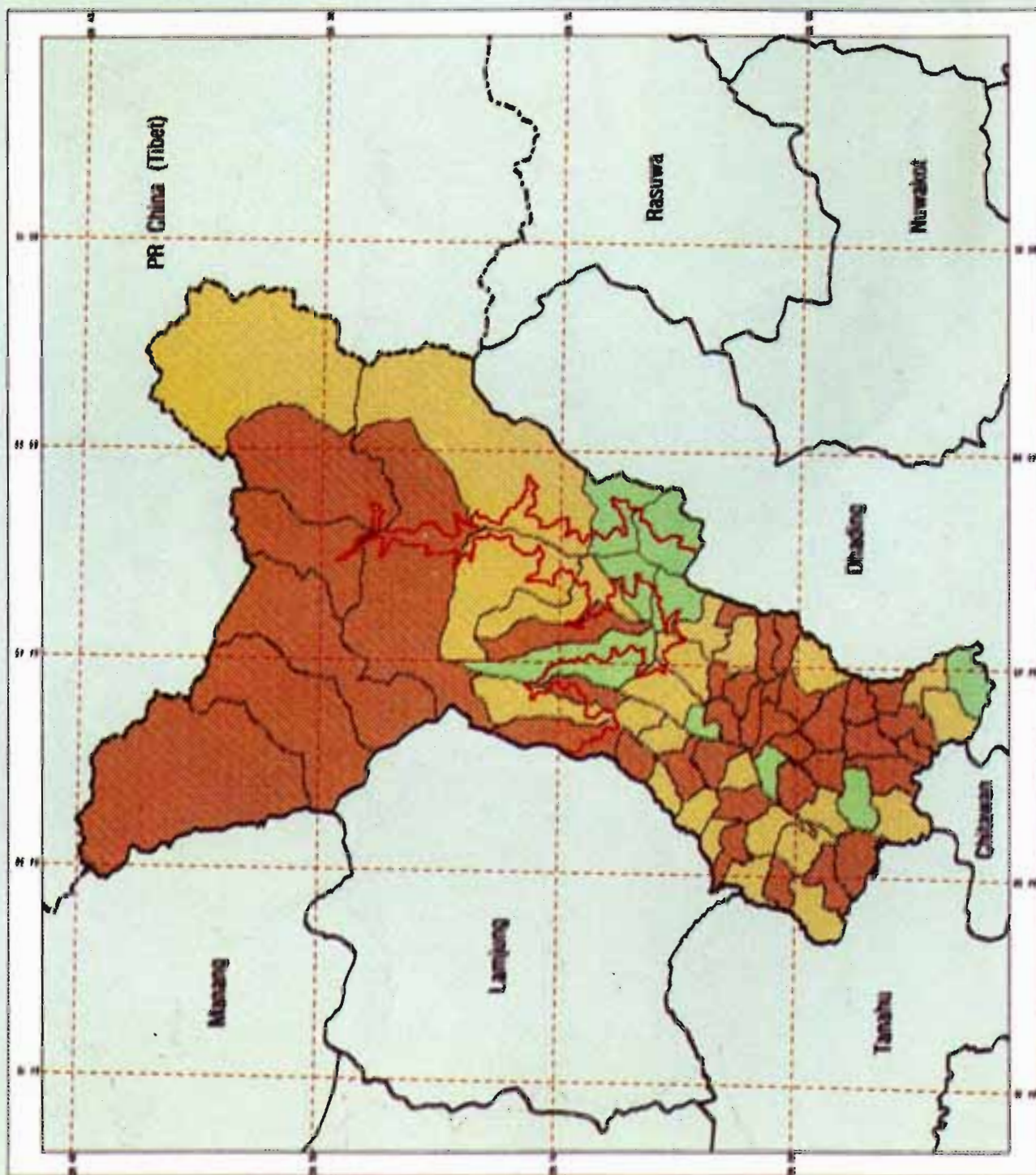
23 VDCs

Surplus Area  
( $120\%$ )

9 VDCs

Temperature Isoline  
( $15^{\circ}\text{C}$ ; approx. 2,000masl)

0 5 10 15 20 km





# Map 20

## Gorkha District

### Western Region of Nepal

#### Land System

#### LEGEND

(area size refers to Gorkha only)



#### SIWALIK REGION



#### MIDDLE MOUNTAIN REGION

moderately to steeply sloping terrain

slopes < 30° (495.9 sq.km)

steeply to very steeply sloping terrain

slopes > 30° (392.9 sq.km)

alluvial plains and fans (54.7 sq.km)

ancient lake and river terraces (61.4 sq.km)

past glaciated mountainous terrain above limit of arable agriculture (560.5 sq.km)

past glaciated mountainous terrain below limit of arable agriculture (326.6 sq.km)

past glaciated mountainous terrain above limit of arable agriculture (560.5 sq.km)

alluvial plains and fans (7.2 sq.km)

steeply to very steeply sloping terrain (690.0 sq.km)

alluvials, colluvials and morainal depositional surfaces (14.8 sq.km)

alluvial plains and fans (7.2 sq.km)

steeply to very steeply sloping terrain (690.0 sq.km)

alluvials, colluvials and morainal depositional surfaces (14.8 sq.km)

alluvial plains and fans (7.2 sq.km)

steeply to very steeply sloping terrain (690.0 sq.km)

alluvials, colluvials and morainal depositional surfaces (14.8 sq.km)

alluvial plains and fans (7.2 sq.km)

steeply to very steeply sloping terrain (690.0 sq.km)

alluvials, colluvials and morainal depositional surfaces (14.8 sq.km)

alluvial plains and fans (7.2 sq.km)

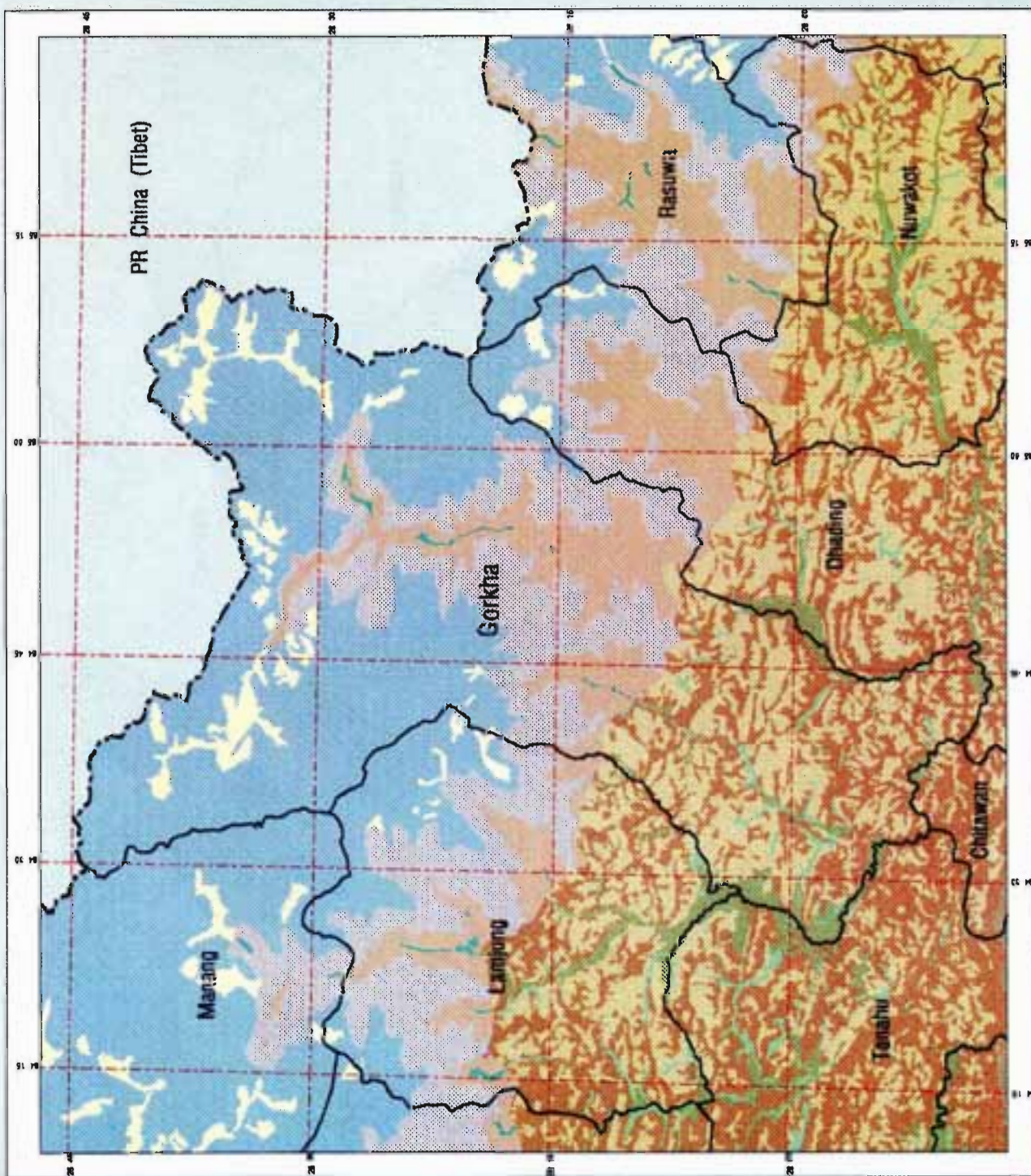
steeply to very steeply sloping terrain (690.0 sq.km)

