Chapter I

Introduction

1.1 Background

The Kingdom of Bhutan is a small and landlocked eastern Himalayan country. It is located between latitudes of 26°45′ N and 28°10′ N and longitudes of 88°45′ E and 92°10′ E. It stretches 150 km from north to south and 300 km from west to east covering a total land area of 40,077 km^2 (MoA, 2002). Bhutan has common borders with only two but giant nations, China in the North and India in the East, West and South. Administratively, Bhutan is divided into 20 *dzongkhag*s (districts) (Figure 1) and districts further sub-divided into 201 *geog*s (blocks equivalent to Tambons in Thailand).

Figure 1. Location of Bhutan showing districts
(Source: Jigten Tours and Treks, 2005).

The country is entirely mountainous with elevation ranging from 160 meters in the South to more than 7,550 meters above sea level (masl) in the North. The variations in climate are correspondingly extreme. The high Himalayan mountains in the northern borders are covered with perpetual snow, while the foot-hills in southern borders are generally hot and humid. There is a considerable variation in climate between valleys and within valleys depending on levels of altitude. Rainfall, in particular, can differ within relatively short distances due to rain shadow effects. Annual rainfall is concentrated in the monsoon season, that is, from mid-June to September. Bhutan has three major landform features: the southern foothills, the inner Himalayas and the higher Himalayas (Central Statistical Organization, 2001). To facilitate agricultural planning the cropping areas have been divided into six agro-ecological zones based on temperature, precipitation and altitude (Table 1) (RGoB and MoA, 2002).

Table 1. Agro-ecological zones of Bhutan.

Agro-Ecological Zones	Altitude (masl)	Mean Max. Temp (^{o}C)	Mean Mini. Temp (^{o}C)	Rainfall (mm)
Alpine	3,600-4,600	12.0	-0.9	<650
Temperate	2,500-3,600	22.3	0.1	650-850
Warm temperate	1,800-2,500	26.3	0.1	650-850
Dry sub-tropical	1,200-1,800	28.7	3.0	850-1,200
Humid sub-tropical	600-1,200	33.0	4.6	1,200-2,500
Wet sub-tropical	150-600	34.0	11.6	2,500-5,500

(Source: RGoB and MoA, 2002).

Though mountainous with harsh terrain, Bhutan is one of the ten global hot spots in environmental conservation. Bhutan’s pristine forests are home to many species of flora and fauna. Although, environmental conservation has always been the core development strategy in five-year plan developments, the most imperative objective of the Royal Government of Bhutan has been ensuring sustained economic growth without undermining the natural resource base, rich cultural heritage, sovereignty and security of a nation-state to attain the enlightened vision of Gross National Happiness (Planning Commission Secretariat, 2000).

Desire for food security, universal health and education and adequate income are reflections for every citizens to live a decent life, whilst preservation of environment and be able to live in harmony with nature are enshrined so that our resource based can support the way of life to perpetuity. At this juncture it might be wise to have a word on the status of the Millennium Development Goals (MDG), the socio-economic development targets set by the United Nations (UN) for year 2015. Bhutan's Gross Domestic Product (GDP) is continuously growing at 7-9 percent annually and is well on track to achieving several of the targets, some possibly before 2015 (RGoB, 2003).

Bhutan has many emerging issues and challenges – rural-urban migration and youth employment are some of the prominent ones. Rural-urban migration is causing shortage of farm labors in the villages and leading towards emergence of urban poverty in the towns.

1.2 Agriculture

Owing to extremely rugged terrain and high altitude, only about 7.7% of Bhutan's land area 40,077 km^2 (MoA, 2002) is suitable for arable agricultural uses including *Tseri* (shifting) cultivation. 72.5% of the total area is under forest cover while 15.7% of the total area is not at all suitable for any productive use (MoA, 2002). Over 79% of the estimated 700,000 Bhutanese are engaged in farming. Most farming is subsistence in Bhutan, involving highly integrated farming systems, with crops, livestock and forest components interdependent on each other. The agriculture sector contributes 38% of the gross domestic product (GDP), which include about 50% from agriculture, 20% livestock and 30% forestry (MoA, 2002). Crop production, livestock and forestry activities are intricately interlinked. Given the close association between the three components of the natural resources, an integrated approach has been adopted towards the development of all the three components under the umbrella of the Renewable Natural Resources (RNR) sector. Bhutan's mountainous and complex topography produces a wide range of agro-climatic conditions, reflecting differences in soil, rainfall, temperature, and slope. This allows diversified agricultural practices with a considerable variety of different crops to be grown. Major food crops include rice, maize, wheat, minor cereals (barley, buckwheat, millet), mustard and legumes (soybeans and other pulses). Main cash crops are: orange, apple potato and ginger.

