LAND RESOURCES ANALYSIS USING GIS FOR SUSTAINABLE AGRICULTURAL LAND USE (A Case Study in Thedtsho and Baap Block, Bhutan)

by

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ABSTRACT

Agricultural land in Bhutan is limited mainly due to the rugged terrain and cold climates. In recent times, both due to increasing population as well as increasing developmental needs and its effects, this limited resource has come under increasing pressure. There is, therefore, an urgency to look into means and possibilities of ensuring land use sustainability. An attempt to begin this could be the gathering of data on the various aspects of land and adopting appropriate techniques and methodologies to understand, analyze and plan its use.

This study focused on the generation of data on land resources, specifically soil. A small area consisting of two administrative blocks were selected. Soil data in the area was gathered which was used along with the geological, slope, land use and land cover factors to prepare a soil map. Using this map, soil suitability for paddy was evaluated including an assessment of soil fertility and nutrient balance. The soil map was also used in combination with other physical and socio-economic parameters to assess and evaluate the area into suitability classes for paddy. On the basis of selected and relevant soil properties and other variables, the area was divided into erosion susceptibility zones. All spatial analysis were done with the use of Geographical Information Systems.

The increasing demand for agricultural land was evident from the fact that all land that were classified as highly suitable as well as moderately suitable were already under intensive cultivation. Most of the land under marginal suitability class were also already under cultivation. There is no way to increase the supply of land to meet the demand that will only increase, other than to increase yield from the existing land through crop intensification and further research and development. The prospects of expanding agricultural land is further limited by the fact that a lot of the area is already degraded or is highly susceptible to erosion.

Given this reality, this study recommends the need to rehabilitate degraded lands where possible, prioritize land use allocation, proper management of areas that has already been brought under plantation (reforestation) and strong coordination among the various organizations involved in the development of the area. Further studies are required to understand more about the fym and guide farmers on the application of fertilizers.

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List of Abbreviations

AIT	Asian Institute of Technology
CARD	Center for Agricultural Research and Development
FAO	Food and Agricultural Organization
GIS	Geographical Information Systems
JICA	Japan International Cooperation Association
LUPP	Land Use Planning Project
MoA	Ministry of Agriculture
NRTI	Natural Resources Training Institute
PPC	Policy and Planning Committee
RNRRC	Renewable Natural Resources Research Center
SPAL	Soil and Plant Analytical Laboratory
SoB	Survey of Bhutan

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1. INTRODUCTION

1.1 General Considerations

Concerns about the decreasing availability of arable agricultural land is on the rise in the face of increasing population pressures. Such concerns are manifested through the continuous expansion of the agriculture domain into marginal lands including forest areas, and the intensive use of available land through the application of fertilizers and irrigation. This course of action, however, has put severe strains on our environment and natural resource base.

Bhutan too shares this global concern. Nature's endowment to Bhutan is one of lofty and cold mountains with rugged terrain and steep slopes, with only 11 percent of the nation's 40,250 sq.km. of total land area constituting the arable portion, and hence amenable for human habitation (MoA, 1990). With an annual population growth rate of 2.3 percent there is a rising pressures on this meagre percentage of arable land.

There is a need to find ways of ensuring the sustainable use of this limited parcel of land. To do this requires a basic understanding of the variables that affect the current utilization of land.

This study focuses on the generation of a database and information related to land use, particularly on soil. It investigates how such information can be used for planning sustainable agriculture land use. GIS technique was used for soil and land suitability classification for paddy in the two blocks under Wangdue Phodrang district in western Bhutan. Areas prone to soil erosion were also be identified and appropriate soil conservation measures recommended.

1.2. Problem Statement

Problems, issues and concerns related to agricultural land use in Bhutan range from limitations posed by the unfavorable physiography to lack of proper planning and institutional capacity.

Physiographically, the rugged mountainous topography, an important limitation of which is in the form of steep slopes that are not only uneconomic to use but are also prone to soil erosion and high elevations pose severe limitations to farming.

Environmental planning and policies in Bhutan seem, in recent times, to concentrate more on the conservation of forest resources and the protection and preservation of wildlife, especially rare and endangered species. Efforts to inventory have, therefore, covered only these portions of the country's natural resources. With the exception of preliminary information on land use and land cover being generated by the Land Use Planning Project in the Ministry of Agriculture, there has not been any clear and concerted effort to collect data on land resources which would facilitate sustainable use of land. Information on soils, which form the basis of any sound land use decisions are very limited, and is almost non-existent because whatever is available has hardly been used as basis in the formulation of any land use policies so far.

An important implication of this issue together with poor institutional capacity has been the lack of proper planning on land use. This in turn has resulted in faulty agricultural practice (for instance, on very steep slopes) and encroachment into the forest lands engendering risks of soil erosion and the degradation in the productive capacity of land. There have also been several cases where conflicts in land use arose - agriculture versus industrial sites or urban settlements. Decisions made and policies implemented in response to such conflicts do not seem to have been based on scientific analysis and findings, but rather on the dictates of policy makers, or so to say top-down approach. But as studies and learning about sustainable development indicate, this is definitely not the right path.

1.3. Objectives of the Study

1.3.1. Developmental Objective:

To help achieve the Royal Government of Bhutan's policy of Sustainable Agricultural Land use.

1.3.2. Specific Objectives:

The specific objectives of this research are to:

1. gather data on soil properties in the study area;

2. evaluate land suitability for paddy considering both physical parameters and socio-economic aspects;

3. identify areas susceptible to soil erosion and formulate conservation recommendations;

4. suggest relevant options for sustaining agriculture land use.

1.4. Scope and Limitation

The study covers the two blocks (sub-district) of Thedtsho and Baap with an approximate area of 5617 hectares under Wangdue Phodrang and Thimphu districts respectively in western Bhutan.

Various maps such as soil, slope, aspect, soil suitability, land suitability classification for paddy, susceptibility to soil erosion are prepared as a part of the research.

Soil data and information has been gathered, compiled, analyzed and made usable for use in future research in similar fields.

This research brings into forefront particular areas within the study area that require soil conservation measures and attention of the policy-cum-decision makers in order to ensure, in its eventuality, sustainability in land use.

However, this research was conducted within the limited availability of the required data. Soil data, for instance, had to be collected from the field and time actually was not available to do a detailed soil mapping worth tallying with the international system of soil classification and taxonomy. As a result, soil map prepared and used in this research is a only a product of the combination of available soil and site information.

Land suitability classification has focused only on paddy and not any other crops. This is, of course, justified in view of the fact that this crop is the single most important crop in the area.

2. LITERATURE REVIEW

2.1. Concept of Sustainable Agriculture

Sustainable agriculture, currently receiving an enthusiastic response in the scientific community and from policy makers, has become a buzz word for the 1980s and 1990s. It is a philosophy aimed at establishing an ecological approach to resource management. The objective is to balance the inherent soil resource and crop requirements in innovative soil and crop management systems. The emphasis is not on maximizing production but on optimizing resource use and sustaining productivity over a long period (Lal and Pierce, 1989).

There are several definitions of sustainable agriculture. Just as there is no universal blueprint of technological options for sustaining agricultural production for all soils and ecological regions, similarly there is no single definition that is widely accepted or applicable. A commonly used definition is that proposed by the Technical Advisory Committee to the Consultative Group on International Agricultural Research. According to this definition, "sustainable agriculture should involve the successful management of resources to satisfy changing human needs .while maintaining or enhancing the quality of the environment and conserving natural resources" (cited by Lal and Pierce, 1989).

Sustainable agriculture has also been interpreted as a "system that, over the long term, enhances environmental quality and the resource base on which agriculture depends; provides for basic human food and fiber needs; is economically viable; and enhances the quality of life for farmers and society." (American Society of Agronomy, in B.A. Stewart, et el 1991).

Alternately, it has also been defined as a "production system through which we can sustain our basic soil and water resources indefinitely and still produce food and fiber without endangering the environment". (Larson - interviewed by Benbrook, 1991).

Given a good database, activities such as land suitability classification, has much to offer in sustaining land use for agriculture. This is because such classification ensures, through its findings and guidelines, the right allocation and use of land according to its suitability. When a parcel of land is allocated for use where it is most suited, there is not only maximization of benefits but also sustainability in the use of limited resource at our disposal.

One of the major issues in sustainable agricultural land use is soil erosion and the degradation of land quality. Efforts towards soil conservation is, therefore, directly oriented in sustaining agricultural land use. Remedies in this regard can be initiated by identifying areas that are most susceptible to erosion and designing conservation measures.

Many studies have been carried out to estimate soil loss due to water erosion. The most well known quantitative method in this field is the Universal Soil Loss Equation developed by Wischmeier and Smith (1958) according to which soil loss is calculated as:

$$E = R.K.LS.C.P$$

In the above formula, R is the rainfall erosivity index which is equal to the mean annual erosivity value divided by 100 ($R = EI_{30}/100$) {E = kinetic energy of the falling raindrop and I = rainfall intensity for 30 minutes); K is the soil erodibility index defined as mean annual soil loss per unit of erosivity for a standard condition of bare soil, no conservation practice, 5° slope of 22 m length; LS is the combined index of slope length (L) and slope steepness (S) factor with defined values of different degrees of slope steepness; C is the crop factor which is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow; and P is the conservation factor for which values are obtained from tables of the ratio of soil loss where contouring and contour strip cropping are practised to that where they are not.

A simple scoring system for rating erosion risk has been devised by Stocking and Elwell (1973, in Morgan, 1986) in Zimbabwe. Taking a 1 : 1000,000 base map, the country is divided on a grid system into units 184 km^2. Each unit is rated on a scale from 1 to 5 in respect of erosivity, erodibility, slope, ground cover and human occupation, the latter taking into account of the density and type of settlement. The scoring is arranged so that 1 is accociated with a low risk of erosion and 5 with high risk. The five factor scores are summed to give a total score which is compared with an arbitrarily chosen classification system to categorize areas of low, moderate and high erosion risk. The scores are mapped and areas of similar risk delineated.

2.2. **Concept of Land and its Analysis**

Land has been defined by the FAO (1976) as "an area of the earth's surface, the characteristics of which embraces all reasonably stable, or predictably cyclic, attributes of the biosphere vertically above and below this area including those of the atmosphere, the soil and the underlying geology, the hydrology, the plant and animal population, the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of land by man".

The concept of land has been interpreted from various perspectives. A basic understanding of land is that of a three-dimensional space which man occupies in his daily living and provides him with physical support. Land is viewed also as a factor of production or capital and as a commodity or consumption good in itself which can be purchased or leased like any other goods. Land likewise have legal implications in terms of property rights of ownership and use by individuals, groups or sovereign powers. An important attribute of land is its location which largely determines its value and use. Land has also been considered as nature itself encompassing all characteristics of the physical environment - the atmosphere, soil, hydrology, flora and fauna. (Guevarra, 1995).

Terrain or *land analysis* is the set of activities which leads to the compilation of terrain characteristics. Terrain or land evaluation uses the characteristics extracted by terrain analysis, along with other properties, to assign a value to a piece of land, expressed either by a numerical value or a judgment of its worth in qualitative terms (Mitchell, 1973).

Terrain or land evaluation is the ranking of land-units according to their capacity to provide the optimum return from use under given management practices. The optimum return is determined in consideration of economic, social and environmental factors (Hewitt & Wambeke, 1982)

Most of these evaluation is done in the context of suitability ranking. There now exist many approaches to land suitability evaluation. Some of them are briefly mentioned below.

i) *Parametric Approach*

According to this approach the various soil and site properties (parameters) that are believed to influence yield are combined in a mathematical formula. Three main kinds of manipulation are recognized:

Additive, e.g.	P = A+B+C
Multiplicative, e.g.	P = A*B*C
More complex functions, e.g.	P = A (B*C*D)

where P is the parametric rating, score or index, and A, B, C, and D are soil and site properties. (McRae & Burnham, 1981)

ii) *Categoric Approach*

This is another type of system developed by the United States' Department of Agriculture (USDA), which divide land into small numbers of discrete ranked categories. The most widely used are Land Capability Classification which consider the number and extent of physical limitations to crop growth as a basis of classification. This system groups soil into eight broad classes, with the risks of soil damage or the limitations in use becoming greater from class U-I to U-VIII (McRae & Burnham, 1981).

iii) *Sequential Approach*

Land is rated initially on the basis of soil properties alone and that rating is successively modified by a series of approximations based on qualities relevant at each level until a final recommendation is reached. The two stage approach to land evaluation suggested by FAO (1976) is a sequential approach.

iv) *Parallel Approach*

Ratings are determined by simultaneously taking all factors into account. The land with the highest suitability for a particular use is identified where the combined limitations are minimal. An example is the parallel approach developed by the FAO (1976).

There are six basic principles (Young, 1978) behind the FAO Framework for Land Evaluation:

1. Land suitability is assessed for specified kinds of use;
2. Evaluation requires a comparison of benefit obtained with inputs needed;
3. A multidisciplinary approach is required;
4. Evaluation is made in terms relevant to local or national conditions;
5. Suitability is for use on a sustained basis, i.e., the use must not bring about severe or progressive degradation; and
6. Evaluation involves a comparison of two or more kinds of use, which are not exclusively agricultural.

Other approaches include *Direct* and *Indirect Method* of land evaluation. The *Direct* method is based on evaluating land directly by trial, that is by growing the crop or building a length of pipeline, to see what happens. The results are applicable only to the specific trial sites and for that particular use. Unless the evaluator has the resources to collect a large amount of data, direct evaluation is of limited value. The more widely used is the *Indirect* method, which assumes that certain soil and site properties influence the success of a particular land use in a reasonably predictable manner, and that the quality of land can be deduced from observations of those properties. (McRae & Burnham, 1981).

v) *Fertility Capability Soil Classification (FCSC)*

The FCSC is a technical classification of soils (developed by Buol et al in the U.S.A) according to their fertility limitations (both physical and chemical) with emphasis on topsoil properties but including relevant subsoil parameters as well. Only quantifiable parameters are used. The FCSC classes indicate the main fertility-related constraints of the soil, which can be interpreted both in general terms and in view of a specific farming system (Sanchez, 1981). This system provides some flexibility in application to various crop types, and is designed around agricultural use of the land. It was improved and tested mostly in the United States of America and South America (Sanchez et al, 1982), in Taiwan (Lin, 1984) for paddy and in Thailand (Eiumnoh, 1984) for general crops (cited by Shrestra et al, 1993)

2.3. **Farming Systems Analysis**

Farming Systems Analysis (FSA) is the body of knowledge that is concerned with the diagnosis and analysis of farm level variables. Because FSA has its root in agricultural research, its objectives and methods are primarily aimed at complementing and directing ongoing applied research in agriculture. A distinguishing feature of FSA in comparison to most classical research in agriculture is its interdisciplinarity and its attempt to integrate the results of various disciplines, in order to understand the linkages between the agro-ecological and socio-economic aspects of a farm. Many of the insights gained in this context, particularly the diagnostic procedures, however, can also be applied in other development-oriented programmes, such as land use planning. FSA derives its theoretical framework largely from systems analysis. It distinguishes between systems at various hierarchical levels, ranging from plant system through the crop and its cropping system, the farm system, to the national system of land use systems.

2.4. **Geographical Information Systems**

According to Burrough (1989), Geographical Information System (GIS) is a "powerful set of tools for collecting, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes".

GIS has also been defined as "an organized collection of computer hardware, software, geographical data, and personnel designed to effectively capture, store, update, manipulate, analyze and display all forms of geographically referenced information" (ESRI, 1989)

According to Aronoff (1981), GIS is a system "designed for the collection, storage and analysis of objects and phenomena where geographic location is an important characteristic or critical to the analysis. The four major components of GIS, according to him are:

1. Data input: the process of converting data from their existing form into one that can be used by the GIS.

2. Data Management: that includes those functions needed to store and retrieve data from the data base. This database can be updated and queried according to need.

3. Data Manipulation and Analysis: using the spatial and non-spatial attribute data in the GIS database to answer questions about the real world. This component of GIS is what distinguishes it from other types of information systems.

4. Data Output: normally called report generation, which may be in the form of maps, tables or texts.

In the field of land use studies, GIS has been applied widely in soil survey and soil data manipulation (Burrough, 1991), in land use survey, land use mapping and land use change monitoring (O'Callaghen & Garner, 1991), in land productivity assessment (Malla, 1992) and in land suitability and capability evaluation (Burrough (1986), Antoine (1991) in Nancy & Jeffrey 1994).

In fact, one area of application that has played a significant role in the evolution of GIS is land use planning. This is a field that encompasses the work of landscape architects, urban and regional planners, natural resource managers, environmental regulators, and others responsible for making decisions as to how geographic resources should be utilized (Donna & Duane, 1990)

GIS have generally been of use to land use planners in the following three major capacities:

- the maintenance of general-purpose data.
- the generation of special purpose information from such data; and
- the utilization of such information in decision-making context.

Increasing capabilities, decreasing costs, and enhanced user-friendliness have all contributed to recent gains in the rate of adoption and widespread use of GIS technology (Nancy & Jeffrey (1994).

2.5. **Land Use Planning in Bhutan**

Systematic planning on land use is of recent origin in Bhutan which began with the inception of the DANIDA funded Land Use Planning Project (LUPP) in late 1992. With this project came into vogue the use of modern tools and techniques such as geographical information systems and remote sensing materials to aid in the evaluation and analysis of land resources, making the activity more rigorous on the whole. Land use mapping, training agricultural personnel, production of many guidelines on sustainable land use, capacity building in the head office through training are some of the major activities that has now been materialized.

Amongst many, the development and documentation of *Sustainable Land Use: Guidelines for Bhutan* (SLUB) deserve a special mention. Its main objective is to "guide planners, policy makers and the staff of the Renewable Natural Resources (RNR) Sector on how to plan for the best use of the land and how to ensure that the implementation of the plans take in account sustainability, public participation and the interest of the Nation" (LUPP, 1995).

Further, "in order to present a concrete example of how planners can conduct the surveys, analyze the results and present the results of the different stages of planning process, a Pilot Study was conducted in Gidakom Valley. The study was also meant for developing land use planning methodologies, especially adapted to the Bhutanese conditions" (LUPP, 1995).

2.6. **Soil Studies in Bhutan**

Literature on soils in Bhutan is very limited since no systematic description or classification of the soils of whole Bhutan have so far been attempted. The most detailed pre-

LUPP soil study was that done by Sinclair Knight (1983) in the four proposed irrigation schemes in Mongar and Trashigang districts. His team defined eight local soil classes based on colour, depth and parent material. They assigned these to five units in the FAO system. Because of the intricate soil distributions, they were obliged to map complexes. They described soil topographic patterns, with red clays on pegmatite ridge crests running down to gray sandy loam in the seepage zones on lower slopes (cited by Ingenieure, 1995).

The JICA (1989) study for the Lhuntshi and Mongar Integrated Agricultural Development Project involved a considerable amount of soil work. Their report contains 23 profile descriptions but no analysis. They classified the soils according to the FAO system, identifying seven units -' Phaeozoms, Cambisols, Acrisols, Gleysols, Arenosols, Regosols, and Lithosols. They identified some topographic and altitudinal patterns in the soil distribution, but these are not as clearly defined as those in the Sinclair Knight further east (cited by Ingenieure, 1995).

Besides the above two efforts, activities related to soils, especially the field work are conducted by the LUPP during their land use mapping field verification period. During the past two years, LUPP has gathered a considerable amount of samples from almost all parts of the country which were analyzed by SPAL. Efforts to map though has not been attempted so far.

2.7. **Use of Aerial Photography in Soil Mapping**

Aerial photographs have been used for several decades in the study of the earth's surface. As a means of illustrating and explaining landscape phenomena, the bird's eyeview which air photographs provide is without rival at comparable costs (FAO, 1967).

Aerial photograph is useful in soil mapping:

1. to study more intensively the physiographic aspects of soils;
2. to extract information about the differences between soil mapping units, mainly of qualitative character, but as far as spatial aspects are concerned, also of quantitative character; leading to
3. in the delineation of the soil boundaries with greater precision and speed.

Aerial photograph, however, is not a boon in all aspects for soil mapping and do suffer from some drawbacks. For instance soil profile cannot be studied on it and differences in soil types, phases and series are not always systematically visible on the surface of the earth and therefore, are not reflected on the aerial photograph.

3. RESEARCH DESIGN AND METHODOLOGY

The overall research methodology adopted in this study is schematically presented in Figure 3.1. It involves the following steps:

3.1. Selection of the Study area:

The Thedtsho-Baap blocks have been selected for the present study based on the following criteria:

1. Emerging problems of decreasing agricultural land are most notable in the area. This area has witnessed a fast developmental pace and already conflicts in land use are visible - agriculture versus urban development.

2. On the surrounding slopes, there are numerous eroded sites which could be interesting and useful to investigate.

3. Aerial photographs (1978), geological information and other required data are available for the area which is comparatively better than other parts of the country.

4. The area is easily accessible by road with only about two hours drive from the office base in Thimphu.

3.2. Land Suitability Evaluation

The *FAO Framework for Land Evaluation* (1976) applied according to the guidelines for rainfed agriculture (FAO, 1983) was followed for the evaluation process because of its structured nature and general acceptance. Various input materials used for the evaluation were:

- Topographical Map - Scale 1:50,000, for deriving slope, elevation and drainage map.
- Land Use Working Map - scale 1:50,000 (LUPP)
- Geological Map - scale 1:50,000, derived from the JICA Groundwater Development Project in Wangdue District, 1994.
- Aerial Photographs - Scale 1:35,000, 1978, Survey of Bhutan.

The following assumptions and conditions underlie the evaluation of land suitability for paddy:

i. The soil map prepared on the basis of land use, slope, geology and on field sampling and laboratory analysis with some extrapolation based on reasoned judgment is sufficient for the present analysis.

ii. Given the smallness of the area , variation in climatic conditions is minimum. This factor is therefore used only as a guide rather than as a specific parameter for the analysis.

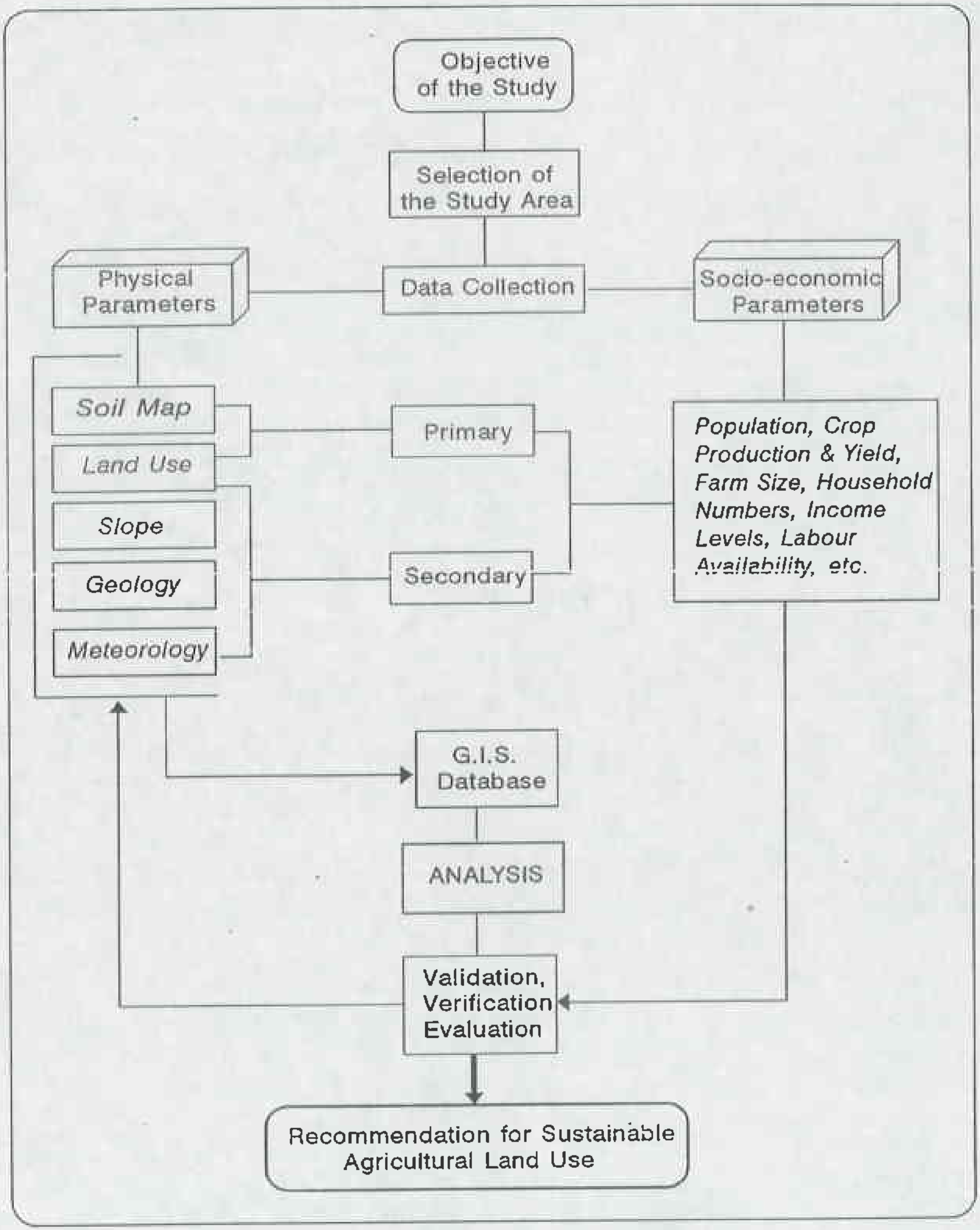


Figure 4.1 - Research Design and Methodology

iii. Ratings considered in this exercise must be seen as a general guideline rather than precise evaluation of relative yields.

iv. Under an extremely high levels of management applied with unusual skill, satisfactory but not economic yields of crops can sometimes be obtained on highly unfavourable environment. The evaluation do not reflect such extreme levels of management.

3.2. **Research Parameters**

Emphasis has been given more to the biophysical factors of soil, physiography, landuse and soil. The consideration of socio-economic variables has been kept minimum and, therefore, used only as a guide in the overall analysis. This was because socio-economic factors, albeit very important, are quite complex and ever-changing, and would not be possible to analyze to reach to a realistic picture within the given time. Biophysical factors are relatively stable and information on its existing situation could be collected much easily.

The various categories of data and their respective parameters are as shown in table 4.1. Also included in the table is the source from where they have been collected.

3.3. Data Collection

3.3.1. Collection of Primary Data

(a) <u>Soil and Farm Yard Manure Sampling:</u>

In order to take soil samplings, first the aerial photo at 1 : 35,000 scale taken in 1978 were collected from the Survey of Bhutan. The aerial photos helped in giving a first hand idea on the physical characteristics of the area. A preliminary visit to the field was made. The sites for soil pits, from where samples were to be taken, were then selected based on the landform characteristics and carefully marked on the aerial photographs. The extension agents of the two blocks were contacted to arrange laborers for digging the pits, the size of which were approximately 1 m breath x 1.5 m length x 1 m height. With the help of staff from LUPP, the soil horizons were marked and samples collected from each horizon. From each pit an average of three samples were taken, the site and the physical properties of which were carefully recorded in the soil recording forms. The samples were then handed over to the SPAL for chemical analysis including texture.

Samples on farmyard manure were also collected from ten different locations. Most of them were, however, from the piles collected nearby the house. This was because at this time of the year, application of FYM for the coming crop cultivation has not yet begun. Where available, samples have been collected from the field. The main objective of collecting the samples were to get an idea about its NPK content and its per unit application in the field.

Table 3.1. Data requirement and their sources

Sl. No.	Categories	Parameters	Sources
1	Soil	Texture; Depth; pH; O.M; NPK	Field Sampling and Laboratory Analysis.
2	Physiography	Slope; Elevation; Aspect	Topographic map and field check
3	Socio-economics	Population; Household number and size; Crop Production and Yield; Farm size; Income levels; Labour available	District Agricultural Office; Central Statistical Organi zation; Field Survey.
4	Landuse	Crops; Pattern; Agriculture and Non-agriculture.	Land use map; Field verification.
5	Climate	Rainfall; Temperature; Humidity.	Meteorological Station; Department of Power.
6	Water Availability	Irrigation Facilities	
7	Major Crops	Paddy; Wheat; and Mustard.	District Agricultural Office; Land use map.

(b) Socio-economic Survey

Socio-economic data on demography, household characteristics, cost of production, labour availability, etc., were collected through semi-structured questionnaires (Appendix E). This was done with the main objective of understanding the simple economic and social indicators of farming systems in the area. The sample size, however, is not statistically calculated, instead a household was selected randomly from each village. The choice of household for interview were based on the guidance and selection of the village headman and the extension agent who are quite familiar about the representativeness of that household about the village.

3.3.2. *Collection of Secondary Data*

To supplement the information gathered from primary sources, reports, documents, literature and publications were utilized as relevant secondary sources of information. Many secondary data were collected directly from LUPP. The district agricultural office, RNRRC, IFAD-PWVDP project, the extension agents and the village headman provided a lot of useful data and information.

3.5 **Data Processing and Analysis**

The processing and analysis of physical resources data were done with the help of PC ARC/INFO (3.4D Plus). The logical flow of the GIS analysis are shown in respective chapters with a flowchart. The analysis of socio-economic data mainly for deriving descriptive statistics such as mean, frequencies, deviations and percentages were done with the use of Windows based Excel (Version 5.0).

Linear combination model using weighted additive parametric approach was adopted for both the evaluation of land suitability for paddy and analysis of susceptibility to soil erosion.

4. THE STUDY AREA ENVIRONMENT

This chapter provides a glance at the geophysical and socio-economic conditions that characterize the area selected for the research.

4.1. **Background Information**

Block	Thedtsho and Baap
Country	Bhutan
District	Wangdue Phodrang and Thimphu
Area	56 km^2, (56,00 Ha).
Population	2808 (1995)
Number of Households	390
Total Agricultural Area	821.36 ha (as per land record) and 963.00 ha (GIS)
Lowest Altitude	1200
Highest Altitude	3000

4.2. **Location and Access**

Thedtsho and Baap are two adjoining administrative blocks under Wangdue Phodrang and Thimphu districts respectively in western Bhutan (Figure 3.1). They are located between 89°49'30" to 89°55'96" East longitude and 27°27'54" to 27°32'40" North latitude.

The two blocks are approximately 65 km from Thimphu city, Bhutan's capital, and is favourably located on either side of the Thimphu-Trashigang (East-West) and Thimphu-Tshirang (West - South) national highways.

