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A systems analysis of soil fertility in the hills of Nepal

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Natural Resources Institute

FINAL TECHNICAL REPORT

A SYSTEMS ANALYSIS OF SOIL FERTILITY IN THE HILLS OF NEPAL

R6043

June 1996

Overseas Development Administration

Executive Summary

The purpose of the project is to improve the sustainability of agricultural systems in the hills of Nepal through the development, with Nepali scientists and farmers, of a soil fertility research strategy for a leading hill agriculture research station. This was achieved through the following outputs:

1. A comprehensive review of soil fertility literature and a series of participatory field studies in representative sites, leading to an improved understanding of the factors affecting soil fertility in the hills of Nepal.
2. The formulation of a medium-term strategy for soil fertility research for the mandate area of Lumle Agricultural Research Centre through workshops between UK and Nepali scientists.
3. The identification and documentation of the present responses of farmers of representative groups to soil fertility issues, and their awareness of and attitudes to alternatives.

The project has contributed to ODA development goals of poverty alleviation, economic growth and the mitigation of environmental problems in several ways:

1. By developing a research strategy for soil fertility research (and long-term links between UK and Nepali institutions) that will provide recommendations to farming households relevant to their needs for sustainable productivity

2. By substantially increasing understanding of farmer attitudes and responses to soil management issues such as soil conservation. This understanding is already contributing to the design of research into soil and water conservation, and will eventually affect the adoption of methods to reduce particulate and nutrient losses from hill farming.

Background

Farming in the hills of Nepal is both complex and precarious. There is extreme variability in environmental conditions between (and sometimes within) farms, and, while most farming families are classed as resource poor, there are social, economic and ethnic differences between households leading to differential adoption of technologies.

Interdependence of resource use between crops, livestock and forests is a key feature of Nepalese hill agriculture, and critical to the cycling of nutrients necessary for crop and livestock production.

Hill agriculture is disadvantaged by a scarcity of arable land, few employment opportunities, poor marketing potential and weak financial and institutional support. It is also viewed as a subsistence activity with few opportunities for advancement. This has led to outmigration, although the population and land pressure continue to rise.

Government statistics (although not always accurate) show a decline in agricultural productivity which is threatening the stability of the human population in the hills where around 45% of Nepal's population lives and which accounts for about half of the country's cultivable land.

Increasing population pressure is leading to forest degradation, soil erosion, lack of fodder and fuelwood and a declining productive livestock population, all of which have a bearing on soil fertility, and therefore on the productive capacity of the land.

Soil erosion in Nepal (and its downstream implications) is not only a consequence of human activity, but is also related to mass wasting, glacial-like outbursts and on-going geomorphological processes of mountain building (Carson, 1985; Ives and Messerli, 1989; Thapa and Weber, 1991).

Lumle Agricultural Research Centre, co-ordinated by the National Agricultural Research Centre (NARC) and supported by the Overseas Development Administration (ODA), has been working within this environment for 25 years. Through farmers surveys, the Centre has **identified soil fertility decline as a widespread, serious and growing problem**, leading in 1987 to the formation at LARC of a cross-disciplinary research thrust (the Soil Fertility Thrust) to address the issue.

Several soil fertility diagnostic surveys (Samuhic Bhraman) have been conducted by LARC to attempt to understand the constraints and opportunities that farmers face with respect to indigenous methods of soil fertility maintenance. While these have helped scientists to appreciate the range of methods used, the rationale behind the practical application of the methods is often complex and as yet not fully understood. Decreasing compost output, because of a reduction in productive livestock numbers, a dwindling natural fodder base, crop intensification and the introduction of high yielding varieties are symptoms of added stress to the system resulting in the abandonment of marginal lands, concentration on limited accessible land and a decrease in numbers if animals kept under the transhumance migration of animals (Kharka system).

A positive effect has been the change in some villages from extensive grazing systems to a stall-fed system, which has led to increased livestock productivity per animal and more efficient resource use, particularly with respect to FYM production.

A number of research sub-projects have been carried out by the LARC Soil Fertility Thrust to investigate the potential of soil fertility enhancing technologies such as compost management, use of legumes, biofertilizers, and green manures, and the use of diluted livestock urine as a topdressing on vegetables. The use of indigenous plants as green manures to improve soil fertility has been largely limited to rice and vegetable nurseries. Despite the identification of several indigenous species of green manuring value, labour shortages and other factors such as problems with their large scale production, have limited widespread uptake.

While it is recognised that this, and soil fertility research elsewhere in Nepal has made a valuable contribution, it is not based on a thorough analysis of all the factors that influence the way in which farmers make decisions concerning the maintenance of soil fertility.

Several recent analyses of soil fertility in the hills of Nepal are available (including Carson, 1992; Tamang, 1992; Shah et al, 1991; Shrechan and Chand, 1991; Biot, 1990; Upadhaya et al, 1991). While all agree that the situation is serious, quantitative data on the spatial and temporal dynamics of the situation are few, and are insufficient to form the basis of a rational strategy for research into soil fertility maintenance.

An ongoing study of soil erosion under forest and arable land in Central Nepal is yielding quantitative soil loss data that will be of direct relevance to the project (Gardner, 1994).

In March 1993, a visit was made by NRI staff to LARC to discuss the possibility of collaboration between the two institutions **to make a comprehensive study of the biophysical, social, economic and institutional factors influencing soil fertility in the hills**, with a view to arriving at a research programme which would have significant impact on correcting the worsening soil fertility situation.

The collaboration was agreed by LARC, and in principle by the National Agricultural Research Council (NARC) and ODA's South East Asia Development Division (SEADD).

A concept note was prepared by the LARC soil fertility thrust, which was used together with further correspondence between LARC and NRI, to develop the proposal for this project.

Project purpose

The project purpose is to improve the sustainable productivity of agricultural systems in the hills of Nepal through the development of a medium-term strategy for soil fertility research based on a thorough understanding of present farmer responses and attitudes and a review of current literature. The research strategy has led to the development of a research programme into key areas where understanding of soil fertility is lacking.

Research Activities

The project was implemented by the Soil Fertility Research Thrust (SFT) of Lumle Agricultural Research Centre (LARC) together with soil scientists from NRI and Reading University. Four main research activities were conducted. Each produced a separate activity report, and copies of these are annexed so that the text of this report can be kept to a minimum. Summaries of the activities are given below:

1. First field campaign; May-June 1994, conducted by Mr J Bennett (NRI) together with the LARC SFT (See Annex for detailed report): The consultant visited Lumle Agricultural Research Centre and its Research Command Area to devise an environmental framework for Lumle's research activities into the decline in soil fertility. Published information was reviewed, the views of informed opinion sought and the environmental and land use character of the area observed to the extent possible in the limited time available. Earlier attempts at physical subdivision of the land at national and regional level were considered.

It was concluded that because of the complex nature of the environment of Nepal attempts to map areas of land having internal uniformity had proved singularly unsuccessful and were likely to continue to be so. It was also clear that any decline in soil fertility (if fertility is in fact in decline) is a consequence of a changing physical and socio-economic environment which has led to pressures on the land use system increasing at a pace greater than the farmers' ability to adapt to them. If there is a problem it is one of falling farm production levels due to limiting factors becoming critical. Declining soil fertility is an effect rather than a cause.

Both these issues can be defined, understood and addressed in terms of the land use system. The main system variants are known and representative sites where particular issues apply can be fairly easily located, though the extent and distribution of systems are less easily mapped.

It was proposed that the farming systems themselves provide the framework for the Lumle Research Command Area, and future activities focus on representative focal points which encompass a range of environmental conditions to which farming systems in the locality are adapted. A study of these systems will identify the main constraints and opportunities and the direction of future research into declining crop production.

Seven representative sites were identified and a preliminary characterisation, to be enhanced in later field campaigns, carried out.

2. A review of literature relating to soil fertility in the hills of Nepal by Liz Kiff, C Turton, JK Tuladhar and R Baker (See Annex for a copy of the review):
The paper is divided into seven sections, beginning with the background to the review as part of the formulation of a long-term strategy for soil fertility research in the Western hills of Nepal. An introduction to the Himalayan mountain environment is given, specifically the hill regions of Nepal and the importance of soil fertility to mountain agriculture discussed.

Soil fertility is defined as including all soil characteristics which influence crop growth and the various components of soil fertility and their interactions are described. Myths are separated from facts with regard to the Himalayan degradation theory and the voluminous literature predicting future catastrophe in the region due to soil erosion and its subsequent effects. A certain degree of soil and nutrient movement is important for maintaining soil fertility lower down the catchment.

Historical development of the hill farming systems and land ownership rights together with the effect of tenureship on resource management is discussed in the second section. The dependence on and contribution to soil fertility, of different components of hill farming systems is described. The interdependence between crop, livestock and silvicultural components of the farming system is explored, as well as the nature and degree of different system's dependence on off-farm forest and grazing resources.

The issue of soil fertility in the Nepalese context is further explored in the third section, including both researchers' and farmers' analyses of soil characteristics and soil productivity. Farmer's classifications of soil types, based on texture, colour and amount of fertiliser required to make them productive, is presented as having greater practical application than the taxonomically based, researcher's classification. Present knowledge of farmers' classifications, however is still incomplete and presents problems of inconsistency between locations. A combination of scientific clarity in classification together with farmers' practical descriptors would produce a more useful system of soil classification.

Chapter four looks at changes that have occurred in land productivity and how these reflect, or have affected changes in soil fertility levels. Use and distribution of fertiliser resources are considered alongside major trends in the cultivation and yield of cereals. Certain apparent trends in cultivated area and cereal yield are traced to dubious quality and bias within official statistics. The quality and contribution of statistics to the debate on soil fertility changes is discussed.

Soil fertility management practices are documented in section five, together with factors that influence farmers' choice of practice. The large body of descriptive literature on farmer practice is complemented by very little on farmer perception and conceptualisation of soil fertility management. This leads to lack of clarity in researcher's understanding of the reason(s) for specific farmer practices. Recent changes in management practices are documented and the trends these suggest in farming system development discussed. Finally major information gaps in researcher's understanding of soil fertility management are listed.

The past and potential contribution of scientific research to understanding the processes involved in soil fertility management is reviewed in chapter six. Use and response to chemical fertiliser on different land types and by different crops is considered, together with problems associated with its use. The various methods, together with their strengths and weaknesses, of fertility enhancement through organic fertiliser additions are documented.

In defining research needs it is emphasised that the integrated nature of the way in which soil fertility is managed as a resource, interacting with other resources such as labour and water, makes problem isolation and focusing research a challenge. Contemporary researches' definitions of required future research focus are given. Finally these are synthesised together with issues arising in the review into a summary of key areas for the focus of future research.

3. Second and third field campaigns; Autumn 1994 and Spring 1995; conducted by Ms Cathryn Turton (NRI consultant) (See Annex for report and appendices):

Farming systems in the hills of Nepal are characterised by strong linkages between three spheres of production; crop, livestock and forest. The links between the components are critical to the cycling of nutrients necessary for crop production and hence soil fertility. In recognition of this, the study adopted a multi-disciplinary approach, using farming systems as the basis for research. The study selected seven representative focal points, covering a range of biophysical and socio-economic conditions to which farming systems have adapted. A variety of both formal and informal methodologies were used in the study.

A review of past literature emphasised the widespread concern over soil fertility in the hills, with soil erosion, declining crop yields and soil degradation the main issues highlighted. Analysis of soil sample data revealed wide variation in fertility status across the hills, according to differences in land type, altitude and soil type.

The majority of farmers reported that soil fertility was declining, both on *khet* and *bari* land. A decrease in soil fertility was also identified as a major contributing factor to crop productivity decline. However, there was considerable variation in the responses of different villages. A logistical regression model indicated that market availability, rainfall, household wealth category and altitude affected the probability of soil fertility decline, on both *khet* and *bari* land. Availability of forest resources and compost:land ratios were key factors influencing the likelihood of soil fertility decline.

Participatory rural appraisal techniques were used to explore farmers' soil fertility management strategies. The results emphasised the integrated nature of the nutrient management system, with up to seven different practices used by farmers. The main changes in soil fertility management over the last 10-15 years have been an increase in the relative importance of FYM/compost, a decline in in-situ manuring, the introduction of chemical fertilisers and a decline in traditional practices such as trash burning, use of green manures and mulches. However, the degree and direction of change differs across villages. Accessibility to roads and markets and/or altitude seem to be the main factors influencing change.

Based on the findings, three soil fertility research domains were recommended and a number of suggestions for research are given.

4. Visits by Professor Peter Gregory (University of Reading) to develop, with LARC staff and other Nepali scientists, a medium-term soil fertility research strategy (See Annex for two visit reports):

First visit (August 1995):

Professor Gregory assessed relevant soil fertility literature and the resources for soil fertility research in Nepal. Following a field trip and extensive discussions with LARC staff and others, a workshop was held at which an outline research strategy was presented. After obtaining feedback on the outline Professor Gregory visited NARC, Winrock and ICIMOD in Kathmandu, and had a meeting in the UK with other institutions involved in on-going or proposed soil fertility research in Nepal, to ensure complementarity of resources and programmes.

Second visit (April/May 1996)

Detailed discussions were held between Professor Gregory and LARC SFT staff about the programme structure of the soil fertility group and the development of links with other research groups. The requirements for new capital and analytical equipment were identified with Dr Tripathi, and a start was made on developing a logical framework for the group.

Three days of field treks were used to identify priority topics for research from the perspective of farmers and to see first-hand some of the practical consequences of soil fertility for crop/tree/vegetable production in the mid-hills of Nepal.

A series of three workshops was held at Lumle to promote the understanding of modern techniques for investigating issues related to soil fertility. The workshops involved lectures, calculation of ^{15}N results, and simple computer modelling of soil organic matter decomposition.

A series of discussions was held with staff of LARC, PAC and NARC to develop a joint research proposal for possible ODA support with the University of Reading to further the implementation of the medium-term soil fertility research strategy.

Outputs

The tangible outputs of the project are the documents included in the Annex to this report which have contributed to our understanding of soil fertility issues in Nepal, and a clear strategy for soil fertility research which is now being implemented by LARC, together with UK research institutions.

All of the anticipated outputs of the project have been achieved.

The new Research Strategy can be summarised as follows:

Strategy Goal
To develop practical options for the management of soil fertility in the major farming systems of the hills of Western Nepal based on a quantified understanding of the major processes and pathways of nutrient transfer and, with consideration of national policies, to communicate these to farmers so that sustainable systems result.

Strategy Objectives
1) To collate existing information on the nutrient cycles of the farming systems in the high, mid and low hills, identify key sub-systems and initiate research to fill the gaps so that the cycles are complete in 3 years.
2) To determine effective means of conserving moisture in manures and composts in ways that are acceptable to farmers within 5 years.
3) To analyse the decomposition/stabilisation of organic manures and the fate of inorganic fertilisers in soils as a prelude to the development of integrated schemes for soil fertility management in different farming systems.
4) To determine the role for nutrient inputs such as fertilisers and legumes in the farming systems of the mid and low hills.

Research priorities
Theme 1: Nitrogen and phosphorus cycles in major farming systems
Theme 2: Long-term fertility experiment on *bari* land
Theme 3: Conservation of nutrients on farm
Theme 4: Loss and redistribution of nutrients by erosion
Theme 5: Trials with inorganic fertilisers
Theme 6: Inclusion of legumes in farming systems.

Contribution of outputs

How outputs contribute to ODA development goals
The contribution to ODA development goals of poverty alleviation, economic growth and environmental conservation will be through the implementation of the medium-term research strategy for soil fertility research by LARC and other NARC research stations, and the application of the knowledge gained about farmers responses to soil fertility issues by this and other research and development projects.

Promotion pathways to target institutions and beneficiaries
The project has developed the knowledge and skills base of senior and junior technical staff (social and natural scientists) of LARC and other Nepali research institutions. The reports arising from the project are a significant body of work that has collected and advanced the material available in the country on soil fertility. The chapter for the book Himalayan Crisis will make this knowledge available on an international scale. Internal reports produced by the project are as follows:

Bennett JG (1994) An analysis of soil fertility systems in the hills of Nepal: Report on the first field campaign; May - June 1994

Gregory PJ (1995) Soil fertility research strategy: Report on a consultancy visit by PJ Gregory for NRI.

Gregory PJ (1996) Soil fertility research strategy: Report on a second consultancy visit by PJ Gregory for NRI; March/April 1996

Kiff E, Turton C, Tuladhar JK and Baker R (1995) A review of literature relating to soil fertility in the hills of Nepal. NRI/LARC

Pound B (Ed.) 1996 Proceedings of a workshop to formulate a strategy for soil fertility research in the hills of Nepal; held at Lumle Agricultural Research Centre, 17-18 August 1995 (in draft)

Turton C (1995) An Analysis of soil fertility systems in the hills of Nepal (report on the findings of field campaigns). NRI/LARC

Vaidya A, Turton C, Joshi KD and Tuladhar JK (1995) A systems analysis of soil fertility issues in the hills of Nepal: implications for future research. Paper presented at the ICIMOD/IDRC workshop "Resource Dynamics in Middle Mountain Watersheds in Nepal", Kathmandu, 10-12 April 1995

In addition a book entitled Himalayan Crisis will be published by Mansell Press in late 1996/early 1997. A chapter has been written for the book based on the literature review carried out as part of this project. The reference is:

Kiff, E, Pound, B and Turton, K (1996 in preparation) Soil nutrient management and changes in agricultural productivity. In: Gardner, R (Ed.) (1996) Himalayan Crisis. To be published by Mansell Press

Follow-up indicated/planned
A proposal has been submitted by Reading University and Rothamsted to the Hillsides Production System of the NRSP to work with LARC, PAC and NARC in Nepal to investigate Nitrogen and Phosphorus nutrient balances in the mid-hills of Nepal. Even in the absence of the proposal being approved, the Soil Fertility Research Thrust of LARC will follow the strategy developed by this project to conduct research into soil fertility.