The agriculture area registered under various land use types, as per ‘RNR Statistics 2000’ are presented in Table 2. Besides, the farming communities have user rights over 7,265.88 ha *sokshing* and 173,307.16 ha of *tsamdrog* (MoA, 2002).

Table 2. Agriculture area registered under various land use types.

Land use type	Total area	
	ha	%
Wet land	22,012.14	19.92
Dry land	48,306.76	43.72
Tseri/Pangzhing	30,458.11	27.57
Orchard	86,55.20	7.83
Kitchen garden	1,063.13	0.96
Total	273,034	100.00

(Source: MoA, 2002).

National level land distribution pattern is presented in Figure 2 showing that 61% of the total national land holding is on the range 0-2.5 acres, only 3% of the total land holding has the size of more than 10 acres and others in between. This, quite remarkably demonstrates the highly equitable distribution of land amongst the citizens to enable food security. About 18 percent of households own less than 1 hectare of land (MoA, 2002). Household with insufficient land of their own enter into tenancy contracts and share cropping arrangements to get supplementary land to meet the requirements.

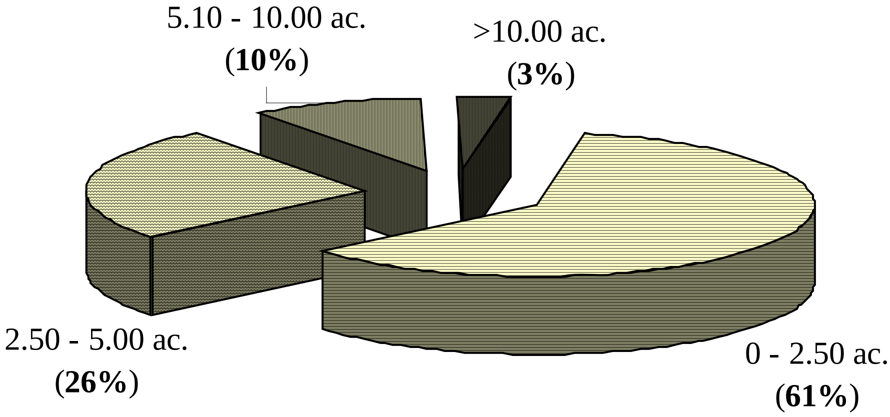

Figure 2. National land distribution in acres
(Source: Department of Land Record & Survey, 2004).

Absolute landlessness among rural households is very low. A maximum of 2.6 percent rural households do not have agricultural land at all. However, they make their livelihoods by tenenting on others farmland or by working as agricultural labors (MoA, 2002).

1.3 Sources of farm soil nutrients in Bhutan

Farmyard manure (FYM) and artificial chemical fertilizers are two main sources of soil nutrients for the Bhutanese farmers. FYM continues to be the single most important source of soil nutrients with at least 139,000 metric tonnes (MT) applied to cereal and horticultural crops in year 2000 (MoA, 2002). Further, it is a popular practice especially in the south to tether cattle in the field. Unlike FYM, chemical fertilizers are mainly restricted to crops with higher returns such as paddy, potato, chilli and tree crops such as apples and oranges. Close to 30 percent of the households reported to have used chemical fertilizers amounting to 1800 MT in year 2000. Urea, *Suphala* (15:15:15 or 17:17:17 of NPK) and single super phosphate (SSP) comprise bulk of the amount used although Muriate of potash (MoP), Calcium ammonium nitrate (CAN), bone meal and borax are also applied in minor quantities (MoA, 2002).

1.4 Rationale

To fit a particular type of farming system in line with soil characteristics of land, one needs to know soil fertility status. By collecting and analyzing representative soil samples, the nutrient contents can be determined which is in turn used to derive the current fertility status of study area as comprehensive current soil fertility status is not known. Knowing soil fertility can help design proper soil management strategy to counteract against uncontrolled soil erosion and improper soil management and more importantly help in adopting meaningful farming system. The problem of soil fertility deterioration may aggravate in future with increasing cropping intensity, use of high yielding crop varieties, low and unbalanced application of chemical fertilizers and decreasing use of organic manure. Bhutan has subsistence agricultural economy where modern science and technology practices are of recent origin. In light of the limited land resources of Bhutan, improved soil fertility management is one of the key factors to increase agricultural production. To this end, soil analysis and determination of total N, available P and K, organic matter (OM), pH, soil texture and soil bulk density is carried out and farmers assessment of overall soil fertility based on linguistic variables be assessed using questionnaire survey. Farmers' assessment and laboratory results are to be compared to find the extent to which we can rely on farmers' assessment. The rationale for studying local knowledge about soils is that most progress towards sustainable land management will derive from the synergy of local and scientific knowledge, then integrating or relating the two knowledge systems is a central issue (Payton et al., 2003).