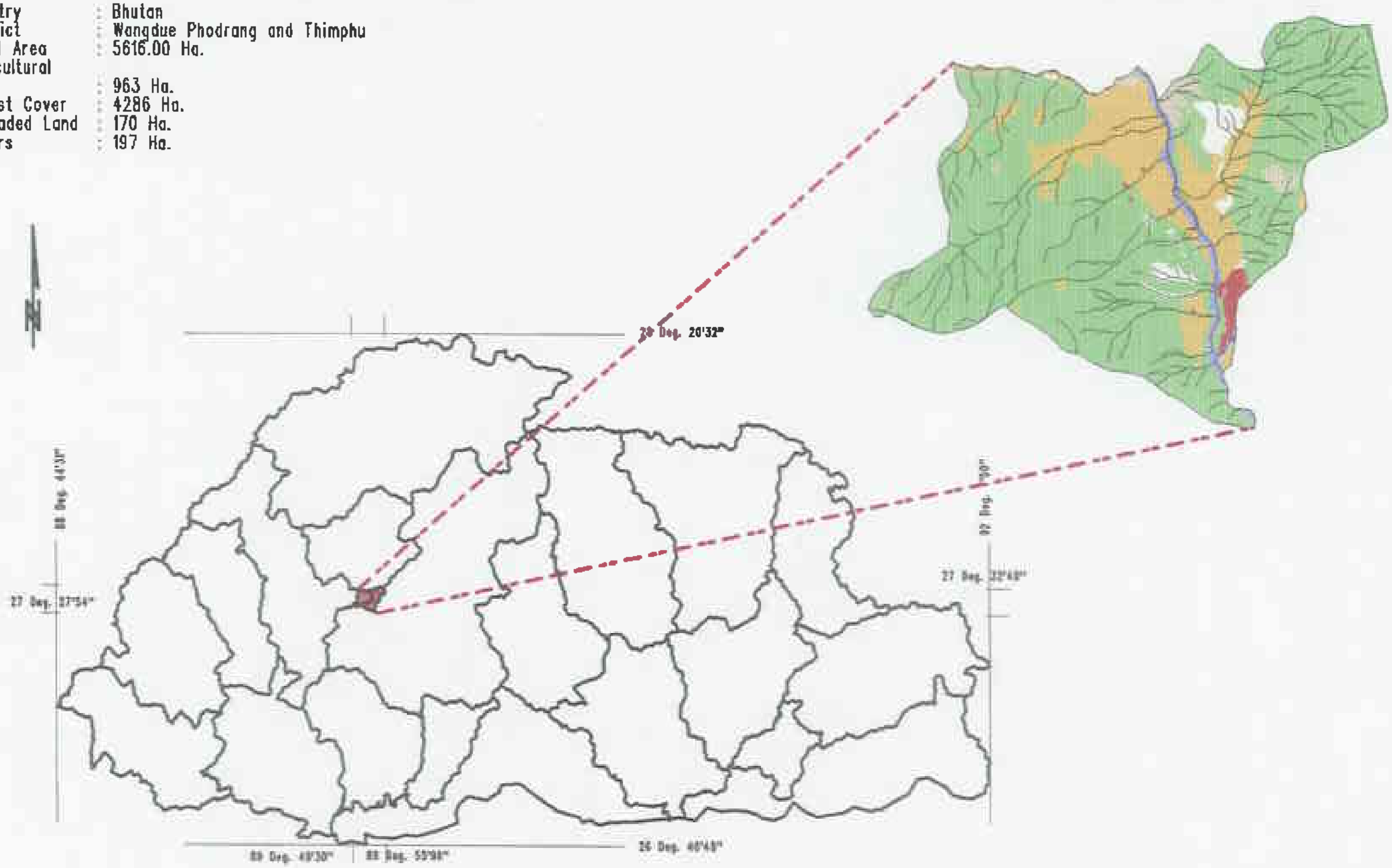
4.3. **The Physical Environment**

4.3.1. *Topography*

The area lies within the mountain systems of Western Bhutan consisting mainly of high mountains, hills and valleys that is drained by river Sunkosh. The valley that expanse approx. one kilometer in width, constitute the main agricultural hub. Flat and leveled land however, is very limited other than the valley on either side of the main river. This is clear from Figure 4.2 and Table 4.1.

The elevation above mean sea level varies between 1200 and 2600 meters although the ridge lines defining the main river watershed reach 3000m.

Country	:	Bhutan
District	:	Wangdue Phodrang and Thimphu
Total Area	:	5616.00 Ha.
Agricultural area	:	963 Ha.
Forest Cover	:	4286 Ha.
Degraded Land	:	170 Ha.
Others	:	197 Ha.



This map, and the maps in the following pages with similar quality prints, were plotted using the facilities in the Mapping Section of the Land Use Planning Project (LUPP) in the Ministry of Agriculture, Thimphu, Bhutan in March, 1996. LUPP also is the source of all the information and data used in preparing these maps.

Fig. 3.1 Location of the Study Area: Thedtsho and Baap Block

Table 4.1. Distribution of the area by various slope categories.

Class	Range (percent)	Area (ha)	Percentage of the Total
1	0 - 3	44.6	0.8
2	4 - 8	161.1	2.9
3	9 - 15	441.7	7.9
4	16 - 25	684.5	12.2
5	26 - 35	1117.4	19.9
6	36 - 50	1781.4	31.7
7	> 50	1385.4	24.7
	TOTAL	5617.7	100.0

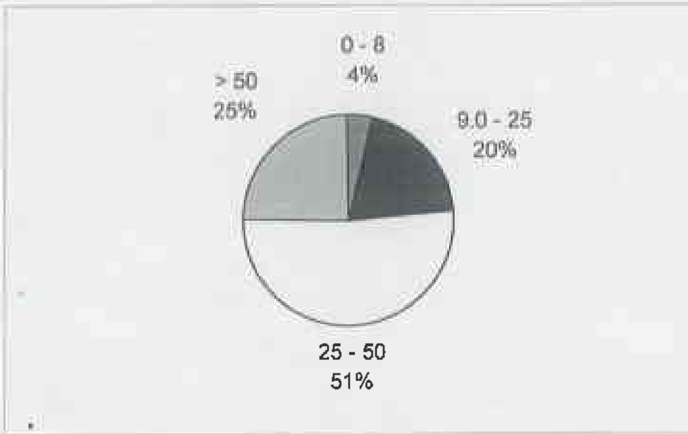


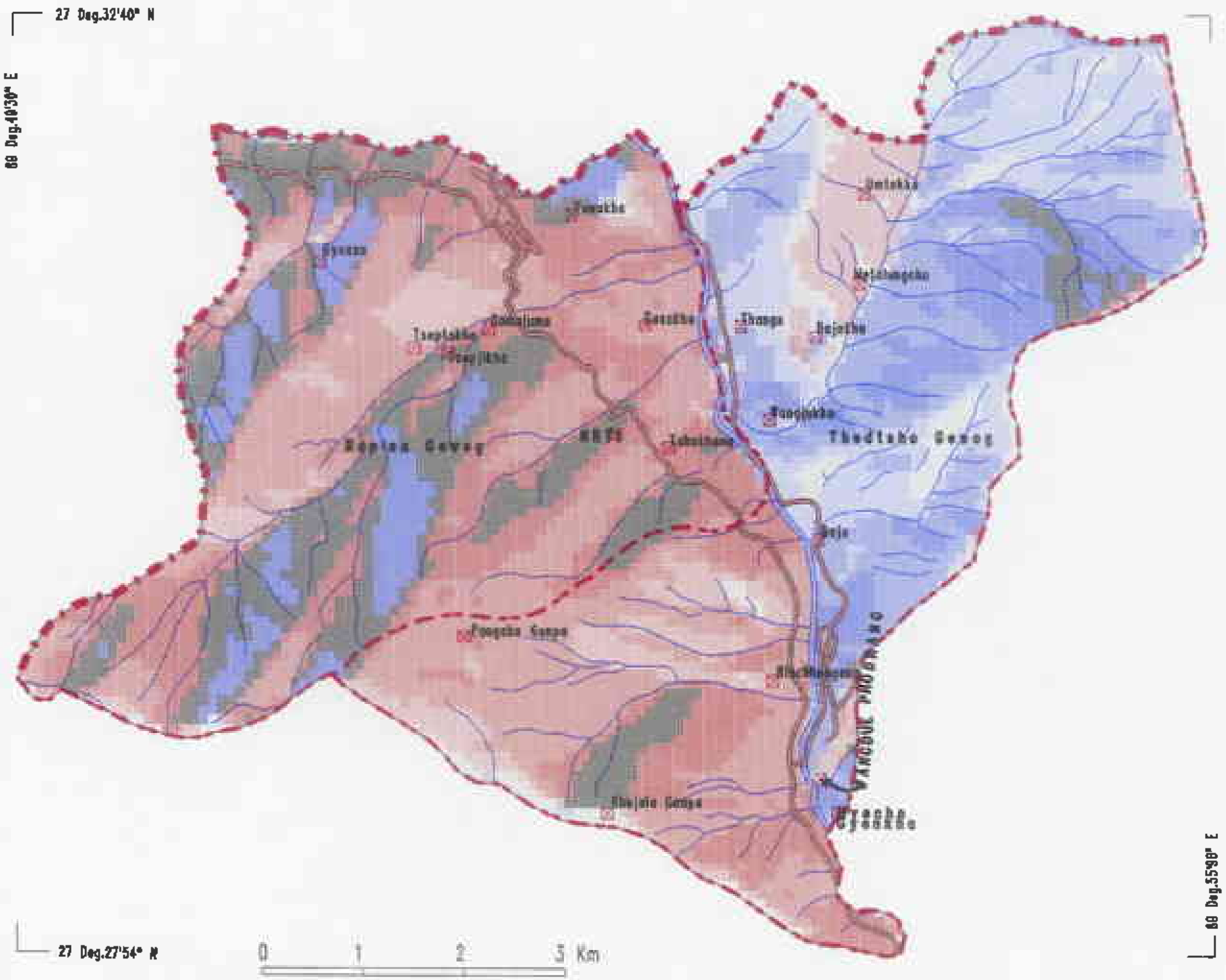
Figure 4.2. Percentage distribution of the area by various slope classes

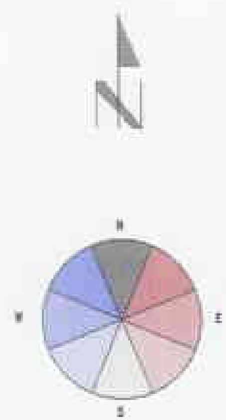
4.3.2. *Climate*

The area falls in the Dry Sub-tropical agro-ecological zone. Its climate is characterized by wet and warm summers and cold dry winters with monsoon related rainfall patterns. Temperatures rarely fall below zero degrees in the lower elevations but at higher elevations, sub-freezing temperatures are common. The mean maximum temperature range from 17.5°C in January to 29°C in June and the mean minimum range from 5.2°C in December to about 21.0 C in August. The absolute minima slightly below freezing occur in December and January at lower elevations. The mean annual rainfall are within the range of 600mm - 800 mm, about 75% being concentrated in the May-September monsoon season.

4.3.3. *Geology*

The JICA project on groundwater development in Wangdue has done detail studies on the geology of the area. The map derived from the report of this project is attached in Figure 4.4





ASPECT	AREA(Ha)	PERCENTAGE
NORTH	757.29	13.48 %
NORTH EAST	1041.84	18.55 %
EAST	1312.64	23.37 %
SOUTH EAST	512.40	9.12 %
SOUTH	240.78	4.29 %
SOUTH WEST	603.08	10.74 %
WEST	619.26	11.03 %
NORTH WEST	528.85	9.42 %

Figure 3.2: Aspect map of the study area

and the description produced below is from the same report with some modifications after field verification by a geologist.

Table 4.3. Mean Monthly Maximum and Minimum Temperature and Rainfall recorded at CARD between May 1985 and December 1995.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature ^{O}C Maximum	17.5	18.5	22.3	25.3	27.8	29.0	27.8	28.4	27.6	25.9	22.1	19.3
Minimum	5.44	8.13	11.2	12.9	17.0	19.5	20.0	19.9	19.1	14.7	8.78	5.18
Rainfall (mm)	11.7	15.8	20.0	44.1	34.8	139.0	154.0	126.0	90.7	35.5	10.6	10.1

(Also see Appendices A)

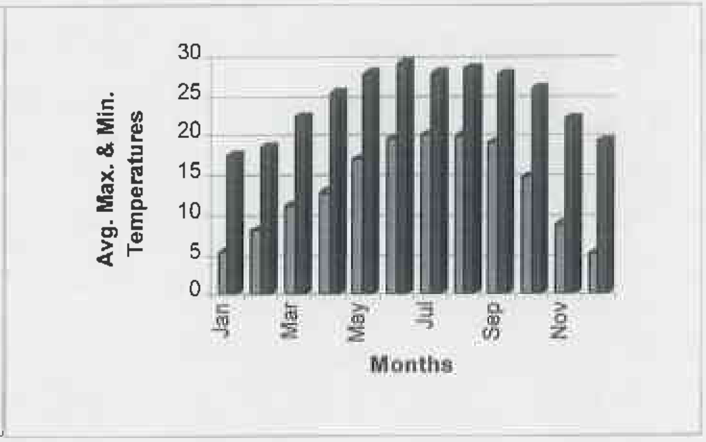


Figure 4.3. Mean Monthly Rainfall and Temperatures

The study area is situated physiographically in the Mountain and Valley belt of the metamorphosed crystalline rocks accompanied by thin cover of the weathered blanket and the Quaternary river terrace deposits at places.

The crystalline rock sequence in the study area has been classified into two series, namely, Thimphu Series and Paro Series. The Thimphu Series is composed of highly metamorphosed rocks such as garnet gneiss, para-gneiss and schists, marbles and quartzite with granitic intrusive. The Paro Series is composed of less metamorphosed pelitic and psammitic rocks such as phyllite and schist with minor showings of stratabound copper layers.

In the field, the highly metamorphosed Thimphu Series lies as a vast sheet covering the less metamorphosed rocks of Paro Series. This reversed metamorphism is a well known fact with regards to other parts of the Himalaya mountains but still remains a major future research priority. Petrographic study indicates great break in continuity of metamorphic grade suggesting fault contact of the two geological series.

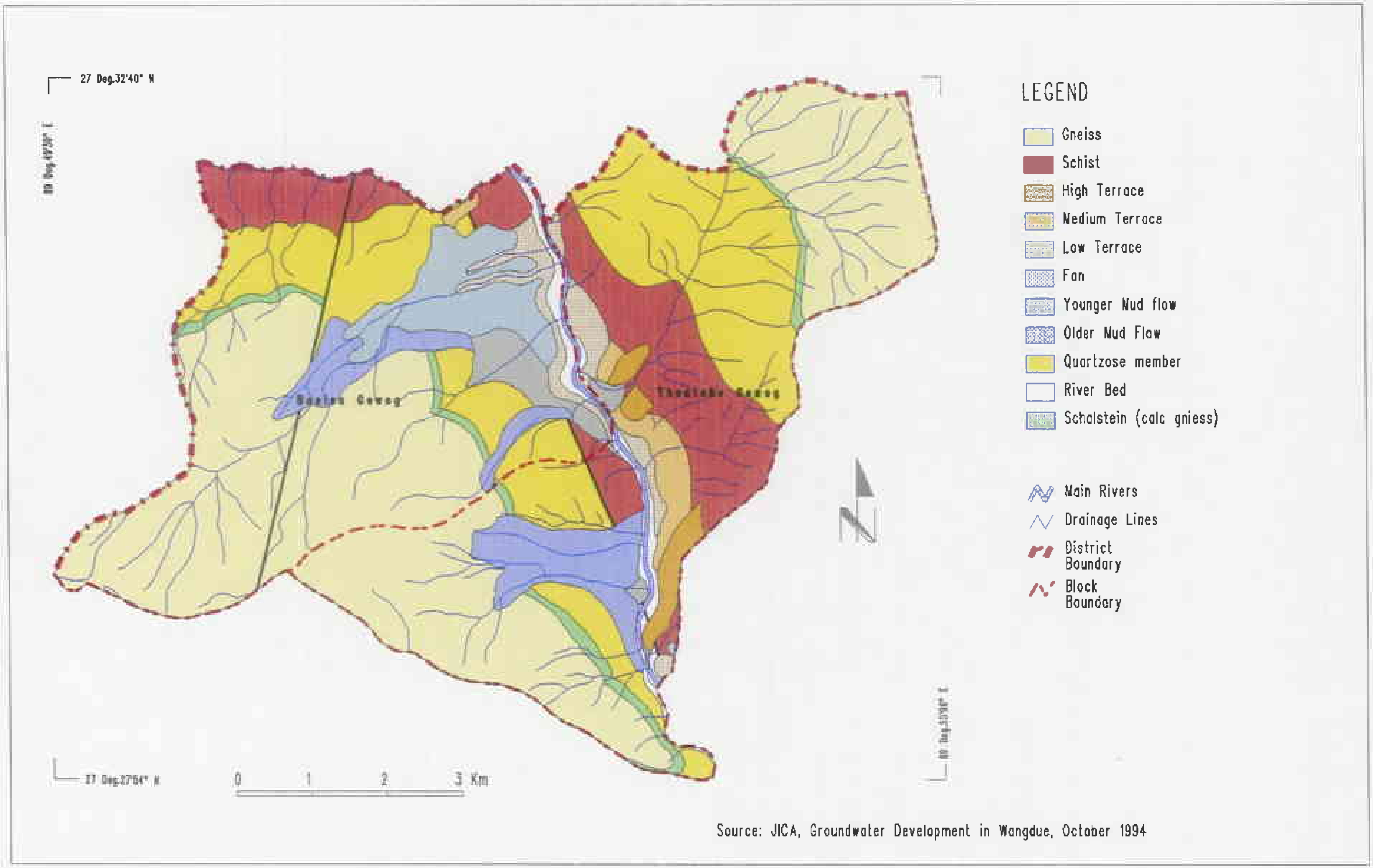


Figure 3.3: Geological Map of the Study Area

4.3.4. *Soils*

Detailed descriptions of the soils in the two blocks based on 22 sampling pits and 64 sample analysis are attached in Appendix D. The soil map with locations of soil sampling pits are shown in Figure 5.2 of chapter V. A brief characteristic features, both physical and chemical, of the two block's soils are as presented below.

The soils of Thedtsho and Baap block are derived from a variety of parent materials consisting of quartzite, gneiss, and quartzitic gneiss. Most of the soils have distinctive red clay loams, although result of textural analysis indicate the dominance of clay and clay loam texture. The soils are mostly mottled and very deep. The pH of the top soil is acid to slightly alkaline while in the subsoil it is generally alkaline. Except for few places, nutrient availability of NPK is generally moderate in the topsoil but low to very low in the subsoil - this is mainly due to the application of farmyard manure and fertilizers.

4.3.5. *Land Use and land Cover*

Given its long history of settlement, almost all areas habitable has already been used for agriculture. As per the existing land use and land cover map about 76.32 percent of the area is

Table 4.4. Land use and land cover and their area distribution

Sl. No.	Landuse/Landcover Type (LUPP Classification)	Symbol used *	Area (Ha)	Percent
1	Broadleaf forest	FB1, FB2, FB3	1124.87	20.0
2	Coniferous Forest	FCc1, FCc2,	2363.69	42.1
3	Scrubby Forest, Shrubs, Bushes	FS	519.64	9.3
4	Natural Pasture	PN	103.97	1.9
5	Plantation (Trees)	FPc, FPb	174.23	3.1
6	Degraded Land	OL	169.96	3.0
7	Water Bodies	OW	132.56	2.4
8	Settlement Area	SE	63.68	1.1
9	Wetland Agriculture (Paddy only)	AWim, AWiv	896.24	15.9
10	Mixed Agriculture	AMm	55.85	0.9
11	Dryland Agriculture	ADum,	11.36	0.2
	TOTAL		5617.68	100.0

(* The Land Cover Classification System for Bhutan is attached in Appendix C).

covered by forest consisting mainly of chirpine in the lower altitudes and broadleaf and highland conifers species in the higher altitudes. Agriculture land constitutes 17.15 percent of the total land area. About 3.03 percent of the area is in the form of degraded land and the rest 3.5

percent consists of open areas, scrubby forests, water bodies and natural pastures. Figure 4.5 presents the land use and land cover map of the study area.

Socio-economics Characteristics

4.4.1. *Population*

There are a total of 390 households under these two blocks with a total population of 2808. The average household size is 7.2 persons with a sex ratio is 1:1 with slightly more males in Baap and slightly more females in Thedtsho block. 23.18 percent of the population are below 15 years, 66.74 percent between 16-59 and 10.08 percent above 60 years. Of the 66.74 percent in the age group between 16-59 years, 59.39 are farming people and the rest 40.61 percent non-farming people. (Population distribution by Age and Sex, and by Farm Labour Availability are attached in Appendices E (a) and E (b) respectively).

4.4.2. *Land Holdings*

The average land holding per household in Thedtsho block is 2.35 acres while in Baap block it is 6.38 acres. The mode of per capita land holding under Baap block is 0.5 - 2.0 acres

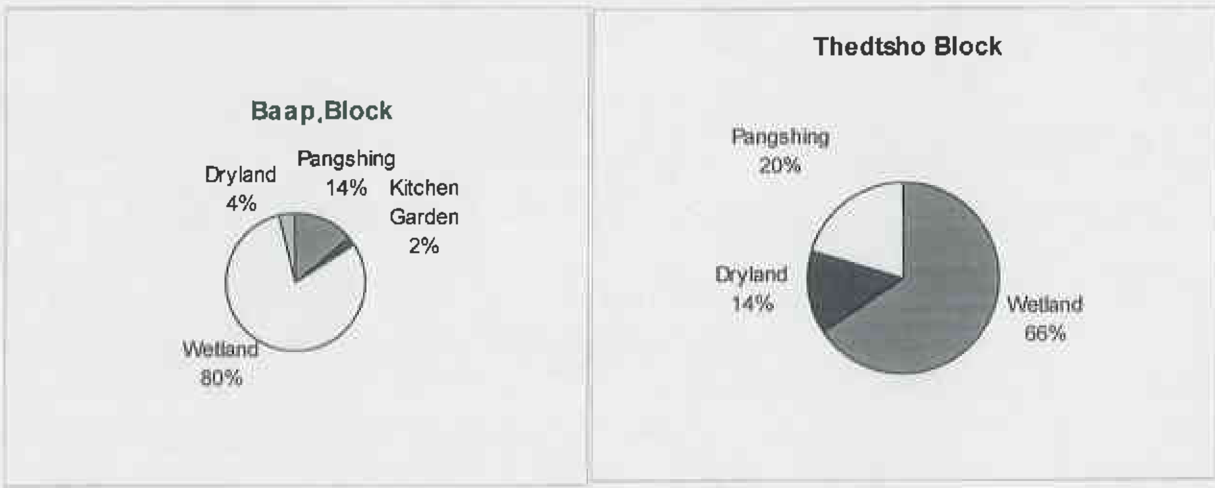


Figure 4.7. Agricultural Land Use in the Study Area

with more than 37 percent of the farmers falling under this category. About 14.08 percent own less than 0.5 acres, 26.25 percent between 2.0 - 5.0 acres and about 10 percent owning more than 5 acres. 11.7 percent of the farmers are landless and subsist on sharecropping or as tenants. (Appendix G contains additional information on Average Land Holding versus the Number of Farmers under Baap Block).

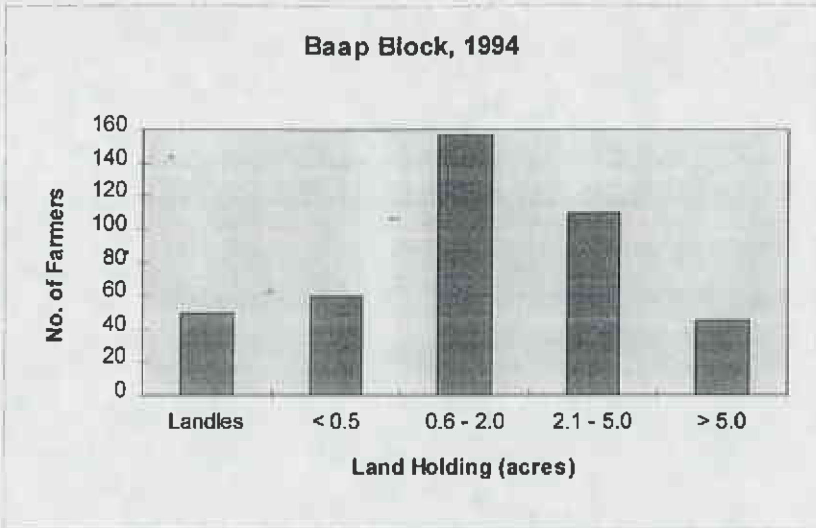


Figure 4.8. Land Holding and No. of Farmers

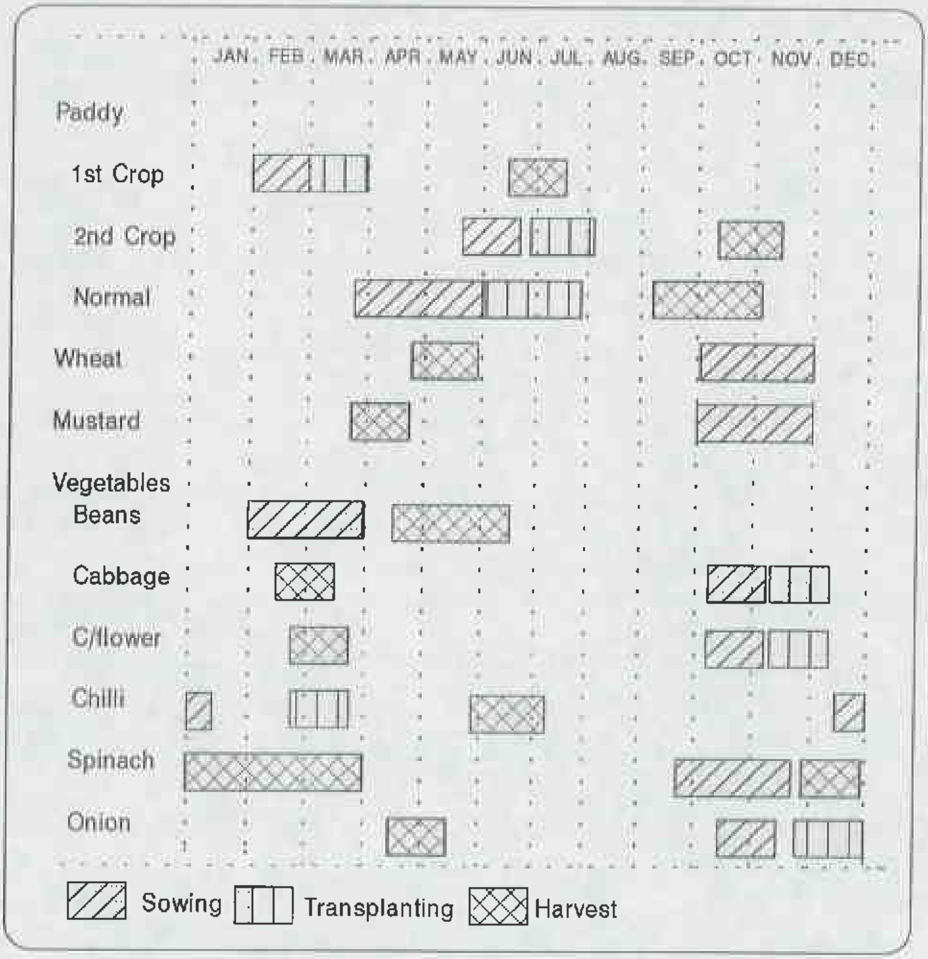


Figure 4.9. Cropping Pattern in the Area

4.4.3. *Cropping Systems*

The cropping pattern of the two blocks is generally as given in figure 4.6.

The most common crop rotation are

- paddy followed by paddy on terraced wetland
- paddy followed by wheat on terraced land
- paddy followed by mustard
- paddy followed by vegetables
- paddy followed by fallow
- orchard (permanent) in dryland
- maize followed by fallow in dryland
- only vegetables in kitchen garden

Most of the farm produce is used for home consumption. Part of the paddy is sold in the form of rice from time to time when the farmers require cash income. In fact for majority of the farmers, rice is the dominant source of cash income throughout the year.

4.4.4. *Livestock*

Livestock rearing forms an integral part of farming in both the blocks. For most of them, livestock is not only a source of milk and other dairy products, but also provides draft power. Livestock excreta constitutes a very important ingredient of fym.

The livestock type and their distribution in the area are as shown in Table 4.9.

Table 4.9. Livestock distribution in the two blocks

Livestock Type	Thedtsho	Baap	Total
Indigenous Cattle	375	1394	1769
Crossed Cattle	61	29	90
Horses	18	83	101
Pigs	275	492	767
Chicken	140	427	567

(Source:LUPP)

4.4.5. *Farming Systems*

Paddy cultivation is the most dominant farming system in both the blocks followed by cultivation of wheat and mustard. Many farmers also cultivate vegetables. Of the total agricultural land in Baap, 521.2 ha are wetland, 68.8 ha dryland, and 29.5 ha kitchen garden and orchard. In Thedtsho, 89 ha are wetland, 9.7 ha dryland, and 8.9 ha tsheri and pangshing.

Double cropping is practised in Rinchhengang village under Thedtsho block. This practice has, however, declined in recent years because it demanded more labour force, the yield is much lower than single cropping, it is prone to attacks by wild animals and birds especially the second crop, and there is lack of subsidy to encourage such practice.

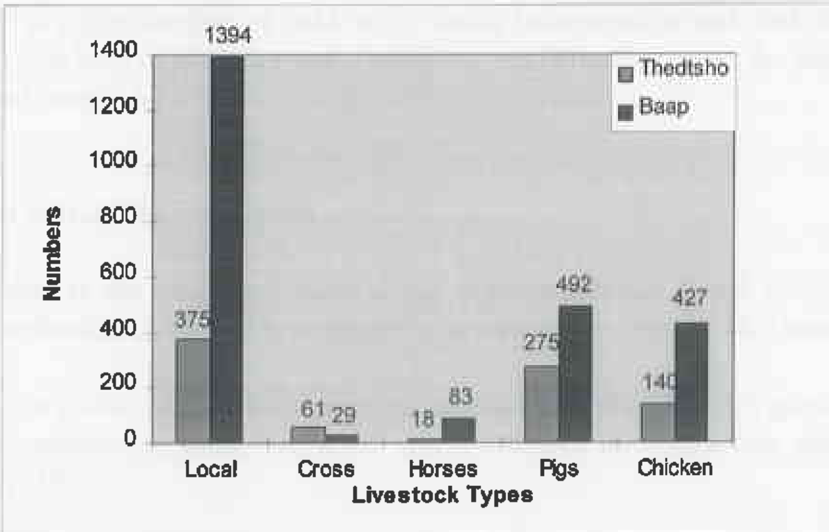


Figure 4.9. Livestock Distribution in the two blocks.

4.4.6. *Infrastructure*

The area is endowed with good infrastructure facilities. Most villages are quite close to the road. There is an agricultural research center - the Renewable Natural Resources Research Center, perhaps the best in the country. There is also a seed distribution center in the block. A standard Class A meteorological station is available nearby the RNRRC. There is the NRTI - Natural Resources Training Institute that imparts training in such fields as agriculture, forestry and livestock. The blocks are also very close to the district headquarters of Wangdue Phodrang where there is school, health centers, market and communication network.

properties. A total of 63 samples were collected from 21 different pits. These samples were then handed over to the laboratory.