Barry Pound
[Farming Systems Agronomist, NRI]

ANNEX

AN ANALYSIS OF SOIL FERTILITY SYSTEMS IN THE HILLS OF NEPAL

A joint project between Lumle Agricultural Research Centre and the Natural Resources Institute

FINAL DRAFT

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

ACAP	Annapurna Conservation Area Project
APP	Agricultural Perspective Plan
CEC	Cation Exchange Capacity
ECA	Extension Command Area
EIS	Extension Impact Study
FYM	Farm Yard Manure
HMGN	Majesty's Government of Nepal
JT	Junior Technician
JTA	Junior Technical Assistant
LARC	Lumle Agricultural Research Centre
LRMP	Land Resources Mapping Project
NRI	Natural Resources Institute
PRA	Participatory Rural Appraisal
RCA	Research Command Area
RRA	Rapid Rural Appraisal
SFT	Soil Fertility Thrust
USDA	United States Department of Agriculture
VDC	Village Development Committee

SUMMARY

This report forms part of an 18 month collaborative project carried out between Lumle Regional Agriculture Centre and the Natural Resources Institute, UK, which aims to draft a comprehensive strategy to guide the development of a future soil fertility research programme.

Farming systems in the hills of Nepal are characterised by strong linkages between three spheres of production; crop, livestock and forest. The links between the components are critical to the cycling of nutrients necessary for crop production and hence soil fertility. In recognition of this, the study adopted a multi-disciplinary approach, using farming systems as the basis for research. The study selected seven representative focal points, covering a range of biophysical and socioeconomic conditions to which farming systems have adapted. A variety of both formal and informal methodologies were used in the study.

A review of past literature emphasised the widespread concern over soil fertility in the hills, with soil erosion, declining crop yields and soil degradation the main issues highlighted. Analysis of soil sample data revealed wide variation in fertility status across the hills, according to differences in land type, altitude and soil type.

The majority of farmers reported that soil fertility was declining, both on *khet* and *bari* land. A decrease in soil fertility was also identified as a major contributing factor to crop productivity decline. However, there was considerable variation in the responses of different villages. A logistical regression model indicated that market availability, rainfall, household wealth category and altitude affected the probability of soil fertility decline, on both *khet* and *bari* land. Availability of forest resources and compost:land ratios were key factors influencing the likelihood of soil fertility decline.

Participatory rural appraisal techniques were used to explore farmers' soil fertility management strategies. The results emphasised the integrated nature of the nutrient management system, with up to seven different practices used by farmers. The main changes in soil fertility management over the last 10-15 years have been an increase in the relative importance of FYM/compost, a decline in in-situ manuring, the introduction of chemical fertilisers and a decline in traditional practices such as trash burning, use of green manures and mulches. However, the degree and direction of change differs across villages. Accessibility to roads and markets and/or altitude seem to be the main factors influencing change.

Based on the findings, three soil fertility research domains were recommended and a number of suggestions for research are given

1 INTRODUCTION

The issue of soil fertility in the hills of Nepal has long been a topic of concern to both researchers and farmers and become the justification for numerous research and development projects. Several recent analyses of soil fertility in the hills are available (Sthapit *et al.*, 1988; Subedi *et al.*; 1989; Shah *et al.*, 1991; Carson, 1992; Tamang, 1992) and all agree that the situation is complex. Differences across the hills in the major soil forming factors; parent material, climate, geology and soil organisms, result in an inherent wide variability in soil properties and fertility status.

For the purposes of this study, soil fertility is taken to mean all those soil characteristics which influence crop growth and impose limitations on yield (Rowell, 1994; Hallsworth, 1969). The main components of soil fertility are:

- structure and porosity - water availability, aeration, rooting depth and bulk density
- nutrient availability - macronutrients, micronutrients and toxicities
- biomass activity

In the past, discussions on soil fertility have often centred on the nutrient status of the soil. However, this ignores the importance of the interaction between complex processes in the soil and is not appropriate in the context of Nepal hill farming. systems. Hill farmers' concepts of soil fertility take into account all of the above three components and the interactions between them.

1.1 Background and objectives of the study

Lumle Agricultural Research Centre (LARC) has a long history of soil fertility research and in 1987, the Soil Fertility Thrust (SFT) was formed to bring together scientists from the relevant sections of the Centre, to address the problem of declining soil fertility. Although considerable information relating to soil fertility issues exists, any attempt to gain a clear overview and insight into the soil fertility situation in the hills is hindered by the lack of an appropriate conceptual framework, within which existing information can be evaluated and analysed. Quantitative data on the spatial and temporal dynamics of the the soil fertility situation are few, and are insufficient to form the basis for a rational strategy for research into soil fertility. In recognition of this, a collaborative project was established between LARC and the Natural Resources Institute (NRI) in 1993, to draft a comprehensive strategy to guide the development of a future research programme.

The aims of the project are:

- to improve the perspectives for sustained agricultural productivity in the hills of Nepal.

The objectives are:

- to identify, quantify and understand the factors affecting soil fertility in the hills of Nepal
- to formulate a long term strategy for soil fertility research for the mandate area of LARC
- identify among representative groupings of households the awareness of, and attitude to, soil fertility related issues

The project was divided into three phases. The first phase was carried out in May/June 1994, with the objective of establishing an appropriate framework for soil research activities. It concluded that the farming systems themselves should provide the framework for research activity. Seven "focal points"[3] that encompass a range of environmental conditions to which farming systems in the locality are adapted were proposed for research activities (Bennett, 1994).

In this, the second phase of the project, a multidisciplinary analysis of the environmental, institutional and socioeconomic factors influencing soil fertility across LARC's Research Command Area (RCA), was carried out from October 1994 to March 1995. Farmers' perceptions and opinions of soil fertility related issues were also investigated. The terms of reference and the schedule of activities of this phase are attached in Appendix 1.

The project's final phase takes place in mid 1995 and will result in the formulation of a long term strategy for soil fertility research at LARC.

1.2 LARC and its research environment

The RCA of LARC covers eight hill districts of the Western Development Region of Nepal (Figure 1.1) and is composed of a wide range of agro-ecological zones within which agricultural production is possible. The farming systems have evolved within the interplay of a wide range of biophysical, socioeconomic and institutional factors, and are extremely diverse and complex.

There are wide variations in altitude (300-3000 m), rainfall (1500-5000 mm pa) and aspect (south or north facing) across the RCA. Wide variability in soil type, geology, land form and availability of irrigation water acts futher to complicate the situation. Poor communication and high transport costs are the major factors limiting the distribution of extension messages, improved varieties and inputs such as chemical fertilisers and pesticides.

[3] These focal points are located throughout the research command area of LARC, each covering an area of between 2-7 Village Development Committees (VDCs)

Figure 1.1 Map of LARC command area showing location of focal points

(ii) Socioeconomic factors

Socioeconomic factors of importance include ethnic diversity, resource status of households, differences in accessibility to roads, markets and new technologies and land tenure agreements. In addition, the demographic dimensions of hill agriculture are important. High population growth rates and a lack of employment and income generating opportunities have led to a drain of able-bodied young people from the hills. Together with the increasing number of children attending school, this has led to problems of labour availability at critical periods. However, these demographic changes have not affected all districts in the hills in the same way. Table 1.1 shows the changes in population density in districts of LARC's command area.

Table 1.1 Population density in districts of LARC command area

District	Population density per sq km	
	1981	**1991**
Kaski	110	145
Lamjung	90	91
Gorkha	64	70
Tanahu	145	173
Syanja	234	252
Palpa	156	172
Myagdi	42	44
Baglung	121	130
Parbat	260	291
Gulmi	207	238
Arghakanchi	132	152

Source: Sharma *et al.*, 1994

An additional socioeconomic consideration is the difference in the roles, responsibilites and perceptions of male and female farmers. This is now receiving increasing recognition from development workers.

(iii) Institutional factors

Changes in the policy, institutional and economic environments have had far reaching effects on hill agriculture. These include infrastructure development, the increasing commercialisation of hill agriculture, implementation of community forestry policies and changes in land tenure and fertiliser supply policies. The impact of these changes has often been highly localised, a situation exacerbated by the lack of a definitive government policy for the development of hill agriculture.

1.3 A systems approach to soil fertility

The farming systems that have evolved in the hills are complex, diverse and predominantly resource poor. At a broad level, they are characterised by strong linkages between the 3 spheres of production: livestock, forest and crop production (Figure 1.2).

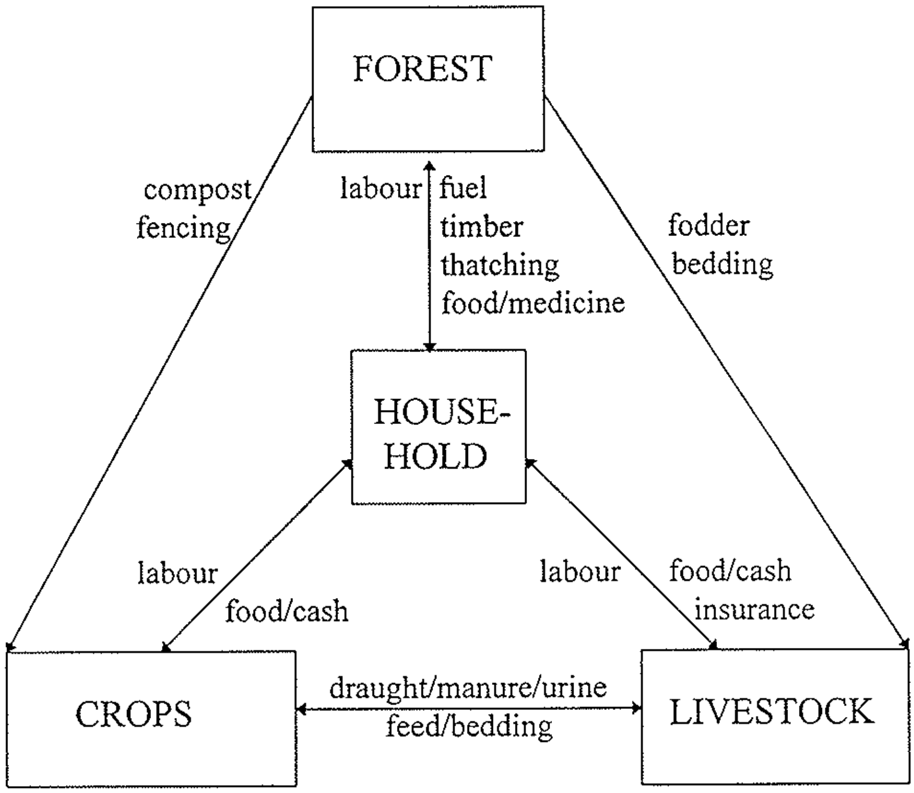


Figure 1.2 The Nepal hill farming system (adapted from Pound *et al.*, 1990).

These linkages have been widely discussed (Carson, 1992) and it is sufficient to emphasise here that, interdependence of resource use is a key feature of Nepalese hill agriculture and critical to the cycling of nutrients necessary for crop and livestock production. The very nature of the hill environment means that traditional closed farming systems, characterised by a high efficiency of internal resource recycling and strong linkages between crop, livestock and forestry components predominate. There is little use of external inputs. The cultivated landscape of the hills of Nepal can be divided into two kinds of land, known locally as *khet* and *bari*. *Khet* land is irrigated, with bunds around the edge of each terrace and is traditionally cultivated to rice. *Bari* land consists of rain-fed sloping terraces, which are rarely flooded and maize dominates the cropping pattern.

The issue of soil fertility lies at the very heart of this system, and is maintained through the transfer of nutrients between the three components (Figure 1.3).

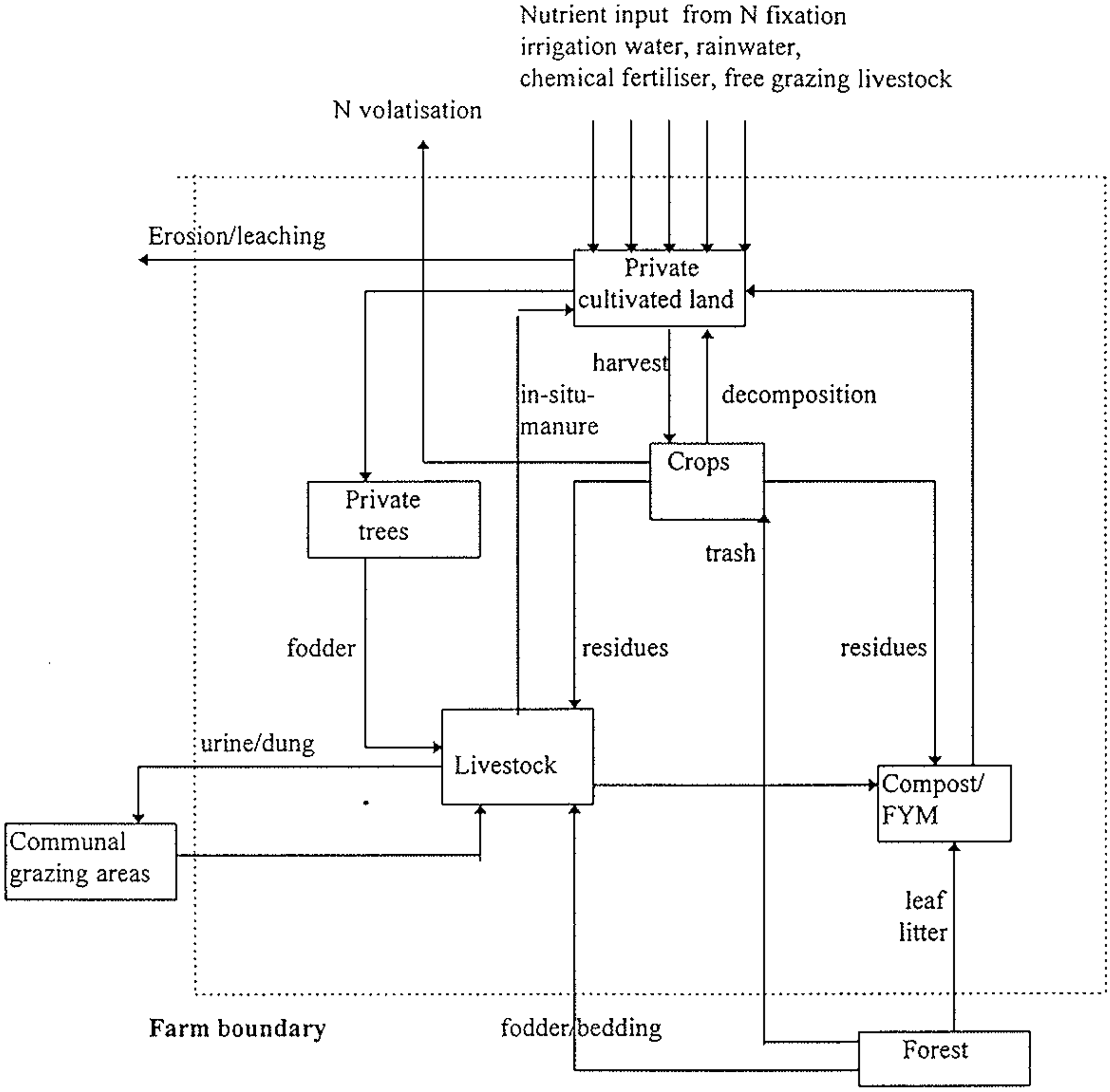


Figure 1.3 Nutrient flows in the hill farming system

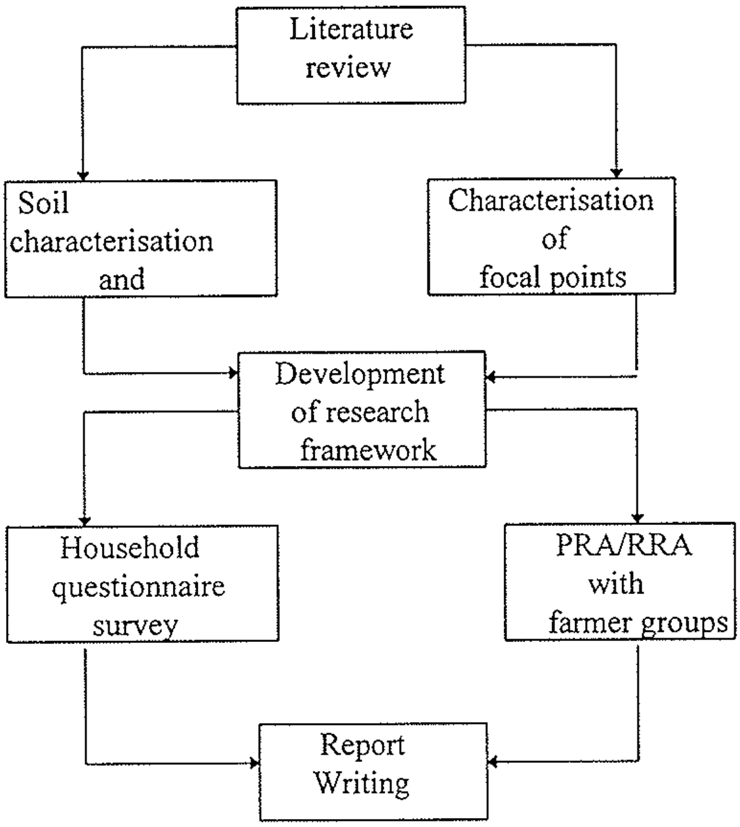
Because soil fertility dynamics are a result of the balance of interactions between the crop, livestock and forest components of the farming system, soil fertility can be viewed as an indicator of the state of "health" of the farming system as a whole. Any decline in soil fertility is a consequence or a symptom of a changing physical and socioeconomic environment, that has led to pressures on all or part of the forest-livestock-crop components, increasing at a greater pace than farmers' abilities to adapt to them. The challenge is to identify the critical factors causing changes in the farming systems of the hills and the corresponding impacts on soil fertility status. This study therefore adopted an holistic approach, investigating the interactions between a range of factors and their impact on soil fertility.