One of the recommendations that emanated out of the Farmer-Extension Fertilizer Use Trials (FEFUT) in Punakha and Wangdue districts is determine soil nutrient status to get relation of fertilizer responses to soil nutrient status and fertilizer recommendation could be refined across soil types and soil conditions (DRDS, 2001).

A quantitative knowledge on the depletion of plant nutrients from soils helps to understand the state of soil degradation and may be helpful in devising nutrient management strategies. Nutrient-balance exercises may serve as instruments to provide indicators for the sustainability of agricultural systems. Nutrient-budget and nutrient-balance approaches have been applied widely in recent years. Soil sampling and analysis provides essential information concerning the current nutrient status of the soils (FAO, 2003). Like in any farming system, soil fertility is fundamental to the productivity and sustainability in Bhutan (Norbu and Floyd, 2001). Land characteristics like soil pH and nutrient status are important to be established for carrying out land evaluation to adopt most suitable farming practice (FAO, 1976).

The Royal Government of Bhutan (RGoB) ever since its 5th Five Year Plan (FYP) from 1981 to 1987 has been consistently pursuing the food self-sufficiency policy. Main goals and objectives of the Ministry of Agriculture in the 9th FYP (2000-2007) plan period are (DRDS, 2001c):

- enhance of rural income
- attain national food security
- conserve and manage of natural resources
- generate employment opportunities

Rice and maize are main food crops in Bhutan. There was about 56% rice self-sufficiency at the beginning of 9FYP in July 2002 and it is targeted to attain 60% national rice self sufficiency by the end of 9FYP in June 2007 through additional domestic production and to improve and sustain the food production for the rural communities. With just 12.6% of wet land out of total arable agriculture land there is almost no scope for horizontal expansion (DoA, 2003). In fact with rapid development flat rice land are decreasing and the overall decreasing trend of agricultural land is presented in Figure 3.

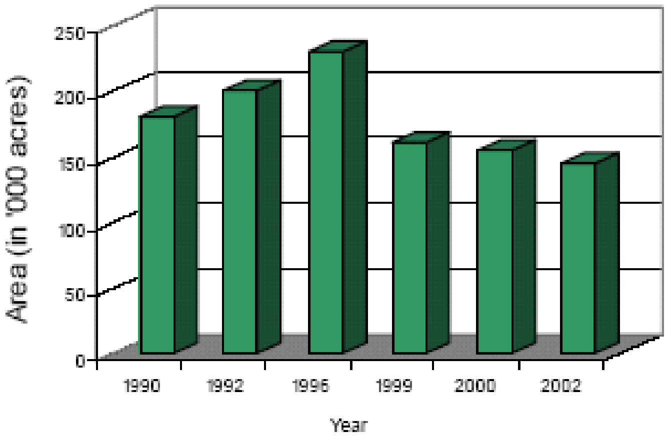

Figure 3. Decreasing trend of agricultural land

(Source: Central Statistical Organisation, 2003).

On the other hand with the high population growth rate of 2.5%, the increase in food production is only likely to offset the growth in population. As such the increase in production can only be attained by increasing production per unit area (DoA, 2003). Therefore, intensification of already cultivated area through use of improved seeds, fertilizers, pesticides and irrigation facilities are necessary. For efficient and effective use of fertilizers, it is necessary to know the spatial distribution soil fertility or nutrient status of land area. An attempt towards this end has been made by this study.

1.5 Objectives of the study

The general objective of the study is to assess the chemical and physical characteristics of the soils of Guma *geog* and obtain current soil fertility status agricultural land by laboratory approach and farmers' techniques. The specific objectives are:

- To determine spatial distribution of soil fertility status using laboratory approach and farmers' techniques
- To develop soil fertility indices based on laboratory approach and farmers' techniques
- To compare the laboratory and farmers' indices of soil fertility status

1.7 Scope and limitations of the study

The study covers soil sampling and chemical analysis for Guma *geog* along with farmers' version of overall soil fertility being assessed using questionnaire survey. The results of laboratory analysis is used to generate surface for soil fertility attributes to determine spatial distribution of main soil fertility attributes of organic C, total N, available P and K, pH, and bulk density. Farmers' linguistic assessment of overall soil fertility is converted to numeric values by scoring to derive farmers' fertility indices, and laboratory results are used to generate soil laboratory fertility indices. These two indices are compared using point to point analysis, and by overlaying of point with map (polygon) data involving queries using attribute data for both the farmers fertility and laboratory fertility. Farmers' indicators of soil fertility are identified and the indicators are weighted to find how farmers weigh each of their indicators.

Limitations of the study are that the study was only based on measures of organic C, total N, available P and K, pH, texture and bulk density for technical soil fertility and farmers' overall assessment of soil general fertility without specific reference to any particular crop for farmers' soil fertility. Soil sampling is limited to 0-20 cm depth. Cation Exchange Capacity (CEC) and base saturation and other soil nutrients are not included.