alluvials, colluvials and morainal depositional surfaces (14.8 sq.km)

alluvial plains and fans (7.2 sq.km)

steeply to very steeply sloping terrain (690.0 sq.km)

alluvials, colluvials and morainal depositional surfaces (14.8 sq.km)





# Map 21

## Gorkha District

### Western Region of Nepal

#### Land Utilisation in 1979

## LEGEND

(area size refers to Gorkha only)

- Sloping Terraces (125.7 sq.km.)
- Level Terraces (434.1 sq.km.)
- Valley Floors (9.4 sq.km.)
- Tars, Foot Slopes (90.9 sq.km.)
- Grazing Land (584.9 sq.km.)
- Forest (897.4 sq.km.)
- Shrubland (243.0 sq.km.)
- Rocks, Sand (847.4 sq.km.)
- Snow and Ice (413.8 sq.km.)
- Urban

0 5 10 15 20 km





Map 22

Gorkha District

Western Region of Nepal

Potential Horticultural

Development Area

LEGEND

SLOPING TERRACES



low-density cultivated (36 sq.km)



medium density cultivated (66 sq.km)

LEVEL TERRACES



low-density cultivated (94 sq.km)



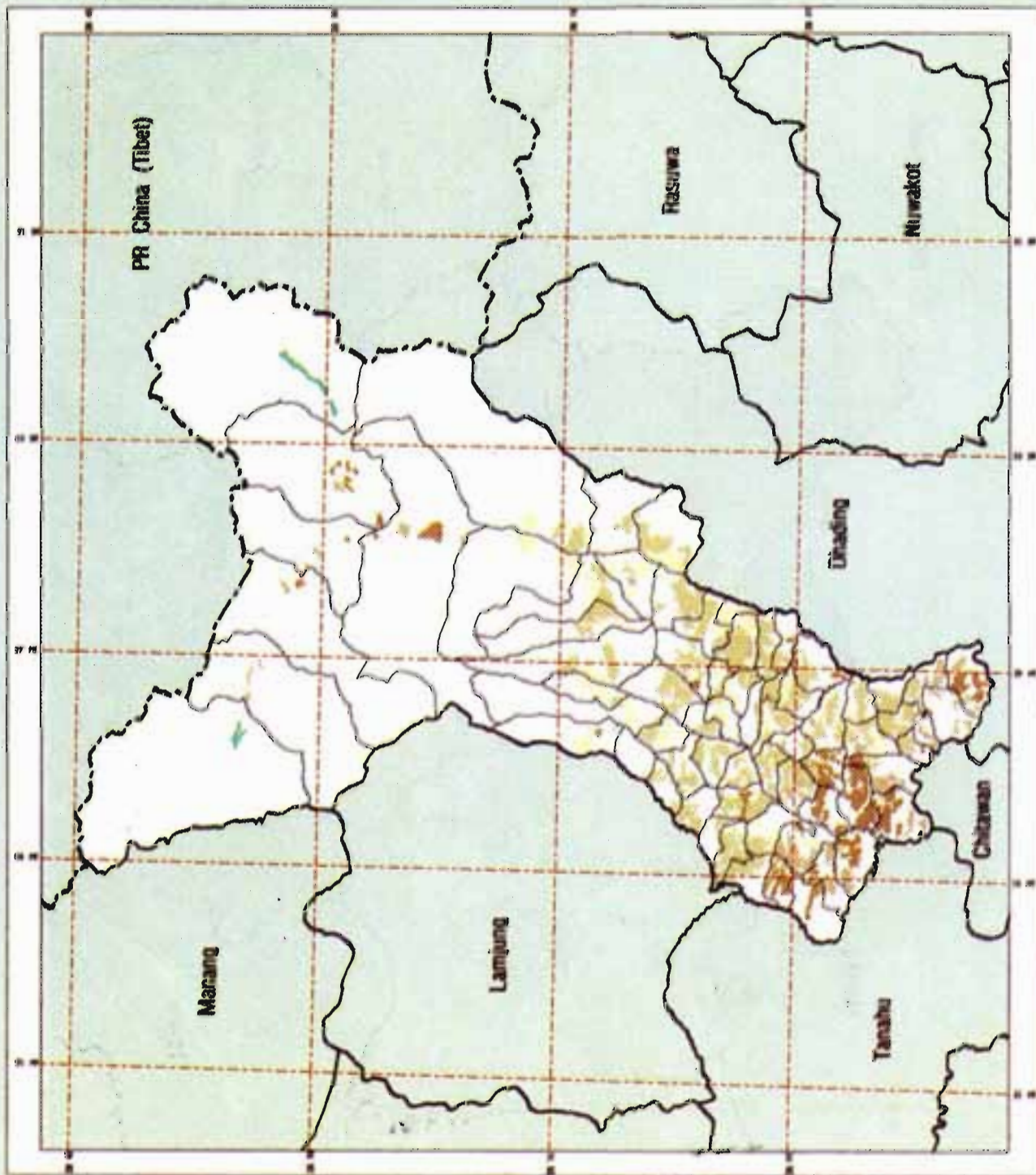
medium density cultivated (244 sq.km)



intensely cultivated (1 sq.km)



FOOT SLOPES AND TARS (6 sq.km)