Whilst it is recognised that issues of soil fertility are important for all land uses in Nepal, this project focuses on soil fertility of cultivated land. Issues associated with forest soil fertility are also crucial, given the one way flow of nutrients from forest to farm, and are gradually receiving recognition elsewhere (Schmidt *et al.*, 1993).

2 METHODOLOGY

The study adopted an integrated approach employing a variety of both formal and informal methodologies (Figure 2.1).

Figure 2.1 Methodology adopted for the study



The first stage comprised a comprehensive review of literature relating to soil fertility issues in Nepal, the full version of which is attached in Appendix 2. Detailed characterisation of the focal points and compilation of available soil data resulted in the formation of a framework for research. Finally, extensive field surveys were carried out to investigate farmers' perceptions of soil fertility status and reasons for changes at the household level.

2.1 Review of soil fertility

The objectives of the review were to establish the existing state of knowledge regarding soil fertility issues in the middle hills and identify information gaps to be addressed by this study. All information related to Nepal was consulted, with particular reference to the *Samuhik Bramin*[4] reports published by LARC over the last 10 years. The main findings of the review together with a compilation of soil analysis

[4] *Samuhik Bhraman* is a form of rapid rural appraisal carried out by a group of scientists from different disciplines

data (both from this and previous surveys) are summarised in chapter 3. This provides a context for the succeeding discussions of soil fertility.

2.2 A framework for research

In the first phase of this project, it was proposed that the farming systems themselves provide the framework for research. Seven focal points covering a range of environmental and socioeconmic conditions to which farming systems are adapted were selected for more detailed investigations (Figure 1.1). The focal points were selected using the following criteria which had been identified in previous studies as having an important influence on soil fertility.

(i) Altitude
(ii) Rainfall
(iii) Fertility management practices
(iv) Accessibility
(v) Differences in proportion of *khet* and *bari*
(vi) Population pressure, land fragmentation
(vii) *Tar* areas
(viii) Cropping intensity
(ix) Livestock management systems
(x) Soil characteriatics
(xi) Forest resources
(xii) Number of trees on private land
(xiii) Out ward sloping terraces

Visits were made to villages located in the focal points during October-December 1994, with the following objectives:

- To characterise and describe the farming systems of the focal points and select representative villages for further detailed studies
- To characterise and classify the range of soils found in the focal points, investigate farmers' perceptions of soil fertility and changes in soil fertility status
- To identify factors affecting soil fertility for the different farming systems

The villages to be visited within each focal point were selected on the basis of LARC staff's past experience and consultation with District Agriculture Development Officers. In each village, a group interview was conducted using a semi-structured checklist. Participatory Rural Appraisal (PRA) techniques were used to collect information on food sufficiency, income sources, fertility management practices, and factors affecting crop productivity and soil fertility.

Interviews were supplemented with transect walks. Along the transect, soil samples of representative soils as identified by farmers were collected, the objective being to support and inform on indigenous soil classifications, which formed the major information source for soil characterisation work.

The output of this stage was a classification of focal point villages into groups, according to similarities in land use systems and identification of a wide range of factors affecting soil fertility. For more detailed study, 13 villages were then selected from these groups, according to degree of participation in first phase, past LARC involvement, representativeness and potential suitability of the site for future LARC research activities. A matrix was constructed showing the relative importance or presence of identified factors in each village. The objective was to have as wide a representation as possible of all factors. After initial selection, there was replacement and addition of some villages to ensure adequate representation of all factors.

2.3 Field Surveys

The selected villages were surveyed during January and February 1995, with the following objectives:

- To quantify the importance of different factors and the relationships between factors contributing to changes in soil fertility and productivity status in different biophysical and socioeconomic conditions
- To investigate the perceptions of soil fertility related issues of different socioeconomic groups (primarily wealth status and gender)
- To identify potential areas for further research and development (and policy recommendations)

Eight field survey teams each consisting of one or two HMGN Junior Technicians/Junior Technical Assistants (JT/JTAs) accompanied by a LARC JT/JTA covered the 13 villages simultaneously. Before leaving for the field, the teams attended a four day training session held at LARC (Appendix 3).

2.3.1 Participatory rural appraisal

Informal group interviews were held in each village. The composition of the groups varied, but generally included farmers from different economic groups, and of different ethnicity and gender. At the beginning of the interview, resource maps were drawn by the villagers. These acted as a focal point for discussions on community forestry, variations in soil fertility status, erosion and changes in the resource base of the village, which were guided by a semi-structured checklist (Appendix 4). Matrix ranking was used to gain an insight into the relative importance of different fertility management practices over time and the roles of men, women and children in soil fertility management (Appendix 5). Social maps were also drawn in some villages to show the location of the households selected for survey

2.3.2 Household survey

A household questionnaire was administered to collect detailed information on households' perceptions of soil fertility and the important factors influencing soil fertility status (Appendix 6).

(i) Sample structure

The basic sample unit was the village. As a major objective of this study was to assess the importance of various factors affecting soil fertility, an equal number of households were interviewed from each village, regardless of the village population. The primary concern was the sufficient representation of identified factors, rather than of individual villages. A total of 520 households were interviewed, 40 from each village.

(ii) Household sample within village

Wealth ranking has long been recognised as a cost effective and accurate way to group farmers into categories of similar wealth status (Grandin, 1988). The feasibility of adopting this approach in the hills of Nepal has been illustrated by several studies (Seeley, 1989; Kiff, 1991abc; Joshi *et al.* 1993; Adhikari *et al.* 1993.) A wide range of variables were used by informants to describe the various wealth groups including, number of large livestock, size of land holding, area of *khet* land, fertility of land, ratio of workers to dependents in household and pension income. However, whilst providing accurate information on a village level basis, direct comparisons of groups across villages, for example a household in group A in one village with that in group A in another, is not possible due to the relative nature of the grouping process.

Thus for practical purposes, this study adopted a standardised set of categories. A review of previous wealth ranking studies in Nepal showed that food self sufficiency is the most common criteria used by informants (both male and female) to group households according to differences in "wealth status" (*op cit.*, 1989, 1991, 1993) and could be used to make direct comparisons of household status of different villages. An additional important criterion affecting the concept of wealth in Lumle RCA, is that of pensions paid by both the British and Indian armies to ex-service men. Households receiving pensions (particularly from the British government) were always assigned to the top one or two wealth groups. Based on these findings, it was decided to group households into the following farmer categories:

Group 1: Food and/or cash surplus for 12 months or more
Group 2: Home grown food lasts between 6-12 months
Group 3: Home grown food sufficient for less than 6 months

Given the nature of this approach, conventional wealth ranking was carried out simultaneously in 3 villages to act as a control. A comparison was then made between the group compositions resulting from the two approaches.

Within each stratum, a random sample of households was drawn in proportion to the size of the group. Gender differences were accounted for by interviewing males and females alternately. Difficulties associated with interviewing women in a society where traditionally, man is the head of the household, have been widely discussed. It was decided at the outset of the survey to aim for 50% female resondents. However in anticipation of difficulties, a lower limit of 35 % female participants was set.

2.4 Data analysis

The responses to the questionnaire were checked and edited before being processed by computer. The data set was scanned for range and consistency and was then analsed using the Statistics Package for Social Sciences (SPSS).

Initially, simple frequency tables and cross tabulations were made to assess the structure of the data. Following this, the first step was an examination of the data on a village basis, focusing on differences both within and between villages according to the independent variables of farmer category, gender and ethnicity. The second step involved a combined analysis of data and the testing of hypotheses relating to specific factors affecting soil fertility. To test the influence of some factors, villages were grouped according to similarities such as altitude, accessibility, land type, rainfall, soil type, Lastly analysis was carried out to assess the associations and relationships between factors and their influence on soil fertility.

Qualitative data from group interviews and PRA exercises were integrated into the findings of the above analysis. They served to support and elaborate on the main findings of the household survey. On-going reference to the resource maps aided interpretation of the findings.

2.5 Quality of the data set

Problems emerged with the design of the questionnaire, which was somewhat biased towards middle and low altitudes and did not address the different situation in high altitudes, especially with regard to the unique soil fertility management practices of these areas.

The method of using food sufficiency status to group households according to similarities in resource status showed mixed results (Table.2.1).

Table 2.1 Comparison of two wealth ranking methods using paired t test.

Village	t value	Criteria used to group households with method 2
Chambas	0.01	
Bahrphirke	0.19	
Talbari	0.01	

The results suggest that categorisation of farmers by food sufficiency status may be a rapid and effective way of classifiying farmers into wealth categories and at the same time enables direct comparisons of households across a large area. Thus for this study it was accepted that grouping households in this way, provided a workable base for considering differences in perceptions of households of different socioeconmic stautus.

3 REVIEW OF SOIL FERTILITY ISSUES

While discussions on soil fertility have a high profile in Nepal, there are little historical quantitative data to support the leading argument that, soil fertility is rapidly declining and threatening the sustainability of the hill farming system. Most work has focused on documenting the land use degradation and deforestation processes that formed the basis for the Himalayan crisis theory (Ives and Messerli, 1989). The current fertility status of soils is unclear and there is little understanding of the significance of any soil fertility decline. This is based, at least in part, on ignorance of soil characteristics and properties and the current nutrient status of soils. Statements such as 'low and declining soil fertility' have little meaning without a reference point.

3.1 Soil classification and characterisation

This section summarises the information available on the soils found in the LARC RCA. In the hills, soils are subject to considerable variation in texture, depth, colour and clay mineralogy over short distances. The problems of applying scientific classifications developed in other areas of the world to the hills are wide ranging (LRMP, 1986; Turton, 1993). They are not necessarily appropriate in the hills of Nepal where, topographic and anthropogenic factors have heavily influenced the formation of soils. It is now widely recognised that the hill farmers of Nepal have their own more appropriate soil classification systems (Turton, 1994; Tamang, 1991,1992; Subedi *et al.*, 1989; Staphit *et al.*, 1988) and researchers and scientists are starting to use these systems to facilitate communication between farmers and themselves (Joshi *et al*, 1994ab).

3.1.1 Researchers' perceptions

The Land Resources Mapping Project (LRMP, 1986) classified the majority of the cultivated soils in the RCA as Entisols, Alfisols, and Inceptisols (USDA soil taxonomy), with the majority of agricultural soils belonging to the latter order (Table 3.1).

Inceptisols are the most common soil order at all altitudes. Within this order, soils on *bari* land can be classified as Ustochrepts and Dystochrepts, the former distinguished by their pale coloured surface horizon and higher base saturation. The soils have a strong colluvial component, are usually moderately deep, coarse loamy to loamy textured and well drained. As altitude increases, Haplumbrepts become more common, and are darker with a higher organic matter content.

Khet soils fall into the two orders of Inceptisols and Entisols. On steeper slopes, *khet* soils are usually Ustochrepts, with Entisols being found in river valleys, where frequent deposition of sediment has occured. Here, Ustifluvents are distinguished by the lack of diagnostic horizons and are mostly coarse textured with a high gravel content, a result of ongoing deposition of river sediments.

Table 3.1 Common soils of the RCA

Order	Sub-Order	Great Group	Land unit[1]	Location	Parent Material	Dominant texture	Notes
Entisols	Fluvents Orthents	Ustifluvents Ustorthents	12,9,13	middle/high mountain (*khet*) high mountain (*bari*)	Active alluvium, landslides	Fragmental sandy rubbly loam	Flood susceptible 35 cm to hard rock
Inceptisols	Ochrepts Umprebts	Dystochrepts Ustochrepts Haplumbrepts	8,11,12,14 8,10,11,12,13,14 11,12,14,14	middle/high mountain (*bari/khet*) middle/high mountain (*bari/khet*) high/middle mountain (*bari*)	Argillaceous rocks; phyllite, gneiss, quartzite	loam/sandy loam sandy loam rubbly loam	mod.drained well drained usually under forest/grazing
Alfisols	Ustalfs	Rhodustsalfs Haplustalfs	10,10	Ancient river terraces (*Tar bari*)	Ancient alluvium, phyllite	clay loam loam/clay loam	*rato mato*

Source: Adapted from LRMP (1986)

1 Land unit Land units are defined by LRMP (1986) as mappable land surfaces, differentiated by position, slope, surface dissection and flooding frequency and by soil characteristics such as drainage, depth, texture, profile development and pH. The numbers refer to the following land units:

Siwalik region

8 Steeply to very steeply sloping hilly and mountainous terrain

Middle mountains

9 Alluvial plains and fans (river channel, alluvial plains, alluvial fans)

10 Ancient lake and river terraces (non-dissected, dissected)

11 moderately to steeply sloping mountainous terrain (<30 degrees)

12 Steeply to very steeply sloping mountainous terrain (>30 degrees)

High mountain region

13 Alluvial plains and fans (active alluvial plain, recent alluvial plain, fans)

14 Post glaciated mountainous terrain below upper altitudinal limit of arable agriculture)

Where Entisols are imperfectly drained, they are classified as Fluvaquents. LRMP (1986) concluded that *khet* soils were not easily classified under soil taxonomy and further characterisation was essential.

The more intense weathering regimes and stable landscapes of ancient river terraces at low altitudes (*tars*), result in heavier textured soils of significant pedogenetic development with a high clay content in the B horizon (Alfisols). These soils are known locally as *rato mato.* The problems associated by farmers with their cultivation are related to their poor physical properties and tendency to surface crusting. Maintenance of organic matter levels is essential, both for preserving soil physical properties and increasing the CEC, which is often low due to the dominant kaolinite mineralogy.

3.1.2 Farmers' perception

Various criteria are considered by farmers to classify soils, with colour and texture being the primary differentiating criteria. *Kalo* (black), *rato* (red), *seto* (white), *yellow (pahelo)* and *khairo* (brown) soils are the most commonly encountered soils. Generally, darker soils have a higher organic matter content and are regarded as more fertile (Tamang, 1992). Texture descriptions used by farmers bear a strong resemblance those used by soil scientists. There is considerable regional variation in the terminology used by farmers to describe soil texture (Table 3.2). Texture is also employed as a secondary differentiating criteria for soils classified by colour.

Table 3.2 The most common textures used by farmers to classify soils

Texture	Local name
Stony	*gagreni, dhungeni, dungay*
Coarse	*phusro, phuko*
Sandy	*balaute, baluwa, burbure, baluwaney*
Loam	*dumuth, pango*
Clay	*chimtay,*
Silty	*kamaro, lisailo*

Sources: Tamang (1991, 1992), Staphit (1988) , Sherchan *et al.,* 1991, Turton *et al.,* 1994

Associated with each soil type is a detailed knowledge of soil properties relating to management. These properties include drainage and water holding characteristics, depth of profile, organic matter content and consistency.

There is wide variability in the names given to soils and properties associated with different soil types which this makes comparisons across different areas difficult. For example, a red soil in one district may have different properties to those in another district. Information relating to indigenous classification systems remains scattered among different reports, however, an attempt is made here to bring together some information regarding those soils most commonly encountered.

Kalo mato is generally regarded as the most fertile soil. It is loamy textured, moderately deep, has a relatively high organic matter content, with a good water holding capacity. It is found on both *khet* and *bari* land and well suited to all major crops. *Dumuth mato* is also regarded favourably, with a good structure and being easy to work. *Rato mato* is found on rainfed land in *tar* areas or gentle slopes in the hills. It has a high clay content in the subsoil and is known as *chimaty rato mato*. Where erosion has occurred, the surface soil may be heavily eroded and coarse textured. In this case, the soil is known as *phusro rato mato* or *kahahre rato mato*. *Chimtay rato mato* presents many problems to cultivation being difficult to manage, requiring more moisture and fertiliser for crop production and is rated less favourably by farmers. Maize, millet and ginger grow well on red soils. *Kamare mato* has a poor structure, low organic matter content, is light coloured and often poorly drained. It is often found on *khet* land but also occurs on *bari* land. *Balaute mato* is coarse textured, well drained and found on steeper slopes or alluvial terraces.