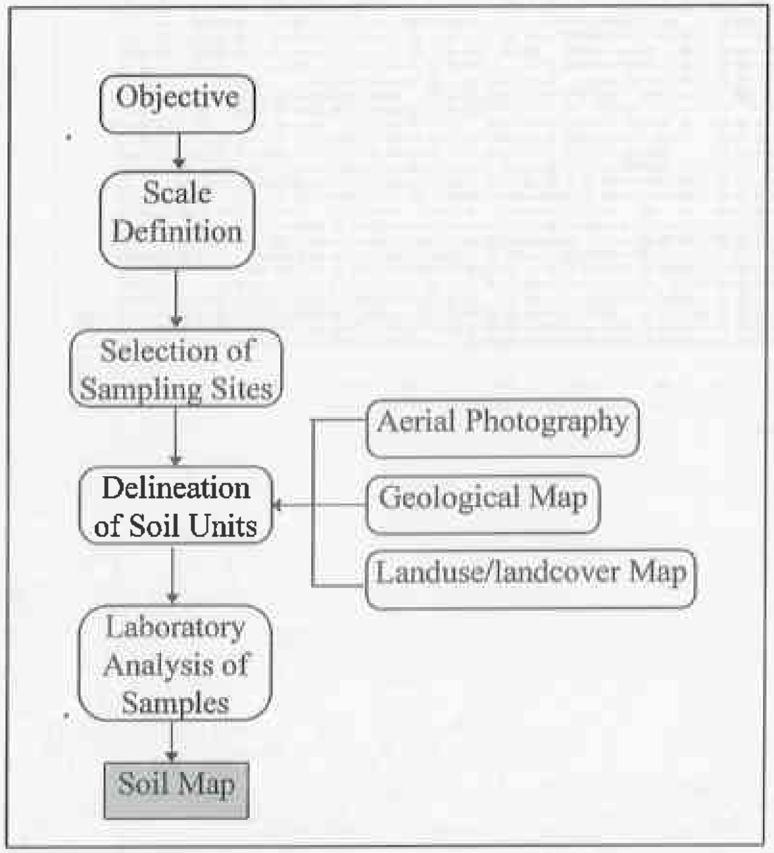


Figure 5.1. Soil Mapping Procedures

The soil units delineated on aerial photos were transferred into the GIS and converted to 50,000 scale. This was then overlaid with the geological map, the result of which was then overlaid with the slope map. Areas with slope greater than 50% were directly excluded from further analysis. On the basis of the analyzed results, certain modifications were made to the soil units. The area was divided into 11 soil units including two additional units for settlement areas and river basin. Each unit is identified by an Arabic numeral with a description of its colour, texture, slope and landuse, as shown in Table 5.1.

Based on the soil units, soil chemical properties such as pH, OM, NPK and soil physical properties such as texture, depth, drainage conditions and slope were given a rating according to the crop requirement of paddy. These ratings were converted to score values (as shown in Table 5.2), the total of which within a soil unit were averaged to get the final score. These scores were then ranged and divided into suitability classes as follows:

Score	**Suitability Classes**
> 2.60	Highly Suitable
2.1 - 2.59	Suitable
1.8 - 2.0	Marginally Suitable
< 1.79	Not Suitable

Table 5.1. Soil Description of the Study Area.

Soil Unit	Nearest Village	Description
1	Matalungchhu	Dark Gray (10YR4/1) to dark grayish brown (10YR4/2); clay loam; on sloping land (7-15 %); terraced agriculture land normally used for paddy (Total pits = 6)
2	Gyonsa	Red (2.5YR4/6) to reddish brown (5YR3/2); sandy clay loam; on steeply sloping land (30- 50%); chirpine forest and open scrubby forest land. (Total pits = 3)
3	Lobeysa	Dark grayish brown (7.5YR4/2); clay; on gently sloping land (7%); terraced wetland used for paddy in summer and mustard and wheat in winter. (Total pits = 1)
4	Tseptokha	Very dark gray (7.5YR3/1); clay loam; on gentle slope (5 - 6%); terraced field presently not cultivated . (Total pits = 2)
5	Wangjokha	Dark grayish brown (10YR4/2); clay loam; very gentle slopes on mid-river terrace (<5%); terraced field mostly used for paddy in summer and wheat in winter. (Total pits = 2).
6	Bajo	Weak red (2.5YR5/2) to dark gray (10YR4/1); Clay loam; valley bottom on low-river terrace; terraced agricultural land. (Total pits = 4)
7	Tshokana	Grayish Brown (2.5Y5/2) to dark grayish brown (10YR4/2); clay; on gently sloping valley bottom; paddy fields, all terraced. (Total pits = 1)
8	Rinchhengang	Dark brown (7.5YR4/1); Sandy loam; steep and dissected terrain with lots of breaks in slopes; paddy field, terraced where possible. (Total pit = 1)
9	Pangsho	Steep, dissected, unused, unusable terrain mostly under forest cover (not surveyed as the topography is unfavourable).
10	None	Very steep land with slope more than 50%; not surveyed.
11		Highly degraded land
12		River bed
13		Settlement areas

5.1.2. *Interpretation of Soil Suitability Classes*

The suitability classes, strictly speaking represent the relative fertility status of the soil and its suitability in terms of such physical properties as depth, drainage, and slope.

(a) Highly Suitable

Soil in this class are very well suited for paddy cultivation and do not have any significant limitations that restrict their use. These soils are quite deep and poorly to moderately well drained. Their texture is clay loam to clay with pH ranging from neutral to slightly alkaline. Nutrient content of NPK and organic matter are low to moderate.

(b) Suitable

Soils in this class are also well suited for paddy crop but do have slight to moderate limitations. Soil texture ranges from clay to sandy clay loam; it is quite deep and moderately well drained to well drained. Nutrient content of NPK and OM are moderate to low and very low.

(c) Marginally Suitable

Soils in this class suffer from certain limitations that will increase the cost of its usage, although it is still suitable for paddy cultivation. They are deep and well drained with loamy sand texture. The pH is either moderately alkaline or acidic. Nutrient content of NPK is very low.

Table 5.2. Soil Units and their Suitability Classification

Soil Unit	Parameters								Score
	A	B	C	D	E	F	G	H	
1	3	3	2	3	1	1	3	4	2.5
2	1.5	1.67	1.33	3	3	0.5	1	1.5	1.69
3	3	4	1	2	3	2	2	2	2.38
4	2	3	2	3	3	1	1	2	2.13
5	3	3	2	3	3	1	1	2	2.25
6	4	4	2	3	3	2	3	2	2.88
7	4	3	2	3	3	2	2	2	2.63
8	1	1	3	3	3	1	1	2	1.88
9	1	2	2	0	4	3	1	1	1.63
10	0	0	3	1	0	0	0	0	0.50
11	0	0	0	3	4	1	1	1	0.63
12	0	0	1	0	0	0	0	0	0.13
13	0	3	0	0	0	0	0	0	0.36

A - Texture, B - Soil Depth, C - Surface Drainage, D - pH, E - Organic Matter
F - Total Nitrogen, G- Available Phosphorous, H- Available Potassium,

(d) Not Suitable

These soils are shallow, excessively well drained and with coarse to gravely texture. OM content is moderate to low. Its major limitation is from slope steepness and susceptibility to erosion.

5.1.3. *Assessment of Soil Fertility*

The term soil fertility is commonly used to describe the soil's ability to support crops through its own nutrients reserves. Fertile soils are formed under favourable climatic conditions from a parent material rich in mineral nutrients with nitrogen reserves originating mainly from biological nitrogen fixation. Such soils produce good yields for many years before the level of one or more nutrients become inadequate.

A term soil productivity is used to describe soil's ability to support crops when cultivated correctly, including nutrient replenishment through the use of organic and inorganic fertilizers to compensate for removal and losses, and to maintain soil reserves. Soils which are naturally poor in nutrient reserves, can be highly productive when fertilized and managed properly. The difference in fertility between these soils and those traditionally regarded as fertile is one of degree rather than principle. All soils sooner or later become exhausted through long-term continuous cropping if the nutrients that are removed in harvest are not replenished.

Soil organic matter is often described as the key factor in soil fertility, but it is only one among a number of factors which determine the suitability of soils for crop production. Fertility is also influenced by soil type, the nature of clays present, water status and biological activity. Productivity of soil is further determined by agronomic factors including disease control, nutrient supply, crop variety and previous management practices.

A horizontal assessment of general soil fertility in the area was done. Each items of the soil sample analysis results were grouped across by horizon to find its mean and standard deviation as shown in Table 5.3.

The overall fertility of the soils in general is quite low. In terms of the vital nutrient availability of N, P and K, they are all very low in the whole profile and in all the sampling sites with a slightly better levels of potassium (all ratings are as attached in Appendix C). The pH is slightly acidic in the topsoil and neutral in the lower layers. On the whole this factor is within the range of favourability for most crops to thrive. The percentage content of organic carbon and its corresponding organic matter content is moderate in the plough layer but very low in the layers beneath. This is mainly due to the application of fym. It was found during the field survey that most of the farmers use fym, almost all of them. As can be seen from the sample analysis result of 10 fym samples, its average content of carbon and nitrogen is 7.21% and 2.28% respectively, both of which are very very high. The content of phosphorous is also very high measuring an average of 35 mg/kg. This contributes to the higher levels of carbon and corresponding organic matter in the top soil.

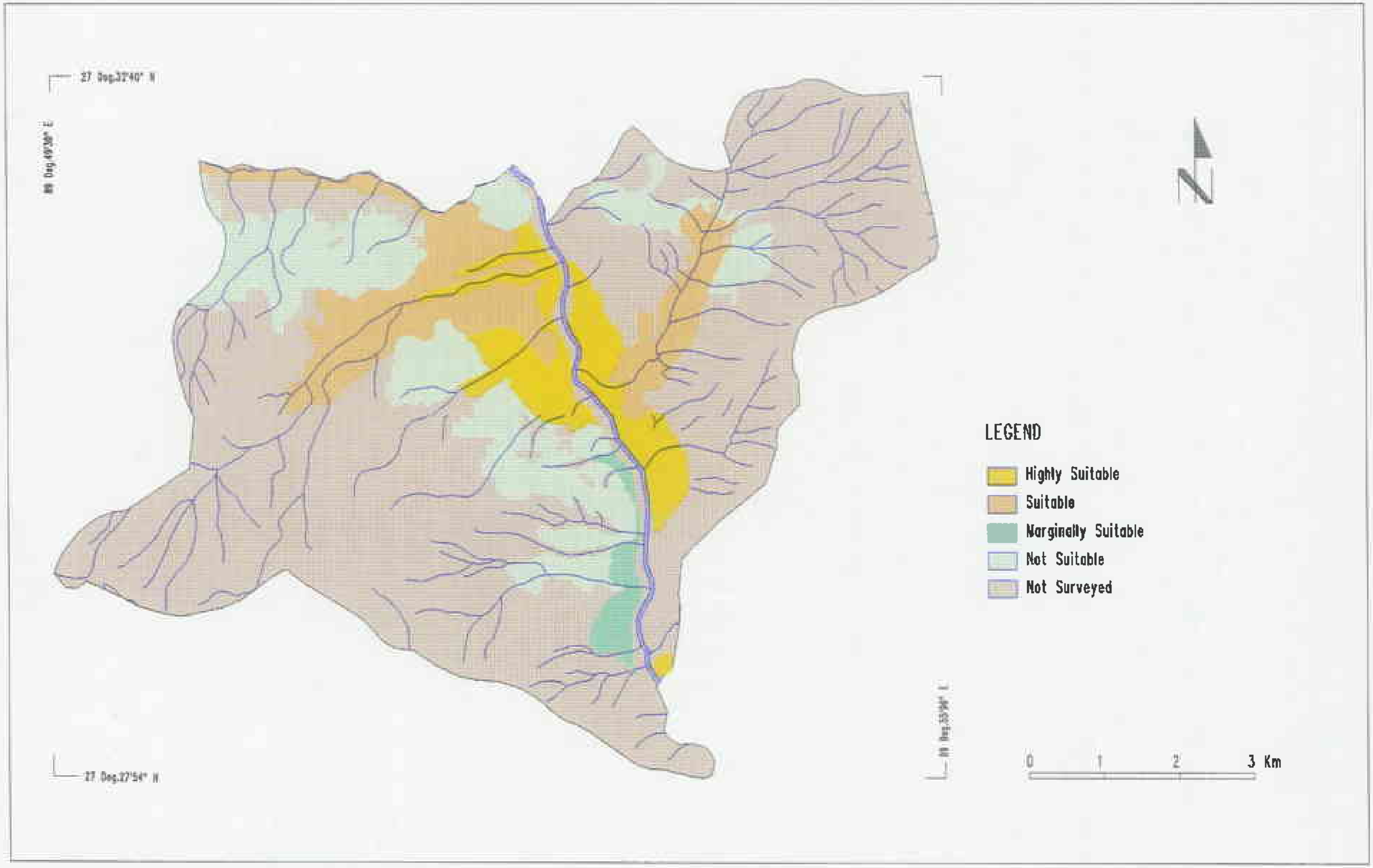


Figure 5.3: Soil Suitability Classification

In view of the fact that fym is widely used by *all* the farmers in the area, it is highly probable that this deduction is near truth. Farmers also do widely use various types of fertilizers, all of which actually has changed the composition and content of the soil in the top layer.

Table 5.3. Soil Fertility Status

	pH (H_2O)	Total C (%)	Total N (%)	N as NH_4 (mg/kg)	N as NO_3 (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
Top Soil							
Mean	5.92 (SA)	1.33 (M)	0.09 (VL)	2.48 (VL)	4.55 (VL)	3.71 (VL)	85.76 (L)
SD	0.61	0.45	0.05	1.85	3.57	4.45	39.88
Second Layer							
Mean	7.43 (N)	0.45 (VL)	0.05 (VL)	1.65 (VL)	1.19 (VL)	3.86 (VL)	60.78 (L)
SD	0.74	0.36	0.04	1.12	1.45	7.34	34.50
Third Layer							
Mean	7.52 (N)	0.35 (VL)	0.03 (VL)	1.32 (VL)	1.19 (VL)	5.05 (VL)	60.02 (L)
SD	0.86	·0.25	0.02	0.88	1.03	7.63	33.15

Note: SA - Slightly Acidic; VL - Very Low; N - Neutral; L - Low.

Table 5.4. Laboratory Result of fym analysis.

Sample No.	Location (villages)	pH		EC 2.5 mS cm	% Total		C:N ratio	Avail. P (mg/kg)
		H_2O	KCl		C	N		
FYM-1	Umtekha	8.7	7.1	0.01	8.3	2.0	4.1	35
FYM-2	Bajothangu	8.1	7.7	0.10	5.7	2.48	2.3	35
FYM-3	Wangjokha	8.5	7.3	0.01	6.6	2.77	2.3	35
FYM-4	Bajo	8.8	7.3	0.01	6.3	2.37	2.6	35
FYM-5	Rinchhengang	8.6	7.1	0.07	8.3	1.95	4.2	35
FYM-6	Tshokana	9.2	8.5	0.95	5.2	0.97	5.3	35
FYM-7	Eusakha	8.7	8.1	0.01	9.2	1.91	4.8	35
FYM-8	Soptsokha	9.3	8.4	0.01	8.2	2.34	3.5	35
FYM-9	Laphuna	8.9	8.5	1.75	6.5	2.56	2.5	35
FYM-10	Lobeysa	9.0	8.4	0.01	7.8	3.42	2.2	35

5.1.4. *Nutrient Balance*

An important aspect of sustainable agricultural land use is the proper management of nutrients in the soil. Understanding about nutrient balance in the soil is the key to nutrient management.

Nutrients available in the soil include those that are available in situ and those from the application of fertilizers and fym. Soil loses nutrients through its removal by plants, leaching, volatalization and erosion.

Nutrient balance provides a clue to how much of it is required by the crops, how much is available in the soil and how much needs to be replenished.

The following conditions underlie the estimation of nutrient balance here:

- Only N, P, and K are considered.

- The estimation of nutrients *available* in the soil is based on the soil map and sample analysis result. Data on this side is fairly sufficient. However, the total loss include only those removed by rice and wheat. Nutrient removal rates by mustard, which is a common crop in the area, is not available. Besides, due to lack of data, it was not possible to estimate nutrient loss through leaching, volatalization and erosion. The high figures of positive balance should be seen in this light.

- All figures are time specific and relate to that point of time during which the samples were collected.

- Additional amount of nutrients made available to the soil through fertilization is based on the mean inorganic fertilizer rates cited by RNRRC (1993-94). Accordingly, both rice and wheat are applied with the same amount and is equal to 17 kg/ha under Thedtsho Block while it is 11 kg/ha for Baap Block. The estimated NPK content of this inorganic fertilizer is 60:40:20.

- The amount of fym applied is on average 6 ton/acre as derived from the field survey. This figure has been used here. Amounts cited by other sources range from 4 - 5 ton/acre to 7 ton/acre.

- Bulk density figures relate to textural classes and has reference to mean bulk density under disturbed conditions.

As shown in Table 5.5., it is clear that, with few exceptions in case of K, the total gain in nutrients far outweights the total loss depicting a very favourable nutrient balance picture. In certain soil units even the nutrients avialable in situ is greater than the nutriets loss. It appears, therefore, that the soils are rich in nutrients to sustain agricultural land use for quite a long time. However, it needs to be reminded here again, of the conditions under which this estimation was carried out. Not in all cases do farmers use fertilizers if fym is applied. Where the fertilizers are used, often it happens that it is applied for the first crop only and not for the second crop. The amount of nutrient removed totally by the two crops considered here and other crops common in the area could be actually quite high. Nutrient removal by crops like mustard has been found to be quite high in comparision to these two crops.

Table 5.5. Estimation of Nutrient Balance

Soil Unit	Depth (cm)	Soil Texture	Bulk Density	Area (ha)	GAIN					Total Gain (kg/ha)	Total Loss[1] (kg/ha)	Balance (kg/ha)
					Nutrient in Soil mg/kg		Total (kg/ha)	Fertilizer (kg/ha)	FYM (kg/ha)			
					N	5.55	14.6	10.2	380	404.8	85	320
1	20	Clay	1.312	131.6	P	6.17	16.2	6.8	51.9	74.9	43	32
		Loam			K	104.2	273.2	3.4	Applied	276.6	138	139
		Sandy			N	0.4	0.4	6.6	380	387	85	302
2	7	Clay	1.373	851.9	P	1	0.9	4.4	51.9	57.2	43	14.2
		Loam			K	112.7	108.3	2.2	Applied	110.5	138	-27.5
					N	6.1	9	6.6	380	395.6	85	311
3	13	Clay	1.14	262.1	P	1	1.5	4.4	51.9	57.8	43	15
					K	52.4	77.7	2.2	Applied	79.8	138	-58
					N	5.7	11.2	6.6	380	397.8	85	313
4	15	Clay	1.312	162.7	P	3	5.9	4.4	51.9	62.2	43	19
		Loam			K	69.95	137.7	1.4	Applied	139.1	138	2
					N	31	81.3	10.2	380	471.5	85	386
5	20	Clay	1.312	27.9	P	4	10.5	6.8	51.9	69.2	43	26.2
		Loam			K	125.8	330.1	3.4	Applied	333.5	138	195
					N	5.7	14.9	10.2	380	405.1	85	320
6	20	Clay	1.312	194.2	P	4.5	11.8	6.8	51.9	70.5	43	27
		Loam			K	45.1	118.3	3.4	Applied	121.7	138	-16
					N	3.43	6.3	6.6	380	392.9	85	308
7	16	Clay	1.14	184.6	P	1	1.8	4.4	51.9	58.1	43	15
					K	60.53	11	2.2	Applied	13.2	138	-125
					N	4.2	10.4	10.2	380	400.6	85	316
8	18	Sandy	1.381	100.4	P	3	7.4	6.8	51.9	66.1	43	23
		Loam			K	94.6	235.2	3.4	Applied	238.6	138	101

[1]The amount of NPK removed by rice is taken as 31,13, and 66 kg/ha respectively when the yield is 1482 kg/ha while that removed by wheat is 54, 30 and 72 kg/ha when the yield is 1998 kg/ha (CHIP).

However, on the whole, the quantification of nutrient status using this approach do indicate a good picture. The availability of K in the soil, for instance, is more than what the crops remove, in most cases. Even when the K available from fym is not included, there is still more of it than that is removed.

From the table we also see that soil units 2 followed by 7 will be depleted of nutrients sooner than other soil units, all other things remaining constant. In soil unit 7 for instance, at the present rate of nutrient removal, the balance that is derived for nitrogen is sufficient to support only little more than three crop cultivations, phosphorous balance is not sufficient to support the next crop while potassium balance is already negative. The above table also makes succinctly evident that these nutrients are mainly available through the application of fym. Without its use, the nutrients available in situ and those added through fertilizers is not sufficient even for the only two crops considered above.

5.2. **Land Suitability Classification for Paddy**

Paddy is the most important crop in the area, occupying about 75% of the total agricultural land and constitutes the dominant source of income for most farmers. As practised in the area, paddy is usually flooded before the rice seedlings are transplanted from the nurseries and water is maintained on the surface until the grain is mature.

Land suitability is the fitness of a given type of land for a defined use (Vink, 1980). Land suitability for paddy can be defined as the fitness of a given land unit for its optimum growth. The consideration of fitness of a given land unit is relative and is categorized on the basis of its capability to support the growth of the selected crop with the given resources and management
conditions.

The main purpose of conducting this particular analysis was to classify the study area into various suitability classes for paddy with the ultimate goal of ensuring sustainability of agricultural land use.

Table 5.6. Guidelines for grouping soils in suitability groups for paddy (USDA)

Limiting Factor	**P - I**	**P - II**	**P - III**	**P - IV**	**P - V**
Effective soil depth (cm)	> 150	100 - 150	50 - 100	<50	-
Texture of surface soil	CL,	C, SCL	SL to LS	Gravely, Slope Complex	-
Fertility; relative nutrient status	very high	high	moderate	low	-
pH 1:1(H_2O)	5 - 7.5	4.5 - 4.9 or 7.6 - 8.0	4.0 - 4.4 or 8.0 - 8.5	< 3.5 or > 8.5	-
Slope (%)	0 - 3	4 - 8	9 - 15	16 - 25	> 25
Soil drainage class	poorly drained	very poorly drained	moderately well drained	well drained	excessively well drained
Elevation (m msl)	< 1200	1200 - 1800	1800 - 2600	> 2600	> 2600

Note: Only those limiting factor that has been used for the classification are shown in the above table.

5.2.1. *Selected parameters for Paddy Suitability Classification*

a. Soil Texture

Soil texture refers to the fineness or coarseness of the soil as determined by the relative proportions of sand, silt and clay. This property of the soil has a direct influence on the permeability and available water content of the solum, and is considered a good indicator of the water holding capacity of the profile.

The fine textured surface soils, high in clay, have more total pore space, and a relative large proportion of it is composed of small pores resulting in a higher water holding capacity. Loam with its properties, intermediate among those of sand, silt and clay, is often considered to be optimal soil for plant growth (Hillal (1980) in Shrestra, 1993). For suitability assessment, however, soil texture is a function of the requirement of the specific crop under consideration.

b. Effective Soil Depth

This refers to the rooting zone where the limiting depth is a lithic contact, paralithic contact, petroferric layer or hard pan, through which it is very difficult or impossible for roots to penetrate. It is a crop specific requirement, determined by the natural rooting habit of the crops. Shallow soils require frequent irrigation to keep growing, restricting the root's uptake of nutrients and available moisture. Deep soils of medium texture and loose structure permit plant to root deeply, provide for storage of large volumes of soil water in the soil, and consequently sustain satisfactory plant growth during relatively long periods between irrigation.

c. Soil Fertility

Soil fertility is the capability of soils to provide the necessary nutrients for plant growth, usually limited to consideration of chemical properties. Usually the several nutrients required by the plant, both major and micro, are combined to arrive at the overall fertility of the soil.

In this study, fertility ratings of the soil has been considered in terms of NPK and accordingly classified as very high, high, moderate and low.

c. Drainage

Soil drainage represents the condition of the soil in relation to its extent, frequency and duration of the period in which water is removed from the soil. The drainage is classified according to the rate of water loss from the soil as very poorly drained, poorly drained, moderately drained, well drained and excessively drained.

Very poorly drained soils presents a condition that the soil will be logged or saturated with water almost throughout the year. This type of drainage prohibits the circulation of oxygen in the root zone rendering the soil deficient in oxygen for the roots to take as components for photosynthesis.

Excessively drained soils are those where water loss is very rapid, either by percolation or surface flow. Such loss of water prevents the development of an anaerobic condition for any appreciable length of time. Water is completely removed that most crop suffer from lack of water.

Table 5.7 Class Ratings and Weightages assigned to various Parameters for Paddy Suitability Classification

Class	Ratings	Range	Score	Class	Ratings	Range	Score
Soil Texture				Effective Soil Depth (cm)			
1	CL,		4	1	Shallow	< 50	1
2	C		3	2	Moderately Deep	50 - 100	2
3	SCL		2	3	Deep	101 - 150	3
4	SL to LS			4	Very Deep	> 150	4
			1				
Surface Drainage				Soil pH (H_2O)			
1	Poorly drained		4	1	Alkaline	> 8.6	0
2	Very poorly drained		3	2	Moderately Alkaline	7.6 - 8.5	1
3	Mod. well drained			3	Neutral	6.6 - 7.5	4
	Well drained		2	4	Moderately Acid	5.6 - 6.5	3
4	Excessively well		1	5	Very Acid	4.5 - 5.5	2
5	drained			6	Extremely Acid	< 4.5	0
			0				
Organic Matter Content (Percent)				Total Nitrogen (Percent)			
1	Very High	> 8.6	2	1	Very High	> 1	3
2	High	5.3 - 8.5	4	2	High	0.50 - 0.99	4
3	Moderately	2.1 - 5.2	3	3	Moderate	0.20 - 0.49	2
4	Low	1.0 - 1.9	1	4	Low	0.10 - 0.19	1
5	Very Low	< 1.0	0	5	Very Low	< 0.10	0
Available Phosphorous (mg/kg)				Available Potassium (mg/kg)			
1	High	> 30	4	1	Very High	> 300	3
2	Moderate	15 - 29	3	2	High	200 - 299	4
3	Low	5 - 14	2	3	Moderate	100 - 199	2
4	Very Low	< 5	1	4	Low	40 - 99	1
				5	Very Low	< 40	0
Slope (Percent)				Elevation			
1	Nearly Flat	0 - 3	5	1	Humid sub-tropical	< 1200	3
2	Gently Sloping	4 - 8	4	2	Dry sub-tropical	1201-1800	2
3	Sloping	9 - 15	3	3	Warm temperate	1801-2600	1
4	Moderately Steep	16 - 25	2		Cool temperate	> 2600	0
5	Steep	26 - 50	1				
6	Very Steep	> 51	0				

d. Soil pH

It is defined as the "negative logarithm of hydrogen ion concentration" (Brady (1974) in Thapa, 1994). It determines the acidic and alkaline properties of the soil. Acid soil are those with a preponderance of hydrogen and aluminum ions in proportion to hydroxyl ions, specifically soil with a pH value < 7.0, most practically with a pH value < 6.6, usually applied to the surface layer or to the root zone. This property has great influence on nutrient uptake by soils.

A high aluminum ion concentration is the most common cause of failure of crops in acid soils because it reduces the uptake of phosphate and also interferes with the plant metabolism. A soil with > 7.0 pH is known as alkaline soil and is also responsible for the nutrient imbalance in the soil.

e. Soil Organic Matter

This refers to the organic fraction of the soil that includes plant and animal residues at various stages of decomposition, commonly determined as the amount of organic material contained in a soil sample passed through a two mm sieve (Brady (1974) in Shrestra, 1993).

It influences the physical properties of the soil and increases the supply and availability of nutrients. The accumulation of organic matter in the soil is greatly dependent on effective soil moisture, climatic factors especially rainfall and temperature and soil drainage.

a. Slope

Slope is the relief of the terrain which is measured in terms of degree or percentage. In a mountainous topography, this parameter is important since it determines the cost of using the land. Where the land is steep, it is more prone to erosion necessitating terracing to maintain and improve farm productivity. For cultivating crops such as paddy that requires stagnant water, the steepness of the slope presents additional difficulties in terms of terracing and the use of farm machinaries.

b. Elevation

This refers to the height above the mean sea level, also termed altitude. In a mountainous terrain, because of variation in slopes, altitudes can vary within miles influencing the types of crop that can thrive. In Bhutan, for instance, paddy normally doesn't thrive beyond 2400 m msl.

c. Irrigation Zone

Availability of artificial water sources to make up for its additional requirement by crop is very important, especially in terms of paddy. Besides, in the study area, cultivation of paddy is dependent on the availability of irrigation water because there is no practice of rainfed paddy cultivation.

On the basis of existing irrigation channels, the area was divided into two separate zones: the irrigated zone below the existing irrigation channels and the non irrigated zone above the irrigation channels.

5.2.2. *Analysis of Land Suitability for Paddy*

The weighted additive method, one form of parametric model, was used for the analysis and classification of land suitability for paddy. The factors that influence the cultivation of paddy were first given a weightage considering the relative importance of their influence on the crop. Consideration of assigning the weightage was also based on the degree of reliability of the factors included for the analysis.

There are certain things to note in this regard. All factors do not have the same influence. Since they vary in the degree of their influence, they will have to be classified accordingly. There could be many factors that actually influence the suitability of land for a specified use, but all of them cannot be included in the analysis.

With this condition, each factor, on the basis of its assumed influence on paddy crop, were ranged and rated giving a score value. These scores were multiplied with the weightage assigned to that factor. The final land suitability class represents the sum of scores multiplied by the weightage. In case where one factor has a score value of zero, the final class will also be zero. This was a modification included during the process of the analysis.

In simple mathematical notation, this process can be represented as follows:

$$SS = \sum (F1 * W1 + F2 * W2 + F3 * W3 + \ldots Fn * Wn)$$

Where

SS is the final suitability score,
F1, F2...Fn represents the the various parameters,
W represents the weightage assigned to each factor, and
n represents the number of factors.

This exercise was carried out using the overlay and analysis function of the GIS.

5.2.3. *Interpretation of Suitability Classification Results.*

(a) Highly Suitable

These are areas that is suitable for paddy without any significant limitations or the necessity of special development or management practices. The minor limitations will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

This class covers those areas that include some parts of Thangu plains, within Bajo, in Tshokana and Eusakha. These are the areas where during the socio-economic survey, it was found that productivity was quite high. In these areas soils, especially in terms of depth, drainage conditions and organic matter content are very favourable. The area is nearly flat; it is at lower elevation and there is sufficient and reliable water from irrigation. Minor limitations include lower levels of nutrients such as nitrogen, phosphorous and potassium in the soil.

All land in this class has already been used.

(b) Moderately Suitable

This class include land that is suitable for paddy cultivation with the application of simple special development and management practices. They have moderate limitations that will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although attractive, will be appreciably inferior to that expected from Class I land. Areas within this class include most of the fields in Matalungchhu, Tseptokha, Tsebjikha and some parts of Bajo, Eusakha and Gamaluma. The moderate limitations here comes from more slope, significantly lower nutrients in the soil, and drainage conditions. All areas within this class has also been already used.