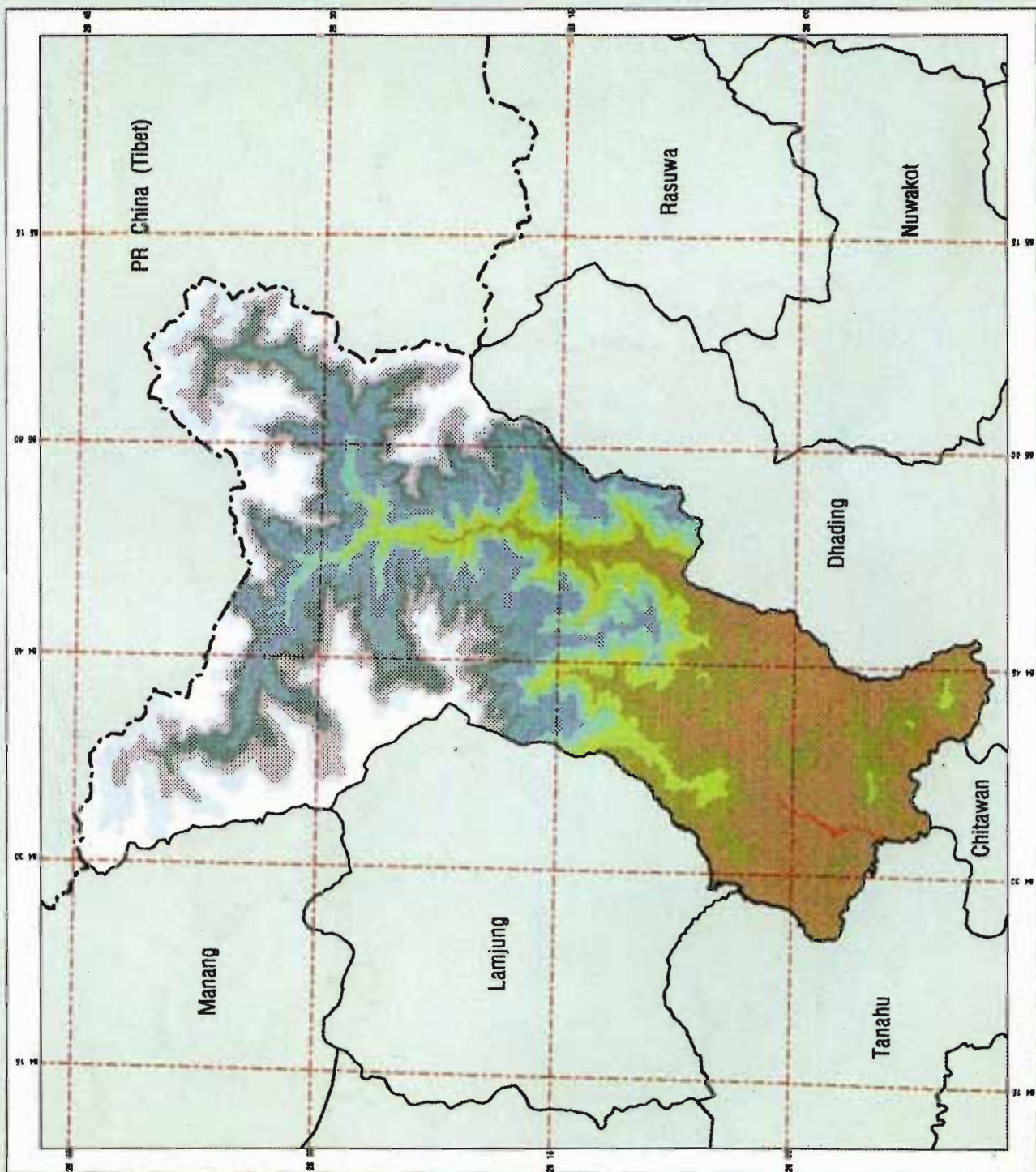
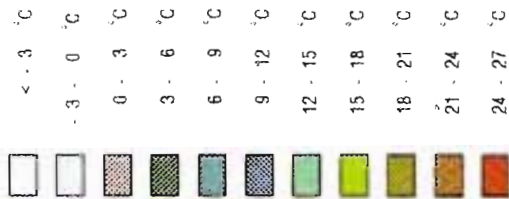
Map 23

Gorkha District

Western Region of Nepal

Mean Annual Temperature

LEGEND





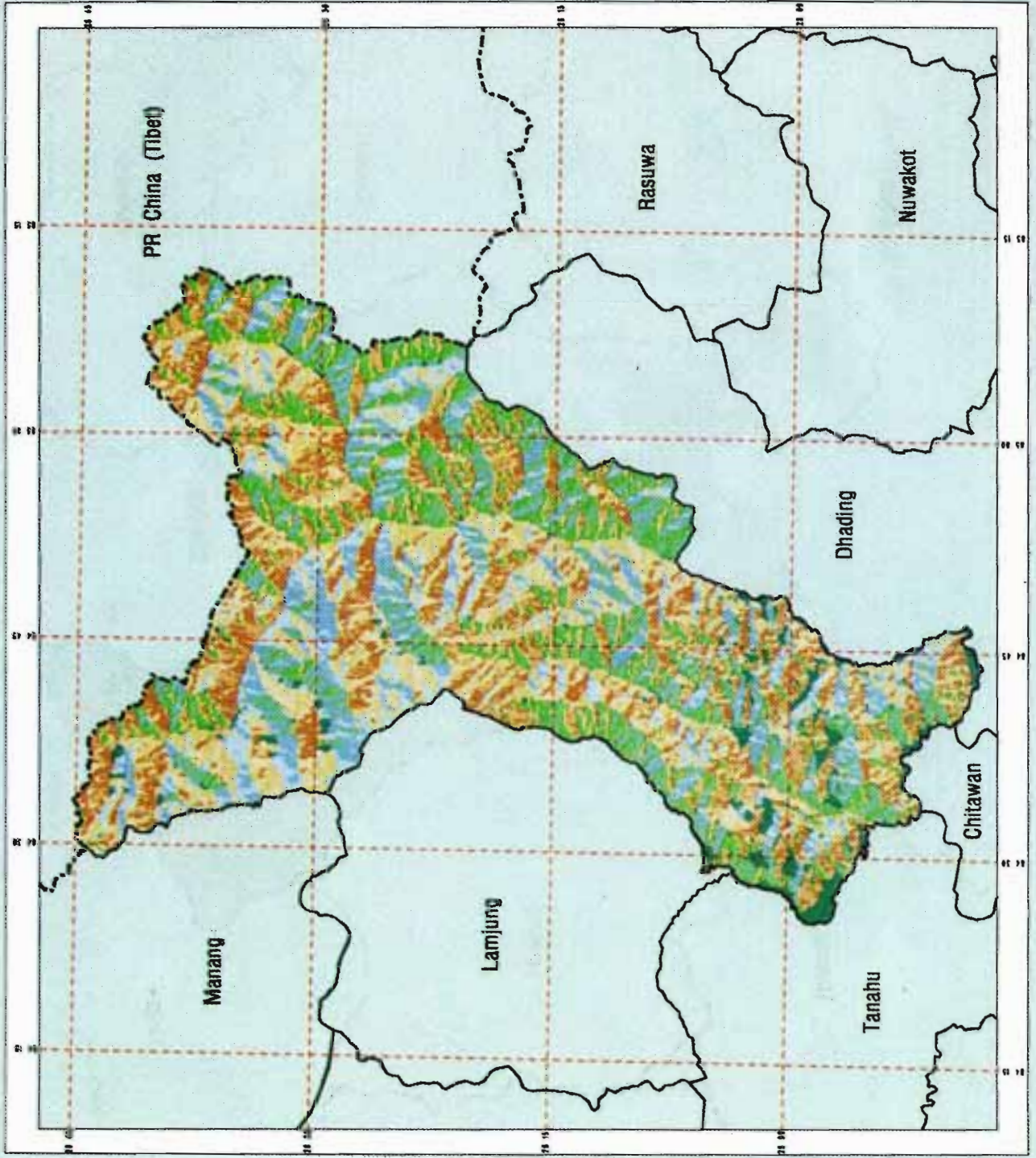
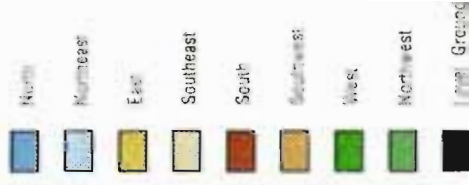
Map 24