3.2 Current soil fertility status

This section attempts to establish a baseline from which assessment of soil fertility status and trends can be placed into context. The discussion is based on a compilation of soil analysis data from the LARC crop cut survey of 1991/92/93 (Tuladhar, 1994) and samples collected during this study. The data relates primarily to the ECA, although some samples were collected from the RCA. The data set covers a wide range of soil types, with over 20 local soil names represented, although there may be some degree of overlap arising from regional variations in terminology. Unfortunately, the samples were collected at different times of the cropping season and analysis was limited to total Nitrogen (N), available Phosphorous (P), exchangeable Pottasium (K), Organic Carbon (OC) and pH. No aggregate data can fully capture the diversity and complexity of soil characteristics in Nepal and the following discussions must be viewed in this context.

3.2.1 General status of soil fertility

The complex lithology and extreme range of biophysical characteristics across the middle hills are reflected in the wide range of values for all soil properties (Table 3.3).

Table 3.3 Summary of soil properties

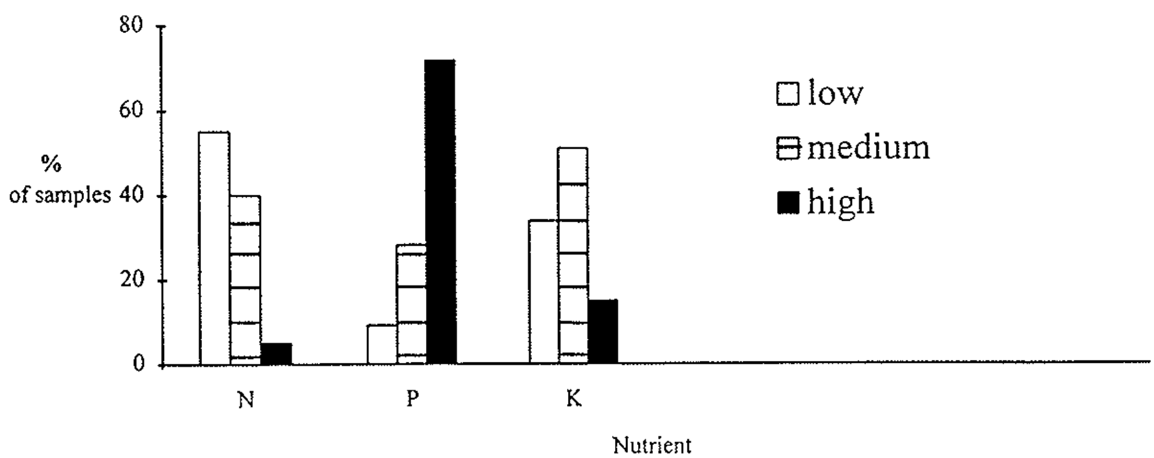
Soil property	mean n=596	rating*	standard deviation	minimum	maximum
pH (in H_2O)	5.6	medium acid	0.55	4.1	7.6
Organic carbon (%)	2.94	low	1.08	0.2	7.0
C/N ratio	12.78	-	4.81	2.4	56.5
Total N (%)	0.25	medium	0.11		0.8
Available P (ppm)	153	high	208.69	1.3	1698
Exchangeable K (me/100g)	0.37	medium	0.39	0.04	4.64

* refers to values given in Landon (1984), see Appendix 7.

Most soil pH values fell within the range of 5 to 6, indicating strongly acid to medium acid conditions, although not as serious as those reported from other middle hill areas (Schreier *et al.*, 1994). Concerns over soil acidification have featured prominently in recent times (Shah *et al.*, 1991) and are related to high leaching rates, the widespread occurrence of acid forming parent material and the increasing use of acid producing chemical fertilisers.

The wide variability in NPK values means that a frequency distribution is a more effective way of assessing nutrient status (Figure 3.1).

Figure 3.1 NPK levels in the RCA



Nitrogen has been reported as the most limiting nutrient to crop production in Nepal (LRMP, 1986) and 85% of samples were low to medium in total N. C/N ratios are relatively high, more than 10 for most soils, which maybe due to the traditional practice of applying semi-decomposed FYM/compost (*bari* land) and slow rates of decompostion due to anaerobic conditions (*khet* land) and/or cooler temperatures (mid/high altitudes). These ratios may indicate serious N deficiencies, given the reported low/medium total N levels of soils.

Phosphorous is the second most important soil nutrient limiting crop production in Nepal (LRMP, 1986). A large variation in available P levels across the surveyed area is evident, but frequency analysis shows that for the majority of soils, the levels are in fact medium to high. However, such conclusions are tentative given the difficulties of interpreting high P values (Landon, 1991).

Levels of Potassium have previously not attracted the concerns of soil scientists due to its relatively widespread occurrence in the bedrock (in the form of mica). However, Figure 3.1 shows that over 60% of values are located in the range of 0.1 to 0.3 me/100g, indicating low to medium exchangeable K status.

3.2.2 Comparison of *khet* and *bari* land

Differences in cropping patterns, management practices and soil processes between the two land types have an affect on the soil properties (Table 3.4).

Table 3.4 Mean values of soil properties of *khet* and *bari*

Soil property	*khet* land (n=249)	*bari* land (n=340)	SE of difference
pH (in H_2O)	5.54	5.64	0.045
Organic Carbon (%)	2.59	3.20	0.085
C/N ratio	12.77	12.78	0.409
Total N (%) *	0.22	0.27	0.009
Available P (ppm) *	122.87	174.34	16.128
Exchangeable K * (me/100g)	0.28	0.43	0.032

* t-test significant at $p<0.05$

Bari soils have significantly higher ($p<0.05$) levels of OC, total N, available P and exchangeable K. This equates with farmers' assessments that *bari* land is usually more fertile than *khet* land. Nutrient losses through erosion particularly on *bari* land and gains from deposition, particularly on *khet* land, have frequently featured as important processess affecting the soil fertility dynamics/equilibrium in the middle hills of Nepal. The implicit conclusion is that *bari* soils experience declining soil fertility and *khet* soils increasing/stable soil fertility. However, the results (Table 3.3) do not support this and it is suggested that the importance and relevance of crop intensities and manuring practices in determining soil fertility status need further study. For example, the crop cut survey and associated data suggest that *bari* soils are relatively fertile because they receive the majority of applied FYM/compost (typically 20-50 t/ha/yr) (Tuladhar, 1994).

The low total N and exchangeable K status of *khet* soils may be related to the highly soluble nature of these nutrients. In addition, low rates of FYM/compost application together with increasing cropping intensities, particularly at low altitudes, may have led to mining of soil nutrients on *khet* land. The increasing use of chemical fertilisers as a top dressing on low altitude *khet* land, does not act as a direct substitute for FYM/compost due to potential high losses from denitrification. There is also the likelihood of high losses of N occurring under the alternate wetting and drying conditions of *khet* land (farmers have little control over irrigation water supply), which result in high redox potentials.

These findings differ slightly from those of Schreier *et al.* (1994) in a watershed study in the middle mountains of Nepal. They examined differences between land uses, whilst holding topography, micro climate conditions and parent materials variables constant. While levels of N, OC and K were found to be higher on *bari* land, P levels were higher on *khet* land. In addition, more detailed soil analysis (BS, Ca, Mg, CBD, Fe) suggested that overall nutrient status is better in *khet* land. This they attributed to nutrient additions from irrigation water, supplemented by nitrogen addition by blue-green algal fixation, and reducing conditions which slow organic matter decomposition. The high use of chemical fertilisers in their study area and the predominance of red soils may account for the differences.

3.2.3 Comparison of different altitudes

Altitude or more specifically, air temperature and soil mosisture regime, has an important influence on soil development. There is a strong correlation of soil properties with altitude (Table 3.5). Soils at higher altitudes are usually more acidic as a result of the high rainfall and stronger leaching conditions.

Table 3.5 Variation in soil properties with altitude

	Low (<1200m)		Mid (1200-1600m)		High (>1600m)	
	n=162		n=170		n=162	
	mean	SEM	mean	SEM	mean	SEM
pH (in H2O)[c]	5.58	0.04	5.50	0.04	5.81	0.04
OC (%)[a,b]	2.18	0.08	3.20	0.07	3.33	0.08
Total N (%)[a,b,c]	0.19	0.01	0.27	0.01	0.29	0.01
Av. P (ppm)[a,c]	112	15.20	192	16.97	130.37	13.30

[a] t-test significant at $p<0.01$ between low and mid altitudes

[b] t-test significant at $p<0.01$ between low and high altitudes

[c] t-test significant at $p<0.01$ between mid and high altitudes

Overall, with respect to macronutrient and OC status, soils are more fertile at high altitude. This is significant between all altitude groups for total N, although the effect is less clear for available P, OC and pH. On *bari* land, this may reflect the higher rates of FYM/compost applications, in-situ manuring practices and lower decomposition rates at higher altitudes. On *khet* land, negligible erosion rates and the receipt of sediment laden irrigation waters meant that in the past a single rice based cropping pattern was sustainable without management inputs and fertilising resources were concentrated on *bari* lands. However, increasing cropping intensities on *khet* land at lower altitudes may be leading to mining of nutrients.

The area of *khet* land decreases with altitude, whereas the importance of *bari* land in the farming system increases and cultivated areas of occur up to 3000m. The variables altitude and land type are thus inter-related. Analysis of variance shows that the effect of altitude on soil properties does not vary with land type. Differences in altitude are significant ($p<0.05$) on soil characteristics being mainly correlated with total N and OC. However, when controlling for altitude, the effect of land type is not significant and therefore altitude is the primary factor influencing soil properties (Table 3.5).

3.2.4 Comparison of different soils

The third major source of variation in properties is that between different soil types. Analysis was done using the local soil classification system as a base. This includes a consideration of soil characteristics associated with management and a relative assessment of soil fertility status. This assessment is based on knowledge of the FYM/compost requirements of individual soils. The two most commonly named soils in the survey were *kalo mato* and *rato mato,* with the former invariably ranked as the most fertile soil. *Rato mato* has a higher clay content and requires more FYM/compost to improve its physical properties and fertility status. *Kalo mato* is usually loamy textured, well drained, moderately deep and requires less FYM/compost than other soils. A comparison of mean values of the two soils reveals the scientific basis of farmers' knowledge (Table 3.6).

Table 3.6 Mean values of parameters for *kalo* and *rato mato*

Soil property	*kalo mato* n=159		*rato mato* n=75	
	mean	SEM	mean	SEM
pH	5.66	0.04	5.55	0.07
OC*	3.08	0.08	2.89	0.11
N*	0.27	0.01	0.22	0.01
P*	183.61	18.59	101.91	19.32

* t-test significant at p<0.05

Organic carbon, total N and available P levels are all lower in *rato mato*. Elsewhere in Nepal, the low P content of red soils is associated with large concentrations of hydrous oxides of Fe, Al and Mn which adsorb P making it unavailable (Shah and Schreier, 1991; Turton *et al.*, 1994). However, *rato mato* have a higher clay content and with adequate precipitation and addition of organic matter are potentially productive.

3.2.5 Important associations of variables

Not surprisingly, significant correlations ($p<0.05$) occur between many soil variables (Table 3.7).

Table 3.7 Matrix of significantly correlated soil variables

	pH	OC	N	P
pH				
OC	-0.20			
N		0.63		
P		0.21	0.13	
K	0.22	0.19	0.16	0.18

* p<0.05

A simpler understanding of these correlations can be achieved using factor analysis. This is a method of condensing a number of variables into a smaller number of underlying constructs or *factors* and obtaining a factor score for each of the variables. These factor scores indicate which variables are most closely associated with each other and weighs those variables heavily in calculating factor scores. In order to simplify the factors so that each variable loads highly on only one factor, the factors were rotated. As it is likely that the factors will be correlated with each other, an oblique rotation was carried out (Table 3.8).

Table 3.8 Oblique rotation factor matrix of soil variables

Variables	Factor 1	Factor 2	Factor 3	communality
altitude	0.53	0.15	0.68	0.76
OC	0.86	-0.25	-0.08	0.81
N	0.82	-0.18	0.08	0.71
P	0.34	0.35	-0.70	0.72
K	0.34	0.69	-0.25	0.65
pH	-0.08	0.80	0.40	0.79
% of variance	32.2	22.4	19.6	-

derived from a 'computer' programme (principal component analysis)

This simplifies the variables to 3 factors. Maximum variability is accounted for by factor 1 where OC, total N and altitude are heavily loaded, with exchangeable K and pH of secondary importance. Available P and exchangeable K are highly loaded on Factor 2, which accounts for 22.4% of the variance underlying all variables. In Factor 3, altitude and available P are the most heavily loaded variables. The close assocation of all variables with each other is illustrated by the communality statistic which indicates the proportion of variance in each variable explained by the 3 factors. If we ignore the close association of total N with OC, it can be concluded that maximum variation is accounted for by OC, with altitude, pH and exchangeable K being of secondary importance.

A similar analysis was done considering *khet* and *bari* land separately. Altitude becomes less important in explaining variability due to its close association with land type, but total N and OC remain important for *bari* land. Factor analysis is less successful for *khet* land accounting for only 59 % of variation, reflecting the greater number of factors influencing the nutrient system of irrigated land. In addition to OC and total N, pH is also important in explaining variability in *khet* land.

These results emphasise the importance of OC as a key determinenat of soil properties. Also of importance is its role in soil productivity through its interactions with soil chemical and physical properties in relation to nutrient release, cation exchange and soil structure. These results stress the critical role of organic matter and emphasise the need for an improved understanding of farmers' FYM/compost application practices. The importance of this relationship is further illustrated by Tuladhar (1994), who using factor analysis for different crop soils, found the soil organic fraction to be an important underlying dimension explaining variation in crop yield

The following conclusions are drawn from the above discussion:

- The overall soil fertility conditions in the surveyed area are poor with respect to total N and exchangeable K
- Altitude accounts for the largest proportion of the variation in other soil parameters
- Significant differences in NPK levels suggest that *khet* land has relatively lower fertility levels
- Farmers' knowledge of soil types and management is strongly related to the underlying chemical properties of the soil
- A large proportion of variation in soil properties can be accounted for by variations in organic carbon. This emphasises the important role of FYM/compost as a balanced nutrient source
- The situation concerning soil fertility decline is unclear but significant differences in current nutrient levels across altitudes suggest that the problem may be more critical at low altitude

3.3 Soil fertility decline

Whilst it is clear that the issue of soil fertility is an important one, the lack of a historical data base hinders quantitative assessment of changes in soil fertility status. In addition, quantification of the actual inputs and outputs of the farming system has not been carried out. A comparison of fertility status of forest and cultivated soils suggests that farmer management has acted to increase the fertility status of soil far beyond their inherent levels (Schmidt *et al.*, 1993). Human activity has resulted in a relative concentration of nutrients on cultivated lands, resulting in an increase in soil fertility from inherent levels. Any change in fertility status may reflect a change in mans' ability to maintain this transfer of nutrients from forest to farm. The following issues figure prominently in recent reports and discussions of declining soil fertility.

3.3.1 Soil erosion

It is now generally acknowledged that the bulk of soil erosion in the Himalaya is attributable to the unparalleled geomorphic activity in the region, high rainfall, highly erodable soils and parent material (Carson, 1985). Stream loads of eroded material are high, but it is estimated that less than 1% of this material originates from cultivated land. However, accelerated man-induced erosion is a contributing factor to any decline in soil fertility on *bari* land. At Pakhribas Agricultural Centre, average soil loss (mean of 3 years), for maize/millet farmers' cultivation practice was 35t/ha/yr. The associated loss of nutrients was 664 kg/ha organic matter, 55.33 kg/ha Total N, 2.53 kg/ha P and 7.88 kg/ha available K (Sherchan and Gurung, 1994). However, such statistics only consider one side of the equation. A rough calculation suggests that soil fertility levels of well-managed bench terraces may be maintained under farmers' practices (Table 3.9).

Table 3.9 Annual nutrient balance of *bari* land under maize/millet system

	N	P	K
Nutrients removed by crop harvest of 1600/1577 kg/ha[a]	80	60	60
Nutrient loss by erosion kg/ha[b]	55	2.5	7.9
Nutrient input from FYM/compost at 15t/ha/yr[c]	150	150	100
Balance	+15	+87.5	+32.1

[a] Riley, 1991

[b] Sherchan and Gurung, 1994

[c] based on FYM/compost content of 0.75% N, 0.75% P, 0.5% K as compiled from laboratory results

3.3.2 Declining Crop Yields

National statistics report a decline in yields of some major staple crops (maize, millet, barley) in the hills over the period 1975 to 1991 (Table 3.10), although the validity of such statistics has been questioned. Yields of wheat and paddy have risen steadily mainly due to the adoption of improved varieities.

Table 3.10 Productivity trend (kg/ha) of major cereals in Nepal

Year	Paddy	Maize	Millet	Wheat	Barley
1970/71	1949	1869	1126	846	924
1975/76	2074	1653	1136	1178	932
1980/81	1932	1624	998	1218	863
1985/86	2016	1421	913	1239	799
1989/90	2366	1599	1162	1415	927

Source: HMGN, 1990

3.3.3 Soil Degradation

Broadly speaking, a decline in soil fertility can be attributed to a change in the physical and/or chemical properties of the soil, which in turn reflects a change in the balance between inputs and outputs in the nutrient system. It is important to qualify the nature of any fertility decline in the Nepal hill context. Many farmers who have used chemical fertiliser complain of a deterioration in soil physical properties. This can be related (at least on *bari* land) to a decrease in FYM/compost application rates (Subedi, 1992; Turton *et al.*, 1994). The presence of organic matter plays a critical role in improving both soil structure and the nutrient holding capacity of the soil. Declines in soil fertility may also be associated with the incorrect use of chemical fertilisers, which have led to nutrient imbalances in the soil.