(c) Marginally Suitable

Land in this class have limitations which in aggregate are severe for its sustained use in paddy cultivation. This limitations will so reduce productivity or benefits, or increase required

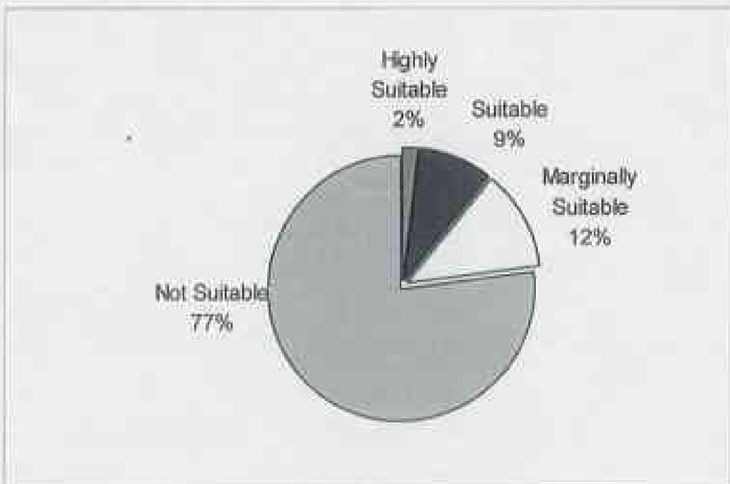


Figure 5.6. Percentage distribution of the Area by Suitability Classes for Paddy

inputs that this expenditure will be marginally justified. The major limitations in this class include slope and lack of reliable water supply.

Some of the used agricultural land around Rinchhengang village fall in this class, mainly due to slope steepness. As discovered during the field survey, this area do actually face more difficulties in cultivation operation in comparison to other agricultural areas in the area.

Table 5.8. Suitability Classes and their Area (GIS)

Suitability Class	Suitability Rating	Frequency	Area (ha)	Percentage
1	Highly Suitable	31	95	1.7
2	Suitable	42	486	8.6
3	Marginally Suitable	109	691	12.3
4	Not Suitable	19	435	77.4
	Total		5618	100

Productivity was found to be rather low, and many people within this village appeared to be relatively poor.

(d) Not Suitable

These are areas that, in its existing state, is not suitable for paddy cultivation. Slopes are steep to very steep, water supply is not available and it lacks in important nutrients. The use of these areas will definitely not justify the expenditure and cost incurred.

This class falls in the red soil areas, most of which are above the existing irrigation channels and the road.

5.2.4. *Farming Systems and Socio-economic aspect*

This section is intended to provide a preview of the socio-economic status and framing system characteristics of the area and to relate it with the findings from the biophysical land resources analysis for paddy land suitability classification. All information presented here are based on the households interviewed during the socio-economic survey. Both the blocks are represented as one unit. Where necessary, the results have been tallied with the actual secondary data.

1. Population features and Occupational Characteristics

Demographic features do not vary much from what has been presented already under the study area profile (Chapter 3).

The main occupation of the people in the area is farming. Almost all of them (about 97%) do only agricultural farming. About 3 percent reported that they do some other work such as going to work in developmental projects, carpentry, and masonry or whatever work is available, in addition to their farm work.

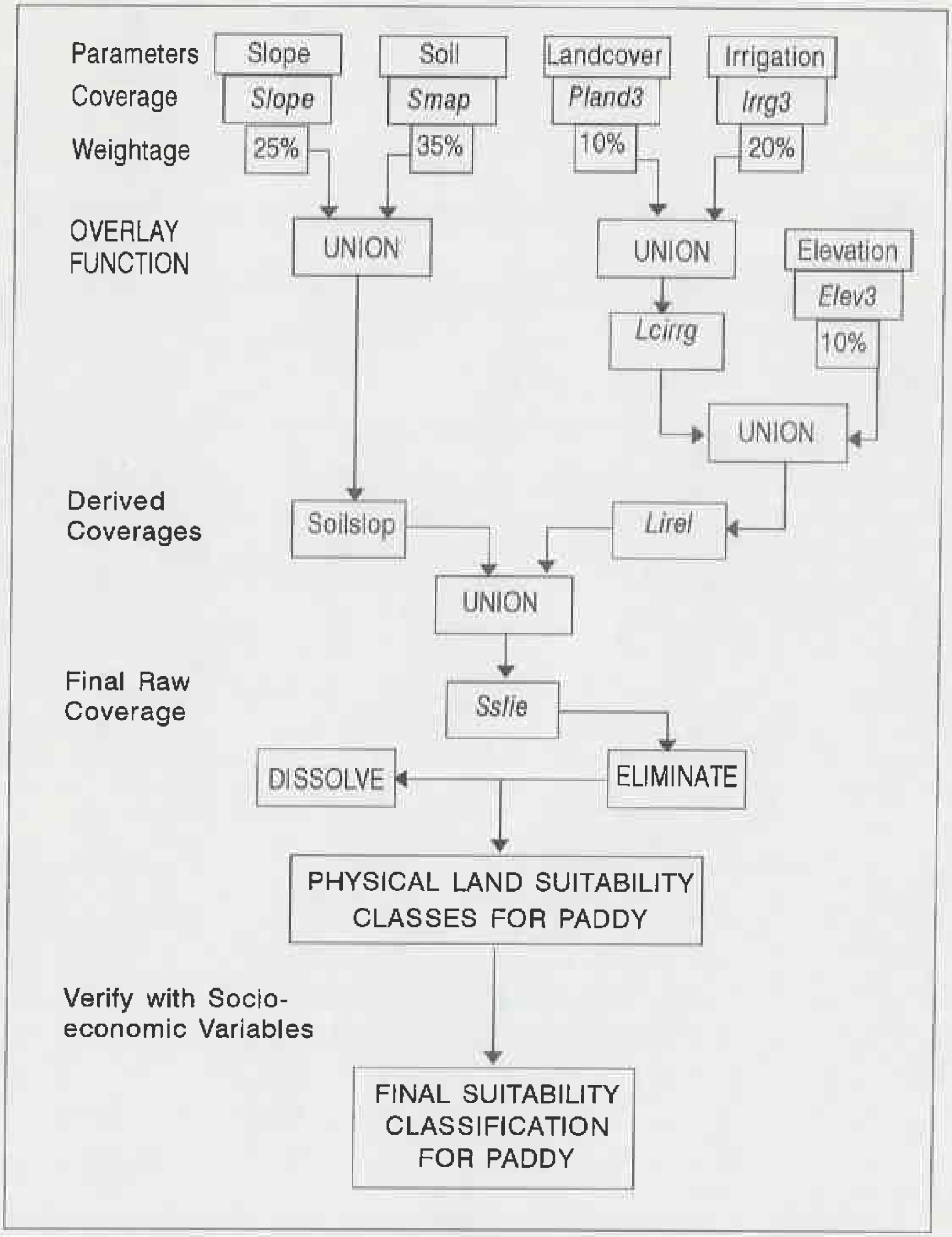


Figure 5.4. Methodology for Land Suitability classification for Paddy

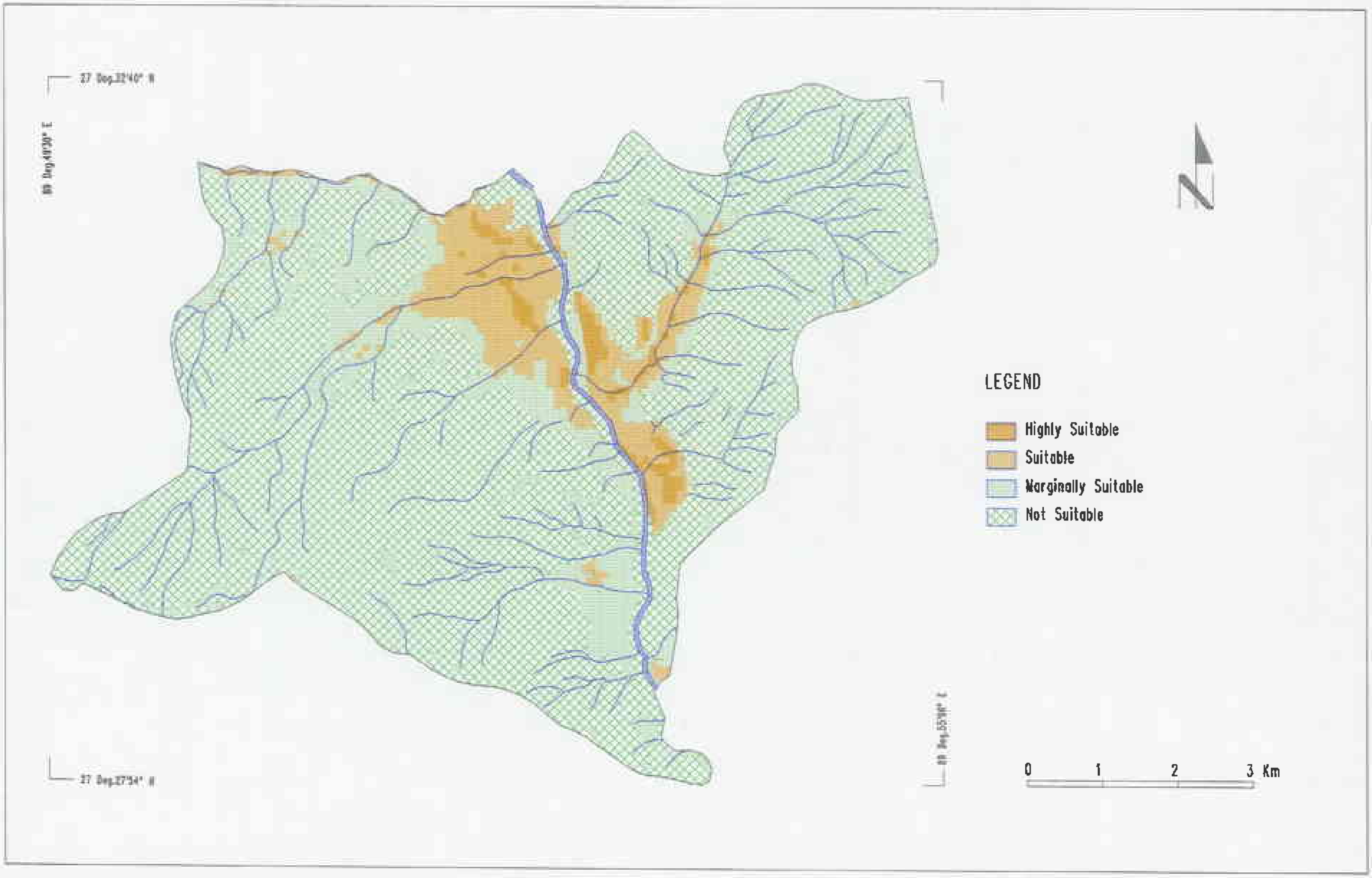


Figure 5.5: Land Suitability Classification for Paddy

2. Land Tenure

There do exist some tenants, some of whom have come from the East, in the area. Otherwise all households do own land for farming. Many of them practice a system of share cropping. About 17 percent of those who own land only farm their land for themselves. About 39 percent cultivate their own land and also go to work in others land with the arrangement of sharing half of the production. There are also cases where this ratio between the tenant and the land owner can be 40 : 60. In still other cases, the landlord takes a fixed amount from the tenant, irrespective of the productivity. Under such practice the tenant can use the land for cultivating crops in winter without having to share the output with the land owner. About 33 percent worked part of their land by themselves and leased out the rest for others. This is rather an alternative engendered by the shortage of labourers.

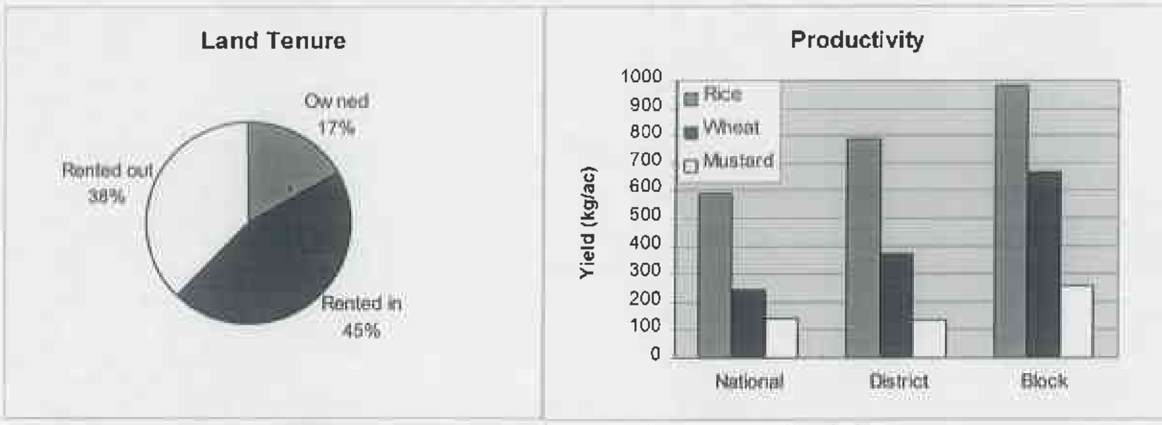


Figure 5.7 - Land Tenure and Crop Productivity

3. Crop Productivity

The productivity of crop in the area is quite high when compared to national and the district averages. The average paddy yield is 979.4 kg/ha as compared to the national 590 kg/ha and the district 788.7 kg/ha. Productivity of other crops such as wheat and mustard are also relatively higher. This is shown in Figure 5.7.

4. Sources of Income and Expenditure

For most of the farmers, the main source of their income is the sale of cereals, particularly rice. The income earned from the sale of rice accounts for more than 43 percent of the total income inflow. Most of the farmers also posses few fruit trees from where they sell in the nearby local market. This source accounts for about 16.7 percent. About 15.5 percent of the income is from the sale of vegetables, mostly tomatoes and chilies. Some farmers sale products of their livestock and others earn from lending their farm machinaries, from off-farm works and sometimes as contribution by their relatives. The percentage of different sources of income and expenditure is as shown in Figure 5.8.

About 35 percent of the expenditure is incurred for fodding. 29 percent of the expenditure goes for social festivals and religious ceremonies. Clothing requirements take about 25 percent. Agricultural investment, mostly for procuring fertilizers, pesticides, weedicides, seeds, altogether makes for about 6 percent of the total expenditure. Farmers also spend about 4 percent of their income for fuelwood collection in the form of vehicle and labour hire.

5. Livestock Rearing

To the extent that most farmers raise livestock, farming systems in the area can be regarded as a sort of mixed system. Most farmers own a pair of working bullocks, young cattle (bullocks and heifers), pigs and chicken. Milking cows were more frequently owned by larger farmers. A typical livestock-owning household may have a pair of oxen, two milking cows, three to four young cattle, three horses, three to four pigs, and few chickens.

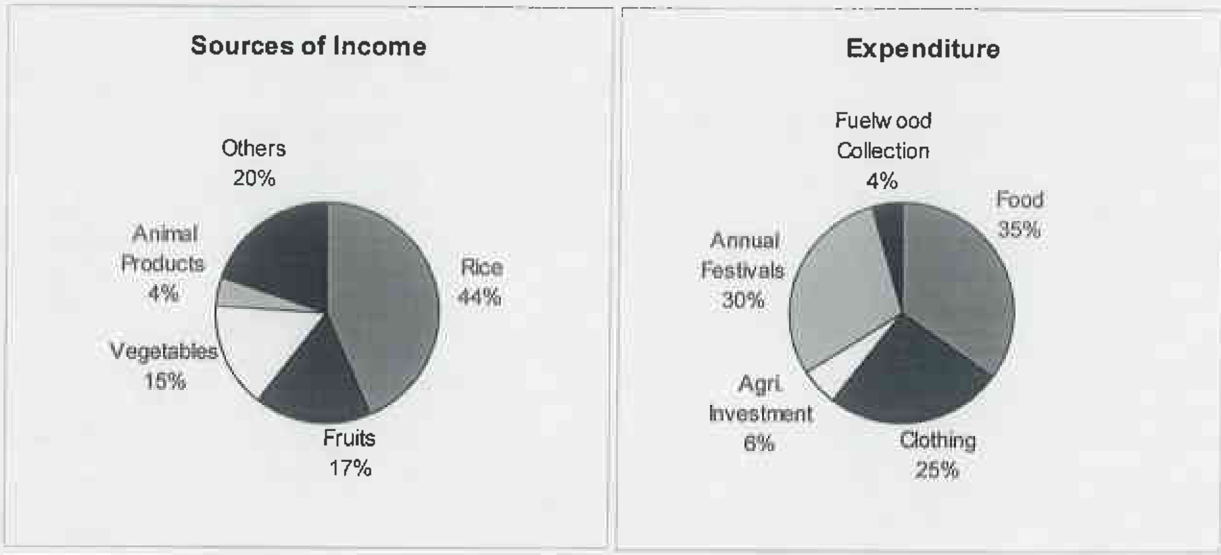


Figure 5.8 - Income and Expenditure

6. Source of fodder

Cattle are let to graze both in the field and forest. There is no restriction from the government in using forest area other than the areas fenced for reforestation, for grazing. When the fields are fallow, mainly during the winter season, grazing is limited within the fields. During summer when the fields are occupied by the crops, they are either taken to the forest or stall fed, depending on size of the herds. Cattle are let into the forest for grazing either when the herd size is large or there is shortage of laboures to herd them. Where the size of herd is small, they are usually stall fed.

7. Gross Margin Analysis for Paddy Production

In order to know the net benefit or loss associated with paddy cultivation, it is desirable to calculate the cost and returns of rice production from the farmer's viewpoint. It has been found that increasing numbers of farmers and an increasing amount of rice is being sold. Purchased inputs are minimum, although over the years, this tendency has also increased.

Gross margin here has been analyzed by calculating the financial costs and returns by using market prices for traded inputs, such as labour, bullock power, seed, etc.

Table 5.9.- Cost of and return to rice production

Activity	No. of Labourers	Nu./acre[1]
Variable Costs		
Land Preparation for seedbed (0.15 acres)		
Cultivation (ploughing and harrowing)	3	135.00
Leveling, digging, seeding	1	45.00
Compost carting and spreading	1	45.00
Weeding	10	450.00
Sub total	*15*	*675.00*
Rice field (1 acre)		
Land preparation & cultivation	16	720.00
Manuring	3	135.00
Transplanting	17	765.00
Weeding	21	945.00
Crop care/irrigation	9	405.00
Harvesting	15	675.00
Threshing / Winnowing	16	720.00
Milling		552.00[1]
Sub Total	*97*	*4365.00*
Input and Marketing		
Seeds	40 dre/acre (paddy)	480.00
Transporting	460 dre/acre (rice)	920.00[3]
Sub Total		*1400.00*
Total (Variable) Cost		6440.00
Gross Return		**7360.00**
Net Return		920.00
Benefit-cost ratio		1.14

[1] 3 dre of rice for milling 40 dre of rice @ Nu. 16/kg (1 dre rice = 1.56 kg rice)
[3] Transporting 1 kg of rice approx. costs Nu. 2.00.

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[1] 1 US$ = 35.5 Ngultrums (Nu).

Table 5.8 presents a financial picture of the benefits of rice production by comparing the costs and returns of rice production.

All costs included are variable costs and includes the cost of growing both the rice seedbed and rice crop, harvest and threshing to milling. Costs of fym and fertilizers or insecticides applied are not included since not all farmers are using them and those who use them vary in amount and the combination of application. Fixed costs such as land tax, permanent improvement in land, depreciation costs of farm tools, are also avoided due to lack of data. The cost of labour per day currently (1996 April) varies between Nu. 40-45 per day. The labour cost has been maintained at Nu. 45 per day since it is more frequent. The market price of rice (more general to white variety) varies between Nu. 15 - 18 per kg and this has been averaged to Nu. 17.

As can be seen from the table, the variable cost of producing an acre of rice is Nu. 6440.00 (US$186.7), when all household resources are valued at their market or opportunity prices.

Net returns, the difference between gross return and total variable costs is Nu. 932.00 per acre. The benefit-cost ratio of cultivating an acre of land for rice is 1.14. In other words, there is a return of as much as 14 percent in cultivating an acre of land with paddy.

8. Problems of Farming

The main problem of farming in the area is the lack of labour especially during the peak labour requirement in summer. Almost 80% of the farmers interviewed during the survey reported this problem.

The second major problem is related to water supply. Problems associated with water supply range from insufficient amount during the peak requirement period, often caused by the breakdown in the canal leading to conflicts in usage. Occurrences of diseases has often been attributed to lack of sufficient water on time.

Many farmers also reported problems related to pest incidence. Some of them allege this has come with the seeds and fertilizers[2] supplied by the extension agents. They were however, fortunate that the riceblast of 1995 didn't have severe affect on them. The supply of fertilizers has also not been regular and often they are not available in the place where they are supposed to be.

None of the farmers, however, sensed any problem related to decline in the fertility of the soils. Their soils are doing fine, and in fact as some reported, over the years, the soil fertility has improved probably due to the application of fym and increasing use of fertilizers. They deduce this from the increasing trend in productivity that they have enjoyed over the years. There are, although, exceptions to this.

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[2] This often happens when fertilizers are applied with high amount of nitrogen content; and also due to over dose.

9. Use of fym and fertilizers

All farmers reported the application of fym in their fields. FYM is a mixture of partially decomposed dung and urine of cattle with the straw, grasses and crop residues that are given as feed for cattle. Farmers usually do not use the dung of horses and pigs because, although more fertile, they encourage more weeds.

FYM is usually carried to the field in a basket which approximates 26.4 kg by weight (depending on moisture content). An average of 58.8 baskets are applied to each *langdo* which makes about six tones per acre. The main constituents of the fym are paddy straw and cowdung at an approximate ratio of 1 : 1.43. Very insignificant additional materials are used other than these two.

Most farmers also used inorganic fertilizers such as urea (60%N) and suphala (15-15-15). The amount of urea applied per acre varied from one bag to less than one bag per acre (21 kg N/acre).

10. Experiences and Visions of the Farmers

All farmers in the area are conscious, and grateful, to the government's noble policy with regard to agricultural development. They expressed that they have been the direct beneficiaries of government's wide ranging assistance encompassing supply of seeds, fertilizers and weedicides at subsidized rates and the development of infrastructure including the research center in their area. They were no less eloquent about the immediate benefit of fertilizers and weedicides. It has saved them so much in terms of labour requirements, and at the same time increased the yields. When asked about the self-sufficiency trend, many of them reported that this situation has also improved and that they are now even able to sell a part of it and earn hard cash. Assuming that the existing policy of the government continues, they see a bright future for their posterity, what with most of them already literate then.

Nevertheless, there are exceptions to these. Some farmers have experienced increasing epidemics in recent years. It was not so much frequent before. Double cropping did bring some excitement and enthusiasm when it was first introduced. It came and was gone. Given the options, they are not very positive to revert to it again. With the exception of few well-to-do farmers, land availability is seen as a major problem in the near future especially if it has to go on dividing. Present alternatives adopted by some farmers include going for sharecropping. Almost all children go to school now and hardly do any farming work; if they are not successful, returning to farmland remains their only option, and if they have to do this, it will take them some time to adjust with the profession they thought they can avoid. The increasing shortage of fuelwood is also seen as a major problem in future.

5.3. Analysis of Susceptibility to Erosion

Two contrasting features of this area are the beautiful and gently sloping terraces covered with luscious green crops of paddy or wheat or even mustard, all full of life, on either side of the majestic Tsangchhu river, *and* the hopeless, bare and desolate appearance of the areas immediately beyond these agricultural field that has been under continuous erosion over the years.

Indeed some areas are badly affected by erosion that has been induced by both natural and manmade factors. In areas nearby Matalungchhu, Bajo and Rinchhengang villages, it has even touched the agricultural fields. It has to be taken seriously that as time goes on, and as the same process continues, things will only get bad if not worse. Farmers (as found during the field survey) in these specific areas did show their concern but expressed their helplessness in not only not knowing what to do but also not being able to do by themselves without support from outside. They can visualize the advantage of having additional land through the conservation of soils but do not have the expertise to execute this vision into reality.

This exercise was carried out to identify which particular sites are susceptible to erosion comparatively on a qualitative basis with the ultimate objective of designing conservation recommendation. Since the analysis doesn't cover quantitative estimation of soil erosion, recommendations are more area specific and focus more on areas that are already degraded or are highly susceptible.

5.3.1. *Selected Parameters and their Ratings for Erosion Susceptibility Analysis*

(a). Slope

Theoretical studies and analysis of the effects of slope gradient on water erosion and numerous field observations and measurements as well as laboratory experiments have shown that slope gradient is one of the major erosion factors. Its effects on the initiation and course of erosion processes may be reduced by other factors, such as soil properties, the soil vegetative cover, etc., but never fully suppressed.

The interdependence of slope gradient and the erosion intensity as given by various authors show that the intensity of the erosion process increases with growing tangential stress and velocity of the surface runoff which are prevalently the function of slope gradient. H.H. Bennet (1955), for instance, found the relationship between slope gradient and erosion intensity as shown in the Table 5.10.

The slope map generated by GIS (see Figure on Derivation of Slope and Slope Map) was used for the analysis with the necessary classification of slope ranges. Given the paramount influence of this factor and the high reliability on it (because slope has been generated through acceptable standard method), this factor carries a very high weightage in the overall analysis.

Table 5.10 - Effect of slope gradient on soil loss after H.H. Bennet

Slope (%)	Soil Loss (t/ha/year)
3.7	44.1
8.0	158.8
12.0	222.4
20.0	243.7

(b). Drainage Density

Drainage density can be defined as the length of streams per unit area. The prevalence of drainage lines causes soils to get collected and moved away from its original place of formation. When there is rainfall, the rain water collects within the drainage line, draining with it soils down the slope. Where there is more drainage, it is therefore, possible that there will be more erosion of soil and vice versa.

Drainage density map was derived from the existing drainage map. A grid map with 250 m^2 grid was generated. This was overlaid with the drainage map and the final drainage density were classified into four categories, viz., very dense, dense, few, and very few or no drainage.

(c). Land Cover and Land Use

The type and nature of land use and land cover has great impact on the rate and amount of soil erosion, as has been empirically proved and established by many earlier researchers. Bare soils, deprived of any vegetative cover, are more vulnerable to erosion than soils that are covered with good vegetative cover. When there is rainfall, the presence of vegetative cover inhibits soils from being detached by the force of the falling raindrop. It enhances the infiltration of rainfall into the soil and slows down surface runoff and thereby improves the physical, chemical and biological properties of the soil. Very important is the soil binding effect of the root system of the vegetation. In winter season the vegetative cover effects an even distribution of the snow cover and reduces the danger of soil from freezing.

The differences in soil erosion under different types of land use and land cover is clear from Table 5.11 Since the present study does not cover the quantitative aspect of erosion, this information has been used only as a guide in the classification of land use and land cover factor as it contributes, positively or negatively, to soil erosion. Rating of this factor in Table 5.4. has been done on the basis of Table 5.11.

(d) Geology

The effect of geological conditions on the origins and course of erosion processes is manifest directly by the resistance of the denuded bedrock exposed to the flow of water, air and indirectly affected by the character of the parent material whose properties are given by the bedrock.

Weathering bedrock often rises to the surface and is denuded by water and wind. In such cases the surface is quickly disturbed and rills, gullies and ravines are formed which spread and deepen quickly.

The indirect affect of bedrock is manifest in the properties of soil forming parent material which conditions the principal properties of soils, namely their structure, texture and the content of mineral and chemical substances which with organic substances regulate the soil formation processes. The soil show varied resistance to the action of surface runoff and wind erosion.

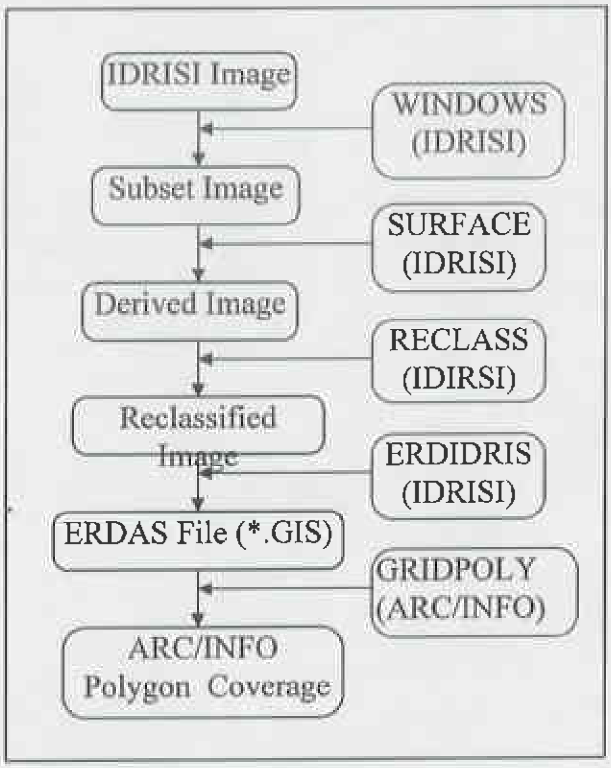

Figure 5.7. Derivation of Slope Map

Table 5.11. Estimated Soil Loss for different land use and land cover (t/ha/year)

Types of Land Use	Soil Loss
Well-managed forest lands	5 - 10
Well-managed rice terraces	5 - 10
Poorly managed sloping terraces	20 - 100
Degraded Range Lands	40 - 200

Source: Laban (1978) in Thapa, 1993.

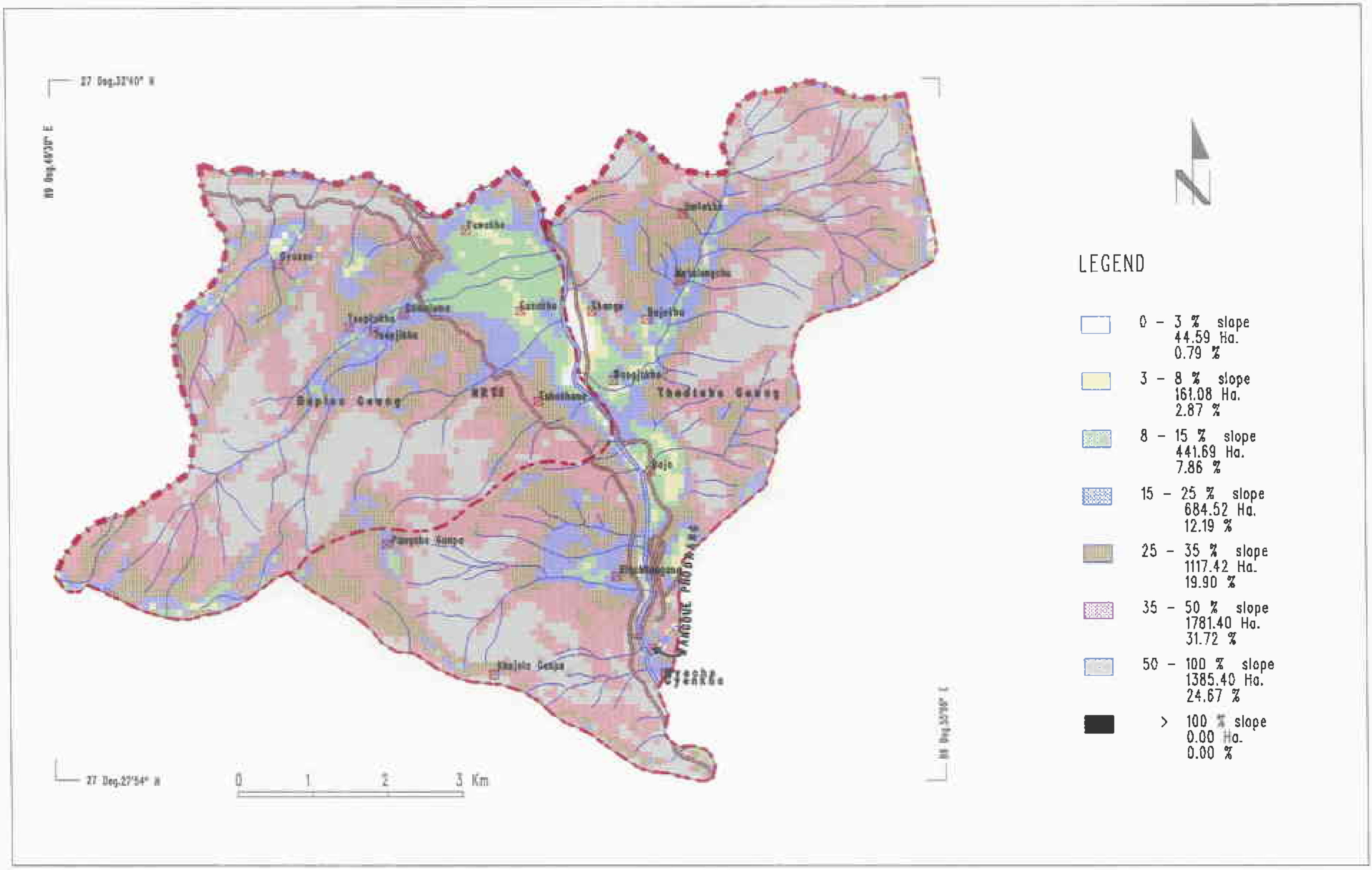

Figure 5.8: Slope Map of the Study Area

Soils formed on limestone and dolomite formations are relatively resistant; less resistant are soils on igneous rocks and least resistant on various sediments, namely sandstone, loam, clay and chalk, flysch formations and loess sediments (Milos, 1980).