Gorkha District

Western Region of Nepal

Aspect

LEGEND





# Map 25

Gorkha District

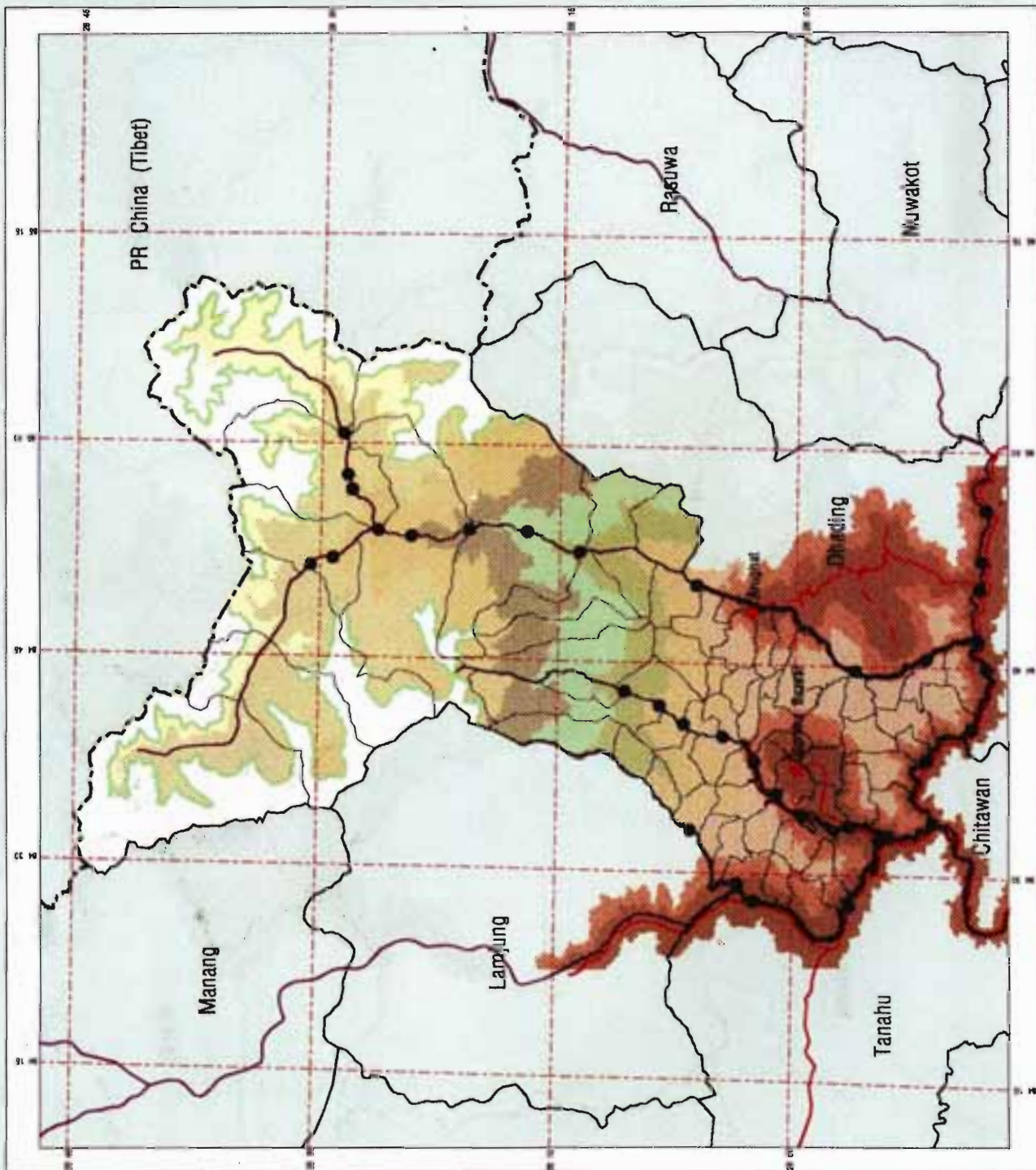
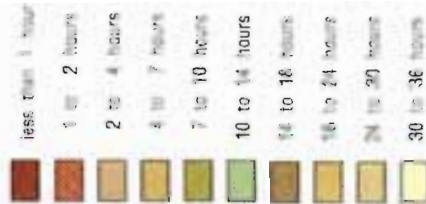
Western Region of Nepal