There is increasing concern over acidification of soils. Shah *et al.* (1991) suggest that in some areas, recent declines in organic matter levels have resulted in a build up of acidity and aluminium toxicity and the soil is in danger of losing its buffering capacity. The situation is further compounded by acid producing chemical fertilisers (especially ammoniacal sources such as ammonium sulphate and urea that produce hydrogen ions during nitrification).

3.4 Factors affecting soil fertility in the hills

The literature suggests a large number of factors contribute to changes in soil fertility and these are summarised in diagrammatic form in Figures 3.3 and 3.4. The most frequently mentioned include, recent changes in policy and institutional environments such as the construction of roads, expansion of community forestry programs, changes in land tenure systems and fertiliser supply policies are all influencing the management strategies of farmers and consequently the fertility status of the soil.

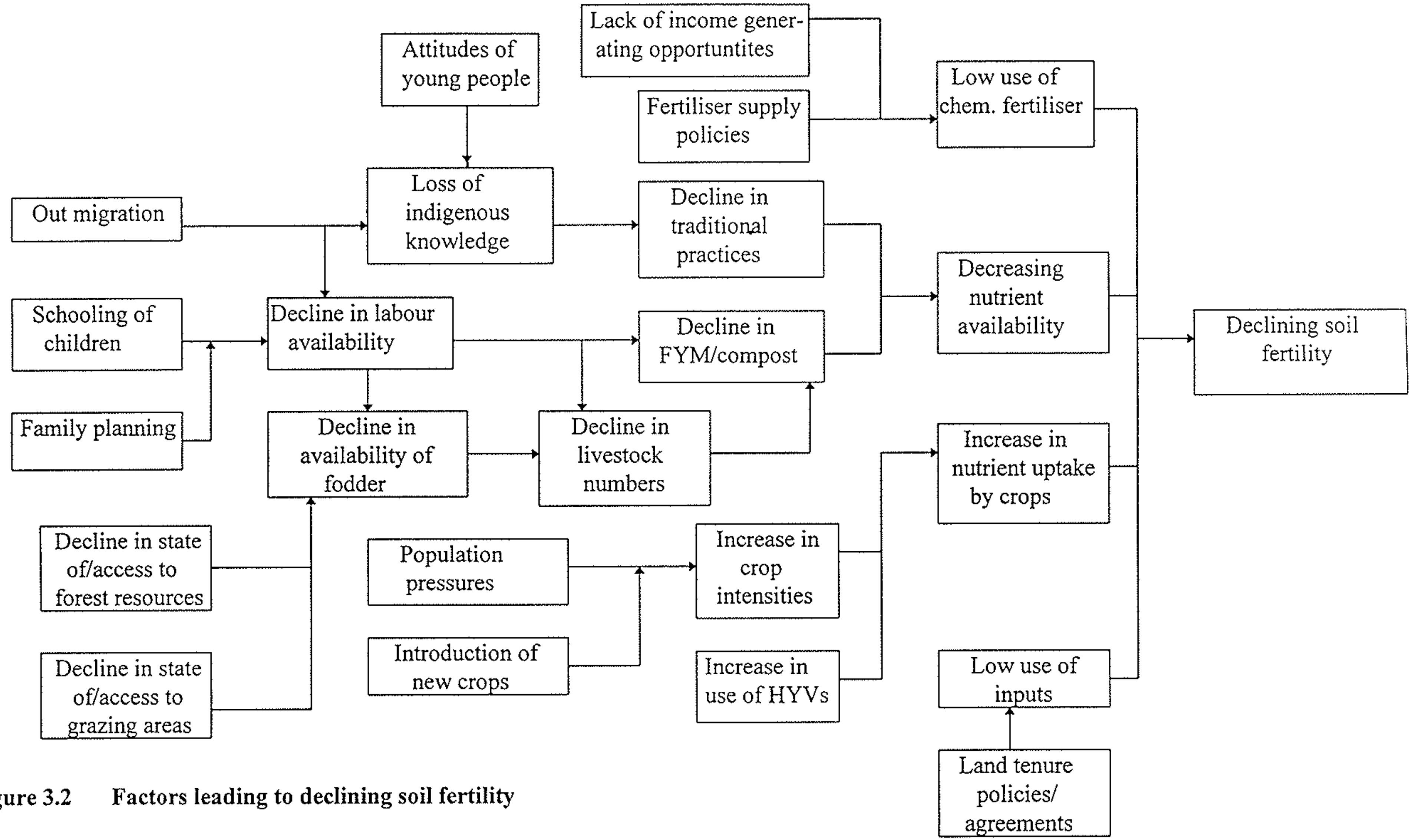


Figure 3.2 Factors leading to declining soil fertility

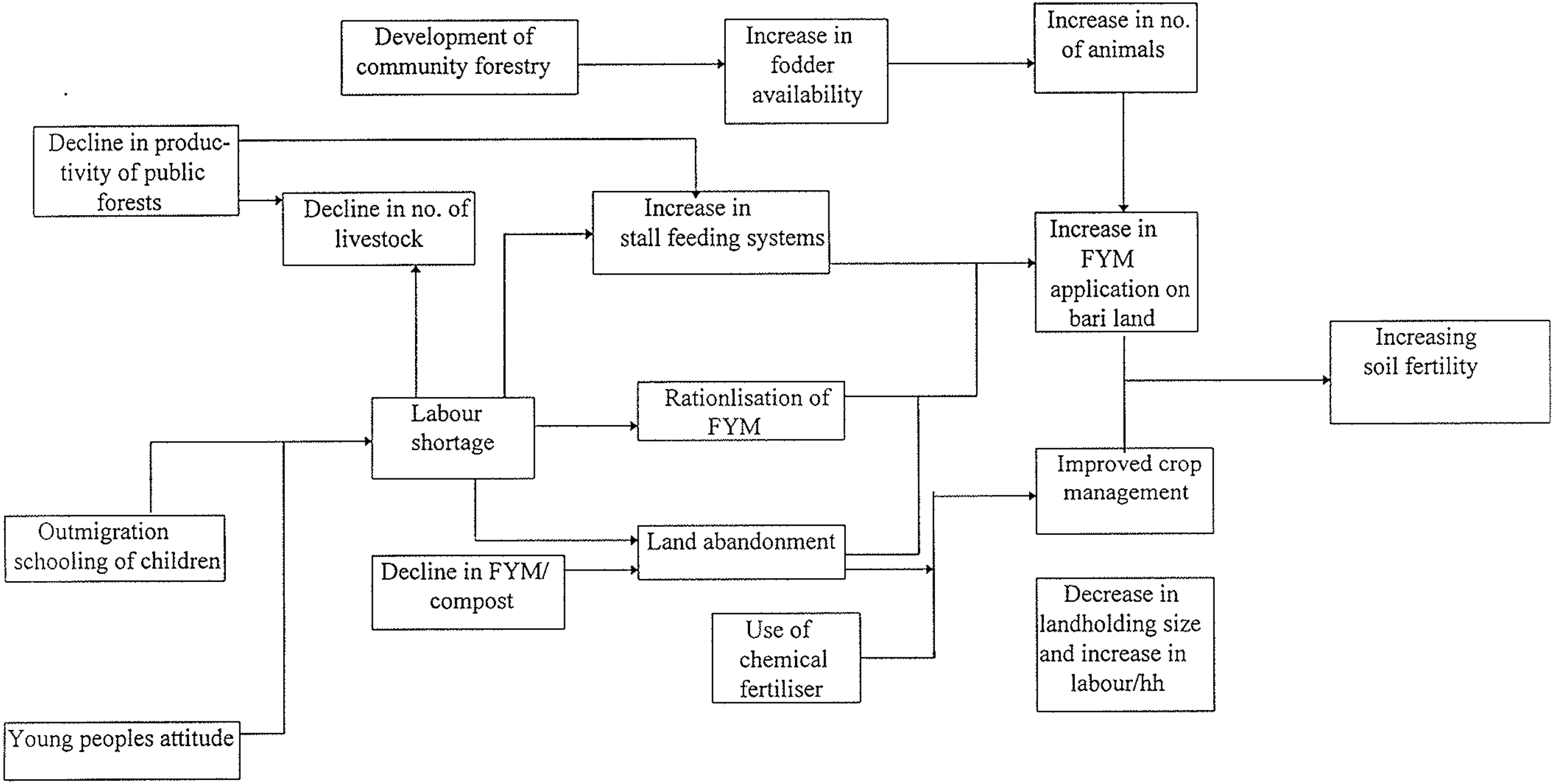


Figure 3.3 Factors leading to increasing soil fertility

4 A FRAMEWORK FOR RESEARCH

In the past, research on soil fertility has been hampered by the lack of an appropriate framework within which the affect of different factors on soil fertility can be analysed. One of the primary objectives of this study was to develop such a framework to enable the identification and understanding of key factors affecting soil fertility in the hills. A heirarchial approach to the development of a framework based on the seven focal points identified in the first phase was employed (Figure 4.1).

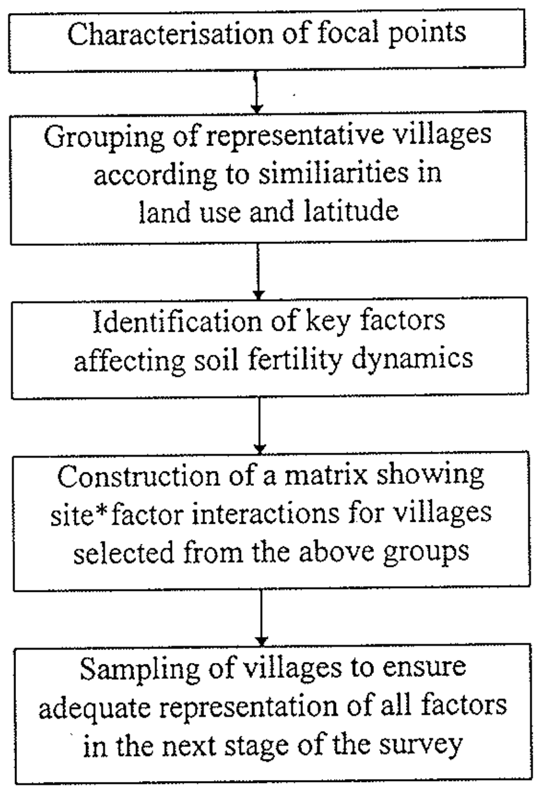


Figure 4.1 The development of a framework for research

4.1 Characterisation of focal points

A total of twenty eight villages located across the seven focal points were visited from October to December 1994 (Table 4.1). A detailed report of the visit to each focal point is contained in Appendix 8.

Table 4.1 **Villages visited during October to December 1994**

Focal point	District	Village/VDC/ward number
1.Arman/Baranja/ Dhamilapani	Myagdi	Neta/Arman/7 Arman/Arman/6 Kimchaur/Arman/
2.Marsyangdi river basin	Tanahun	Baradi/Aboo Khairani/2 Satrasayaphat/Aboo Khairani/1 Chambas/Bhanu/8
	Gorkha	Barh Phirke/Palungtar/7 Dudatar/Dhuwakot/1,3
	Lamjung	Phedikuna/Bhoteodar/9 Khaltegaun/Archal Bat/5,6,8 Ghoretar/Tarkughat/8 Bhaisi khola/Tarkughat 9
3.Tansen area	Palpa	Naya Tola/Kusum Khola/9 Bowa Pokhara Thuk/Bowa Pokhara/1 Deurali/Deurali/3
4.Dhampus, Tanchok, Landruk	Kaski	Kotgaun/Dhampus/6 Majhgaon/Lumle/1,2,3 Landruk/Lumle/9
5.Kurkhot,Pang, Durlung	Parbat	Chanaute/Durlung/7 Kapalchaur/Durlung/6,9 Kurkhot/Kurkhot/1,2,5 Pang/Pang/1,2
6.Baidi area	Tanahun	Talbari/Baidi/5 Khalte/Baidi/4 Kota Gau/Kotabesi/2
7.Pokhara-Seti river valley	Kaski	Hyanja/Hyanja/9 Vijayapur/Rakhi Sainik/Vasti/Sisuwa/3

4.1.1 Focal point 1: Arman, Baranja area of Myagdi district

This area is located in the middle/high mountain region (1300-2000m), a days walk up the Myagdi valley from the district head quarters of Beni, which is itself a one day walk from the nearest road head at Baglung. Steeper slopes are dominated by extensive forests and most cultivated land occurs on moderate to steep slopes (LRMP, 1986).

Four soil types are found; *kalo mato, rato mato, dhungen kalo mato* and *kamero mato. Dhungen mato* is most common and is shallow with a surface soil stone content of about 40%. *Kalo mato* is found on *khet* and is most preferred, followed by *rato mato. Kamero mato* covers a small area of *khet* area and is of poor fertility.

Bari is the most important land use in all three villages and covers 75-85% of total cultivated area. Overall crop production has decreased. Maize relayed with millet is the predominant cropping pattern in Neta and Arman, whereas in Kimchor these two crops are generally grown separately. Other important crops are potato, buckwheat, barley and amaranthus. Cropping intensity on *khet* is lower with one (Kimchor) or two (Neta, Arman) crops, either maize-rice or rice-wheat a year. Improved spring maize varieties and chemical fertilisers have increased production in some areas. Otherwise cropping patterns in this area have changed little over the last 20 years.

Low and erratic rainfall is regarded as the major factor affecting crop production. This has served to discount the role of soil fertility as a constraint. However, soil fertility is reported to be declining. FYM/compost forms the basis of crop nutrition, with most going to *bari* land. Therefore a second crop (spring maize) in *khet* necessitates application of chemical fertiliser. However, not surprisingly, these villages have little access to the chemical fertilisers. Decline in manure output resulting from reduced capacity to keep adequate livestock number is evident. However in Neta, FYM/compost output is reported to increase by up to three folds resulting from fewer, but better managed livestock under the stall fed system and use of leaf litter. In-situ manuring is now limited to Kimchor. Top soil erosion which was linked to forest litter collection, declining regeneration process and deforestation and accelerated runoff is recognised as a problem in Kimchor.

The average number of cow and buffalo per household ranges from four to six. The cattle population has decreased and emphasis has shifted to buffalo which are kept under stall-fed system.. All forests are being maintained through traditional regulations, but are deteriorating. Dependence on natural forest for firewood and leaf litter is high (up to 100%) but dependence for fodder has been restricted through local regulations.

All three villages exist primarily on subsistence farming and food sufficiency status of the households across the area is low. Kimchor is relatively better off because of its potential to export seed potato, and also crops are less prone failure due to drought due to its higher altitude. The other two villages have very little income generating opportunities. Magar is the dominant ethnic group in the area, although Arman itself is predominantly Bhramin/Chetri.

4.1.2 Focal point 2: Marsyangdi river basin

This area covers the districts of Tanahun, Gorkha and Lamjung. It is a low altitude area (385-760m) along the Marsyangdi river and its tributaries. There are two dominant land systems in the area, namely *tar* land and moderate sloping mountainous terrain and wide variation in land use patterns and farming systems are evident.

In *tar* areas, *bari* land is predominant. The soils are mainly highly weathered reddish-brown to reddish yellow, deep, sandy clay loam/clay loam in texture, classified as Alfisols (USDA) and known locally as *rato mato*. By definition the soils are quite fertile, however they are lowly rated by farmers. This is probably because of their poor physical properties (high clay content and weak structure) which make management difficult. Usually two crops per year are grown, with *ghaiya* (upland rice) the dominant summer crop. Legumes (blackgram, soybean) are a common winter crop. On more fertile land or that with a higher moisture availability, maize is cultivated.

On moderately sloping land in Lamjung district, *khet* is the dominant land use. Recent years have seen an intensification of the cropping patterns and now three crops a year are grown. Double rice cropping followed by a winter cereal or vegetables is the most common cropping pattern on land with asssured irrigation facilities whilst maize -rice-wheat pattern is more common where irrigation facilites are more limited.

In all except two villages, total crop production has increased mainly due to intensified cropping patterns on *khet* land, use of new varieties, increased use of chemical fertilisers and improved crop husbandry. However, *tar* areas have benefited to a limited extent as they have only small proportions of *khet* land. The general trend of soil fertility was reported to be declining with *bari* land more severely affected due to declining availability of FYM/compost and diversion of fertilising resources to the more productive *khet* land. Farmers, throughout the area, place more emphasis on *khet* management, even when it forms only a small proportion of total land area. FYM/compost application is the most important fertility management practice on *bari*, accounting for 80-100% of nutrient contribution. However, chemical fertilisers replace FYM/compost as the dominant nutrient source on *khet* land.

Livestock numbers are low (One to three large ruminants/household) and are declining in eight out of the nine visited villages. The reason can be traced back to the effects of increasing cropping intensity. This has led to a decrease in winter grazing area and labour availability. Stall feeding is now the most popular management practice, but no increase in FYM/compost availability was reported. Government forest is the most important source for fodder and fuel in all villages, except for Lamjung district where fodder needs are met from private land. Farmers are responding to shortages in fodder and fuel by planting trees on private land throughout the area. Most villages have community forests.

Villages are mainly mixed communities of Bhramin/Chetris, Magar, Gurung and occupational castes. A feature of this area is increasing in-migration of people from remote parts of Gorkha and Lamjung in search of better living conditions. The major constraints of farmers are the lack of irrigation facilities (especially in *tar* areas). Availability of FYM/compost and chemical fertilisers ranks only third or fourth amongst farmer identified problems.