The important role of geological conditions in the complex process of erosion is evident and should not be ignored.

(e) Soil Texture

The erodibility, i.e., the soil's vulnerability to erosion, is determined to a great extent by the soil texture. Investigations on the effects of soil texture on erosion processes have shown that sandy soils are least susceptible to erosion. This is because as compared with other soils they are highly permeable; at low consistence the major proportion of heavier soil particles resist the kinetic energy of water (and of wind too) for the longest period of time. Thus sandy soils have lower run-off rates, and are more easily detached, but less easily transported than silt soils. Clay soils are not easily detached, but lower infiltration rates may lead to greater run-off and increased erosion. Silt soils tend to have the greatest erodibilities since particles are easily detached and transported, and consolidation of subsoil, or subsoil with higher clay contents, can lead to greater run-off.

Although this factor is very important, the weightage given here has been kept low since the soil map prepared here doesn't fulfill all the standard requirements.

5.3.2. *Erosion susceptibility Analysis*

A simple scoring system for rating erosion susceptibility was used. Each erosion susceptibility class was rated on the scale from 1 to 4 in respect of slope, drainage density, land use and land cover, and soil texture. The scoring is arranged so that 1 is associated with a low susceptibility and 4 with high susceptibility to erosion. Each factor was given a weightage on the basis of their role in instigating erosion. The factor scores with their weightages were summed to give a total score to get a final susceptibility class.

5.3.3. *Interpretations of the Results*

(a) Eroded Areas

This class has been directly mapped during the field survey. They are open eroded areas with prominent gullies and landslips. It includes those degraded lands nearby Matalungchhu, on either side of Bajo and nearby Rinchhengang villages. They are devoid of any vegetative cover and contain lots of drainage.

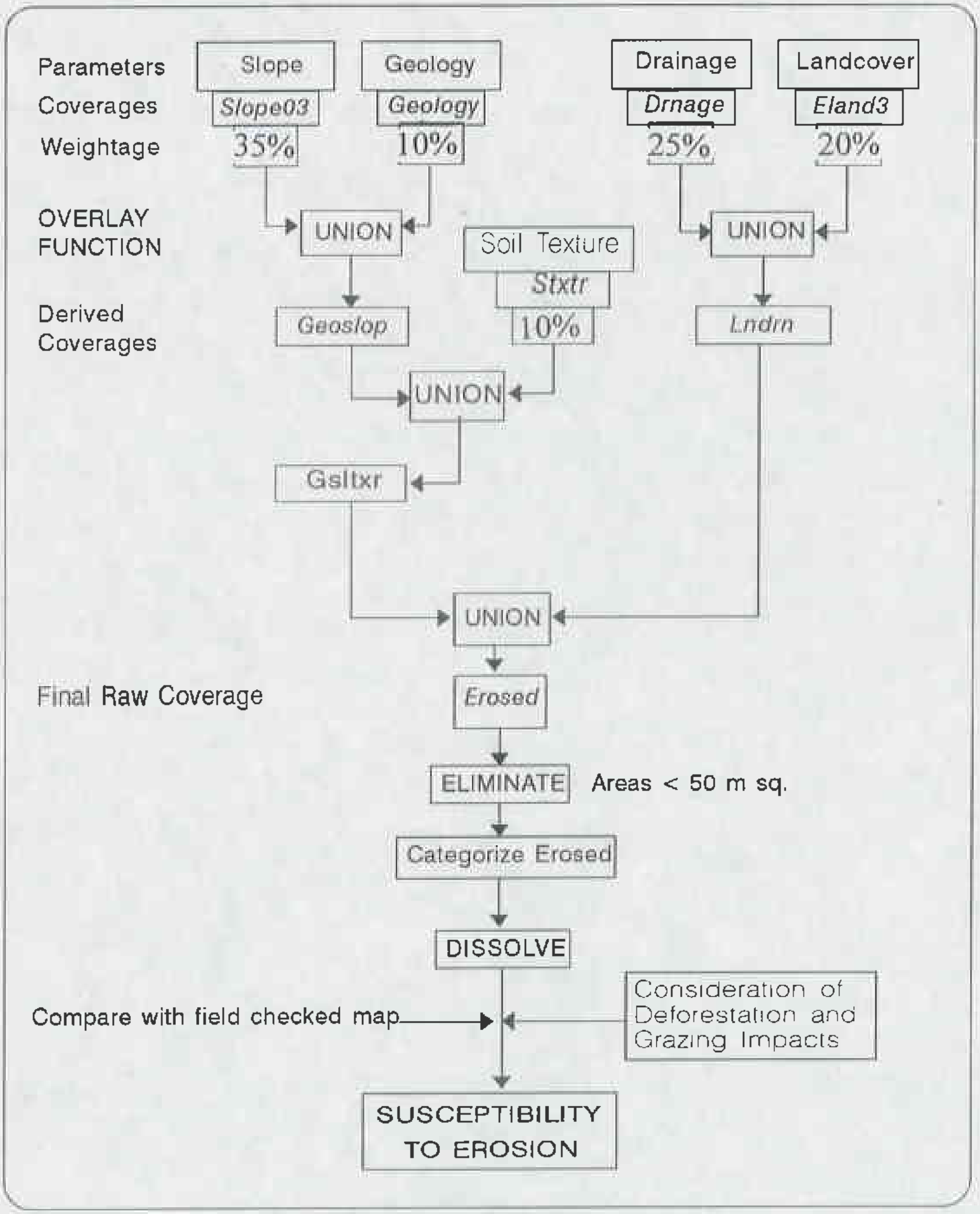

Figure 5.12 - Methodology for Erosion Susceptibility Analysis

Table 5.12. Selected Parameters and their Ratings for Erosion Susceptibility Zonation

Class	Range	Rating	Score	Weight
Slope				
1	> 50 %	Very steep	4	35 %
2	16 - 50 %	Steep	3	
3	9 - 15 %	Sloping	2	
4	4 - 8 %	Gentle slope	1	
5	0 - 3 %	Nearly flat to flat	0	
Drainage (k m/250m^2)				
1	> 5	Very Dense	4	25 %
2	>= 4 and <= 4.9	Dense	3	
3	>= 1.2 and <=3.9	Few	2	
4	< 1.2	Very few	1	
Soil Texture				
	Gravely to Slope complex		4	10 %
1	SiL to SL		3	
2	SC to L		2	
3	C to CL		1	
Landcover/landuse				
Class	**Type**		**Score**	**Weight**
1	Open Eroded Areas (OL)		4	20%
2	Dryland Agriculture (AD), Natural Pasture (PN)		3	
3	Coniferous Forest (FC) and Forest Scrub (FS)		2	
4	Broadleaf Forest (FB), Terraced field (AW)			
Geology				
1	Quartzose·member, Older Mudflow, Schist		3	10 %
2	Gniess, Younger Mudflow, High Terrace		2	
3	Medium Terrace, Low Terrace, Fan, Schalstien.		1	

Table 5.13. Susceptibility to Erosion and area

Susceptibility Class	Susceptibility Rating	Frequency	Area (Ha)	Percent
1	Degraded Land	10	164.5	2.9
2	Highly Susceptible	81	384.0	6.8
3	Moderately Susceptible	224	968.8	17.2
4	Susceptible	247	2084.9	37.1
5	No or Very Less Erosion	155	1887.0	33.6
6	Not Considered (River Basin)	1	127.5	2.3
	Total		5617.7	100

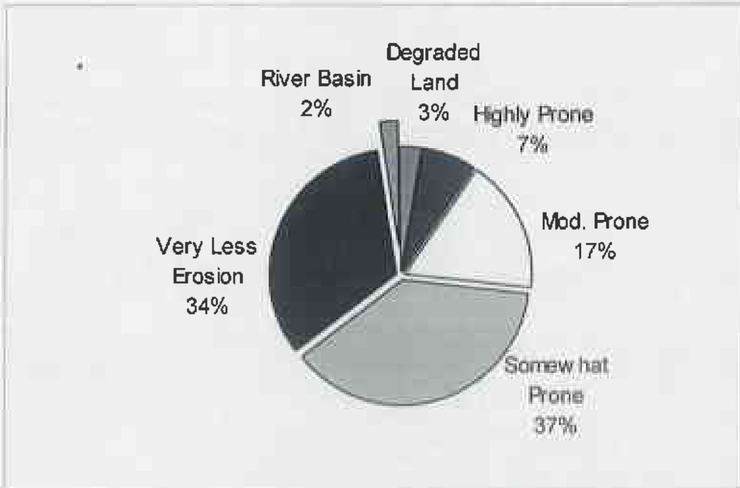

Figure 5.12 Distribution of the area by Erosion Susceptibility classes

(b) Highly Susceptible

This class include areas that are highly susceptible to erosion. Problems of soil erosion within this class are mainly due to slope steepness, dense drainage pattern and sparse vegetative cover. Due to the variability of the landscape and other factors (that are considered for the analysis) areas in this class has wide spatial distribution, although dominant on the western side of the valley, particularly areas opposite to Matalungchhu village.

(c) Moderately Susceptible

Areas within this class are susceptible to erosion although not as much as class I. Erosion here is also mainly due to the steepness of the slope and sparse vegetative cover. These areas are mainly on sloping lands. Most of them fall immediately nearby and surrounding those areas in class II.

(d) Susceptible

These areas are quite safe from erosion but will be affected by erosion if there is increased human intervention in the form of deforestation and grazing without any conservation works.

(e) Very Low or No Erosion

These areas include mainly terraced paddy fields and others under good vegetative cover Slope is nearly flat to gently sloping. Drainage density is minimum.

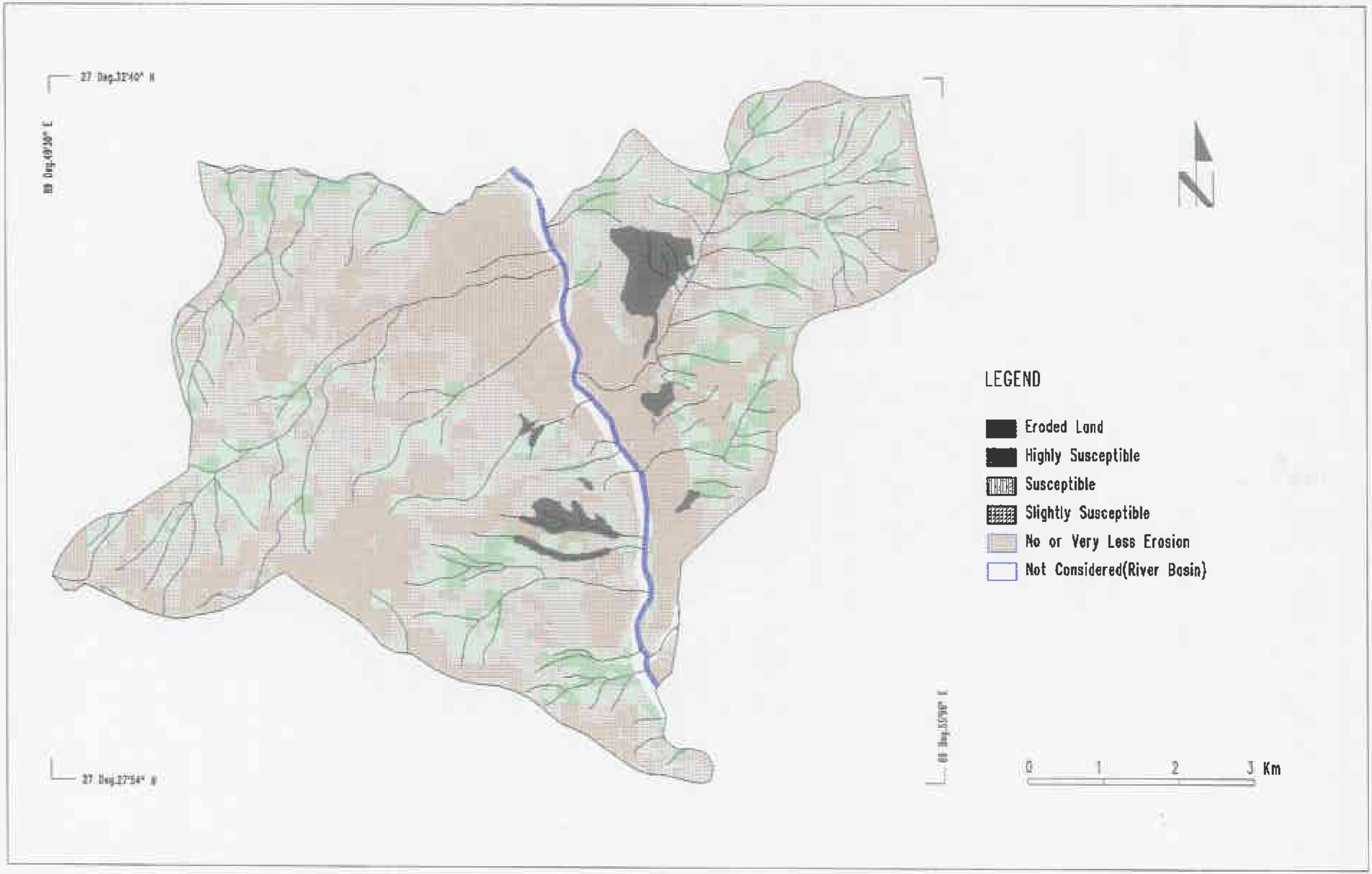

Figure 5.8: Erosion Susceptibility Map

From the above discussion it has become clear that there is a need to embark on efforts to conserve soil from erosion. It is to this important aspect that we will turn our attention in the next section.

5.4. **Relevant Options on Sustainable Agricultural Land Use**

The concept of sustainability, as has been reviewed in the previous chapters, encompass a wide range of issues. Strategies aimed to achieve it accordingly demands an integrated and interdisciplinary approach.

The guidelines drawn hereunder are based on the priority need of the situation as it exists in the area. Available land for agriculture has already reached its limit and the probable options seem to be executing proper land use planning and crop diversification and/or intensification. Given the extent to which the area has been affected by erosion, soil conservation efforts are also required.

5.4.1. *Soil Conservation Measures*

The main areas affected by erosion are sloping areas. Erosion from terraced fields is considered to be minimum, although it can't be said with certainty since erosion does take many forms. Leaching could be taking place, for instance, but the textural characteristics and nutrient status at different horizons from selected sample analysis indicates that this tendency is minimum. Existing dryland fields featured under highly susceptible class. Actual field situation is the dominance of landslips and gully erosion, most of them associated with irrigation canals and road construction.

In order to formulate a realistic soil conservation recommendation, the existing measures are reviewed, including the causes of its failure and strategies suggested.

The IFAD-PWVD project is, perhaps the major agency that has included soil conservation as one of its major activities. Efforts in this regard include the following:

1. Field implementation of soil conservation activities encompassing:

- Improved mechanical stabilization and protection works in relation to irrigation construction and renovation.
- Introduction of surface erosion reducing measures on sloping dryland.
- Farmer implemented gully control works in private land.

2. Preparing training materials that includes description on the causes of soil erosion in the area and possible techniques that can be employed to halt different forms of erosion.

3. Conducting theoretical and field training for irrigation and forestry staff on the subject of slope stabilization and gully control. A farmer training workshop on the same subject was

- to guide future development, and
- to reduce present and future conflicts.

'In principle, through land use planning activities, a nation, a region or a locality strives to steer future development of land use pattern or the physical environment in a direction that is regarded as desirable'. (Hague, 1987, in Guevarra)

Land use planning is an instrument used to guide development in the spatial context. There are several elements underlying effective land use planning. A referral system is necessary to guide planning decisions and activities. This would include land use policy, relevant land use data and a set of criteria for land use allocation.

In order to guide spatial development for the achievement of desirable land use which would balance the interest of private entities in land development pursuits with that of public interest, some form of public control of land use by the state is necessary. These include administrative, legal and fiscal means for direct or indirect public intervention.

The institutional framework is also an important dimension in land use planning. To make land use planning effective, the involved institutions, both private and public, must be capable to undertake the complex task.

Concern over appropriate land use and management necessitates the integration of environmental factors into the planning process which traditionally have been dictated by political and economic considerations. In this regard, land evaluation is an indispensable tool to directly incorporate environmental factors in appraising the suitability of specific land use to guide the decision making process.

In the context of the study area, decisions to change the use of land must be prioritized based on sound judgement and study. Prime agricultural lands must be protected from being diverted to any other forms of use.

5.4.3. *Crop Intensification and Diversification*

Crop diversification, defined as planting secondary crops and rice simultaneously in dry season, is inevitably needed for farmers to achieve better living standard through obtaining higher incomes.

Pressures to introduce non-rice crop into the cropping patterns of rice-based irrigation systems occur because of two principle reasons:

- If the price of rice declines, or even if it remains stable in the context of generally rising economy, than farmers and irrigation systems managers may seek more profitable alternative crops;

- In climates where conditions are favourable for the growing of rice during much of the year, but either too dry or too wet for rice during some other season, then it may be desirable to enhance the productivity of land by introducing non-rice crops during the dry (or colder) season.

We should distinguish these two types of situation by calling the first diversification and the second intensification. However, it has become usual to classify all strategies that are concerned with the introduction of non-rice crops into rice-based systems as "diversification".

The objectives of diversification should be to:

- enhance the incomes of farmers, by developing a market responsive system;
- improve the benefits derived per unit of water used for irrigation; and
- enhance agricultural sustainability through the maintenance of soil fertility.

Experiences in other developing countries, however, indicate that such efforts are not without constraints, the most typical of which are:

- marketing difficulties for non-rice crops;
- labour shortage at peak periods such as harvest;
- lack of monitoring arrangements;
- lack of mechanization;
- lack of flexibility in the irrigation systems;
- inadequate drainage systems;
- lack of knowledge of technologies, both for the production and post-harvest phases, for new crops.

Strategies to promote diversification and intensification must, therefore, evolve with due consideration of such experiences faced by other countries. Some important strategies towards this goal can include the following:

- development of market research and market information systems;
- coordinated provision of inputs (including water) and credit;
- improved extension services;
- creating opportunities for increased cropping intensity, especially by reducing inter season gaps and by better synchronization of planting and harvest dates;
- crop insurance, contract farming, and other procedures that reduce risks taken by farmers in embarking on cultivation of crops that are unfamiliar or that have volatile price patterns;
- development of logistics, infrastructure and post harvest support.

6. CONCLUSIONS AND RECOMMENDATIONS

The conclusion drawn here are not limited to the result derived from the analysis alone. It includes knowledge gained during field survey, discussions with researchers and planners, and an account of the prevailing field situation.

On the whole the conclusions from this research are the following:

The integration of social, economic and political considerations along with the geophysical factors would give a more realistic result than simply considering the geophysical factors alone. However, in as much as these factors determine the utilization of land, their analysis do give us clues on how land use sustainability issues can be dealt with. Slope, soil characteristics, elevation etc., actually influence land use and lack of their understanding would prove detrimental to land use sustainability in the long run.

Areas that are highly suitable for paddy crop, as per the analysis conducted in this research, is very less accounting for only 2 % of the total land in the area or just a meagre 95 hectares. Moderately suitable land account for 9% of the total or about 486 hectares. About 12% or 691 hectares is only marginally suitable. In brief, not only the usable land for agriculture is limited but within this also land of good quality is very limited.

Approximately 3% of the total land in the area is already degraded to the extent that their rehabilitation looks an impossible task. Further, about 7% of the total land seem to be highly susceptible to erosion, which without conservation measures will only soon be completely degraded. Mainly because of the slope and sparse vegetative cover factor, as much as 17% and 37 % of the area are moderately susceptible and susceptible to erosion.

The advantage of the use and application of GIS for land suitability classification has been highly appreciated. Looking back to those days when one had to manually prepare and overly maps, there is so much to appreciate about the blessings that GIS brought. It is indeed compelling to repeat that GIS does save time, enables the storage of volumes of data, its manipulation and analysis, and facilitates convenient presentation of the results. One needs, of course, to be clear about its capabilities and limitations, and more so, clear of what one wants to get from it.

Fertility assessment of the soil indicated a rather low to very low nutrient status of the soils despite the use and application of fym and fertilizers by most farmers in the area. However, the estimation of nutrient balance show that the amount available is much more than what is required by the crops. When related to crop yields, results from the latter seem to be more closer.

The application of farm yard manure seem to have some affect on the fertility of the soil. The analysis of fym samples indicated very high amount of major nutrients like nitrogen, phosphorous and potassium in the fym. Most of the soils in the top layer contain moderate to low amount of these nutrients, an effect which can be attributed to the fym application.

Recommendations

There is a need to establish a good soil database. Soil mapping need to be carried out not only for the area, but also the whole country. It becomes very difficult, frustrating at times, when the very basic data is not available. Long term agricultural land use planning will depend much on better understanding of this factor. A lot of soil samples has already been collected by LUPP from all over the country. This is a big strength towards this endeavour. There has been a proposal for soil survey project, which unfortunately has not yet begun.

With regard to the open eroded areas, it appears that attempt to rehabilitate them will not justify the cost incurred therein. However, in areas where it is affecting or has high probability of affecting paddy fields, immediate measures need to be taken. Those eroded areas, mainly around Bajo monastery and above Rinchhengang were previously terraced agricultural fields. They are accessible to irrigation. Possibilities of reclaiming these areas through agroforestry, for instance, could be considered.

With the increase in population, urbanization will take place. Expansion of urban areas should be carefully planned and where possible, priority should be given to agricultural land use. There are indications all over that this requirement is nowhere near. The confiscation of land for school construction in the prime agricultural land nearby Bajo is a typical example of the low profile unsustainable planning by the involved decision makers and planners. It has, however, been good to know that the ministry is taking stern measure in recent times to safeguard the agricultural lands from being converted to other use.

Coordination among the various organizations and agencies actively involved in the development of the area will be very important. Sharing data and information, expertise and finding common methods to help improve the condition of the people in the area should be their main goal.

The zonation of areas into susceptibility classes indicated the presence of a lot of areas in different locations under highly susceptible class. These areas need to be given priority in programmes such as reforestation and soil conservation activities.

On the sloping land above and nearby Umtekha village and the highly eroded areas, strips of trees could be grown with pastures in between. This area will need to be fenced and pastures will only be allowed for cutting and/or harvest but not free grazing. This activity could begin, for instance, by allocating a certain parcel of land to the interested farmers. Such initiatives would green the area, provide fresh pasture and above all conserve soil.

In so far as the focus of the research conducted by RNRRC (formerly CARD) is concerned, it has mainly concentrated on soil nutrient management, fym composition and its amount applied, and crop yield. Farming systems data and information still seem to be lacking. Data on population, household and farm size, for instance, vary from one source to another. It is recommended that efforts should be made to gather, update and maintain with certain standards to help researchers in future to arrive at realistic conclusions. Data on meteorology was also found to be highly variable, some of which was actually recorded were missing, many do not tally with each other. This also needs to be looked into by the concerned authorities.

Recommendations for future research

In case where there is need to take soil samplings for use of soil data, sites other than the ones from where samples were taken during this research could be selected. The pit specific soil information are correct and reliable as far as its analysis and interpretation using the existing facilities are concerned. Where the need to obtain time series soil data, the present result can be used as one of the main inputs - they are all dated and timed.

Scope to further increase crop yield will rest on the timely and appropriate use of fym and fertilizers. In this regard, it is recommended that there is a need to conduct studies on nutrient balance and nutrient cycling besides the existing focus on nutrient management. Understanding this phenomena will go a long way in helping to actually realize sustainability in agricultural land use.

The amount of fertilizers applied by farmers presently is largely dependent on the availability of manure and labourers. In order to ensure the correct utilization of fym, its optimal application rates for a given soil type and crop need to be understood and determined.

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Appendix A - (a) Monthly Rainfall recorded at CARD, Wangdue, from May 1985 to Dec. 1995

Year	JAN	FEB	MAR	APR	MA Y	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total	Avg.
1985	NS	NS	NS	NS	20.6	80.5	195	110	103	130	8.2	42	688	86
1986	NS	NS	NS	NS	32.9	265	155	109	78.8	65.5	0	11	717	89.6
1987	4.1	5.8	42.3	113	35.5	104	116	147	102	80.3	0.3	3.7	754	62.9
1988	0	6.2	17.5	35.5	50.9	94.8	165	126	35.5	4.4	9.4	5.2	550	45.8
1989	12.4	58	38.2	1	NS	326	203	65.4	132	18.8	2.1	0	857	77.9
1990	0.7	3.1	20.1	79.7	34.1	117	206	87.3	138	62.8	0	14.5	764	63.7
1991	13.4	18.9	13.2	14.2	96.5	151	116	174	115	3	0	11.4	727	60.6
1992	5.7	0	1.2	62.1	25.2	103	223	102	23.4	10.8	0	16.3	573	47.8
1993	22.9	15.2	18.4	46.1	13.9	68.4	24	190	108	7.8	10.5	0.5	525	43.7
1994	31	17.7	15.5	40.2	30.3	119	134	167	39.7	1	0.3	0	596	49.6
1995	15.2	17.5	13.8	4.9	7.7	103	155	112	123	6.4	86	6.2	650	54.2
Mean	11.7	15.8	20.0	44.1	34.8	139	154	126	90.7	35.5	10.6	10.1		
S.D	10.4	17.3	12.7	36.6	24.8	81.3	56.5	38.7	40.6	42.8	25.4	12.1		

(b) Monthly Maxi.and Min. Temperatures recorded at CARD from May 1985 to Dec. 1995.

Year		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1985	Max	NS	NS	NS	NS	27	29	26	30.7	28.7	27	21.7	19.1
	Min	NS	NS	NS	NS	17.4	19.4	20.2	20.5	20.1	17.2	12	8.7
1986	Max	15.6	17	21.1	22.2	25.4	30.4	25.9	27	27.2	23.1	22	18.6
	Min	8.5	9.4	12.1	13	12.1	16.7	19.5	19	17.7	13.1	9.1	4.4
1987	Max	19.3	21.1	22.2	25.1	27.8	29.1	27.4	26.4	26.6	24.9	22.7	19.9
	Min	3.7	6.4	11	11.9	16.2	19.5	19.7	19.3	18.9	14.3	8.5	4.5
1988	Max	18.4	19.8	21.7	25.3	28.7	28.5	28	27.3	27.5	28.3	24.2	21.5
	Min	5.3	7.7	10.9	13	16.7	19.2	22.0	19.7	18.8	12.5	6.2	5
1989	Max	17.7	17.8	22	26.1	NS	28.3	27.6	28.1	27.7	26.8	21.4	18.5
	Min	3.8	5.8	10.6	11.7	NS	18.9	19.7	19.1	17.8	17	9.5	2.1
1990	Max	18.2	17.2	21.9	23.2	27.6	28.8	27.8	28.4	27.4	24.6	23.6	19.5
	Min	8	8.9	9.7	13.4	17.8	20.5	20.5	20.5	19.9	14.4	7.6	6.4
1991	Max	15.6	19	23.2	25.4	26.9	27.9	27.6	28	26.9	26.1	21.5	18.4
	Min	5.3	12.5	15.8	14.7	17.8	20.2	20.8	20.6	22.1	14.6	8.7	4.2
1992	Max	18	16.1	22.7	26.9	27.1	29.7	27.7	29.1	28.9	25.7	18.8	19.1
	Min	4.9	7.2	11	13.5	19.2	19.3	19.5	19.6	17.9	14.5	6.1	2.8
1993	Max	15.6	20.6	22.5	24.7	27.8	29	29.4	28.7	27.5	26.2	23.1	20.9
	Min	5.4	7.3	8.8	12.5	17.9	19.2	20.2	19.9	18.8	16	11.5	6.0
1994	Max	19.6	18.9	23.0	22.7	29.1	29.8	31.0	30.6	28.6	25.7	21.9	18.8
	Min	4.8	7.8	11.4	13.3	17.6	20.0	20.5	20.0	19.5	14.0	7.9	4.7
1995	Max	16.5	17.4	22.4	26.6	30.3	28.8	27.4	28.1	26.3	26.4	22.7	17.6
	Min	4.7	8.3	11	12.4	17.7	21.1	19.6	20.2	19.0	14.0	9.5	8.2
Mean Max.		17.5	18.5	22.3	25.3	27.8	29.0	27.8	28.4	27.6	25.9	22.1	19.3
Mean Min.		5.44	8.13	11.2	12.9	17.0	19.5	20.0	19.9	19.1	14.7	8.78	5.18

Appendix B - The Land Cover Classification System for Bhutan
(adopted by the PPC, MoA in Nov. 1994)

Symbols	Landuse/Landcover Type	Description
FB1, FB2, FB3	Broadleaf Forest	Hardwoods comprising 80% by crown density (the arabic numerals 1,2,3 represent crown density as 10-40%, 40-80% and >80% respectively).
Fcc1, FCc2	Coniferous Forest	Coniferous forest with chirpine species generally between 700-2000m msl, occasionally with broadleaf species e.g., oak.
FS	Scrub Forest	Areas of srcubland and scrub forest dominated by woody species
PN	Natural Pastures	Areas of predominantly grassy vegetation or native meadow
FPc, FPb	Plantation	Plantations of >50% coniferous species and plantations of >50% broadleaf species respectively
OL	Landslips and Open Eroded areas	Areas in which there is clear evidence of erosion, natural or manmade, including landslips and scree slopes
OW	Water Spreads	Wide rivers and lakes
SE	Settlement areas	Towns, villages and other small areas of concentrated settlement, often associated with small areas of agricultural land and gardens
AWim, AWiv	Wetland Cultivation	Irrigated, bench terraced, cultivated land - rice based cropping system: may include some small pasture and orchard areas. (m for on mountain slopes and v for valley bottom sites).
AMm	Mixed Cultivated Land	Areas where irrigated or rainfed cultivated land and tsheri combine in a complex mix: often associated with settlement and small orchard/kitchen garden/pasture areas on mountain slope sites
ADum	Dryland Cultivation	Rainfed ,terraced (constructed on slope, not flat as in the bench terraced wetland), cultivated land - maize and potato based cropping system: may include some small pasture and orchard areas: on mountain slope site.