Accessibility of Road

Infrastructure

## LEGEND

Walking Time to the Closest Road





# Map 26

Gorkha District

Western Region of Nepal

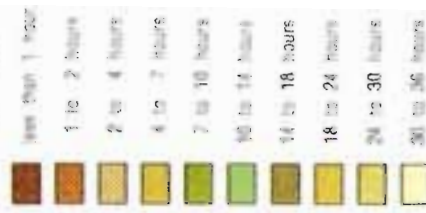
Accessibility of Road

Infrastructure including

proposed road to Arkhiet

## LEGEND

Walking Time to the Closest Road



Road network

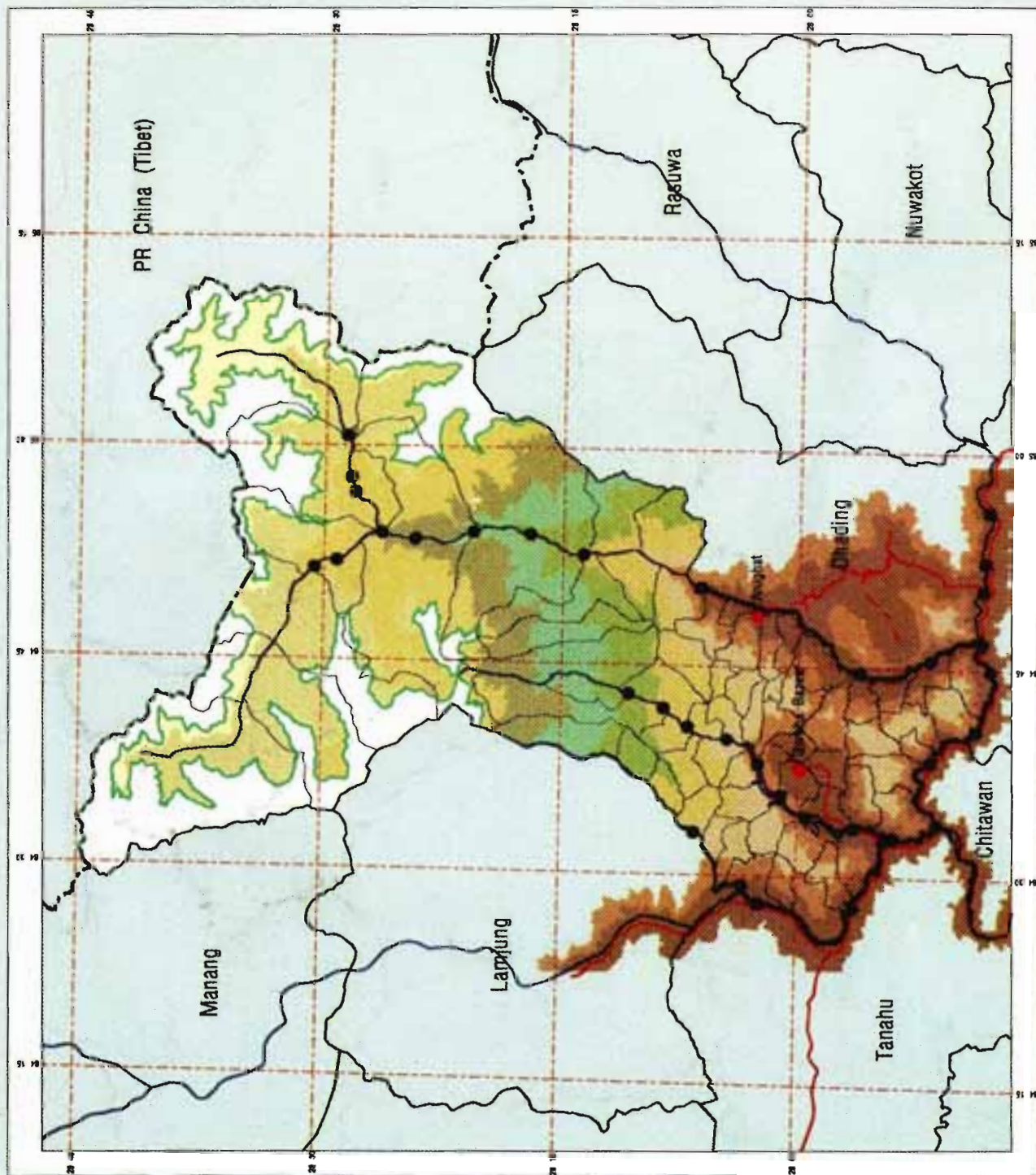
Road under construction

Road planned

Drainage system

Contour line 4,700 m

Bridge





Map 27

Gorkha District

Western Region of Nepal

Accessibility of Bazaar

LEGEND

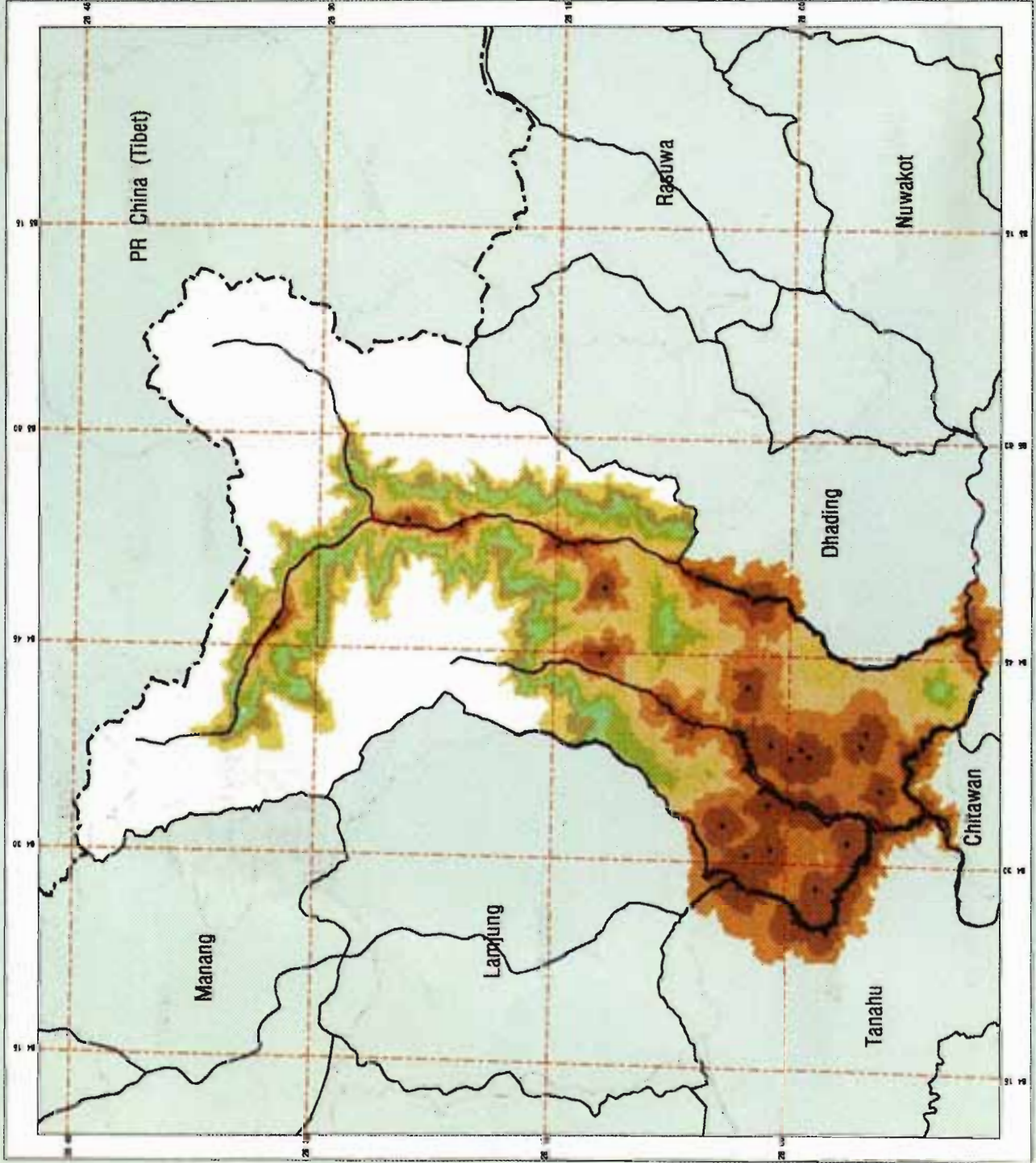
Walking Time to the Closest Bazaar



• Bazaar

• Major source of land

W Major river





# Map 28

## Gorkha District Western Region of Nepal Agricultural Land Suitable for Mango Trees

### LEGEND

#### SUITABLE LAND



northwestern to eastern slopes  
(6,460 ha)



southeastern to western slopes  
& level land (9,440 ha)

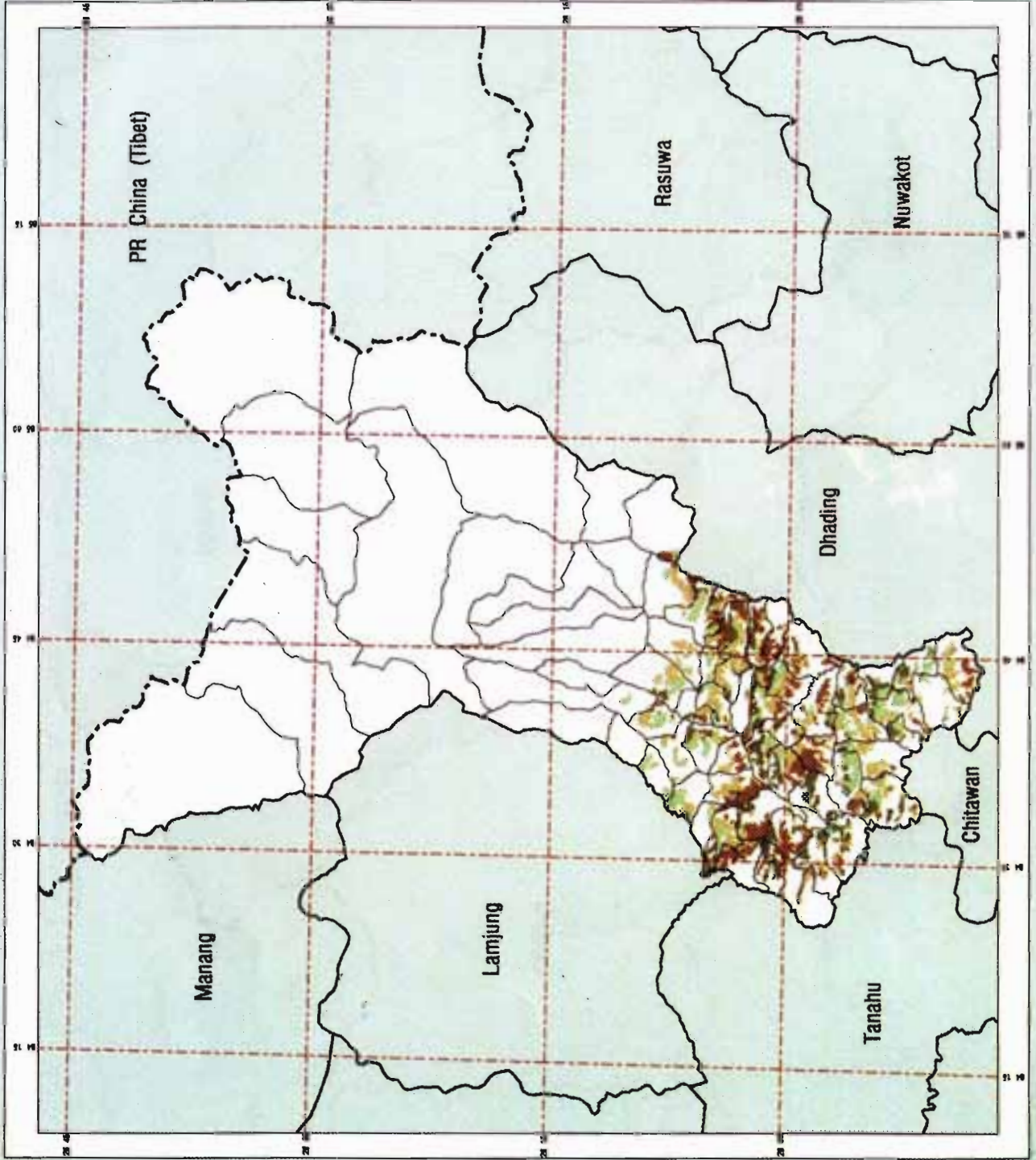
#### MODERATELY SUITABLE LAND



northwestern to eastern slopes  
(8,040 ha)



southeastern to western slopes  
& level land (10,300 ha)