4.1.3 Focal point 3: Tansen area of Palpa district

This focal point is located in the middle mountain region (1100-1600m) with good road access. The farming system in the area is dominated by outward sloping *bari* land cultivation, only half (on average) the households have access to small areas (<0.05 ha) of *khet* land. Forest areas and grazing land occur on steeper slopes, and high rates of degradation and erosion were observed. Large areas of *Khar* grass are also present. *Rato mato* are by far the most common soil type in the area but these are coarser in texture than those in other areas and were classified as Inceptisols by LRMP (1986). They are generally coarse textured/loamy soils with a high stone content and commonly found on steep outward sloping terraces. Their low clay/silt content is indicative of high rates of surface erosion. Red soils with a higher clay content (*rato chimtaylo mato*) are found on more gentle slopes.

Crop intensities are relatively low and in most places, only summer crop production is guaranteed. Moisture availability is the most important constraint. The cropping system is dominated by maize, which is usually inter-cropped with different legumes (rice bean, soybean, horsegram). Ginger cultivation is increasing in importance and is grown as a mixed crop with maize. The most striking feature of the cropping system is the extent of mixed cropping. It is common to see large fields subdivided and cultivated with different crops. Such arrangements may be influenced by moisture and fertility gradients, which are a prominent feature of large outward sloping fields. Important changes in the cropping system have been the decline in millet (and to a lesser extent barley) cultivation, due to declining moisture availability, changing tastes, and high labour requirements.

Agroforestry is a prominent feature of the farming system. Planting of fruit (banana and citrus) and fodder trees on terrace risers provide for much of the households' requirements and act as an erosion check on outward sloping terraces. Private land is the most important source of fodder, fuel and litter for all villages. Well-managed forests close to the villages also provide good supplies of fuel and forest litter and are a stark contrast to degraded grazing areas on denuded hill tops. This may be the reason for the relatively high numbers of livestock, the majority of which are stall fed. The number of large livestock per household is relatively high compared to other focal points, with an average across the villages of four to six per household. Cows and goats are raised under the semi-extensive management system whereas buffaloes and in some cases goats, are stall fed.

The main ethnic groups of the villages were Magar, with numbers of occupational castes and Bhramin/Chetris. In contrast to other focal point areas, settlement is scattered and most households live on their individual farmsteads. Off-farm income makes an important contribution. Permanent migration to the terai in search of better land is a feature and areas of abandoned land are evident. Land holdings are relatively large (0.5-1 ha) and compared to other focal points, share cropping is uncommon.

4.1.4 Focal point 4: Dhampus, Landruk, Tanchok area of Kaski district

Focal point 4 is located on the middle mountains/high mountains border (1300-1800m) to the north of LARC. Terrain is moderately to very steeply sloping. Dense forests which are protected by the ACAP are found on steeper slopes. *Kalo mato* is the most common soil and rated highly by farmers. Originally occurring under forest, it has a well developed profile, with high organic matter levels in the surface horizon. On steeper slopes, coarser textured soils known as *baloute* are found. They are generally shallower, stony and are expected to be acidic due to high leaching rates.

Bari land is the main agricultural land use in Tanchok and Landruk, but *khet* is more important in Dhampus. Cropping patterns on *bari* are dominated by the maize/millet system, although maize inter-cropped with soybean is also popular. In Landruk, barley, pea and wheat are common winter crops. A single rice crop is grown on *khet*.

Overall crop production has remained constant over the last 10 years. On the one hand, adoption of late maturing maize varieties and off-farm employment opportunities in the winter season have led to lower cropping intensities on *bari* land. However, new high yielding varieties and slight increases in cropping intensities on *khet* appear to have compensated for this. The issue of soil fertility is closely related to these changes. *Bari* land is considered more fertile than *khet* and soil fertility has remained constant or in some places is increasing as a result of decreases in the area of cultivation due to shortages of labour and fertilizing material which results in better management of remaining *bari* lands. However, soil fertility status is declining on *khet* due to higher cropping intensities, inappropriate use of chemical fertiliser, diversion of manure to *bari* land and a decline in the practice of insitu manuring. Livestock numbers have declined in recent years, however a shift towards stall feeding systems has meant that manure availability has remained constant. Landruk benefits from migratory sheep herds which graze there in the winter. Forest resources both private and communal are abundant, although restrictions on access to natural forest are imposed by the Annapurna Conservation Area Project (ACAP).

Gurung is the dominant ethnic group in the area and Occupational groups are found in all villages. Landruk is a mixed community with equal numbers of Gurung, Bhraman/Chetris and Magar. Land tenancy agreements are common in all villages, the recipients usually being the occupational groups. Land size, availability of labour and fertilising material seem to be the factors influencing the decision to rent out land. Tenants are usually allocated land furthest from the village.

In conclusion, the main features of the farming system are the low cropping intensities, relatively large land holdings, abundant forest resources, out-migration. The area is located within the ACAP and this, together with the importance of tourism to the area, has important effects on the farming system restricting the availability of forest resources and providing market facilities and off-farm income opportunities. However, this effect was observed to be mainly limited to a few households located alongside the trekking routes.

4.1.5 Focal point 5: Kurkhot, Pang, Durlung area in Parbat district.

This area is located in the low/mid mountains (800-1450m), two hours walk from the Pokhara to Baglung road. The area can be divided into three physiographic units; moderate sloping terrain, steeply sloping terrain and ancient alluvial terraces known as *tars*. Degraded forest and grazing land is found on steeper slopes (LRMP, 1986). In contrast to other *tar* areas, irrigation facilites in Pang and Kurkhot allow intensive cultivation and the area is dominated by *khet* land. The most common soil types are *kalo mato* and baloute *mato* on steeper slopes with *rato mato* and *kalo mato* in *tar* areas.

Cropping intensities on *khet* land on sloping land are low, however in irrigated *tar* areas of Kurkhot and Pang most land is under triple cropping. Maize/millet is the dominant cropping pattern on *bari* land. Livestock numbers are low and declining throughout the area, with the usual number of cow/buffalo per household ranging from one to three. The most dramatic decline has been in the number of goats, due to degradation of grazing areas and decline in the winter fallow. Most large livestock are stall fed, although the semi-extensive system is common in Durlung, where livestock graze on fallow land in the winter. All forests close to the villages are severely degraded, with little undercover or forest litter. Community forest groups exist in all villages and some new plantations are evident.

The dominant ethnic groups are Gurung in Durlung and Bhramin/Chetris in Kurkhot/Pang. Off-farm income is important especially in Durlung through army pensions and labouring. Land tenancy agreements are common in Durlung. All the communities are located relatively close to the main road, although the effect of its construction seems to have been minimal. Access to inputs has changed little, as even before the road these sites had few problems, due to proximity to towns (Kurkhot and Pang) and supplies from LARC (Durlung).

4.1.6 Focal point 6: Baidi area in Tanahun district

It is located near the Kali Gandaki river, a days walk from the main Mugling-Bharatpur road. The focal points covers two distinct land forms: moderate to steep slopes and *tar* land. Altitude ranges from 220-750m. The main ethnic group in Baidi are Thakuri and Bhramin/Chetris and Gurung are found on *tar* land along the Kali Gandaki.

On moderate to steep slopes, *bari* land is more common with small areas of *khet* located along the Masti Khola. Agriculture is affected by the relative inaccessibility of the site and remains traditional in nature. Features of many hill farming systems such as degraded forest resources, declining livestock numbers and out migration are absent from this area. The area of cultivated land has expanded in recent years encroaching onto forest land. Maize-mustard, maize-tori and maize-buckwheat are the most common cropping patterns, with two crops a year, rice-maize or rice-wheat) on *khet* land. Overall crop production has increased due to the introduction of a second crop on *khet*, new varieties, more labour, land expansion and good soil management. Soil fertility is declining on *bari* land due to erosion but increasing on *khet*, as a result of deposition of sediments from *bari* land and good management. Farmers follow an integrated approach to soil fertility management and over eight different practices were identified. The traditional practice of planting millet nurseries in newly burnt forest (koriya) is still a common. In-situ manuring in winter provides nutrients for summer crops, FYM/compost from stall fed cattle (in summer) is used for winter crops. The number of livestock is high averaging five to six cows/household. Goats also play an important role in manure supply and as a result numbers are increasing. Goats are increasingly being stall fed due to farmers recognition of the nutrient content of their manure. Forest resources are plentiful and private planting is increasing.

Along the Kali Gandaki, large areas of *tar* land and alluvial fans are cultivated. *Rato mato* is the most common soil type; on adjacent slopes and low lying land close to the river, the soil is coarse textured and extremely poor, due to deposition of river sediments. Large scale irrigation schemes in these *tar* areas have enabled increases in cropping intensities and now three crops a year on common on *khet* land. Maize-millet or maize-blackgram is the most common pattern on *bari* land. Overall crop production has increased due to increasing crop intensities and introduction of new varieties on *khet* land. Soil fertility is declining due to a lack of manure and degradation of forest resources. Relatively high numbers of large ruminants are kept in this area (5-6 on average). FYM/compost is the most important nutrient source. Although supply has increased due to the switch to stall feeding systems, this has not kept pace with increasing demands due to crop intensification. The use of chemical fertiliser is increasing but only on *khet* land. Many people from this area migrate to the terai for employment.

4.1.7 Focal point 7: Seti river valley

Close to Pokhara, the main valley of the Seti River is described as an ancient river terrace composed of calcareous, gravely, fluvial deposits. These deposits are the result of a glacial dam outburst flood which occurred 600 years ago (LRMP, 1986). As a result the soils are coarse textured, (*balaute/baluwa*), stony and of variable depth. There is little evidence of pedogenetic development, and they can be classified as Fluvents (USDA soil taxonomy). Large scale irrigation schemes have to some extent compensated for low inherent fertility of soils and led to considerable intensification of cropping patterns in the last 10 years on *khet* land. Rice-maize-wheat is the most common pattern, but depending on households needs and market opportunities, tori, vegetables and potato are also important. The area of *bari* land is small and maize-millet pattern is dominant.

Overall crop production has increased due to intensification and new varieties. No clear trend in soil fertility emerged. Generally *bari* land was considered more fertile than *khet*, but the supplementary use of chemical fertilisers seems to be sustaining soil fertility on *khet* despite higher cropping intensities. Soil fertility management systems are characterised by a movement away from more integrated approaches with abandonment of in-situ manuring and fallowing practices. FYM/compost remains the most important source of nutrients for *khet* land. Although livestock numbers are relatively low (1-3 on average) stall feeding management system is practised and the manure retrieval rate is good. There are few fodder trees because of the abundance of crop residues. All fodder needs are met from private lands.

The situation is quite different however, in the village of Sanaik Vasti, where 70% of nutrients come from chemical fertilisers. Use is prompted by low livestock numbers, extremely poor soils and cash incomes from pensions.

In the Seti valley, the farming system is influenced by good access to roads and markets, but this does not always act in favour of agricultural production. For example, there is a reluctance to grow vegetables due to availability in the bazaar and labour shortages resulting from off-farm income opportunities. The latter factor seems to particularly affect livestock numbers. Bhramin/Chetris and occupational castes are the most common, but there are a large number of resettled Gurung households. Food sufficiency situation is relatively low and is a reflection of the importance of off-farm income; these communities do not depend on agriculture.

In summary, the farming system is characterised by high cropping intensities, relatively high use of inputs and the importance of off farm employment. Unlike in other hill areas, links between the forest and livestock components of the farming system are weak. Inputs from outside the system compensate for this.

4.2 Grouping of villages

The villages surveyed in the focal points were grouped according to similiarities in land form, land use (primarily the proportion of *khet* and *bari*) and altitude. This approach broadly follows that employed by LRMP (1986) in their description of land systems. The resulting groups of villages are illustrated in Figure 4.2. The unique land use system in Palpa did not however fit neatly into the LRMP classification, being dominated by large outward sloping terraces.

4.3 Village by factor interactions

The objective of this study is to assess the situation of soil fertility from a systems perspective and consider the major factors known to influence soil fertility. Adequate representation of these factors in the villages selected for survey was therefore essential. To achieve this, key factors affecting the farming system were identified and a matrix was constructed showing the presence or relative importance of all factors in each of the surveyed villages (Figure 4.3).

This approach was adopted to ensure that the selected factors were adequately represented. This does not necessarily imply that the villages themselves are 'representative' of others in the middle hills.

Figure 4.2 Land systems of the surveyed villages (adapted form LRMP, 1986)

Figure 4.3 Matrix of site by factor interactions for selected villages

Factor	Kapalchaur	Pang	Bahrphirke	Chambas	Tanchok/ Landruk	Kimchor	Arman	Nayatola	Deurali	Talbari	Khalte	Hyanja
Focal point	5	5	2	2	4	1	1	3	3	6	6	7
Rainfall[1]	high	medium /high	low	medium	high	medium	low	low	low	medium	medium	high
Altitude	1200-1350	500-635	500-635	500-580	1500-1800	1600-2000	1300-1400	1150-1600	1150-1600	740	240	950
Aspect	SW	S	S	SE	W/NW	NE	NE	W	W	NW	S	all
Landform	mod sloping	*Tar*	*Tar* slopes	mod slopes	mod steep slopes	outward slopingte rrace	mod steep slopes	outward sloping terrace	outward sloping terrace	mod slopes	*tar* valley	floodplain
Landuse Khet:*Bari*	3:1	3:1	1:3	1:3	1:3	1:4	1:5	1:7	1:5	1:2	3:1	3:1
Soil type	loamy	loamy	loamy	sandy loamy	loamy	sandy loamy	loamy	loamy	loamy clay	sandy loamy	sandy loamy	sandy loamy
Irrigation[2]	PI	I	RF PI	RF PI	RF PI	RF PI	RF PI	RF PI	RF	RF PI	RF I	RF I
Forest rsources	Poor (I)	Poor (I)	Poor (D)	Poor (D)	Good (I)	Good (D)	Medium (D)	Good (D)	Poor (I)	Good (D)	Poor (D)	Poor (D)
Crop intensity	*khet* 1 *bari* 2	*khet* 3 *bari* 2	*khet* 2/3 *bari* 2	*khet* 2 *bari* 2/3	*khet* 2 *bari* 3	*khet* 2 *bari* 1	*khet* 2 *bari* 2	*khet* 1/2 *bari* 2/3	*bari* 2/3	*khet* 1/2 *bari* 2	*khet* 2/3 *bari* 2	*khet* 2/3 *bari* 2/3

Livestock: management[3] numbers[4]	SE,SF 1-3	SF 1-3	SF 2-3 CB 3-4 G	SF 2-12 CB	SE 3-4 CB 1-2 G	SF, SE 4-6 CB	SF, SE 4-6 CB	SF, SE 4-6 CB	SF, SE 4-6 CB	SF, SE 5-6 CB 12 G		SF 2-4
Ethnicity[5]	GM, B/C	B/C, O	B/C, O	B/C, GM, O	GM, B/C, O	M, B/C, O	B/C, O	M	M, B/C, O	T	T	B/C, O, Newar
Food sufficiency[6] (% hholds) 1 2 3	62 38 0	49 28 23	25 50 25	40 40 20	-	33 33 33	48 34 48	20 75 5	70 30 0	-	-	-
Income opportunity[7]	L, S, P CP	CP, S	CP, P, B	CP, P	T, P	CP, LP, P	LP, CP	Ct	S	LP, CP	LP, CP	CP, S
Land tenure[8]	70:30	99:1	95:5	98:2		95:5	99:1	99:1	92:8	98:2	-	-
Landhlding	-	-	15-20	15	15	20	-	14-17	12	-	-	-
Market	medium	good	good	good	good	poor	poor	medium	medium	poor	poor	good
Distance to road	3 hrs	1hr	1 hr	0 hr	3 hr	1.5 day	1.5 day	30 min	45 min	1 day	1 day	0
Access to input/credit	medium	high	medium	medium	high	low	low	medium	medium	low	low	high
Out migration	low	none	none	none	medium	low	low	low	medium	medium	medium	none
Participation[9]	1	3	2	2	-	3	2	3	1	3	2	-
Village hh no.	80	120	big	670	105	155	62	86	84	49	-	-

Key to matrix

1 Rainfall - low <1500mm, medium 1500-2500mm, high >2500m

2 Irrigation - RF = rainfed, I = irrigated, PI= partially irrigated

3 Livestock management - SF = stallfed, SE = semi extensive:

4 Livestock numbers - CB = cattle/buffalo, G = goat

5 Ethnicity = GM = Gurung/Magar; B/C = Bramin/Chetri; O = occupational; T = Thakuri

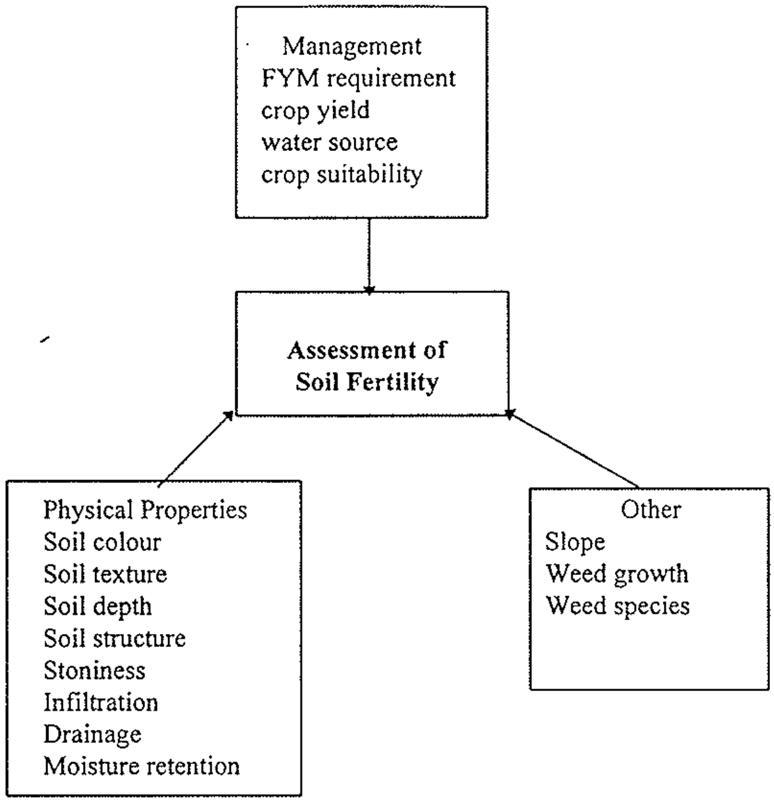
6 Food sufficiency 1 = < 6 months, 2 = 6-12 months, 3 = > 12 months

7 Income opportunity = CP = crop products, LP = livestock products, P = pension, S = sevice, B = business, T = tourism, Ct = citrus, L = labouring

8 land tenure -ratio of owner to tenant cultivators

9 Participation of villagers in group discussions - 1 = poor, 2 = medium, 3= good

Figure 4.4 Farmers' assessment of soil fertility



Soil physical properties such as texture, moisture retention and internal drainage are all important parameters for farmers. Although chemical properties are not considered explicitly, they are considered implicitly through knowledge associated with FYM/compost applications The relative importance of each of indicators in Figure 4.4 varies according to whether the farmer is referring to *bari* or *khet* land. Thus infiltration rate, texture, and slope of land are more important to farmers when assessing the fertility of *bari* land, whereas water sources and drainage are more important indicators on *khet* land.