NB: Only those land cover types found in the study area are included in the above table.

Source: LUPP, MoA, Thimphu, Bhutan.

Appendix C - Soil Chemical Properties Rating and Range applied for the Study (with courtesy from LUPP, MoA, Bhutan)

Range	Ratings	Comments
		pH (H_2O)
>= 8.6	Alkaline	Very high pH: the soil is likely to exhibit salt problems, and extreme caution has to be taken if the soils are to be irrigated, as they may become extremely hard or compact, and salt may collect at the surface. These are called saline-alkalline soils, and probably very rare in Bhutan.
7.6-8.5	Mod. Alkaline	Moderately high pH: the soil is most likely rich in calcium (and magnesium), and has a good structure. However, phosphorous and a few other nutrients may bind tightly to the soil in this pH range. NPK will probably have to be added through fertilizers or fym
6.6-7.5	Neutral	Preferred pH range: liming is not necessary, and most nutrients have the highest availability at this range. Ca & Mg will generally be available in adequate amount. P is most available in this range but NPK addition will be required.
5.6-6.5	Slightly Acid	Slightly low pH: this range is acceptible for most crops. However, some of these soils will be on the edge of showing Al poisoining, and they will be rather low in nutrients like Ca and Mg. NPK will have to be added to maintain soil fertility.
4.5-5.5	Very Acid	Low pH: the soil will almost certainly have high Al levels which will be poisoinous to most crops and low P may be a problem. Ca and Mg levels will be low. Fertilizer application is recommended only after liming to a higher pH level.
< 4.5	Extremely Acid	Very low pH: A problem, and several nutrient deficiencies will occur. No fertilizer should be applied before liming to a higher level. Several different nutrients may have to be applied to obtain even reasonable yields.
		Electrical Conductivity (mS/cm)
>= 2.00	Very High	Plant growth and yields will be severely restricted for most crops; levels this high usually signify high Na content.
0.80-1.99	High	Plant growth and yield may be restricted
0.40-0.79	Medium	most crops will not be damaged by these levels of soluble salts.
0.15-0.39	Low	No problems envisaged for crops growth but these levels may signify generally low fertility
< 0.15	Very Low	very low EC levels probably signify a low nutrient status, especially of the exchangeable bases and important nutrients of Ca, Mg, and K
		Total Nitrogen (%)
>= 1	Very High	probably no N-fertilizers requirement in the long term
0.50-0.99	High	good level of reserve-N, lower N-fertilizer additions accordingly
0.20-0.49	Moderate	may need N feertilizers in the short term
0.10-0.19	Low	would greatly benefit from further additions of N
< 0.10	Very Low	in great need of N-fertilizer, except poor yields.
		Available Nitrogen as NO_3 (mg/kg)
>= 50	Very High	N-fertilizer not required for most crops
30-49	High	N-fertilizer may be required at low doses
15-29	Moderate	N-fertilizer may be required at medium doses
5-14	Low	Deficiency indicated, N-fertilizer/more fym required (check NH_4 result)
< 5	Very Low	strong deficiency indicated, N-fertilizer/more fym necessary (check NH_4 result)

Appendix C - (contd..)

Available Nitrogen as NH4 (mg/kg)		
>= 50	Ver y High	no fertilizer requirement
30-49	High	no fertilizer requirement
15-29	Moderate	possible fertilizer/more fym requirement but check NO_3 result
5-14	Low	fertilizer requirement, more fym but check NO_3 result
< 5	Very Low	almost certainly needs fertilizer/more fym but check NO_3 result
Range	Rating	Comments
Available Phosphorous (ppm)		
>= 30	High	P rich soil - fertilizer/more fym not necessary
15-29	Moderate	probably sufficient P in the short term
5-14	Low	P deficient - P-fertilizers/more fym recommended
< 5	Very Low	P deficient - P-fertilizer/more fym essential for good yields
Available Potassium (K in mg/kg)		
>= 300	Very High	K-fertilizer not needed
200-299	High	K-fertilizer unlikely to be necessary for most crops
100-199	Moderate	K-fertilizer may give economic response to some crops
40-99	Low	K-fertilizers probably ncessary for good yields
< 40	Very Low	K-fertilizer essential for good yields
Base Saturation (%)		
80-100	Very High	almost all the exchange sites are saturated - a generally fertile, neutral or slightly alkaline soil, or soil with a significant limestone content
60-80	High	a generally fertile soil with a near neutral pH
40-60	Medium	a soil with possible fertility problems, due to inherent infertility, slightly acid pH, or a measurable Al content
20-40	Low	probably an inherently infertile or acid soil
0-20	Very Low	very few exchange sites are occupied - probably an inherently very infertile or strongly acid soil

Rating	CEC	Ca	Mg	K	Na
Very High	>= 40	>=20	>= 8	>= 1.2	>= 2
High	25-39.9	10-19.9	3-7.9	0.6-1.19	0.70-1.99
Moderate	15.0-24.9	5.0-9.9	1.5-2.9	0.30-0.59	0.30-0.69
Low	5.0-14.9	2.0-4.9	0.5-1.4	0.10-0.29	0.10-0.29
Very Low	< 5	< 2	< 0.5	< 0.10	< 0.10

Appendix D (a) - Population Distribution by Sex and Age, Baap Block, 1994.

		Sex		Age			
	Villages	Male	Female	<15 years	16-59 years	> 60 years	Total
1	Chasa	75	60	31	93	11	135
2	Eusakha	154	152	68	214	24	306
3	Gamaluma	103	105	53	140	15	208
4	Matalungchhu	120	120	50	158	32	240
5	Tseptokha	85	75	36	104	20	160
6	Tshokana	108	102	41	146	23	210
7	Wangjokha	63	77	40	81	19	140
8	Yuwakha	144	117	58	177	26	261
9	Shekha	69	57	37	79	10	126
	TOTAL	921	865	414	1192	180	1786

Source: Extension Office, Lobeysa, Baap Block.

Appendix D (b) - Population Distribution by Farm Labour Availability, Baap Block, 1994

Sl. No.	Villages	No. of Farming HH	Farming People	Non-Farming People	Average Farming People/HH	Avg. Non-Farming People/HH	Average Population/ HH
1	Chasa	21	65	28	3.09	1.33	6.42
2	Eusakha	45	108	106	2.40	2.35	6.80
3	Gamaluma	25	74	66	2.96	2.64	8.32
4	Matalungchhu	29	108	50	3.72	1.72	8.27
5	Tseptokha	22	58	46	2.63	2.09	4.81
6	Tshokana	23	79	67	3.43	2.91	9.13
7	Wangjokha	16	50	31	3.12	1.93	8.75
8	Yuwakha	33	95	82	2.87	2.48	7.90
9	Shekha	22	71	8	3.22	0.36	5.72
	TOTAL	236	708	484	3.05	1.98	7.35

Source: Extension Office, Lobeysa, Baap Block

Appendix E (a) - Agricultural Land Use Types under Baap Block (in acres) 1994.

Sl. No.	Villages	Wetland	Dryland	Tsheri/ Pangshing	Kitchen Garden	Total
1	Chasa	65.3	13.5	21.10	3.40	103.3
2	Gamaluma	73.05	8.92	33.08	4.76	119.8
3	Matalungchhu	123.63	2.57	5.38	2.48	134.1
4	Pachakha	130.09	4.46	11.26	5.14	150.9
5	Tseptokha	42.78	3.00	12.65	1.11	59.5
6	Tshokana	66.71	0.62	8.46	4.21	80
7	Wangjokha	98.53	0.83	2.97	3.18	105.5
8	Yuwakha	234.27	23.48	78.77	2.02	338.5
	Monk Body	111.70	0.96			112.7
	TOTAL	1058.57	58.34	173.67	26.30	1316.9
	Percent	80.38	4.43	13.19	1.99	100

Source: Extension Agent Office, Lobeysa, Thimphu

Appendix E (b) - Agricultural Land Use (in acres) Types, Thedtsho Block, 1992.

Sl. No.	Villages	Wetland	Dryland	Pangshing	Total
1	Naysagaykha	10.43	2.64	10.03	23.10
2	Naraji	5.45	6.53	9.95	21.93
3	Naylaykha	11.15	2.20	7.99	21.34
4	Matalungchhu	21.07	3.05	0.81	24.93
5	Thangu	14.09	1.16	5.26	20.51
6	Rinchhengang	85.87	14.49	10.47	110.83
7	Bajo	3.07	3.15	3.61	9.83
	TOTAL	151.13	33.22	48.12	232.47
	Percent	65.01	14.29	20.70	

Source: LUPP (1993)

Appendix F - Average Land Holding (acres) versus Number of Farmers in Baap Block, 1994.

Sl. No.	Villages	Landless	0 - 0.5	0.5 - 2.0	2.0 - 5.0	> 5.0
1	Chasa	7	8	21	11	6
2	Gamaluma	11	3	16	9	8
3	Matalungchhu	1	4	8	20	8
4	Tseptokha	5	2	17	6	4
5	Tshokana	3	3	17	6	5
6	Wangjokha	2	5	14	11	5
7	Yuwakha	14	17	38	21	4
8	Pachakha	6	16	25	26	5
	TOTAL	49	59	156	110	45
	% of the Total	11.7	14.08	37.23	26.25	10.74

Appendix G: Typical Costs of Rice inputs and outputs

Input /Output	Qualifier	Value	Unit	Comments
Output Market Prices				
Rice	White Variety	15-18	Nu/kg	High price in July to September and low price in November to January
	Red Variety	18-20	Nu/kg	Same as above (1 dre = 1.56 kg)
Threshing	Pedal thresher	60	Nu/d	15 dre rough rice for machine without operator
		80	Nu/d	For machine and operator
	Power thresher	15	%	6 dre rough rice for each 40 dre threshed
Rice Milling		7.5	%	3 dre rice for each 40 dre threshed
		55.0	%	Milling recovery for local rice varieties
Labour	Cash/kind	40.0	Nu/d	Both men and women are usually paid 40-45 per day.
	Meals	20.0	Nu/d	cash or 6 dre rough rice. Three meals and some drinks are normally provided.
Cultivation	Bullocks	80.0	Nu/d	Nu. 80 or 2 days of labour equivalent paid to the owner for a pair of bullocks for plowing or harrowing.
	Plowmen	40	Nu/d	as indicated under labour
	Power tiller	70-80	Nu/h	Power tiller charges range from 70 to 80 per hour and is usually used in flat areas
Imputed Prices				
	Compost	100	Nu/t	Compost is not sold in the market, although it may be exchanged. The RNRRC research farm buys compost at Nu. 150 for a 1.5t trailor load; Nu 50.0 is deducted for transport, etc.
	Rice Straw	300	Nu/t	Grain-straw ratio = 1:1.8. Rice straw is rarely sold. The livestock farm at Wangchuktaba in Thimphu buys rice straw at Nu. 250-300/t; this price doubles by the feeding scarce period at the end of winter.
	Transport cost	2.0	Nu/kg	Rice is normally sold in Thimphu. Fare from the area to the city is Nu. 32 each way + Nu. 20 for a 40-kg sack of rice.

Appendix H - Some Photographs of the area

(a) Areas affected by Gully Erosion around Matalungchhu Village

(b) Evidence of Grazing Factor in Erosion; above Bajo

(c) View of the Valley from the North

(d) View of the Valley from the South

Appendix I - Interpretation of Soil Physical and Chemical Properties

NB: Beneath each table of the field description sheet, involved personnel in describing the soils are mentioned as RA, DKB, and DD. They are:

RA - Mr. Richard Allen, Land Use Planning Specialist, LUPP, MoA, Bhutan.

DKB - Mr. Deo Kumar Biswa, Assistant Land Use Planner, LUPP, MoA, Bhutan.

DD - Mr. Dungkar Drukpa, Planning Officer (GIS), LUPP, MoA, Bhutan.

PIT No. DT - 1 **Date of Sampling: 22/01/1996**

Coordinates (GPS): 27°29.13 N & 89°38.28 E
Location: Between Pokto and Phatsha villages
Altitude: 1480 msl
Parent Material: Quartzitic mainly
Landform: Terraced (broad to narrow); mid valley
Slope and Aspect: 8 - 10 %, SW
Landuse and Vegetation: Paddy field surrounded by artemisia & few broad leaf shrubs
Surface features: Paddy stubbles and residues of paddy straw
Effective soil depth: 0 - 110 cm
Profile drainage: Moderately well drained
Moisture condition: Moist to very moist
Microtopography: Quite uneven due to animal hoofs & wide to narrow cracks developed due to irrigation

Horizon	AP	B1	B2	B3
Depth (cm)	0 -18	18 - 55	55 - 87	87 110
Colour	brown	dark grey	dark greyish brown	dark greyish brown
Mottles	common, fine, medium, distinct	common, fine medium faint, (few distinct)	common to fine faint rusty	common to many + fien to red rusty
Consis- tency	firm, slightly moist	firm, slightly moist	firm, moist	slightly firm, moist
Texture	silty clay loam & fine sand	fine to medium sand	clay loam, very sticky, distinct fine to medium sand fraction	clay loam, very sticky, distinct, fine to medium, sand fraction
Structure	weak medium to coarse	angular blocky, weak to medium blocky	very weak medium	blocky
Coarse Material	not seen	not seen	very few to fine angular micaschist fragments	few fine mica fragments
Roots	many fine to medium fibrous	very few fine fibrous	not seen	not seen
Pores	common fine tubular	common to fine medium tubular	many to fine	medium tubular

(Described by RA, DD & DKB)

Notes:

- *Mottles commonly follow root channels (drawdown mottles)*
- *Soil red once dried and patches of red soil observed around the pit*
- *B3 - Tendency to prismatic structures*
- *Clay movement not observed, soil gets quite hard once dried*
- *Augured from 110 cm to 160 cm & seen dark grayish brown, many distinct mottles*
- *Clay loam textured soil, common fine muscovite fragments, moist to very moist with depth.*

Horizon		Ap	B1	B2	B3
Depth (cm)		0-18	18-55	55-87	87-110
pH	H_2O	5.7	8.3	8.5	8.5
	KCl	4.5	7.0	7.2	7.0
EC mS/cm		0.04	0.04	0.04	0.02
Total C%		1.9	0.6	0.4	0.4
OM %		3.3	1.0	0.7	0.7
Total N%		0.16	0.08	0.05	0.16
C:N ratio		111.8	7.5	8.0	2.5
Avail. P mg/kg		6	20	11	11
Avail. K mg/kg		127.7	141.4	107.0	89.9
Avail N mg/kg as	NH_4	1.6	1.3	1.4	1.3
	NO_3	7.5	1.6	0.9	3.0
Exchangeable Cations meq/100g	Ca	7.1	11.1	10.0	8.9
	Mg	1.5	2.6	2.3	2.0
	K	0.81	1.13	0.83	0.77
	Na	0.23	0.29	0.20	0.22
	Sum	9.64	15.12	13.33	11.89
CEC meq/100g		13.4	15.8	12.9	11.3
exture (Pipette Method)	C	42.8	44.0	41.5	42.1
	Si	30.0	26.7	25.9	27.1
	S	27.2	29.3	32.6	30.7

DATA SUMMARY FOR PIT DT-1

This site is a fallow land used for summer rice and is located between Pokto and Phatsha villages at an altitude of 1480m msl under Thedtsho block. It is moderately sloping mid-slope site facing south-west and is covered by paddy stubbles. Wide to narrow cracks were developed mainly due to irrigation and the field is surrounded by artemisia and few broadleaf shrubs.

The soil is derived mainly from quartzite, deep, moderately well drained, and brown (10YR 4/3) to dark gray (10 YR 4/2) in colour. Mottles are common, faint and distinct, gets to many and rusty with depth and commonly follow root channels. The soil is firm and slightly moist throughout with weak, medium to coarse subangular blocky structures. Coarse materials were not observed except for few fine micaschists at lower layers. Many fine, medium, fibrous roots were observed to 55 cm. Common to many, fine, tubular pores were observed throughout the layer. The profile was augured from the base of the pit to 150 cm - has same colour, is distinctly mottled and has common fine muscovite fragments. It gets moist to very moist with depth.

Chemically, the topsoil is slightly acid with a pH of 5.7 but gets more alkaline with depth. EC, a measure of salt concentration, is very low throughout the profile, a characteristic that is widely associated with soils in Bhutan. Total C & OM is moderate in the topsoil (0-18cm) but decreases with depth. Both total N and inorganic N are low to very low throughout the profile; available P is low in the topsoil but moderate in the second layer and still lower thereafter; available K is moderate but low at the last observed layer. Exchangeable cations like Ca, Mg and Na are low in the topsoil but becomes moderate with depth.

PIT No. DT - 2 **Date of Sampling: 22/01/96**

Coordinates (GPS):	27°29.13 N & 89°38.28 E
Location:	Between Pokto and Phatsha villages
Altitude:	1500 msl
Parent Material:	Quartzitic mainly
Landform:	Small ridge between two low lying paddy fields
Slope and Aspect:	7.5 %, SW
Landuse and Vegetation:	Paddy field surrounded by artemisia
Surface features:	Flat terraces with slight undulations due to harvest and cultivation operations
Effective soil depth:	0 - 95 cm
Profile drainage:	Moderately well drained
Moisture condition:	Slightly moist throughout
Microtopography:	Quite uneven due to animal hoofs & widespread cracks developed due to irrigation

Horizon	AP	B1	B2
Depth (cm)	0 -18	18 - 64	64 - 95
Colour	yellowish brown	very dark greyish brown	brown
Mottles	common, fine to medium, yellow, brown distinct	patchy, common, distinct medium yellow brown and red brown	few medium reddish brown
Consis- tency	slightly firm, very hard when dry	extremely hard when dry	very hard, slightly moist
Texture	sandy clay loam	sandy clay	sandy clay loam
Structure	weak to medium, blocky	weak, coarse, blocky angular	coarse, weak blocky massive
Coarse Material	not seen	few medium quartz fragments	some fragments of quartz
Roots	common, fine to medium fibrous	few fine to medium	not seen
Pores	common, fine to medium tubular	common, fine to medium tubular	common, fine to medium

(Described by RA, DD & DKB)

Notes:

- sign of soil fauna activities
- slightly rounded boulder (quartzitic) more observed near the pit
- more coarse textured (with medium coarse sand) than DT - 1

Horizon		Ap	B1	B2
Depth (cm)		0-18	18-64	64-95
pH	H_2O	6.3	7.5	7.5
	KCl	4.9	6.1	6.0
EC mS/cm		0.02	0.02	0.01
Total C%		1.2	0.8	0.6
Ooganic Matter %		2.1	1.4	1.0
Total N%		~~0.9~~ 0.09	0.4	0.4
ratio		113.3	20.0	15.0
Avail. P mg/kg		20.0	35.0	35.0
Avail. K mg/kg		108.4	112.9	144.4
Avail N mg/kg as	NH_4	1.4	1.4	1.9
	NO_3	8.8	0.4	1.4
Exchangeable Cations meq/100g	Ca	4.0	7.2	8.2
	Mg	1.0	1.7	2.0
	K	.56	.76	.86
	Na	.17	.12	.13
	Sum	5.73	9.78	11.19
CEC meq/100g		7.8	12.4	13.6
Texture (Pipette Method)	C	28.2	27.9	33.4
	Sl	30.2	17.0	28.8
	S	41.6	54.3	37.8

DATA SUMMARY FOR PIT DT-2

This site is in the fallow paddy field at the front of a small ridge between Phatsha and Pokto, facing south-west. It is located at an altitude of 1500m msl in a mid-slope position and has rice stubbles as surface cover. There are slight undulations on the surface due to cultivation and harvest operations. Signs of soil fauna activity and slightly rounded boulders were seen near the pit.

Physically, the soil is quite deep, moderatelly well drained and derived mainly from quartzite. The topsoil is yellowish brown (10YR 5/4), changes to very dark grayish brown (10YR3/2) and to dark yellowish brown 7.5YR 4/4) at 64-95cm. Mottles are quite common, fine to medium, yellowish brown and distinct at the upper layer while at lower layer it get to few, medium and reddish brown. The soil is slightly firm but gets very hard when dry and at lower layer it is slightly moist. Structure is weak, medium to blocky at 0-18 cm but gets weak, coarse and blocky angular to weak coarse blocky and massive with depth. Few medium quartzitic mica and carbon coarse materials were observed at the low levels. Common to fine and medium fibrous roots were seen to 64 cm depth. The pores are common, fine, medium and tubular througout the profile.

The pH is neutral throughout ranging from 6.3 - 7.5. EC is low. OM levels are moderate in the top soil but gets low with depth. Total N as well as available ammonium N is very low throughout the profile and available N as nitrate is low in the top soil and very low thereafter. Available P is moderate from 0-20 cm but very high in the subsoil. Available K is moderate throughout the profile although it slightly increases with depth - exchangeable K is low throughout the profile. Exchangeable Ca is low from 0-18 cm but moderate thereafter. Exchangeable Mg levels are low in the topsoil but gets moderate thereafter. Exchangeable Na levels are low throughout the profile.

PIT No. DT - 3 **Date of Sampling: 22/01/96**

Coordinates (GPS):	27°29.13 N & 89°38.28 E
Location:	Below Boekha-Potokha village (below a monastry)
Altitude:	1425 msl
Parent Material:	Quartzite
Landform:	Paddy terraces on valley mid
Slope and Aspect:	19 %, SE
Landuse and Vegetation:	Paddy field surrounded by artemisia
Surface features:	Bunds of paddy terraces, residues of harvested paddy straw & few boulders
Effective soil depth:	0 - 100 cm
Profile drainage:	Moderately well drained
Moisture condition:	Subsoil is moist from recent rains
Microtopography:	Uneven due to more cattle grazing during off season

Horizon	AP	B1	B2
Depth (cm)	0 -18	18 - 50	50 - 100
Colour	dark grey	dark greyish brown	greyish brown
Mottles	many, medium, distinct yellow, brown and moist	few, fine to medium distinct rusty	few, fine distinct rusty
Consis-tency	slightly friable, moist	hard, slightly moist,	slightly firm, moist
Texture	silty clay loam and fine sand	sandy clay loam (medium) sand	sandy clay loam
Structure	weak, fine to medium, subangular blocky	very weak and blocky	very weak to massive
Coarse Material	not seen	few very fine mica flakes	few fine mica flakes
Roots	common, fine to medium fibrous	few, fine fibrous	not seen
Pores	common, fine to medium tubular	common, fine to medium tubular	common, fine tubulars

(Described by RA, DD & DKB)

Notes:

- *mostly similar to DT-1 and DT-2, but has the tendency to become hard.*

Horizon		Ap	B1	B2
Depth (cm)		0-18	18-50	50-100
pH	H_2O	5.7	8.4	8.5
	KCl	4.4	7.2	7.2
EC mS/cm		.02	0.03	0.04
Total C%		1.0	0.3	0.4
OM %		1.7	0.5	0.3
Total N%		0.08	0.03	0.03
C:N ratio		12.5	10.6	6.6
Avail. P mg/kg		3.0	3.0	2.0
Avail. K mg/kg		135.5	104.8	107.0
Avail N mg/kg as	NH_4	1.1	1.4	1.2
	NO_3	3.8	0.7	1.6
Exchangeable	Ca	2.8	5.9	6.5
Cations	Mg	0.7	1.4	1.4
meq/100g	K	0.5	0.49	0.47
	Na	0.12	0.19	0.22
	Sum	4.12	7.98	8.59
CEC meq/100g		7.4	7.7	8.4
Texture	C	22.1	22.4	23.2
(Pipette	Z	27.2	27.9	29.3
Method)	S	50.6	49.7	47.6

DATA SUMMARY FOR PIT DT-3

This site is located below Boekha-Poktokha village on a mid-slope site at an altitude of 1425m msl facing southeast. It is a terraced wetland area which was under paddy in the previous season. Presently it is covered by rice stubbles and occasional cow dungs. Some boulders were seen on the riser terrace walls; indications of cattle trampling obviously due to winter grazing were also observed.

It is a very deep, moderately well drained soil derived mainly from quartzite. It was bit wet at the time of sampling, probably due to the recent rains. It is brown, dark grayish brown, and grayish brown as one moves down to ttowards the lower layers. Mottles are many, medium, distinct yellowish brown in the topsoil but gets to few fine medium distinct and rusty with depth. Consistency is slightly friable between 0-18 cm, hard and slightly firm down to 100cm. Structure is weak to very weak to 100 cm. Coarse materials are not seen in the topsoil but there are few fine mica flakes between 18-100cm. Common fine fibrous roots were seen to 50 cm.

Chemically, the soil is slightly acid with a pH of 5.7 but gets alkaline thereafter. EC is very low.Total C and N, OM as well as available N as ammonium and nitrate N are very low throughout. Available P is also very low while available K as well as exchangeable K are moderate throughout the profile. Exchangeable Ca and Mg are low in the topsoil but exchangeable Ca gets moderate after 50cm. Exchangeable Na is also low throughout.

Pit No. DT - 4 **Date of Sampling: 22/01/96**

Coordinates (GPS): 27°29.13 N & 89o38.28 E
Location: Across the valley (opposite to Boekha)
Altitude: 1440m msl
Parent Material: Quartzite
Landform: Mid slope site
Slope and Aspect: 7 %, SW
Landuse and Vegetation: Paddy field, no crops
Surface features: Few weeds, some animal excreta
Effective soil depth: 0 - 105 cm
Profile drainage: Moderately well drained
Moisture condition: Slightly moist to moist
Microtopography: Similar to DT-3

Horizon	AP	B1	B2
Depth (cm)	0 -23	23 - 60	60 - 105
Colour	greyish brown	grey	dark grey
Mottles	few, rusty, fine to medium distinct	few, fine, medium, faint, rusty	many, distinct fine and medium rusty
Consis-tency	firm, slightly moist,	very hard, slightly moist	hard, slightly moist (moist than Ap and B1)
Texture	fine sandy clay loam	sandy clay loam and few coarse and fine sandy clay loam	gritty sandy clay loam
Structure	weak, fine medium, blocky	weak, medium to coarse blocky	weak blocky to massive
Coarse Material	not seen	coarse sand and rare fine mica	common sand and rare mice
Roots	common, medium, fibrous (many in places)	very few, fine fibrous	not seen
Pores	few coarse, common fine tubular	many fine to medium tubular	common, fine and medium tubular

(Described by RA, DD & DKB)

Notes:

- *B2 - Some of the old rock structures can be seen - very weathered.*

Horizon		Ap	B1	B2
Depth (cm)		0-20	20-67	67-90
pH	H_2O	5.6	7.6	7.6
	KCl	4.4	5.9	5.9
EC mS/cm		0.02	0.01	0.02
Total C%		1.7	0.3	0.2
OM %		2.9	0.5	0.3
Total N%		0.13	0.04	0.04
C:N ratio		13	7.5	5.0
Avail. P mg/kg		2.0	2.0	1.0
Avail. K mg/kg		106.7	68.9	54.5
Avail N mg/kg as	NH_4	2.4	1.6	1.59
	NO_3	3.6	0.7	1.7
Exchangeable Cations meq/100g	Ca	3.9	6.1	5.4
	Mg	0.9	1.2	1.1
	K	0.51	0.45	0.36
	Na	0.09	0.09	0.07
	Sum	4.9	7.84	6.93
CEC meq/100g		9.4	8.5	6.8
Texture (Pipette Method)	C	24.3	24.6	22.2
	Si	36.4	29.8	29.1
	S	39.4	45.6	48.7

DATA SUMMARY FOR PIT DT-4

This fallow land used for summer rice is located across the valley opposite to Boekha in Thedtsho Block. The sampling site is located at an altitude of 1440 msl. It is a gently sloping mid-slope site with few weeds and animal excreta as surface cover. Parent materials consists of quartzite.

Physically, the profile is deep and the soil apparently is well drained but was a bit wet at the time of sampling, probably due to recent rains. The plough layer is brown in colour with dark to dark greyish brown at depth. Mottles are quite common, medium sized and prominient throughout the layer. The soil is friable to hard, also with depth. Structurally, this is weak, fine to medium blocky soil. The whole layer does not have significant coarse materials. Fine to medium fibrous roots are present as in many other agricultural soils. Common, fine, tubular pores were observed throughout the profile.

Chemically, the top soil is slightly acid with pH of 5.6 and the rest lower layers seemed to be moderately alkaline. EC, a measure of salt concentration is very low throughout the whole profile. OM level is moderate in the topsoil but very low thereafter. Total N is significantly low. The amount of available nitrogen as NH_4 and NO_3 are also significantly low. Available P is very low with moderate, low to very low K levels. Exchangeable cations like Ca, Mg, K and Na are moderately low throughout the whole profile.

PIT No. DT - 5 **Date of Sampling: 22/01/96**

Coordinates (GPS):	27°29.13 N 89°38.28 E
Location:	on a small spur above DT - 9
Altitude:	1420m msl
Parent Material:	Quartzite
Landform:	Small spur
Slope and Aspect:	7 %, SW
Landuse and Vegetation:	Paddy field, no crops
Surface features:	Few weeds, some animal excreta
Effective soil depth:	0 - 90 cm
Profile drainage:	Well drained
Moisture condition:	Slightly moist
Microtopography:	Similar to DT-3

Horizon	AP	B1	B2
Depth (cm)	0 -23	23 - 60	60 - 105
Colour	brown	dark grey	dark greyish brown
Mottles	common, medium, prominent brown	common, faint, fine and medium rusty	common to many distinct medium rusty
Consis-tency	very slightly moist, slightly friable	very slightly moist, very very hard	very hard slightly moist
Texture	fine sandy clay loam	gritty sandy clay loam	sandy clay loam +
Structure	weak, fine medium, blocky	weak, medium coarse blocky angular	weak, medium to coarse, subangular blocky
Coarse Material	not seen	few pieces of weathered quartz	occasional fine quartz pebbles and mica flakes
Roots	common, medium to fine fibrous	few, fine fibrous	not seen
Pores	common, fine medium tubular	common fine	common, fine tubular, common to many variable

(Described by RA, DD & DKB)

Notes:

Horizon		Ap	B1	B2
Depth (cm)		0-23	23-60	60-105
pH	H_2O	5.5	7.2	7.5
	KCl	4.1	5.5	5.7
EC mS/cm		0.02	0.01	0.01
Total C%		0.9	0.2	0.2
OM %		1.6	0.3	0.3
Total N%		0.09	0.04	0.04
C:N ratio		10.0	5.0	5.0
Avail. P mg/kg		5.0	4.0	3.0
Avail. K mg/kg		92.5	27.6	32.3
Avail N mg/kg as	NH_4	1.8	1.5	1.8
	NO_3	6.2	0.9	2.3
Exchangeable	Ca	2.8	9.9	5.6
Cations	Mg	0.5	1.0	1.1
meq/100g	K	.39	.20	.23
	Na	.07	.08	.14
	Sum	3.76	6.18	7.07
CEC meq/100g		6.8	7.5	10.1
Texture (	C	16.2	16.6	22.7
(Pipette	Si	32.5	31.9	28.1
Method)	S	51.2	51.5	39.2

DATA SUMMARY FOR PIT DT-5

This site at approximately 1420 msl is on a south west facing small spur above Matalungchhu village on the terraced land used for summer paddy cultivation. It is presently fallow and covered with few weeds, rice stubbles, occasional cattle dungs and cracks in the soil. The soil is well drained and slightly moist.