# Map 29

Gorkha District

Western Region of Nepal  
Agricultural Land Suitable  
for Banana

## LEGEND

### SUITABLE LAND



northwestern to eastern slopes  
(9,430 ha)



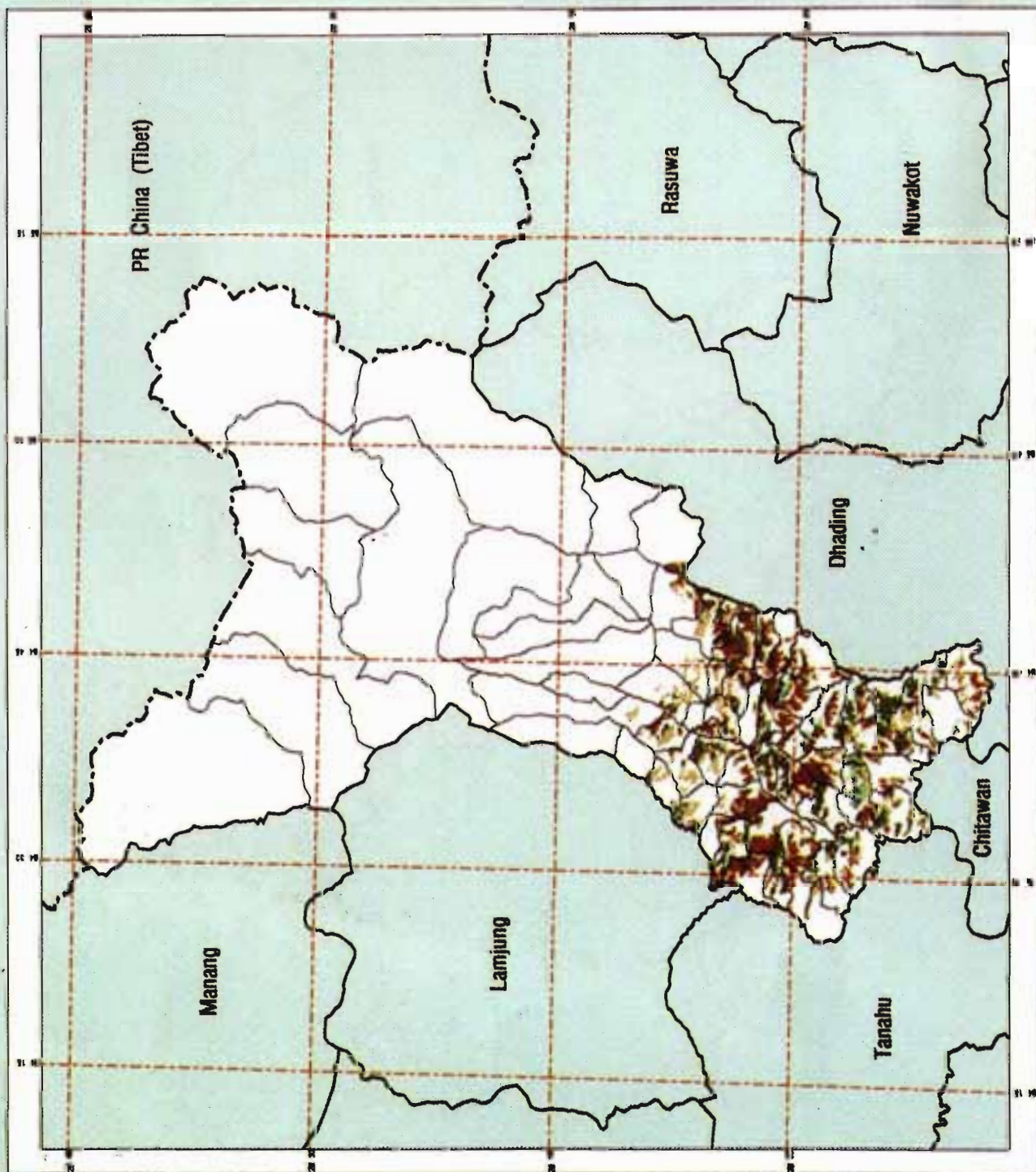
southeastern to western slopes  
& level land (12,870 ha)



MODERATELY SUITABLE LAND  
northwestern to eastern slopes  
(2,410 ha)



southeastern to western slopes  
& level land (6,670 ha)





Map 30

Gorkha District

Western Region of Nepal  
Agricultural Land Suitable  
for *Santala* Trees

LEGEND

SUITABLE LAND



northwestern to eastern slopes  
(5,290 ha)



southeastern to western slopes  
& level land (6,020 ha)

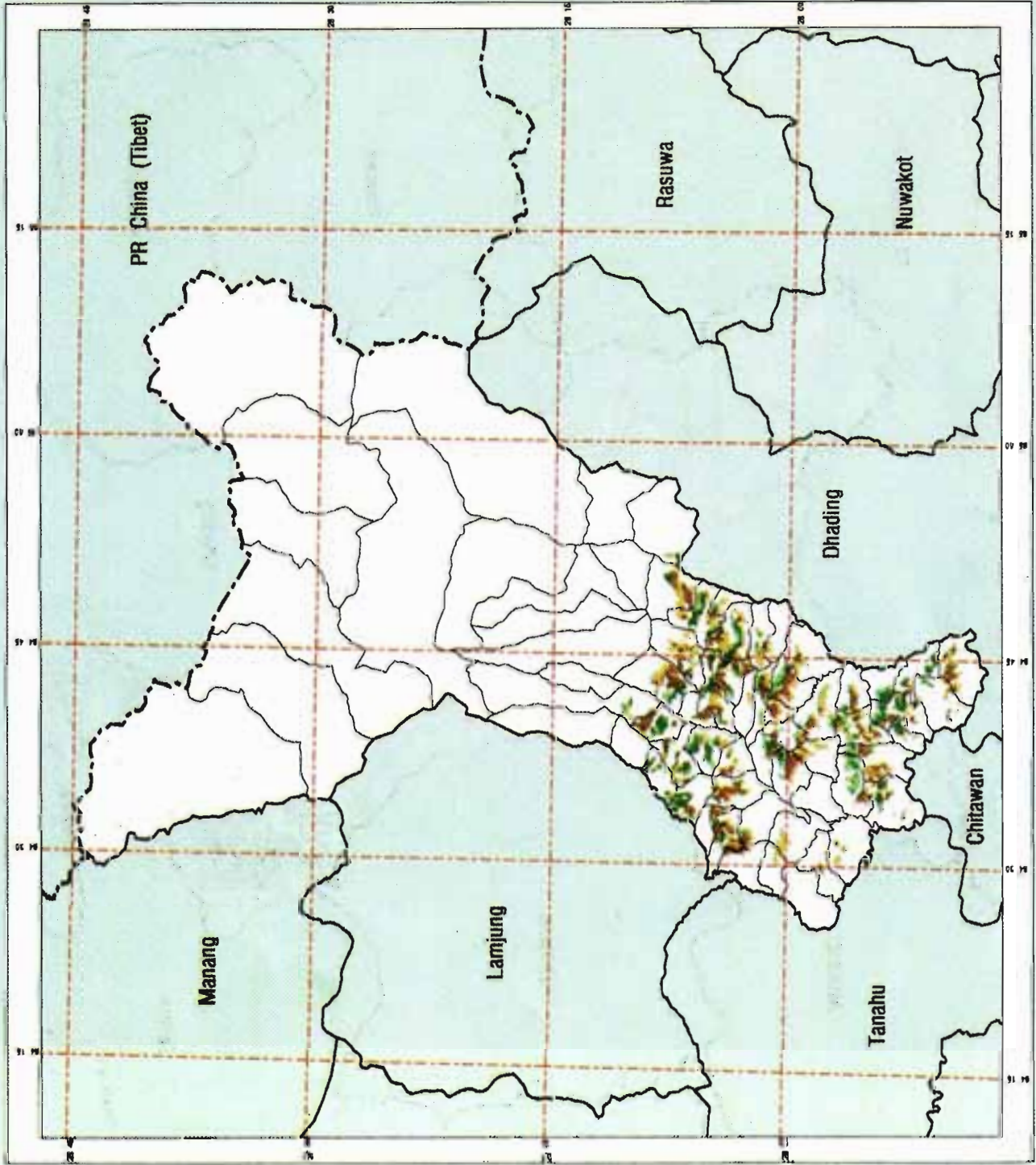
MODERATELY SUITABLE LAND



northwestern to eastern slopes  
(4,190 ha)