Farmers, like soil scientists, make the distinction between soil productivity and soil fertility[5], yet recognise the interdependence between these two properties. This is illustrated by a summary of a discussion held with farmers in the village of Pang.

[5] Soil productivity is a measure of a soils' ability to produce a particular crop or sequence of crops, under a specified management system and is usually measured in terms of yield/unit area. Soil fertility is the inherent capacity of a soil to supply nutrients to plants in adequate amounts and adequate proportions (Brady, 1984).

> Although crop yields have increased (soil productivity), soil properties have deteriorated (*mato bigrio*) and the soil is becoming less "fertile" (*ruckho*) (soil fertility). This can be attributed to an increase in the use of chemical fertilisers (with a parallel decline in use of FYM/compost) which brings about increases in yield, but at the same time have a negative effect on soil properties and the ability of the soil to supply nutrients in the long run.

One of the farmers most important indicators of fertility is the nutrient requirement of individual soils. In every case, the ranking of soil fertility status was inversely related to the FYM/compost requirement of soils. Thus a soil which is ranked lowest in terms of fertility is ranked highest in terms of FYM/compost requirement.

Long term trends of soil fertility are not at the forefront of most farmers' minds, as they are more concerned with immediate annual variations in yield. On rainfed *bari* land, long term trends in soil productivity are masked by large annual variations in yield resulting from climatic factors. Crop production is more stable on *khet* land due to availability of irrigation water and thus underlying trends clearer. However, *khet* soils are considered less stable than *bari* soils, because of the annual nutrient and humus influx brought by irrigation water.

5 FARMERS' VIEWS OF SOIL FERTILITY

This chapter presents the results of in-depth field surveys carried out in the 13 selected villages. It aims to integrate the findings from the household survey with information from the PRA and group discussions. Section 5.1 looks at the soil fertility situation in the surveyed area and examines some of differences between the villages. This is followed by a look at the reasons given by farmers to account for changes in soil fertility. Section 5.3 assesses the impact of changing soil fertility on crop productivity. The remainder of the chapter explores the importance of different factors as they affect soil fertility. The final section discusses the inter-relationships between these factors and presents a tentative model for predicting the probability of a decline in soil fertility. All discussion on soil fertility trends in this chapter refers to farmers' perceptions and opinions.

5.1 Perceptions of soil fertility status in the surveyed area

Declining soil fertility is a concern for the majority of farmers, regardless of land type (Figure 5.1). These results are similar to those from the Extension Impact Study (EIS) (LARC, 1994), where 56% of farmers reported an overall trend of declining soil fertility.

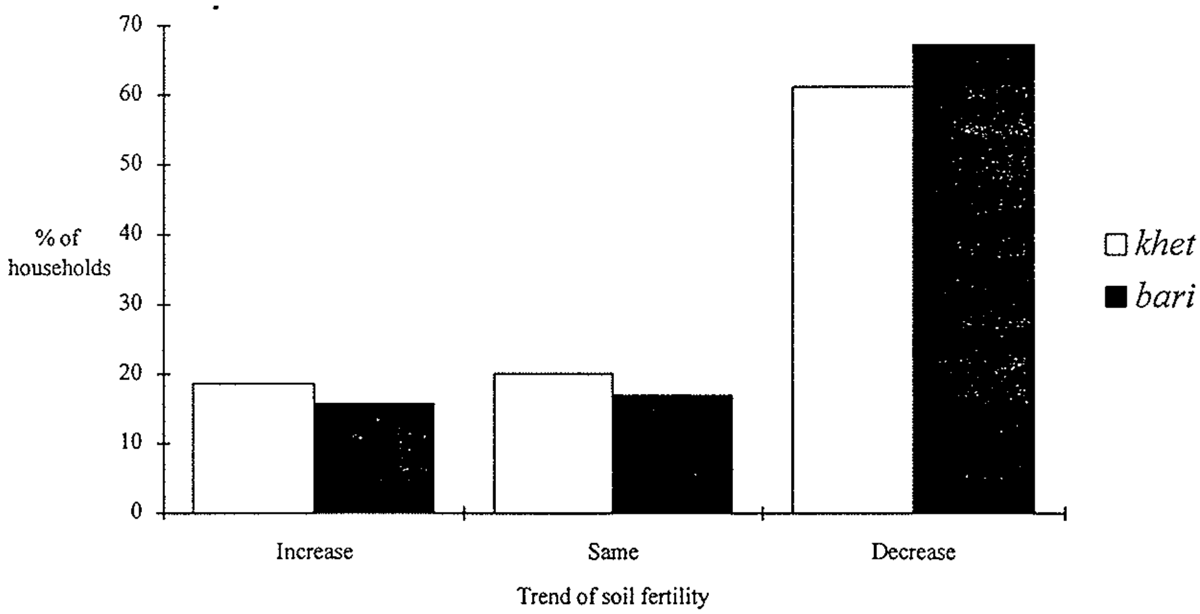
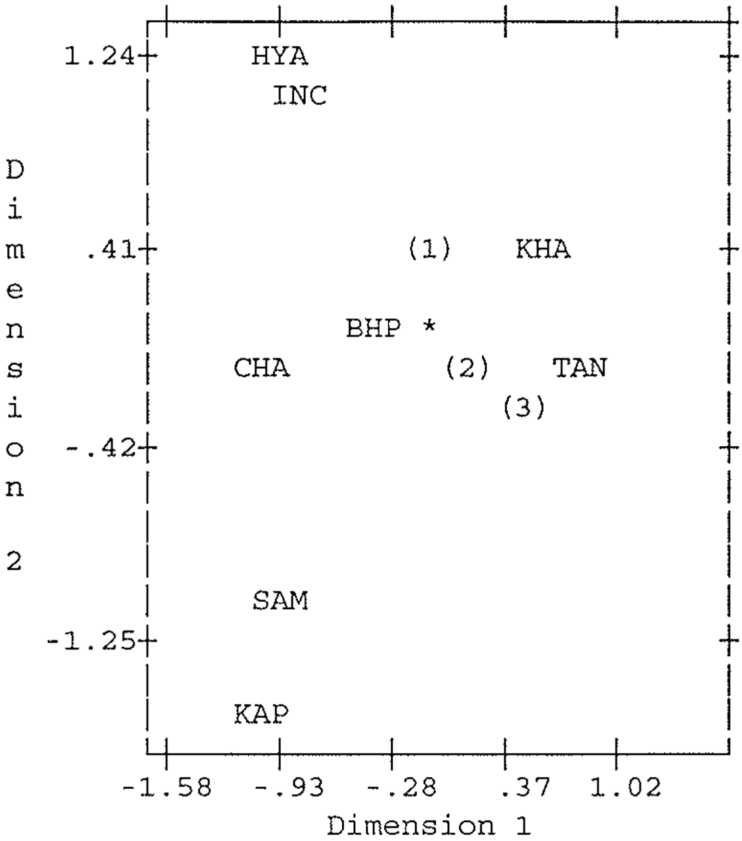


Figure 5.1 Fertility trend on *khet* and *bari* land

There is a significant (p=0.001) positive relationship between fertility trend on *khet* and *bari* land, indicating that for the majority of households the trend in fertility is the same regardless of land type. However, the overall picture obscures the considerable inter-village variation in soil fertility trends. The similarities and differences in soil fertility trends of villages were examined using correspondence analysis, the results of which are displayed graphically in Figures 5.2 and 5.3.

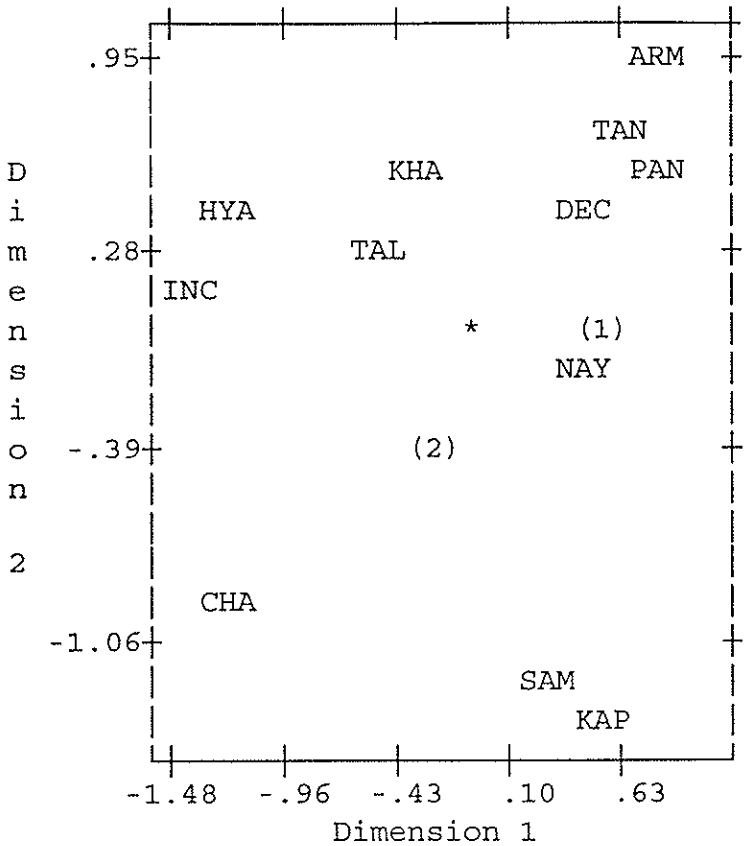
Figure 5.2 Row and column scores for soil fertility trend on *bari* land by



SUMMARY OF MULTIPLE POINTS IN THE PLOT

POINT	DIM1	DIM2	ACTUAL LABEL OR NAME
(1)	-.06	.47	TAL
(1)	-.06	.47	KIM
(2)	.46	-.01	DEC
(2)	.25	-.13	NAY
(2)	.41	-.14	LAN
(2)	.57	-.15	DEO
(3)	.49	-.21	ARM
(3)	.72	-.31	PAN

Figure 5.3 Row and column scores for soil fertility trend on *khet* land by village



SUMMARY OF MULTIPLE POINTS IN THE PLOT

POINT	DIM1	DIM2	ACTUAL LABEL OR NAME
(1)	.70	.04	LAN
(1)	.57	-.03	DEO
(2)	-.18	-.38	BHP
(2)	.08	-.45	KIM

The labels in both plots correspond to the following;

ARM=Arman, KIM=Kimchor, CHA=Chambas, BHP=Bahrphirke, NAY=Naya Tola, DEO=Deorali, TAN=Tanchok, LAN=Landruk, KAP=Kapalchaur, PAN=Pang, TAL=Talbari, KHA=Khalte, HYA=Hyanja

INC=Increasing soil fertility, SAM=Same, DEC=Decreasing

In Figure 5.2, a group of villages, namely Naya Tola, Landruk, Deorali, Arman, Pang and Tanchok are found close to, or coincide with, the 'decreasing' plot, indicating that the majority of farmers in these villages reported a decline in soil fertility on *bari* land. In Talbari and Kimchor, fewer farmers, although still a majority, reported declining soil fertility. The remaining 4 villages are located further away from the 'decreasing' plot. Kapalchaur is found close to the 'same' plot, Hyanja to the 'increasing' plot and Chambas and Bahrphirke between the two. These latter three villages are situated in low altitude with good road access. Kapalchaur is a mid altitude village dominated by *khet* land of low cropping intensity.

There is a less discrete clustering of villages in Figure 5.3 indicating that the soil fertility situation on *khet* land varies more widely across villages. In Kapalchaur, the majority of respondents reported unchanged soil fertility, whilst in Hyanja the majority reported an increase. Bahrphirke and Kimchor lie close to the centre of the plot due to the variation in responses from these villages. Arman, Tanchok and Pang are dominated by declining soil fertility, as are Khalte and Talbari to a lesser extent. As on *bari* land, responses for declining soil fertility were higher in mid and high altitude villages and those in inaccessible areas.

5.2 Reasons for soil fertility trend

Farmers gave a wide range of reasons to account for changes in soil fertility[6] (Table 5.1).

Reasons for decreasing soil fertility are similar for *khet* and *bari* land, although their relative importance varies. Overall, soil erosion is the most important reason for declining soil fertility on *bari* land, followed by the closely associated reasons of declining rates of FYM/compost application, degradation of forest resources and changes in the livestock management system. Changes in livestock management systems such as the decline in in-situ manuring practices, have particularly affected soil fertility status in high altitudes.

On *khet* land, soil fertility decline is associated with low and/or declining FYM/compost application. At lower altitudes, this decline in the availability of nutrients has occurred simultaneously with an increased demand on the soils nutrient reserves due to crop intensification. Surprisingly, erosion was also recognised as an important problem on *khet* land and the logic behind this is discussed in section 5.4.2. A large number of farmers emphasised the negative effects of chemical fertiliser on soil fertility of both *khet* and *bari* land. The problem is more common on *khet* land, where higher doses of fertiliser are used and FYM/compost application rates are lower.

[6] Although originally farmers were asked to rank in order of importance up to 3 reasons it became evident during the survey that, reasons given were not mutually exclusive and were closely related to each other. Therefore the totals given in Table 5.1 represent % of households giving that reason. Regardless of rank

Table 5.1 Farmers' reasons for increasing and decreasing soil fertility on *khet* and *bari* land

Reasons for change in soil fertility	percent of farmers *bari* land[1]		percent of farmers *khet* land[1]	
	increase	decrease	increase	decrease
use of chemical fertiliser	32.5	20.6	47.1	33.2
change in crop intensity	23.8	9.0	40.0	22.8
change in FYM application	78.8	48.0	71.4	49.1
labour availability	40	17.2	24.3	19.8
change in livestock management practices	12.5	24.7	2.9	19.8
soil erosion	1.3	66.6	0	44.4
moisture/climate	21.3	4.7	31.4	8.2
change in forest resources	1.3	29.7	0	25.9
change in livestock population	0	7.3	0	7.3
land improvement practices	2.5	0.3	1.4	0
other soil fertility management practices	6.3	0	8.6	1.4
miscellaneous	0	1.2	0	0.4

Whilst the majority of responses indicate a decrease in soil fertility, a substantial number of households reported unchanged or increasing soil fertility status (38% on *khet*, 33% on *bari*). Reasons for increasing soil fertility are closely related to changes in soil fertility management. The increasing use of FYM/compost on *khet* land and application of chemical fertilisers has increased the overall supply of nutrients. This pattern can be illustrated by looking at changes in soil fertility management practices over the last 10-15 years in Chambas where 86% and 65% of farmers reported increasing/static trend in soil fertility of *khet* and *bari* land respectively. During the group discussion, farmers constructed a matrix indicating the relative importance of each management practice in maintaining soil fertility, both now and in the past.

Farmers distributed a total of 20 maize grits among the practices according to their importance Figure 5.4).

Management practice	Present		10-15 years before	
	khet	*bari*	*khet*	*bari*
FYM/compost	10	10	0	7
Chemical fertilisers	5	5	5	2
Burning trash	3	2	0	5
Legumes	2	3	0	2
In-situ manuring	0	0	0	4
Fallowing	0	0	15	0
Total	20	20	20	20

Reconstructed from a diagram made by a group of farmers in Chambas (Appendix 5)

Figure 5.4 **Contribution of management practices to soil fertility in Chambas**

The most noticeable feature is the increasing contribution of FYM/compost on *khet*. The traditional belief that the rice-fallow system maintains or increases soil fertility has been abandoned and there is increasing cultivation of legumes and green manures (Sesbania sp.). Increased crop intensities on *khet* land resulting from demographic pressures have also necessitated the move towards a more integrated management strategy, which now includes the practice of burning trash in the field.