Physically, the soil is derived from quartzite, is quite deep, brown to dark gray and dark reddish brown, slightly friable topsoil but very hard subsoil, weak structured and occassional patches of weathered quartzite. Roots are present to 67 cm and the whole profile is porous.

Chemically, the profile is slightly acid in the topsoil and neutral at the subsoil. EC is significantly low. OM levels are low to very low, total N is very low and avaialble N as NH_4 as well as NO_3 are very low. Available P is very low and available K is low in the topsoil and very low at the subsoil. Exchangeable K is moderate to low. Exchangeable Ca is low in the topsoil and moderate thereafter. Exchangeable Mg is low throughout and exchangeable Na is very low throughout.

PIT No. DT - 6 **Date of Sampling: 22/01/96**

Coordinates (GPS):	27°29.13 N 89°38.28 E
Location:	Below Wangjokha
Altitude:	1270m msl
Parent Material:	Colluvium and alluvium
Landform:	Mid-terrace overlooking the Tsangchhu river "low terrace"
Slope and Aspect:	3%, SW
Landuse and Vegetation:	Terraced rice field, left fallow
Surface features:	Few weeds, some animal excreta
Effective soil depth:	0 - 90 cm
Profile drainage:	Moderately well drained
Moisture condition:	Slightly moist
Microtopography:	

Horizon	AP	B1		B2
Depth (cm)	0 -19	19 - 34	34 - 74	74 - 100
Colour	dusky red	greyish brown	pale brown	pale brown (very mixed)
Mottles	common, fine, distinct rusty	vert fine, distinct rusty	common, distinct, fine and medium	common, distinct, medium dark brown & black
Consis-tency	slightly firm, slightly moist	slightly firm, slightly moist	firm, slightly moist	friable, moist
Texture	fine sandy clay loam	silty clay	silty clay	coarse sandy loam
Structure	weak, fine medium, subangular blocky	very weak, fine medium subangular blocky	weak, medium coarse blocky	massive
Coarse Material	very fine mica	common fine mica	much fine mica, occasional small stones, both rounded and angular	10% stones, rounded and angular, much fine mica
Roots	common, fine fibrous	very few, fine fibrous	very few fine fibrous	not seen
Pores	common fine medium tubular	few, fine tubular	common fine and medium and tubular	common, fine and medium tubular

(Described by RA, DD & DKB)

Notes:

- *slightly layered soil and has both alluvial and colluvial origin.*
- *most of this soil is derived from colluvial micaceous quartzite*

Horizon		Ap	B1	B2	Bc
Depth (cm)		0-19	19-34	34-74	74-100
pH	H_2O	5.9	7.5	7.9	7.8
	KCl	4.8	6.0	6.1	6.2
EC mS/cm		0.03	0.02	0.02	0.01
Total C%		1.6	0.6	0.4	0.2
Organic Matter (%)		2.8	1.0	0.7	0.3
Total N%		0.14	0.07	0.05	0.02
C:N ratio		11.4	8.5	8.0	10.0
Avail. P mg/kg		10.0	6.0	2.0	2.0
Avail. K mg/kg		50.3	54.5	51.1	28.3
Avail N mg/kg as	NH_4	2.1	1.9	1.8	1.1
	NO_3	15.5	4.2	1.1	0.5
Exchangeable	Ca	7.0	8.2	8.2	4.3
Cation	Mg	1.2	1.6	1.6	0.8
meq/100g	K	0.32	0.45	0.45	0.20
	Na	0.17	0.15	0.13	0.07
	Sum	8.67	10.4	10.38	15.37
CEC meq/100g		13.0	11.8	12.8	6.1
Texture	C	22.2	24.9	26.7	9.7
(Pipette	Z	45.9	46.7	48.9	18.4
Method)	S	31.9	28.4	24.4	71.9

DATA SUMMARY FOR PIT DT-6

This site is below Wangjokha village on a terraced fallow land. A stream flows between the site and the village and a motarable road runs below the site. Except for this particular terrace which was not cultivated due to its use for paddy threshing, the rest of the surrounding terraces were used for wheat cultivation. It is on a mid-river terrace overlooking the Tsangchhu river, facing north-west and at an altitude of 1240 msl. Few rounded boulders were seen on the terraced bunds and the surface is covered with paddy straw and husks.

It is a slightly layered soil, mainly derived from colluvial micacious quartzite although several rounded boulders were also observed, indicating alluvial influence. It is dark brown in colour, firm in consistency, weak, and fine to medium subabgular blocky structure and quite porous. Roots were observed to 74 cm and the coarse material consisting of very fine mica were observed in the upper layers and thereafter rounded stones were seen.

Chemically, the topsoil is slightly acid and thereafter gets moderately alkaline. EC is very low. OM levels are moderate in the topsoil but becomes very low after the second layer. Total N is low to very low with depth, available N as NO_3 is moderate at the surface plough layer but becomes very low thereafter; available N as NH_4 is low throughout the profile. Available P is low to very low with depth; available K is also low in the upper three layers but becoms very low in the lowest horizon, while exchangeable K is moderate except for low level in the in the lowest horizon. Exchangeable Ca is moderate but low in the lowest horizon observed. Exchangeable Mg is low in the topsoil, becomes moderate and then decreases with depth. Exchangeable Na is low throughout.

PIT No. DT - 7 **Date of Sampling: 22/01/96**

Coordinates (GPS):	27°30.59 N & 89°53.63 E
Location:	Bajothango
Altitude:	1260 msl
Parent Material:	Mixed colluvium and alluvium
Landform:	"Low river terrace" overlooking the Tsangchhu river
Slope and Aspect:	5%, W
Landuse and Vegetation:	Terraced rice field, no crops presently
Surface features:	Minor undulations due to cattle tramplings, rice stubbles
Effective soil depth:	0 - 100 cm
Profile drainage:	Well drained
Moisture condition:	Slightly moist to moist, increasing with depth
Microtopography:	Moderate even flat terraces

Horizon	AP	B1	B2	B3
Depth (cm)	0 -20	20 - 60	60 - 85	85 - 100
Colour	weak red	weak red	dark greyish brown	dark brown
Mottles	few, fine, distinct rusty	common, fine to medium distinct orange brown	few patches, fine to medium rusty	rare faint medium
Consis-tency	hard, slightly moist	hard and dry	slightly firm, moist	slightly firm, moist
Texture	fine sandy clay loam	medium to coarse sandy clay loam	medium to coarse sandy clay loam	fine silty loam, very fine sand fraction
Structure	weak, fine to medium blocky	weak, medium to coarse angular	weak, medium subangular blocky	weak, firm and medium subangular blocky
Coarse Material	common fine mica	common fine mica	common fine mica, occasional coarse sand	not seen
Roots	common, fine to medium fibrous	very few, fine fibrous	not seen	not seen
Pores	very few tubular	common fine tubular	few fine tubular	few fine tubular and few, very fine mica

(Described by RA, DD & DKB)

Notes:

- *augured to 147 cm; at 110 very loamy fine sand*
- *deeper loam coarse sand with quartz particles at about 146 cm*

Horizon		Ap	B1	B2	Bc
Depth (cm)		0-20	20-60	60-85	85-100
pH	H_2O	5.0	8.1	8.3	8.2
	KCl	4.6	6.3	6.8	6.8
EC mS/cm		0.02	0.02	0.02	0.01
Total C%		1.3	0.2	0.3	0.3
Organic Matter (%)		2.2	0.3	0.5	
Total N%		0.1	0.03	0.03	0.03
C:N ratio		13.0	6.6	10.0	10.0
Avail. P mg/kg		1.0	1.0	1.0	2.0
Avail. K mg/kg		45.4	46.5	56.0	37..2
Avail N mg/kg as	NH_4	1.6	1.7	0.9	0.2
	NO_3	2.3	0.8	1.2	0.7
Exchangeable Cation meq/100g	Ca	4.4	5.7	6.3	5.2
	Mg	1.0	1.2	1.1	0.9
	K	0.25	0.33	0.31	0.29
	Na	0.04	0.07	0.13	0.13
	Sum	5.69	7.30	7.84	6.52
CEC meq/100g		5.3	7.8	7.4	6.2
Texture (Pipette Method)	C	26.0	23..7	17.8	13.0
	Si	32.7	28.6	33.4	59.9
	S	41.3	47.7	48.8	27.1

DATA SUMMARY FOR PIT DT-7

This site is a terraced fallow paddy field on a west facing valley in Bajo Thangu at an altitude of 1260m msl. It is covered by rice stubbles and there are some minor undulations due to cattle trampling. It is about 300m away from Tsangchhu river.

The soil is derived from a mixed alluvium and colluvium parent material, although dominated by alluvium materials. River borne rounded stones were seen in the topsoil. It is deep, well drained, slightly moist to moist which increases with depth, grayish brown to dark grayish brown, hard to slightly firm consistency, with weak, fine to medium subangular blocky structures. Common fine micas were observed throughout the profile with occassional coarse sand and quartz particles at 140 cm depth. Roots were observed to 60 cm and the whole profile is porous.

Chemically, the profile has neutral topsoil and gets moderately alkaline thereafter. EC is very low. OM levels are moderate in the topsoil but very low in the subsoil. Total N as well as available N as NH_4 and N as NO_3 are significantly low throughout the profile. Available P is low and available K is low to moderate with depth. Exchangeable Ca is low in the topsoil but moderate thereafter. Exchangeable Mg is low and exchangeable Na is very low throughout the profile observed.

PIT No. DT - 8 **Date of Sampling: 23/01/96**

Coordinates (GPS):	27°30.42 N & 89°53.78 E
Location:	Nearby Wangjokha (above to the northeast side)
Altitude:	1320m msl
Parent Material:	Some alluvial influence on mainly colluvial soi, silt mostly formed from micaceous quartzite
Landform:	"Upper river terrace" overlooking the Tsangchhu river
Slope and Aspect:	11%, W
Landuse and Vegetation:	Terraced rice field, no crops presently
Surface features:	Weeds, rice stubbles & few scattered straws
Effective soil depth:	0 - 100 cm
Profile drainage:	Moderately well drained
Moisture condition:	Slightly moist to moist
Microtopography:	Moderate even flat terraces

Horizon	AP	B1	B2
Depth (cm)	0 -20	20 - 56	56 - 100
Colour	very dark greyish brown	dark greyish brown	greyish brown
Mottles	common, faint, rusty, fine to medium	common, fine & medium distinct rusty	common to medium fine & medium distinct & orange brown
Consis-tency	friable, moist	slightly firm, moist	very hard, slightly moist
Texture	silty clay loam	sandy clay loam	sandy clay loam
Structure	weak, fine to medium subangular blocky	weak, subangular blocky, medium	weak, medium coarse subangular blocky
Coarse Material	common very fine mica, occasional quartz sand particles	lots of much very fine mica, rare pockets of quartz fragments	lots of fine mica, occasional pockets of quartz fragments
Roots	common, fine to medium fibrous	(fresh) fine to medium fibrous	not seen
Pores	common, fine tubular, few medium	common, fine medium tubular	common, fine tubular

(Described by RA, DD & DKB)

Notes:

- *augured to 173 cm - down at bottom beyond 150 cm, it gets coarse loamy sand, with lots of mica in it.*

Horizon		Ap	B1	B2
Depth (cm)		0-20	20-56	56-100
pH	H_2O	6.2	7.5	7.9
	KCl	4.7	5.6	6.1
EC mS/cm		0.02	0.01	0.01
Total C%		1.5	0.3	0.2
OM %		2.6	0.5	0.3
Total N%		0.13	0.03	0.03
C:N ratio		11.5	10.0	6.6
Avail. P mg/kg		7.0	5.0	3.0
Avail. K mg/kg		54.0	30.6	37.1
Avail N mg/kg as	NH_4	1.8	1.5	1.6
	NO_3	7.0	0.4	0.1
Exchangeable Cations meq/100g	Ca	5.9	5.9	5.6
	Mg	1.1	1.2	1.2
	K	0.27	0.21	0.24
	Na	0.15	0.04	0.05
	Sum	7.42	7.35	17.09
CEC meq/100g		10.0	7.9	9.0
Texture (Pipette Method)	C	24.8	24.3	20.9
	Si	39.7	30.1	27.3
	S	35.4	45.6	51.8

DATA SUMMARY FOR PIT DT-8

Sited near Wangjokha village on its north-east side in the fallow terraced paddy field, it is a mid-river terraceat an altitude of 1320m msl facing west. Some regrowth of weeds following recent rains, rice stubbles and very few straw covers the site with moderately uneven microtopography probably due to cattle trampling and harvest operations.

The soil is mainly derived from micacious quartzite with some alluvial influence on mainly colluvial soils. It is deep, moderately well drained, dark tovery dark greyish brown, mottled, friable to hard in consistency, medium textured and weak structured. Common, very fine mica and occassional quartz and sand particles were seen. Roots were observed to 56 cm and the whole profile is porous.

Chemically, the profile is slightly acid in the topsoil and moderately alkaline thereafter. EC, a measure of salt concentration is very low throughout the whole profile. OM levels are moderate in the topsoil but very low in the subsoil, total N as well as available N as NH_4 are very low throughout the profile while available N as NO_3 is low in the topsoil and very low thereafter. Both available P and K are low, decreasing further with depth. Exchangeable Ca is moderate throughout, exchangeable Mg is very low, exchangeable K is low while exchangeable N is low to very low.

PIT No. DT - 9 **Date of Sampling: 23/01/96**

Coordinates (GPS):	Not recorded (see map - Figure ..)
Location:	Between DT - 5 and DT - 8 on a tributary valley
Altitude:	1340m msl
Parent Material:	Colluvial soil, mainly from gniess and quartzite
Landform:	Tributary valley
Slope and Aspect:	8%, SW
Landuse and Vegetation:	Terraced paddy field, nothing cultivated presently
Surface features:	Rice stubbles, too much of cattle trampling
Effective soil depth:	0 - 90 cm
Profile drainage:	Well drained
Moisture condition:	Slightly moist to moist
Microtopography:	Moderate uneven flat terraces due to trampling by cattles

Horizon	AP	B1	B2
Depth (cm)	0 -22	22 - 54	54 - 90
Colour	dark greyish brown	greyish brown	greyish brown
Mottles	few, fine to faint, rusty	few, fine & medium faint rusty	few fine to medium distinct
Consis-tency	slightly firm, moist	hard, slightly moist	hard, moist
Texture	sandy clay loam	sandy clay loam	sandy clay loam
Structure	weak, fine to medium subangular blocky	weak, medium angular blocky	medium angular blocky
Coarse Material	few fine mica	common fine mica	more mica than above
Roots	common, fine to medium fibrous	few fine fibrous	not seen
Pores	common, fine tubular,	common, fine to medium tubular	common, fine to medium tubular

(Described by RA, DD & DKB)

Notes:

- *the terraces above this site are wet - could have been irrigated but there were no indication of cultivation.*

Horizon		Ap	BI	B2
Depth (cm)		0-22	22-54	54-90
pH	H_2O	6.7	8.6	8.6
	KCl	5.3	7.2	7.3
EC mS/cm		0.02	0.03	0.03
Total C%		1.0	0.2	0.3
OM %		1.7	0.3	0.5
Total N%		0.1	0.01	0.01
C:N ratio		10.0	20	30
Avail. P mg/kg		1.0	2.0	3.0
Avail. K mg/kg		54.1	55.7	64.1
Avail N mg/kg as	NH_4	1.7	2.2	2.1
	NO_3	3.4	0.8	2.3
Exchangeable	Ca	6.7	9.1	8.9
Cations	Mg	0.8	1.7	2.0
meq/100g	K	0.32	0.44	0.52
	Na	0.21	0.35	0.30
	Sum	8.09	11.59	11.72
CEC meq/100g		11.0	9.8	10.9
Texture (	C	28.5	30.2	31.1
(Pipette	Si	31.0	31.7	31.7
Method)	S	40.5	38.1	37.2

DATA SUMMARY FOR PIT DT-9

This site is on a tributary valley, facing southwest at an altitude of 1340m msl further upstream of Wangjokha village. It is a terraced paddy field, presently fallow and covered by rice stubbles, and too much of trampling by cattle. The slopes raising on its either sides are covered with artemisia and broadleaf shrubs. The terraces above the site are quite wet, probably irrigated but with no indications of cultivation.

Physically, the soil is derived from weathered gniess and quartzite colluvium; it is deep, dark grayish brown to grayish brown, mottled, slightly fiem to hard, medium textured, and weak to medium structures. Fine mica, increasing in amount with depth, were observed throughout. Roots were seen to 54 cm and the profile is porous.

Chemically, the pH is neutral but gets alkaline with depth. EC is very low. OM levels are low to very low. Total N as well as available N in the form of NH_4 and NO_3 and available P are significantly low. Available K is low while exchangeable K is moderate. Exchangeable Ca is moderate throughout, while exchangeable Mg and Na are low to moderate.

PIT No. DT - 10 **Date of Sampling: 23/01/96**

Coordinates (GPS):	Not recorded (see map -Figure ..)
Location:	Nearby Tsangchhu river within the new school construction site
Altitude:	1310m msl
Parent Material:	Alluvium, mixed alluvium
Landform:	"Lower river terrace"
Slope and Aspect:	<3%, SW
Landuse and Vegetation:	Terraced paddy field, apparently unused for some years
Surface features:	Various types of weeds, few rounded boulders seen around
Effective soil depth:	0 - 100 cm
Profile drainage:	Well drained
Moisture condition:	Slightly moist
Microtopography:	Moderate uneven mainly due to cattle trampling

Horizon	AP	B1	B2
Depth (cm)	0 -18	18 - 46	46 - 100
Colour	greyish brown	weak red	weak red
Mottles	few, fine faint, orange brown	patchy common, medium distinct	common, medium faint and distinct orange brown
Consis-tency	hard, slightly moist	very hard, slightly moist	hard, softer than B1, slightly moist
Texture	sandy loam	sandy loam	sandy loam
Structure	weak, fine to medium subangular blocky	weak to moderate medium, angular blocky	weak, medium subangular blocky
Coarse Material	not seen	occasional very fine mica	few fine mica
Roots	common, fine to medium fibrous	few fine fibrous	few, fine fibrous, roots down to 70 cm
Pores	common, fine tubular,	common, fine medium tubular	common to many, fine and medium tubular

(Described by RA, DD & DKB)

Notes:

- *augured to 160 cm - river sand from 140 cm; fine, medium pure sand from 140 cm*

Horizon		Ap	B1	B2
Depth (cm)		0-18	18-46	46-100
pH	H2O	6.7	8.5	8.1
	KCl	5.1	6.4	6.4
EC mS/cm		0.01	0.02	0.01
Total C%		1.0	0.2	0.2
Organic Matter (%)		1.7	0.3	0.3
Total N%		0.08	0.01	0.02
C:N ratio		12.5	20.0	10.0
Avail. P mg/kg		4.0	1.0	3.0
Avail. K mg/kg		38.0	22.2	33.4
Avail N mg/kg as	NH_4	1.7	1.0	3.3
	NO_3	2.3	0.1	0.1
Exchangeable Cations meq/100g	Ca	5.4	5.8	5.0
	Mg	1.3	1.3	1.1
	K	0.29	0.26	0.25
	Na	0.07	0.05	0.01
	Sum	7.06	7.41	6.36
CEC meq/100g		8.7	7.7	8.1
Texture (Pipette Method)	C	23.9	21.3	15.9
	Si	35.2	32.7	37.8
	S	41.0	46.0	46.3

DATA SUMMARY FOR PIT DT-10

This site is nearby the new school construction area in Bajo village facing southwest at an altitude of 1310 msl. It constitutes the lower river terrace and is quite close to the Tsangchhu river. It was previously terraced paddy field but has now been abandoned for some years, probably because the area is included as school premise. The ground is covered by various types of weeds and grasses that is usually associated with abandoned land.

Physically, the soil is very deep, well drained and derived mainly from mixed alluvium . The soil is grayish brown with hard to very hard consistency to 46 cm and firm thereafter. Structure is weak to medium subangular blocky. No coarse materials were seen in the topsoil except for occassional few micas in the lower layers. Roots were observed to 70 cm and the whole profile is porous. The profile was augured from the base of the pit to a depth of 140 cm and the augured profile comprised of fine medium pure sand.

The topsoil has a neutral pH and moderately alkaline below. EC is very low. OM levels are low in the topsoil and very low thereafter. Total N as well as available N as NH_4 and NO^3 are very low. Available K is very low throughout while exchange-able K is low. Available P is also very low throughout. Exchangeable Ca is moderate throughout while exchangeable Mg is low throughout. Exchangeable Na is very low.

Horizon		Ap	B1	B2
Depth (cm)		0-20	20-78	78-97
pH	H2O	6.3	7.6	8.0
	KCl	4.8	6.1	6.4
EC mS/cm		0.02	0.02	0.01
Total C%		0.8	0.2	0.3
Organic Matter (%)		1.4	0.3	0.5
Total N%		0.06	0.02	0.02
C:N ratio		13.3	10.0	15.0
Avail. P mg/kg		1.0	1.0	6.0
Avail. K mg/kg		196.8	26.7	23.5
Avail N mg/kg as	NH_4	2.1	1.0	0.1
	NO_3	55.0	0.4	0.1
Exchangeable Cations meq/100g	Ca	3.6	4.5	5.1
	Mg	0.8	1.0	0.9
	K	0.83	0.21	0.20
	Na	0.05	0.02	0.05
	Sum	5.28	6.43	6.25
CEC meq/100g		6.7	6.5	6.1
Texture (Pipette Method)	C	20.3	26.9	14.6
	Si	34.7	29.0	26.7
	S	45.0	44.1	58.7

DATA SUMMARY FOR PIT DT-11

This site, facing west is in Bajokha village overlooking Wangjokha village and northeast behind Bajo Lakhang (monastary) at an altitude of 1360m msl. It is a terraced fallow paddy field. Nearby, there is a hut of a Sharchokpa (Easterners) couple, with few young orange, guava, banana, cyprus and peach trees. The surface is covered with rice stubbles, few cow dung, some husks and straw appearing dark gray mainly due to the decomposition of weedy leaves. A lot of cracks characterize the surface microtopography.

Physically, the soil is very deep, moderately well drained, and derived from quartzite. The topsoil (0-20cm) is dark grayish brown, becomes dark yellowish brown at 20-78cm layer and very dark grayish brown after 78cm. It is mottled, slightly firm to friable with weak crumb and subangular blocky structures. The topsoil is silty clay loam, becomes fine sandy clay and clayey loam with much sand at the lowest layer observed. Occassional quartzite mixed with mica were observed. Roots were seen to 78cm and the profile is porous. From the base of the pit, the profile was augured to 147 cm - no hard rock was encountered but becomes very sandy after 97 cm.

Chemically, the pH is neutral till 78 cm and becomes alkaline thereafter. EC is very low throughout the profile. OM level is low in the top soil and very low in the sub soil. Total N is also very low. Available P is very low increasing slightly at the lowest layer observed. Availalble K is moderate in the top soil but very low in the sub soil. Available N as NH_4 is very low throughout the profile but available N as NO_3 is very high (55mg/kg) is the top soil and very low thereafter. Exchangeable Ca is low in the top soil and moderate between 20-97cm. Exchangeable Mg is low throughout. Exchangeable K is high in the top soil but

PIT No. DT - 11 **Date of Sampling: 24/01/96**

Coordinates (GPS): 27°29.13 N & 89°38.28 E
Location: Bajokha, overlooking Wangjokha village and behind the bajo monastry
Altitude: 1360 msl
Parent Material: Quartzite
Landform: mid slope site
Slope and Aspect: 12%, W
Landuse and Vegetation: Terraced paddy field, not cultivated, some guava, banana, peach, and cyprus plants nearby
Surface features: Rice stubbles, few cow dung, some husks and straw nearby
Effective soil depth: 0 - 97 cm
Profile drainage: Moderately well drained
Moisture condition: Moist due to recent rains
Microtopography: Moderate uneven due to cattle trampling and harvest operations, lots of cracks

Horizon	AP	B1	B2
Depth (cm)	0 - 20	20 - 78	78 - 97
Colour	dark greyish brown	dark yellowish brown	dark brown
Mottles	common, faint to prominant rusty patches	few localized, prominant, common faint reddish brown	faint, common rusty patches, some sign of carbon patches
Consis-tency	slightly firm, slightly moist and compact	quite firm, slightly moist	friable, fairly moist
Texture	silty clay loam	fine sandy clay	sandy clayey loam, highly micaceous
Structure	weak, crumb	weak crumb, subangular blocky	fine crumb, subangular blocky
Coarse Material	occasional quartz	occasional quartz mixed with mica	not seen but somewhat micaceous
Roots	few, medium, common fine fibrous	few, fine fibrous	not seen
Pores	common, fine tubular, few medium interstitial	few medium, common fine	common, medium, few fine

(Described by RA, DD & DKB)

Notes:

- *augured to 147 cm; at 110 very loamy fine sand*
- *deeper loam coarse sand with quartz particles at about 146 cm*

PIT No. DT - 12   Date of Sampling: 24/01/96

Coordinates (GPS):	27°29.66 N & 89°54.25 E
Location:	Bajo (just below the sloping land)
Altitude:	1320m msl
Parent Material:	Mica schist
Landform:	Moderately, gently, highly terraced
Slope and Aspect:	4%, SW
Landuse and Vegetation:	Terraced rice field, fallow presently
Surface features:	Rice stubbles & lots of fresh weeds sprouting
Effective soil depth:	0 - 96 cm
Profile drainage:	Fairly well drained
Moisture condition:	Dry top soil
Microtopography:	Marks of tractor wheel and cattle trampling, lots of cracks

Horizon	AP	B1	B2
Depth (cm)	0 -22	22 - 65	65 - 96
Colour	grey	dark grey	dark brown
Mottles	few prominant, common faint reddish	common, faint rusty	very faint, common, bright rusty patches
Consis-tency	slightly firm, slightly moist	compact, slightly moist	slightly friable, moist
Texture	silty clay loam	sandy clay loam	sandy loam
Structure	weak subangular blocky	compact, angular blocky,	Loose, weak
Coarse Material	occasional quartz	not seen	not seen
Roots	few, medium, common fine fibrous	very few	fine fibrous
Pores	common. medium, many fine tubular	few, medium to common fine tubular	common, fine tubular

(Described by RA, DD & DKB)

Notes:

- *fertilizers like urea (47 % nitrogen) and Suphala (15:15:5: NPK) applied; field ploughed by power tiller*

Horizon		Ap	B1	B2
Depth (cm)		0-22	22-65	65-96
pH	H_2O	5.3	7.8	7.8
	KCl	4.2	6.0	6.4
EC mS/cm		0.03	0.01	0.01
Total C%		1.3	0.2	0.1
Organic Matter (%)		2.2	0.3	0.2
Total N%		0.10	0.03	0.02
C:N ratio		13.0	6.6	5.0
Avail. P mg/kg		3.0	4.0	10.0
Avail. K mg/kg		46.7	27.6	39.2
Avail N mg/kg as	NH_4	3.2	0.6	0.7
	NO_3	2.7	0.4	0.7
Exchangeable Cations meq/100	Ca	0.6	5.4	4.3
	Mg	0.4	1.3	1.0
	K	0.28	0.25	0.24
	Na	0.03	0.06	0.03
	Sum	1.31	7.01	5.57
CEC meq/100g		8.9	7.0	5.1
Texture (Pipette Method)	C	25.8	14.5	15.4
	Si	41.4	59.0	25.0
	S	32.7	26.6	59.7

DATA SUMMARY FOR PIT DT-12

This site is in Bajo village facing south west at 1320 msl below the steeply sloping area from where the flat land begins. It is a terraced paddy field, fallow presently and covered by rice stubbles and lots of fresh weeds. The microtopography looks disturbed due to the use of tractor and cattle trampling because of which there are lots of cracks.

The soil here is derived from micaschist, fairly well drained, deep gray, dark gray to dark brown in colour, somewhat mottled, and slightly firm to slightly friable. The texture in the top layer (0-22) is mostly silty clay loam, in the second layer (22-65) sandy clay loam with much sand and sandy loam in the bottom layer observed. Structure is weak subangular blocky from 0-22 cm, compact angular blocky from 22-65 and loose weak throughout the profile. Occasional quartz were seen between 0-22 cm and no coarse materials thereafter. Roots were observed to 65 cm and the whole profile is porous.

Chemically, the profile is slightly acid in the topsoil and moderate alkaline thereafter. EC is very low. OM is moderate in the topsoil and very low thereafter. Total N as well as N as NH_4 & NO_3 is very low throughout. Available P is very low to 65 cm but low from 65-96 cm. Available K is low in the topsoil but very low 0-22 cm to moderate from 22-65 and low from 65-96 cm. Exchangeable Mg is very low in the topsoil and low thereafter. Exchangeable Na is very low throughout .

PIT No. DT - 13 **Date of Sampling: 24/01/96**

Coordinates (GPS):	27°29.13 N & 89°38.28 E
Location:	Above the Thimphu-Wangdue road below Rinchhengang village
Altitude:	1260m msl
Parent Material:	Alluvium
Landform:	Middle river terrace
Slope and Aspect:	7%, NE
Landuse and Vegetation:	Terraced rice field, fallow presently, ploughing started
Surface features:	Many boulders, lots of rice stubbles, activity going on for first paddy crop
Effective soil depth:	0 - 85 cm
Profile drainage:	Poorly drained
Moisture condition:	Moist due to irrigation
Microtopography:	Half even, half uneven due to ploughing activity, cattle trampling and lots of cracks developed in the soil

Horizon	AP	B1	B2
Depth (cm)	0 -18	82 - 45	45 - 85
Colour	dark grey	dark brown	very dark greyish brown
Mottles	common faint rusty,	patchy, prominant, common faint rusty	not seen
Consis-tency	slightly friable, lumpy when moist	friable, moist	quite friable,
Texture	silty clay loam with lots of fine sand	loamy, 80 % sand	sandy
Structure	weak	fine crumb	weak
Coarse Material	fine to medium quartz particles	coarse to medium quartz	boulders of quartz
Roots	common fine fibrous	Not seen	not seen
Pores	common, medium, tubular	few, medium interstitial, common fine tubular	abundant, fine tubular

(Described by RA, DD & DKB)

Notes:

- *only two sanples taken*
- *very stony after 85 cm, not possible to augur, pit depth limited by contact of stone layer*

Horizon		Ap	BI
Depth (cm)		0-18	18-45
pH	H_2O	5.6	7.2
	KCl	4.0	6.0
EC mS/cm		0.03	0.02
Total C%		1.6	0.4
Organic Matter (%)		2.8	0.7
Total N%		0.13	0.04
C:N ratio		12.3	10.0
Avail. P mg/kg		3.0	6.0
Avail. K mg/kg		94.6	56.9
Avail N mg/kg as	NH_4	6.2	2.1
	NO_3	4.2	3.1
Exchangeable Cations meq/100g	Ca	4.7	5.4
	Mg	1.3	1.5
	K	0.50	0.31
	Na	0.30	0.23
	Sum	6.80	7.44
CEC meq/100g		11.7	9.6
Texture (Pipette Method)	C	28.3	12.7
	Z	29.5	15.9
	S	32.2	71.4

DATA SUMMARY FOR PIT DT-13

This site at an altitude of 1250 msl facing north east is about 130 metres above the Thimphu - Trongsa highway, between the seed distribution centre and Rinchengang village. On its right site (if you face the river Tsangchhu) is a dry drainage line and above its left are two chortens (stupas). It is a terraced paddy field quite damp due to irrigation and ploughing just began for the second paddy crop. Ploughing has not yet touched the pit site. Boulders constitute terrace bunds and there are a lots of rice stubbles in distinct rows.