southeastern to western slopes  
& level land (6,390 ha)





Map 31

Gorkha District

Western Region of Nepal

Agricultural Land Suitable

for Peach Trees

LEGEND

SUITABLE LAND



northwestern to eastern slopes  
(30 ha)



southeastern to western slopes  
& level land (65 ha)

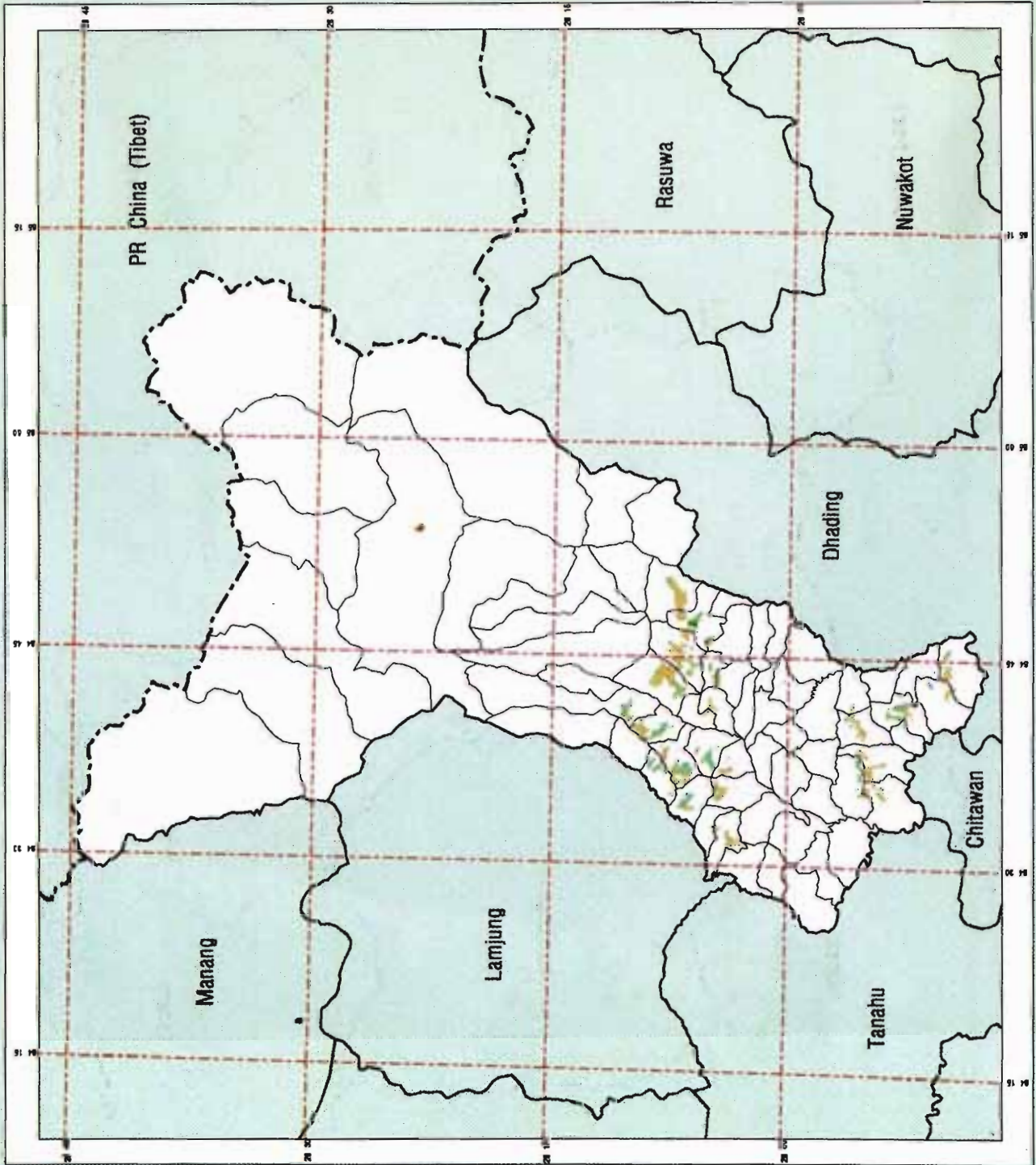
MODERATELY SUITABLE LAND



northwestern to eastern slopes  
(1,970 ha)



southeastern to western slopes  
& level land (3,160 ha)





# Map 32

Gorkha District

Western Region of Nepal

Agricultural Land Suitable  
for Apple Trees

## LEGEND

### SUITABLE LAND

northwestern to eastern slopes  
(1,170 ha)

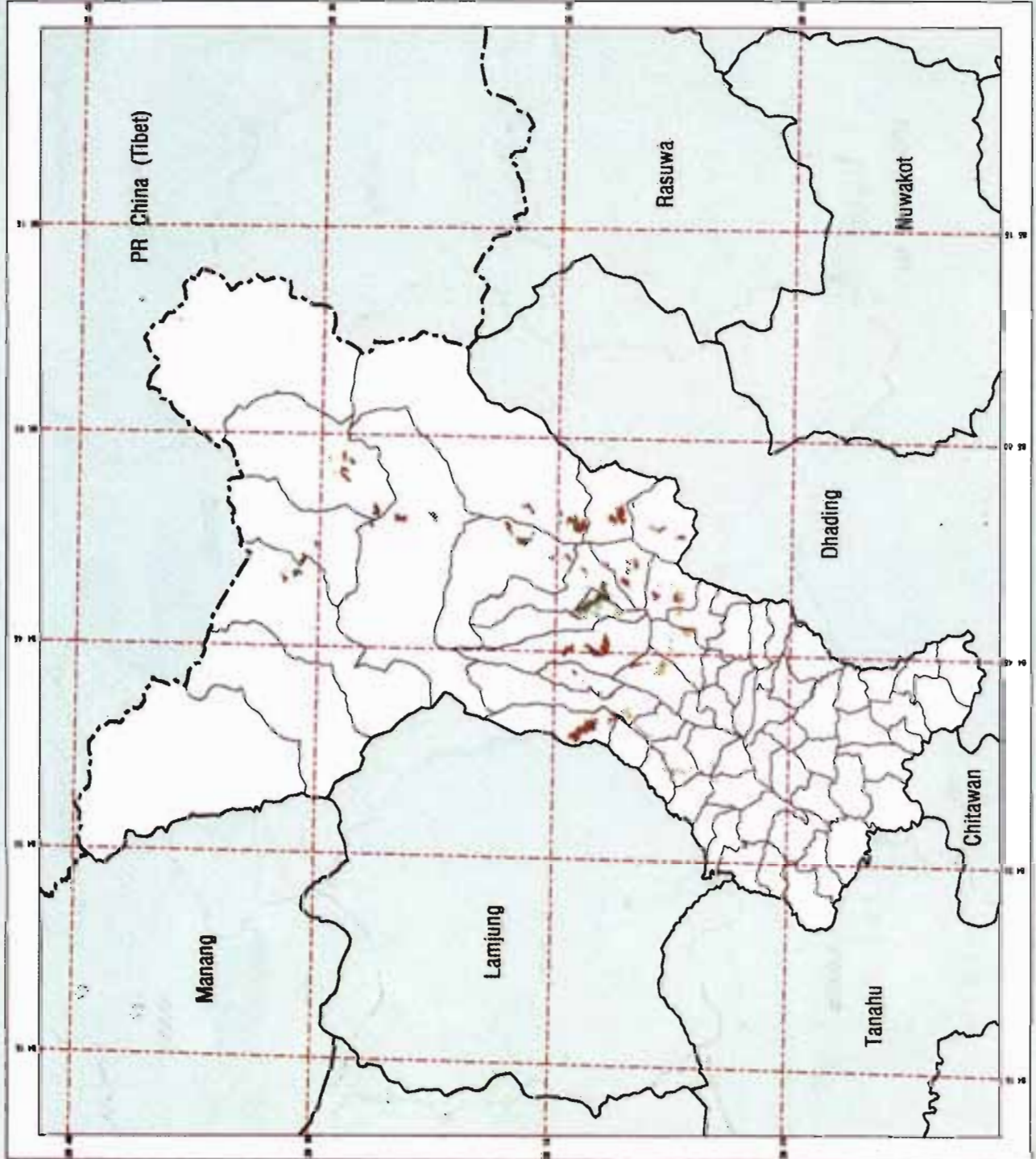
southeastern to western slopes  
& level land (1,720 ha)

### MODERATELY SUITABLE LAND

northwestern to eastern slopes  
(510 ha)

southeastern to western slopes  
& level land (590 ha)

0 5 10 15 20km





Map 33

Gorkha District

Western Region of Nepal

Potential Potato Growing

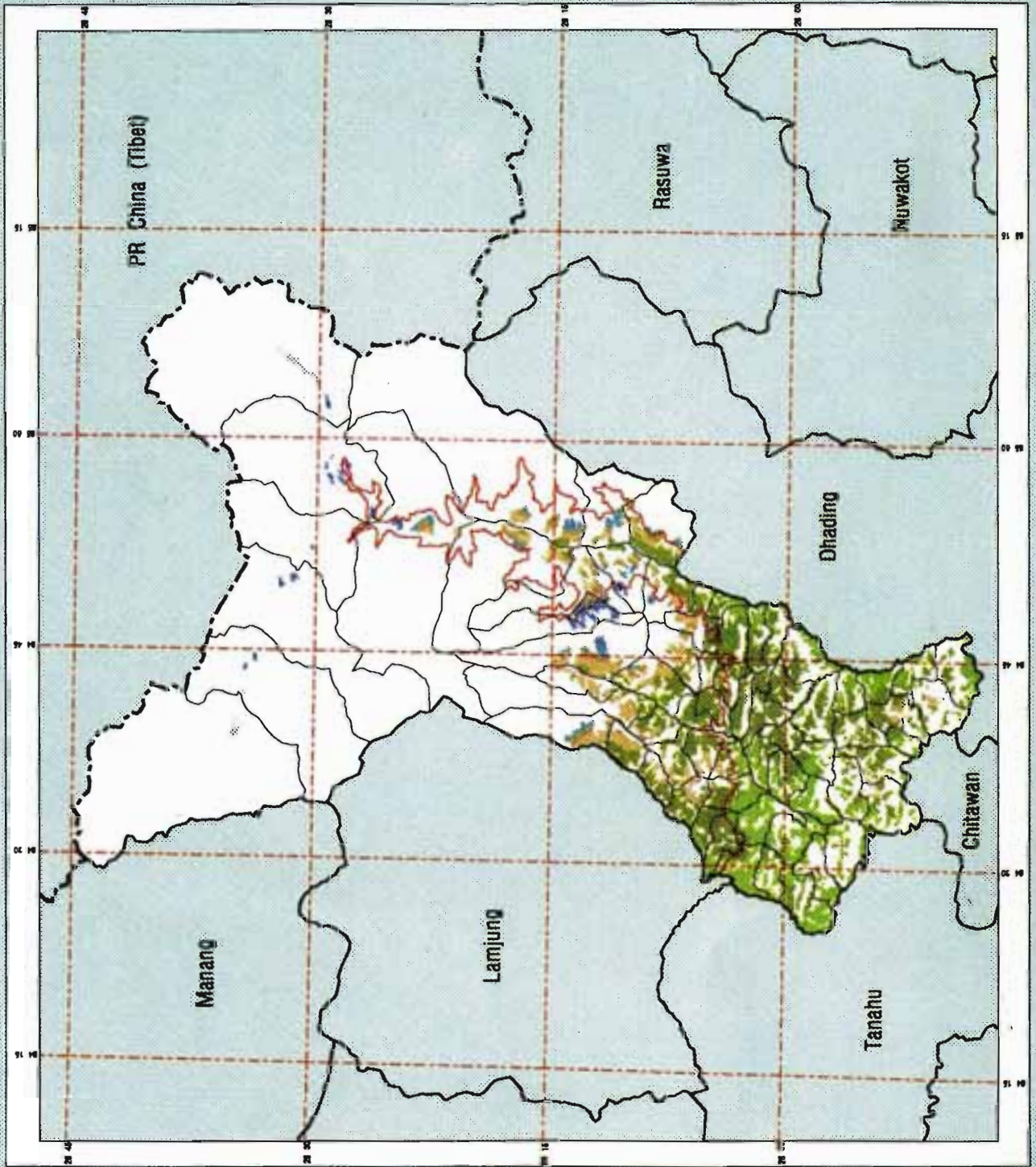
Area and Season

LEGEND

- September - April/May (1,340 ha)
- October - March/April (3,690 ha)
- November - February/March (13,350 ha)
- December - February (10,220 ha)
- February - December (650 ha)
- March - November (600 ha)
- April - October (60 ha)
- May - September/October (230 ha)
- June - September (120 ha)

Boundary between humid (north) and subhumid (south) moisture regime

0 5 10 15 20 km







**PLATES**







Agricultural land at Nareswhar in the Middle Mountain Region of Gorkha District, about 900masl; Manaslu Himal is in the background

Paddy fields in the subtropical/subhumid zone along the Budhigandaki River; about 1,000masl, eastern slope







Agricultural land (wheat, buckwheat, maize) and pasture areas in warm temperate subhumid zone at Philim, Sirdibas VDC, Budhigandaki River; about 1,750masl, western slope



Field with *Amaranthus spp* in cool temperate/humid zone at Ripchet, Chumchet VDC; terrace above Shyar Khola at about 2,500masl.





Dense coniferous forest and pasture land below Ganesh Himal in the alpine/perhumid zone, Chumchet VDC above 3,500masl; northern slopes



Summer grazing area (*kharka*) for cattle and buffaloes in the upper valley of the Daroundi Khola, Barpak VDC; about 3,000masl





A shelter for cattle (*goth*) in the upper valley of the Daroundi *Khola*, Barpak VDC; 3,000masl



Extensive pasture areas in the alpine/perhumid zone the Chulung *Khola* valley, Sirdibas VDC; 3,500masl, southern slope



The Shyar *Khola* valley in the cool temperate/humid zone; densely forested areas on northern slopes; cultivated fields, pastureland on southern slopes



Sheep flock grazing above the confluence of Budhigandaki river and Shyar *Khola*, Bihi VDC; 3,000masl





Inaccessibility; A woman crossing Trishuli Ganga by cable cart in southern Gorkha



Potato harvest in Ripchet, Chumchet VDC; 2,500masl



## **Participating Countries of the Hindu Kush-Himalayan Region**

\* **Afghanistan**  
\* **Bhutan**  
\* **India**  
\* **Nepal**

\* **Bangladesh**  
\* **China**  
\* **Myanmar**  
\* **Pakistan**

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