Physically, the profile is quite deep, dark gray from 0-18 cm, dark brown from 8-45 and very dark gray brown from 45-85 cm. Mottles were observed from 45 cm, it is lumpy and friable, silty clay loam from 0-18 cm and quite sandy below, weak structured and fine to midium quartz particles to 45 cm and boulders thereafter. Roots were seen to 18 cm and the profile is porous. The depth of the pit was limited by stone layer. From the base of the pit it was augured to 85 cm - very sandy.

The soil is acid from 0-18 cm and neutral from 18-45 cm. EC is very low. OM level is moderate in the topsoil and very low in the subsoil. Total N as well as Na as NH_4 is low to very low, while available N as NO_3 is very low throughout. Available P is very low in the topsoil and low in the subsoil.

Available K is low throughout while exchangeable K is moderate throughout. Exchangeable Ca is low in the topsoil and moderate in the subsoil. Exchangeable Mg is low in the topsoil and moderate in the subsoil.

PIT No. DT - 14 **Date of Sampling: 25/01/96**

Coordinates (GPS):	27°29.13 N & 89°38.28 E (need to refer map, not reliable - GPS problem)
Location:	Top of Umtekha village above the road
Altitude:	1670m msl
Parent Material:	Gniess
Landform:	Highly degraded land; huge gully near the pit; steep
Slope and Aspect:	30%, E
Landuse and Vegetation:	Open forest scrub
Surface features:	Highly exposed, few patches of artemisia, and thorny berry bushes
Effective soil depth:	0 - 50 cm (augured to 80 cm)
Profile drainage:	Well drained
Moisture condition:	Dry
Microtopography:	Very uneven, highly hoofed, lots of rill erosion features

Horizon	AP	B1	B2
Depth (cm)	0 - 7	7 - 28	28 - 50
Colour	dark reddish brown	reddish grey	yellowish red
Mottles	insignificant (quite micaceous)	not seen	very faint blocky dark brown
Consis-tency	slightly friable, slightly moist	slightly friable, slightly moist	slightly firm, slightly moist
Texture	sandy loam	sandy clay loam	sandy loam
Structure	weak	fine crumb, weak subangular blocky	moderately weak
Coarse Material	fine quartz grains	Not seen	not seen
Roots	abundant fine fibrous, few woody	common fine fibrous	common fine fibrous
Pores	few, medium, interstitial	common, fine tubular,	common, fine tubular

(Described by RA, DD & DKB)

Notes:

- *on the outer surface soil looks quite red, but it was not a red below*

Horizon		Ap	B1	B2
Depth (cm)		0-7	7-28	28-50
pH	H_2O	6.3	6.2	6.5
	KCl	5.3	5.1	5.0
EC mS/cm		0.02	0.02	0.01
Total C%		1.4	1.6	0.7
Organic Matter (%)		2.4	1.8	1.2
Total N%		0.13	0.10	0.01
C:N ratio		10.7	16.0	70.0
Avail. P mg/kg		1.0	1.0	1.0
Avail. K mg/kg		122.2	67.0	118.7
Avail N mg/kg as	NH_4	6.0	4.8	2.0
	NO_3	0.7	0.1	0.1
Exchangeable	Ca	3.6	4.3	2.0
Cations	Mg	1.2	1.3	1.4
meq/100g	K	0.64	0.33	0.69
	Na	0.16	0.15	0.24
	Sum	5.60	6.08	4.33
CEC meq/100g		7.5	11.9	9.7
Texture	C	12.9	21.9	3.2
(Pipette	Si	18.9	19.8	48.4
Method)	S	68.2	58.2	48.5

DATA SUMMARY FOR PIT DT-14

This is an open forest scrubby area located on a ridge at the top of Umtekha vilage at an altitude of 1670 msl. It is a steep sloping, highly degraded land forming huge and deep gullies. Surface area is highly exposed except for patchy occurances of artemisia and thorny berry bushes. There was a clear sign of over-grazing with highly hoofed ground surface.

Physically, it is well drained, deep and dry soil. Parent materials consists of gneiss. Soil colour varies from very dark reddish brown to yellowish red. The mottles are quite faint and insignificant. The soil is friable to firm with depth. Structurally, this is a weak, subangular blocky soil. The whole layer does not have significant coarse materials except fot some quartz grains seen in the first layer. Common, fine fibrous to few woody roots are present. Few medium interstitial pores were observed.

Chemically, this is a slightly acid soil with pH ranging from 6.2 to 6.5. EC, a measure of salt concentration is low throughout the whole profile. The OM level is moderate in the topsoil but low in the subsoil. The amount of available nitrogen as NH_4 and NO_3 are significantly low. Available P is very low throughout the profile, while available K is moderate from 0-7cm and from 28-50cm but low between 7-28cm. Exchangeable cations like Ca, Mg, and Na are low except for moderate K levels throughout the whole profile.

PIT No. DT - 15 **Date of Sampling: 24/01/96**

Coordinates (GPS): 27°30.53 N & 89°52.15 E
Location: In the forest above ex-district administrator's house overlooking Lobeysa locality
Altitude: 1548m msl (GPS record)
Parent Material: Gniess colluvium
Landform: Steep mountain slope
Slope and Aspect: 50%, NE
Landuse and Vegetation: Thick chirpine area with lots of regeneration, some artemisia, and other broadleaf shrubs
Surface features: Dominated by chirpine trees, dead twigs and stumps, and thick layer of pine leaves
Effective soil depth: 0 - 150 cm
Profile drainage: Fairly well drained
Moisture condition: Dry
Microtopography: Indications of pit dug before, lots of trials left by cattle grazing

Horizon	AP	B1	B2
Depth (cm)	0 - 7	7 - 45	45 - 77
Colour	very dark greyish brown	dark reddish brown	brown
Mottles	occasional carbon patches	not seen, micaceous	very faint, light brown patches
Consis-tency	slightly friable, moist	friable	slightly firm
Texture	sandy clay loam	sandy clay loam	sandy loam (71% sand)
Structure	weak	slightly crumb, subangular blocky	loose, subangular blocky
Coarse Material	few medium gniess grains, full of micas	occasional quartz and gniess grains, common mica flakes	band of weathering gniess, more towards the lower horizon
Roots	few, woody, common, medium, few fine fibrous	common, woody, few fine fibrous	occasional woody
Pores	few, coarse microscopic	common, fine tubular	insignificant vascular pores

(Described by RA, DD & DKB)

Notes:

- *quite sandy with increasing depth - tested by auguring down to 150 cm where it becomes quite rocky, mainly gniess with quartzite intrusion*

Horizon		Ap	B1	B2
Depth (cm)		0-7	7-45	45-77
pH	H_2O	6.0	6.1	6.4
	KCl	4.9	4.7	4.5
EC mS/cm		0.01	0.01	0.01
Total C%		1.7	0.2	0.1
Organic Matter (%)		2.9	0.3	0.2
Total N%		0.01	0.01	0.01
C:N ratio			20.0	10.0
Avail. P mg/kg		1.0	1.0	6.0
Avail. K mg/kg		103.2	24.0	24.6
Avail N mg/kg as	NH_4	6.3	1.8	0.6
	NO_3	0.1	0.1	0.1
Exchangeable Cations meq/100g	Ca	3.8	1.8	1.7
	Mg	1.5	1.0	0.9
	K	0.43	0.16	0.14
	Na	0.07	0.07	0.09
	Sum	5.8	3.03	2.83
CEC meq/100g		11.5	8.5	6.7
Texture (Pipette Method)	C	20.9	19.9	9.0
	Z	22.5	22.7	19.3
	S	56.6	57.3	71.6

DATA SUMMARY FOR PIT DB-1 (15)

This site is on a steeply sloping north east facing young chirpine forest overlooking Lobeysa locality at an altitude of 1548 msl. The forest is fairly dense with approximately 10-15 metres tall chirpine trees and lots of regeneration. Some artemisia and other coniferous as well as broad leaf shrubs were also seen. Surface feature are dominated by chirpine trees, lot of stumps (not very dry), fallen and dead twigs and thick pine leaves. No stones were seen. There were indications of pit dug before nearby and a lots of cattle tracks.

Physically, the soil is very deep, dark brown to dark reddish brown, somewhat mottled friable, and weak to slightly crumb subangular blocky. Coarse material comprising gneiss, micas and quartz were observed. Roots were seen to 77 cm and the whole profile is porous.

Chemically, the profile is slightly acid with very low EC. OM level is moderate in the topsoil but very low in the subsoil. Total N as well as Na in the form of NO_3 is very low throughout while N as NH_4 is bit higher in the topsoil and low thereafter. Available P is very low to 45 cm and bit higher below. Available K is moderate in the topsoil but very low thereafter and exchangeable K is moderate in the topsoil and low thereafter. Exchangeable Ca is low in the topsoil and very low thereafter. Exchangeable Mg is moderate in the topsoil and low thereafter. Exchangeable Na is very low throughout.

PIT No. DT - 16 **Date of Sampling: 24/01/96**

Coordinates (GPS):	27°29.13 N & 89°38.28 E
Location:	Above Tsebegu village
Altitude:	1690m msl
Parent Material:	Colluvium dominated by gniess
Landform:	Terraced spur
Slope and Aspect:	6%, NE
Landuse and Vegetation:	Terraced paddy field, not cultivated
Surface features:	Rice stubbles, weeds sprouting, burnt straw, one boulder prominant in the field, some boulders as terrace bunds
Effective soil depth:	0 - 100 cm
Profile drainage:	Moderately well drained
Moisture condition:	Slightly moist
Microtopography:	Very uneven due to cattle trampling, at one place made uneven by a prominant boulder

Horizon	AP	B1	B2
Depth (cm)	0 - 10	10- 42	42 - 80
Colour	dark grey	very dark grey	dark reddish brown
Mottles	common, faint light brown patches	rare faint reddish brown patches	pockets of distinct green coatings
Consis-tency	slightly firm, moist	firm, moist	slightly friable, moist
Texture	silty clay loam	gritty sandy + clayey loam	sandy loam
Structure	slightly weak, subangular blocky	crumb, angular blocky	loose and non-coherent
Coarse Material	occasional quartz	occasional quartz and gniess	boulders of gniess
Roots	few, medium, common, fine fibrous	common, fine fibrous	few, fine fibrous
Pores	few fine tubular	few medium, fine tubular	common, fine and medium tubular

(Described by RA, DD & DKB)

Notes:

- *pit depth limited by stones; with increasing depth, found highly weathered gniess; no fertilizers applied, only fym, production seem to be good with fym also*

PIT No. DT - 17 **Date of Sampling: 24/01/96**

Coordinates (GPS):	$27_o29.13$ N & $89_o38.28$ E
Location:	Tongmetsekha village (below Tseptokha & Tsepjikha)
Altitude:	1480m msl
Parent Material:	Quartzitic gniess and colluvium
Landform:	Highly terraced, mid slope side facing Gayegang monastry
Slope and Aspect:	5%, NE
Landuse and Vegetation:	Cultivated wheat about a month ago
Surface features:	Lots of bouldrs seen surrounding the terraces, clods due to ploughing
Effective soil depth:	0 - 148 cm
Profile drainage:	Moderately well drained
Moisture condition:	Slightly moist
Microtopography:	Uneven due to ploughing for whaet cultivation

Horizon	AP	B1		B2
Depth (cm)	0 - 20	20 - 45	45 - 90	45 - 77
Colour	dark grey	dark grey	grey	very dark grey brown
Mottles	rare occasional patchy, light brown patches	common faint, few prominant	common faint rusty	few carbon patches
Consis-tency	slightly friable, moist	compact when moist	slightly firm	lumpy
Texture	silty clay loam	gritty sandy clay+	Sand + loam	fine sandy clay loam
Structure	weak coherent	subangular blocky	moderately fine subangular blocky	coherent, weak
Coarse Material	occasional quartz	occasional quartz	occasional quartz	not seen
Roots	common, fine fibrous	common, fine fibrous	few fine fibrous	not seen
Pores	few, medium tubular	few, medium to common, fine tubular	common fine tubular	few medium to common fine tubular

(Described by RA, DD & DKB)

Notes:

- *FYM was applied; usually the farmer used to apply fertilizers also but this year she did not.*

Horizon		Ap	B1	B2	B3
Depth (cm)		0-20	20-45	45-90	90-95
pH	H_2O	5.9	6.7	7.1	7.2
	KCl	5.0	5.4	5.6	5.7
EC mS/cm		0.04	0.02	0.01	0.01
Total C%		2.2	0.9	0.4	0.5
Organic Matter (%)		3.8	1.6	0.7	0.9
Total N%		0.15	0.15	0.05	0.02
C:N ratio		14.6	6.0	8.0	25.0
Avail. P mg/kg		2.0	1.0	2.0	1.0
Avail. K mg/kg		92.1	77.2	68.5	79.1
Avail N mg/kg as	NH_4	5.5	4.5	2.6	2.5
	NO_3	7.7	3.9	0.7	0.2
Exchangeable -	Ca	7.9	8.5	7.2	8.7
Cations	Mg	2.3	2.6	2.1	2.4
meq/100g	K	0.88	0.54	0.46	0.56
	Na	0.60	0.38	0.31	0.36
	Sum	11.68	11.96	10.07	12.02
CEC meq/100g		16.2	16.1	12.1	16.5
Texture	C	21.7	23.5	21.2	19.7
(Pipette	Si	24.1	22.3	19.3	21.0
Method)	S	54.2	54.2	59.5	59.3

DATA SUMMARY FOR PIT DB-3 (17)

Facing north east at an altitude of 1620 msl in Tongme Tsekha below Tseptokha and Tsepjikha village, this site is on a terraced field presently cultivated to wheat. It is a highly terraced, mid slope site facing Gayegang Lhakhang. A lot of boulders were seen surrounding the terraces with lots of clods probably due to ploughing activity.

The soil is very deep, moderately well drained with dark gray, gray and very dark gray colour with depth. It is somewhat mottled, slightly friable but compact when moist and lumpy in the lowest layer observed. The topsoil textured is silty clay loam, gets gritty sandy clay with much clay from 20-45 cm, sand and loam between 45-90 cm and sandy clay loam between 90-148 cm. It has weak subangular block structures. Roots were observed to 90cm and the whole profile is porous. Coarse materials consisting of occasional quartz were seen to 90 cm.

Chemically, the profile is slightly acid on the surface (0-20 cm), and neutral thereafter with very low EC. OM level is moderate between 0-20 cm and continously decreases further down. Total N is low between 0-45 cm also decreasing with depth while available N as NH_4 and NO_3 is low in the topsoil and very low thereafter. Available P is very low while available K is low throughout the profile. Exchangeable Ca and Mg is moderate all over while exchangeable K is high in the topsoil and moderate thereafter. Exchangeable Na is moderate throughout the profile.

PIT No. DT - 18 **Date of Sampling: 24/01/96**

Coordinates (GPS): 27°29.13 N & 89°38.28 E (not reliable, see map)
Location: On a depressed mudflow area approximately 300 m above the river between Chhimi Lakhang and Eusakha village
Altitude: 1360m msl
Parent Material: Colluvium
Landform: Highly terraced, a bit lower terrace than the general valley
Slope and Aspect: 5%, NE
Landuse and Vegetation: Terraced rice field, not cultivated
Surface features: Normal uncultivated terrace field, lots of colluvial boulders seen at the terrace ridges.
Effective soil depth: 0 - 95 cm
Profile drainage: Fairly well drained
Moisture condition: Dry, moist due to recent rains
Microtopography: Cracks and cattle trampling

Horizon	AP	B1	B2	B3
Depth (cm)	0 - 14	14 - 48	48 - 70	70 - 95
Colour	dark greyish brown	dark brown	brown	very dark grey brown
Mottles	common, faint rusty patches	occasional rusty faint patches	few faint grey patches	not seen
Consis-tency	slightly friable, moist	firm, moist	slightly friable, moist	friable
Texture	silty clay loam	fine sandy clay loam	silty loam (lots of sand)	sandy clay loam
Structure	moderately weak, subangular blocky	moderately weak angular blocky	weak subangular blocky	crumb weak
Coarse Material	occasional quartz	occasional quartz	micaschist	quartz
Roots	few medium, common, fine fibrous	few, fine fibrous	not seen	not seen
Pores	few, medium and fine tubular	common, medium and fine tubular	many fine tubular	common fine tubular fine

(Described by RA, DD & DKB)

Notes:

- *Soil gets wetter with depth. Augured down to 135 cm. No mottles and no change in colour, soil generally as B3.*

Horizon		Ap	B1	B2	B3
Depth (cm)		0-14	14-48	48-90	90-95
pH	H_2O	5.4	6.7	7.1	7.1
	KCl	4.0	4.9	5.3	5.4
EC mS/cm		0.01	0.01	0.01	0.01
Total C%		1.2	0.4	0.3	0.2
Organic Matter (%)		2.1	0.7	0.5	0.3
Total N%		0.06	0.06	0.03	0.02
C:N ratio		20.0	6.6	10.0	10.0
Avail. P mg/kg		1.0	1.0	3.0	23.0
Avail. K mg/kg		52.4	42.4	38.0	39.8
Avail N mg/kg as	NH_4	1.5	0.8	0.8	0.4
	NO_3	6.1	0.9	0.3	0.2
Exchange able	Ca	7.9	3.5	4.7	3.8
Cations	Mg	1.1	1.6	1.3	1.3
meq/100g	K	0.33	0.34	0.28	0.31
	Na	0.22	0.22	0.14	0.11
	Sum	9.55	15.66	6.42	5.52
CEC meq/100g		8.6	10.6	9.3	9.3
Texture	C	36.5	23.3		
(Pipette	Sl	25.6	31.2		
Method)	S	37.9	45.5		

DATA SUMMARY FOR PIT DB-4 (18)

The site is about 300 metres above river Tsangchhu on the Lobeysa side at an altitude of 1360 msl facing north east. It is a terraced paddy field, fallow presently, in a depressed mudflow region. A lot of colluvial boulders were seen on the terraced ridges.

Physically, the soil is deep, fairly weel drained, with dark grayish brown at 0-14 cm, dark brown between 14-90 cm and very dark grayish brown colour at 90-95 cm. It is mottled, slightly friable, firm to friable in consistency, and has moderately weak subangular blocky to weak angular blocky and crumb sturctures. The op soil is texture is silty clay loam, and at 14-48 cm fine sandy clay loam, becomes silty loam with much sand at 48-70 cm and finally sandy clay loam at 90-95 cm. Occassional quartz and micaschist were seen. Roots were observed to 48 cm and the profile is porous. From the base of the pit, the soil was augured to 135 cm - no change of colour, no mottles observed, and soil generally as B3.

Chemically, the profile has slightly acid topsoil and neutral subsoil. EC is very low. The top soil has moderate levels of OM but in the subsoil it is significantly low. Total N as well as N as NH4 and NO3 is very low throughout the profile. Available P is very low to 90 cm and moderate below. Available K is low between 0-48 cm but very low thereafter. Exchangeable cations like Ca is moderate in the topsoil but low thereafter; Mg is low between 0-14 cm, becomes moderate at 14-48 cm and low again thereafter; K is moderate between 0-48 cm, becomes low at 40-90 cm and moderate again; and Na is low throughout.

PIT No. DT - 19 **Date of Sampling: 24/01/96**

Coordinates (GPS):	27°30.70 N & 89°52.85 E
Location:	Between Eusakha village (above a house) and DT- 18 site
Altitude:	1390m msl
Parent Material:	Colluvium
Landform:	Mid slope side; highly terraced, even slope generally, raised ground surface
Slope and Aspect:	7%, E
Landuse and Vegetation:	Fallow terraced paddy field
Surface features:	Burnt straw and rice stubbles
Effective soil depth:	0 - 76 cm
Profile drainage:	Poorly drained
Moisture condition:	Moist
Microtopography:	Cattle trampling, cracks developed due to dryness

Horizon	AP	B1	B2
Depth (cm)	0 - 13	13 - 50	50 - 76
Colour	dark greyish brown	dark grey brown	very dark grey
Mottles	common, prominant few faint brown patches	quite faint light brwon patches	few to common faint yellowish patches
Consis-tency	slightly firm, dry	firm, moist	firm, moist
Texture	heavy clay + silty clay	silty clay loam + clay	fine sandy clay + loam
Structure	moderately weak,	sub angular blocky	subangular blocky
Coarse Material	rare quartz	not seen	not seen
Roots	many fine fibrous	few fine fibrous	not seen
Pores	few, medium few fine tubular	few fine tubular	occasional medium, common fine tubular

(Described by RA, DD & DKB)

Notes:

- *Quite heavy clay - cemented type clay; less biological activity; very deep soil*

Horizon		Ap	B1	B2
Depth (cm)		0-13	13-50	50-76
pH	H2O	5.2	7.4	7.9
	KCl	3.8	5.9	6.2
EC mS/cm		0.01	0.01	0.02
Total C%		1.4	0.3	0.2
Organic Matter (%)		2.4	0.5	0.3
Total N%		0.09	0.03	0.02
C:N ratio		15.5	10.0	10.0
Avail. P mg/kg		1.0	1.0	1.0
Avail. K mg/kg		78.4	121.0	86.6
Avail N mg/kg as	NH_4	1.1	1.6	0.1
	NO_3	0.8	0.4	0.1
Exchangeable Cations meq/100g	Ca	3.9	4.7	7.6
	Mg	1.9	2.9	3.2
	K	0.40	.74	0.67
	Na	0.19	0.24	0.22
	Sum	6.42	8.48	11.69
CEC meq/100g		14.8	17.6	16.4
Texture (Pipette Method)	C	33.9	31.1	35.1
	Sl	33.6	28.1	27.1
	S	32.5	38.8	37.8

DATA SUMMARY FOR PIT DB-5 (19)

This site is on a mid slope facing east at an altitude of 1390 msl below Eusakha village. It is fallow paddy field, highly terraced with general even slope and raised ground surface. Observed surface features include rice straw, some of them burnt and rice stubbles with lots of cracks obviously due to dryness.

This soil is derived from colluvium parent material, very deep, poorly drained with very dark grayish brown at 0-13 cm, very dark grayish brown at 13-50 cm and very dark gray at 50-76 cm. Mottles are prominent in the top soil but gets faint, although present throughout the layers observed. It is slightly firm and dry in the topsoil and firm and moist in the sub soil. Top soil texture is heavy clay with lots of silt, changes to silty clay loam with lots of clay at 13-50 cm and fine sandy clay loam, also lots of clay at 50-76 cm. It has weak to sub angular blocky structures with roots to 50 cm. Profile is porous and rare quartz were seen in the top soil.

This profile is very acid with a pH of 5.2, gets neutral at 13-50 cm and moderately alkaline thereafter. EC is very low. Organic matter is moderate in the topsoil, obviously due to the application of compost (fym) and very low in the sub soil. Available P and total N as well N in the form of NH_4 and NO_3 are very low throughout. Available K is low in the topsoil, becomes moderate at 3-50 cm and again low at 50-76 cm. Exchangeable cations like Ca and Na are low throughout bar moderate Ca at 50-76 cm, while others like Mg and K are moderate to high - K is high between 3-76 cm while Mg becomes high at 50-76 cm.

PIT No. DT - 20 **Date of Sampling: 25/01/96**

Coordinates (GPS):	27°30.36 N & 89°53.05 E
Location:	Between the Thimphu-Wangdue road and the Tsangchhu river, below NRTI complex
Altitude:	1350m msl
Parent Material:	Gniess
Landform:	Highly terraced, quite irregularly sized terrace with sudden break in slope below the sampling site
Slope and Aspect:	13%, NE
Landuse and Vegetation:	Terraced field, not cultivated
Surface features:	Rice stubbles, some straw, few dungs
Effective soil depth:	0 - 110 cm
Profile drainage:	Moderately drained
Moisture condition:	Slightly moist
Microtopography:	Uneven due to cattle trampling and harvest operations; lots of cracks and very dry

Horizon	AP	B1	B2
Depth (cm)	0 - 13	13 - 84	84 - 110
Colour	very dark greyish brown	dark greyish brown	dark brown
Mottles	few prominant, common faint light red	quite common faint rusty patches	not seen bar micaceous faint yellowish patches
Consis-tency	slightly friable, slightly moist	hard and compact, slightly moist	slightly friable, moist
Texture	silty, heavy clay loam	fine sandy, silty clay loam	heavy clayey loam
Structure	moderately weak,	weak subangular blocky	weak subangular blocky
Coarse Material	not seen	full of biotite mica	few quartz
Roots	common, fine fibrous	common, fine fibrous in the upper layer and not seen below	not seen
Pores	common, medium and few tubular	few medium to few fine tubular	common fine tubular

(Described by RA, DD & DKB)

Notes:

- *Soil gets wetter with depth. Augured down to 135 cm. No mottles and no change in colour, soil generally as B3.*

Horizon		Ap	B1	B2
Depth (cm)		0-13	13-84	84-110
pH	H_2O	7.6	7.5	5.2
	KCl	6.0	5.7	3.8
EC mS/cm		0.04	0.01	0.02
Total C%		0.40	0.30	1.10
Organic Matter (%)		0.70	0.50	1.90
Total N%			0.04	0.09
C:N ratio			7.50	12.2
Avail. P mg/kg		1.0	1.0	1.0
Avail. K mg/kg		93.5	66.2	59.6
Avail N mg/kg as	NH_4	0.4	0.5	0.7
	NO_3	0.1	0.1	3.7
Exchangeable Cations meq/100g	Ca	9.1	8.2	7.1
	Mg	2.6	2.6	1.6
	K	0.58	0.47	0.28
	Na	0.24	0.20	0.13
	Sum	12.52	11.47	9.11
CEC meq/100g		15.8	12.4	15.7
Texture (Pipette Method)	C	31.3	33.5	29.2
	Si	26.8	32.3	36.6
	S	41.8	34.2	34.2

DATA SUMMARY FOR PIT DB-6 (20)

This site currently fallow is used for summer rice and is about 500 m downslope of the Thimphu-Wangdue road overlooking Bajo area. The altitude reading is 1350 msl and it faces north east. It is a moderately sloping, highly terraced araea with a large number of breaks of slope. Surface features include some rice stubbles, straws and cow dung. The area was quite dry and a lot of cracks were observed.

Physically, it is a moderately drained slightly moist soil. The profile is rather dee. Parent material consists of gneiss. Microtopography is uneven due to cattle trampling and harvest operations. Soil colour varies from very dark greyish brown to dark grey brown. The mottles are quite faint and few in number. The soil is friable except for the middle layer from 13-84 cm depth. Structurally, this is a weak, subangular blocky soil. This is mainly a silty clayey loam soil. The whole layer doesnot have significant coarse materials except for some biotite micas sen in the second layer. Common, fine fibrous roots are present as in many other agricultural soils. Common, fine to medium tubular pores were obseerved throughout the profile.

It is neutral to moderately alkaline but very acid below 84 cm. EC, OM level, total N as well as N as NH4 and NO3 and available P are significantly low; available K is moderate throughout. Exchangeable cations such as Ca, Mg and K are moderate while Na is low throughout the profile.

PIT No. DT - 21 **Date of Sampling: 25/01/96**

Coordinates (GPS):	27°30.06 N & 89°53.33 E
Location:	Below the Lobeysa saw mill (woodcraft factory) above Tshokana village
Altitude:	1340m msl
Parent Material:	Colluvium, gniess
Landform:	Mid slope, highly terraced
Slope and Aspect:	6%, NE
Landuse and Vegetation:	Terraced field, not cultivated
Surface features:	Some burnt straw, cow dung and feew boulders
Effective soil depth:	0 - 88 cm
Profile drainage:	(Not recorded)
Moisture condition:	(not recorded)
Microtopography:	Uneven due to cattle trampling and harvest operations, some cracks

Horizon	AP	B1	B2
Depth (cm)	0 - 14	14 - 68	68 - 88
Colour	greyish brown	dark grey	strong brown
Mottles	variable prominant, common faint red brown	few prominant common faint red yellow patches	quite faint localized grey patches
Consis-tency	slightly friable, moist	quite friable, moist	slightly firm, moist
Texture	fine silty clay loam	gritty sandy loam	heavy sandy loam
Structure	fine crumb subangular blocky	compact subangular blocky	loose weak
Coarse Material	not seen	few quartz	localized pockets of weathering gniess
Roots	common, fine fibrous	few fine fibrous	not seen
Pores	few coarse common medium fine tubular	few coarse common medium fine tubular	common fine vesicular

(Described by RA, DD & DKB)

Notes:

- *Augured down to 104 cm - soil becomes sandy after 88 cm with bit yellowish colour that B2 horizon*

PIT No. DT - 22 **Date of Sampling: 25/01/96**

Coordinates (GPS):	27°29.88 N & 89°53.50 E
Location:	Above the raod below NRTI site
Altitude:	1380m msl
Parent Material:	Colluvium
Landform:	Lots of gully erosion on the surrounding areas
Slope and Aspect:	40%, NE
Landuse and Vegetation:	Chirpine forest with a crown density of less than 40%
Surface features:	Dry grass, few chirpine trees, few stones, twigs, bushes, etc.
Effective soil depth:	0 - 89 cm
Profile drainage:	Well drained
Moisture condition:	dry, slightly moist due to recent rains
Microtopography:	Highly uneven due to break of slope and erosion

Horizon	AP	B1	B2	B3
Depth (cm)	0 - 8	8 - 24	24 - 42	42 - 89
Colour	brown	dark brown	reddish brown	red
Mottles	not seen	very faint localized red brown patches	not seen	not seen bar sandy
Consistency	friable, slightly moist	friable, slightly moist	friable, slightly moist	friable, slightly moist
Texture	gritty sandy loam	fine sandy clay loam	fine sandy clay	fine sand + clay loam
Structure	weak subangular blocky	loose non-coherent	loose subangular blocky	loose subangular blocky
Coarse Material	few gniess gravels	not seen	few quartz	gniess
Roots	few woody, common, fine fibrous	few woody, common fine fibrous	common woody few fine fibrous	few fine fibrous
Pores	few coarse tubular	few coarse tubular	common fine tubular	few coarse common fine few medium

(Described by RA, DD & DKB)

Notes:

- *No samples collected (soil in this site was studied on a road cutting)*