In conclusion, it is apparent from farmers' responses that no one reason can be considered in isolation from another. For many respondents it was possible to trace the relationship between the three reasons given, for example, increasing chemical fertiliser, declining FYM/compost application rates and shortages of labour.

5.3 The impact of declining soil fertility on crop productivity

The importance of soil fertility to the farmer lies any impact on crop productivity and one criterion used by farmers to assess soil fertility is crop yield. The overall pattern of crop productivity trend was similar to that for soil fertility, with soil fertility trend on *khet* and *bari* being significantly related to the trend of crop productivity for maize, *ghaiya*, rice and spring maize (p=0.001). Figure 5.5 illustrates the relative importance of major factors reported by farmers to be affecting crop productivity[7].

[7] Similar to the reasons given for changes in soil fertility, those for crop productivity were related to each other and thus totals given represent % of total households mentioning the reason regardless of rank

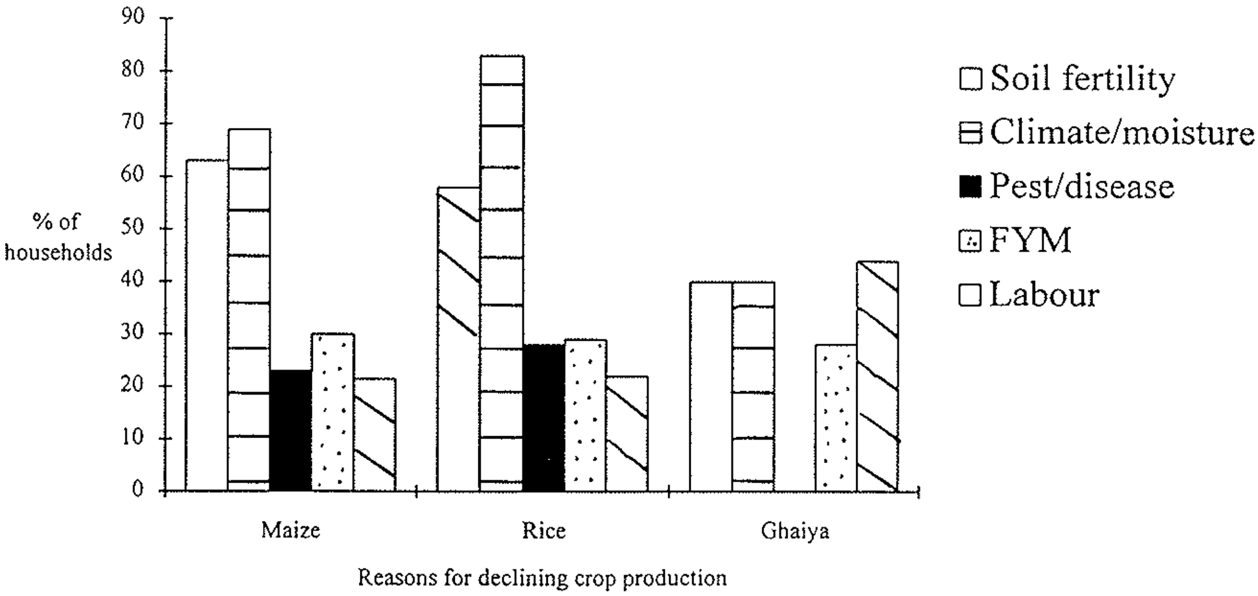


Figure 5.5 Factors affecting maize, rice, *ghaiya* productivity

Soil fertility is perceived as the second most important reason for declining crop productivity. Crop productivity was reported to be increasing in the same villages reporting an increase or no change in soil fertility. Hyanja is an interesting case, with approximately 61% and 55% of farmers reporting productivity increases for rice and maize respectively. Farmers here emphasised the change in supply of nutrients, with increasing applications of FYM/compost and chemical fertilisers. The increase in productivity of rice in Chambas (75% of farmers) is likewise closely related to changes in soil fertility management (Figure 5.4).

5.4 Factors affecting soil fertility status and trends

The main factors affecting soil fertility were summarised in Figures 3.2 and 3.3. These diagrams formed the basis for the formulation of hypotheses linking the effect of these factors to soil fertility trend. The effect of some of these factors such as accessibility and market availability, cropping intensity, rainfall, aspect and altitude was examined on a village basis with villages grouped according to the parameters given in Figure 4.3. The influence of other factors such as ethnicity, category, and land use were investigated at the household level.

5.4.1 Factors investigated at village level

Cross tabulations were used to test the effect of altitude, aspect, rainfall, accessibility and market availability. The residual values and levels of significance are shown in Table 5.2.

Table 5.2 Summary table of residual values for expected trend in soil fertility and different factors

	Khet			*Bari*		
	increase	same	decrease	increase	same	decrease
Altitude high	-8.4	-0.2	8.6	-4.3	-7.7	12
mid	-16.2	12.3	3.9	-16.1	12.0	4.1
low	24.6	-12.1	-12.5	20.4	-4.4	-16.1
chisq p	p=0.001			p=0.001		
Rainfall high	-0.4	4.9	-4.5	-0.6	5.1	-4.4
medium	10.5	-3.9	-6.6	0.9	-5.8	4.9
low	-10.1	-1.0	11.2	-0.3	0.8	-0.5
	p=0.001			p=0.07		
Aspect NE	8.2	11.1	-19.3	12.3	17.5	-29.7
N/NW	2.9	-6.8	3.9	-1.0	-5.9	6.9
S	-2.9	-8.8	11.7	-6.3	-9.2	15.5
W	-8.2	4.6	3.7	-4.9	-2.4	7.3
chisq p	p=0.001			p=0.001		
Accessability 0hr	20.4	-2.4	-18.0	20.4	5.4	-25.8
<2hr	-18.9	14.9	4.0	-15.3	13.4	1.8
>2hr	-1.5	-12.5	14.0	-5.1	-18.9	24.0
chisq p	p=0.001			p=0.001		
Market good	20.4	-2.4	-18.0	20.4	5.4	-25.8
medium	-26.7	12.5	14.2	-23.3	8.5	14.7
poor	6.3	-10.1	3.7	2.9	-14.0	11.1
chisq p	p=0.001			p=0.001		

(i) Altitude

Hypothesis: Soil fertility decline is a more serious problem at low altitude, due to increasing cropping intensities and the degraded state of natural resources

There was a significant difference in soil fertility trends in high, mid and low hills for both *khet* and *bari* land. The incidence of declining soil fertility was greater in high altitudes. The incidence of increasing soil fertility was greater in low altitudes, with middle altitudes have a greater incidence of static soil fertility. The pattern is the same for *khet* and *bari* land and thus the hypothesis is rejected.

The results are perhaps surprising given that soil analysis results established a positive relationship between soil nutrients and altitude. In addition, higher livestock numbers, better forest resources and lower cropping intensities were expected to positively influence soil fertility in higher altitudes. The explanation lies in changes associated with the following factors given by farmers at different altitudes to account for declining soil fertility (Figures 5.6 and 5.7)

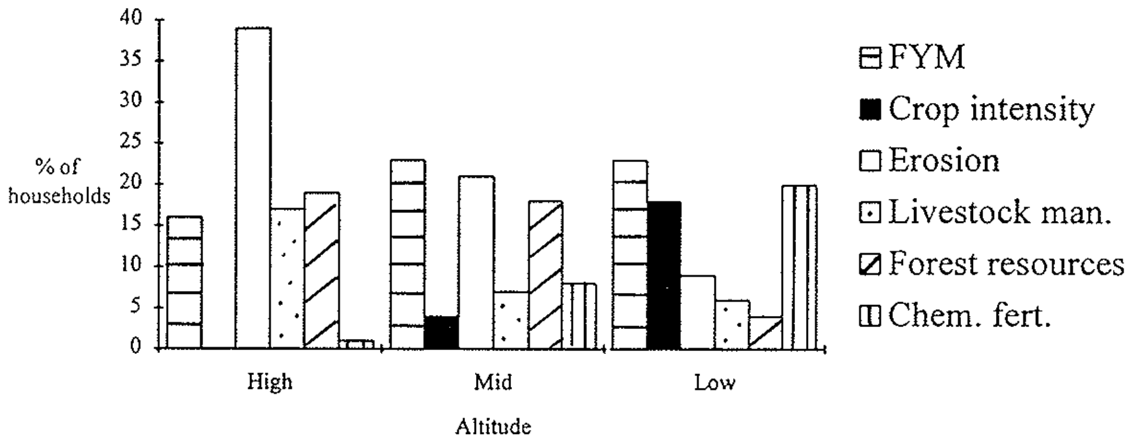


Figure 5.6 Reasons for declining fertility on *bari* land at different altitudes

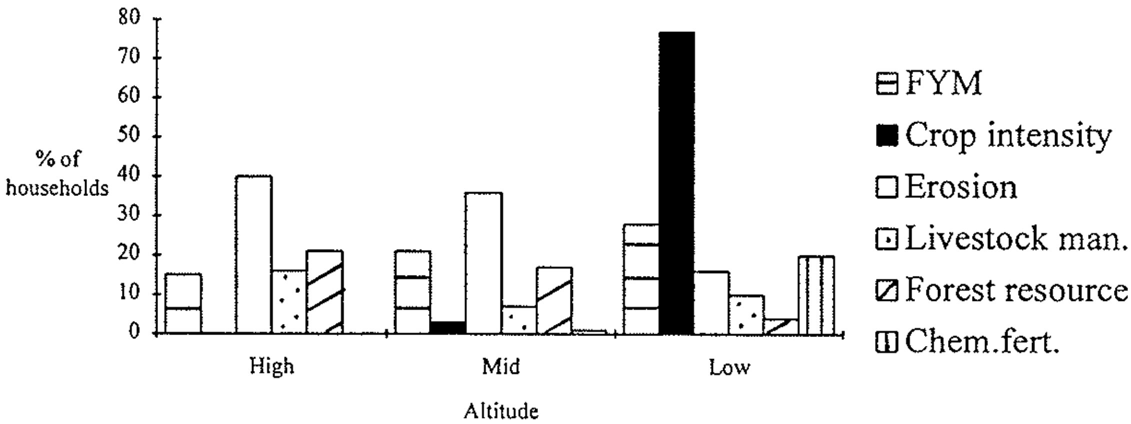


Figure 5.7 Reasons for declining fertility on *khet* land at different altitudes

Erosion, degradation of forest resources and changes in livestock management practices becoming more important as altitude increases. On the other hand, the negative effects of chemical fertiliser and increasing cropping intensity are more important at lower altitudes. This pattern is evident for both *khet* and *bari* land.

Erosion dominates the picture in high altitudes for both *khet* and *bari* land and may be related to the higher precipitation in this zone. The effect of heavy rainfall may be over emphasised in this study, as the high altitude villages in the survey are found in high/medium rainfall areas (Kimchor, Landruk and Tanchok). The changing livestock management systems, decline in forest resources and FYM/compost application rates are secondary contributing factors to soil fertility decline in high altitude. The decline in importance of in-situ manuring/*goth* systems, together with the disappearance of migratory sheep flocks was reported from all 3 high altitude villages.

Declining availability of FYM/compost was emphasised in mid and low altitudes. The use of chemical fertilisers has only partially substituted for the lower rates of FYM/compost application. On the contrary, the negative effect of chemical fertilisers on soil fertility is an important problem in the eyes of farmers.

(ii) Rainfall

Hypothesis: Soil fertility declines are more serious in high rainfall areas due to greater rates of erosion

A significantly higher number of farmers than expected reported a decline in soil fertility on *khet* and *bari* land in low rainfall areas (Table 5.2). Higher rainfall would be expected to lead to greater erosion and leaching rates with corresponding losses of soil nutrients, however in this case the hypothesis is rejected.

(iii) Aspect

Hypothesis: Soil fertility is declining in low rainfall areas and/or those of south or south/east aspect due to the degraded nature of forest resources on these slopes.

Studies elsewhere in Nepal have suggested that the fertility status of soils is lower on south facing slopes (Schmidt *et al.* 1994). This is attributed to higher inputs of organic matter and slower decomposition rates on wetter, cooler north facing slopes. There is no information on differences in fertility trend for slopes of different aspects. This study suggests that, in addition to the lower nutrient levels of south facing slopes, declining soil fertility trend is also more common on slopes of southern aspect (Table 5.2) and the hypothesis is accepted.

(iv) Accessibility/Market

These two factors were linked in the following hypothesis:

> Soil fertility is a problem in areas close to roads and markets due to high cropping intensities and increasing reliance on chemical fertilisers

Both factors had a significant effect on soil fertility trend. A larger proportion of farmers reported an increase in soil fertility on both *khet* and *bari* land in the roadside villages of Chambas and Hyanja (Table 5.2). This may be related to the intensive use of chemical fertilisers in these villages. In both Chambas and Hyanja, over 80% of farmers use chemical fertilisers and there has also been a commensurate rise in FYM/compost applications (Figure 5.4). A higher proportion of farmers reported unchanged or declining soil fertility in villages away from road heads.

There was a similar relationship between soil fertility trend and market accessibility (Table 5.2). The general trend was of increasing soil fertility in villages close to markets and decreasing or unchanged soil fertility in villages further away. Accessibility and market availability are closely linked to altitude and much of the recent infrastructure development has taken place in the low hills.

To conclude, declining soil fertility is a less common problem in accessible areas and/or those close to markets and the hypothesis is rejected.

(v) Soil type

Hypothesis: Soil fertility problems are more severe on some soil types such as red soils (*rato mato*)

During the initial site visits, soil characterisation activities revealed wide variability in soil type both within and between villages. This variability often extended to the farm level, with households cultivating a number of different soil types. The spatial complexity in soil types is compounded by the fragmentation of land holdings, with each household possessing on average four to five parcels of land, scattered throughout the village. The importance of soil type (in the scientific classification sense) as a factor influencing households perceptions of soil fertility, is further altered by the long history of cultivation. This has significantly changed the inherent properties of soils to such an extent that, present management practices are more important than inherent fertility levels in determining the fertility status of the soil. Recognition of the importance of management was reported by Tamang (1991), with farmers stating that any soil can be made productive given the availability of sufficient resources. This situation made it impossible to explore the relationship between trend in soil fertility and soil type and the hypothesis remains unproved.

In the past, serious fertility problems have been reported from red soil areas of Nepal. As a result, special attention has been paid to the study of their physical and chemical properties (Shah *et al.*, 1991; Turton *et al.*, 1994). However, in the two villages dominated by red soils (Chambas and Bahrphirke) a greater proportion of farmers reported an increase in soil fertility on *bari* land The direct relationship between red soils and fertility decline is therefore rejected *(v) Crop intensity*

Hypothesis: Increasing crop intensities at low altitudes are leading to a decline in soil fertility.

This hypothesis was tested by LARC (1994). It found that the incidence of perceived increase was less (but not significant) for households in the LARC extension area and linked this to the impact of the centre in providing new varieties which in turn led to an increase in crop intensities.

Results from this survey showed no significant relationship between high crop intensities and fertility decline. Indeed the incidence of increasing soil fertility on both *khet* and *bari* land was found to be greatest in villages with higher cropping intensities such as Chambas, Hyanja and Bahrphirke (Figure 4.3).

Table 5.1 shows that an increase in cropping intensity does not feature as a major reason for declining soil fertility on *khet* or *bari* land. The key to the question seems to be not so much in the cropping intensity, as in the fertility management practices of farmers. Thus the hypothesis is not proved.

5.4.2 Factors investigated at the household level

This section investigates the relationship between forest resources, livestock systems, erosion, ethnicity, land holding, labour availability, land tenancy and household category on soil fertility trends reported by individual households.

(i) Forest resources

Hypothesis: Soil fertility declines are linked to a shortage of fodder, bedding material and leaf litters.

The forest is the main external source of nutrients for the household farming system; being an important source of fodder, bedding materials and leaf litter. This one way flow of nutrients from forest to farm is causing increasing concern over forest soil fertility. In addition, the degraded nature of many forests particularly in low and middle altitudes has resulted in high erosion rates (Gardiner and Collins, 1993).

Many farmers highlighted degraded forest resources as a reason for declining crop productivity (Figures 5.6 and 5.7). Only 25% of farmers reported an increase in the availability of forest resources over the last 10-15 years. Over 97% of cases reporting a decrease in forest access came from the low hills indicating extreme pressure on forest resources.

The effect on soil fertility comes mainly through the declining availability of fodder (and thus decreasing livestock numbers) and leaf litter. The impact of degrading forest resources will be different according to the degree to which communities rely on forests as opposed to trees, shrubs and grasses on private land. The forest *(ii) Livestock systems*

Hypothesis 1 Soil fertility decline is linked to a decline in the number of livestock numbers

Hypothesis 2 A shift towards stall feeding systems is having a beneficial effect on soil fertility status

Nepal has the highest density of livestock per cultivated area of land in the world (Sharma *et al.*, 1994) and FYM/compost is the major source of nutrients in hill agriculture. The total availability of FYM/compost is affected both by the total number of livestock units per household and the management system. In this study, the highest numbers of livestock units[9] were found in the low and high hills (Figure 5.9).

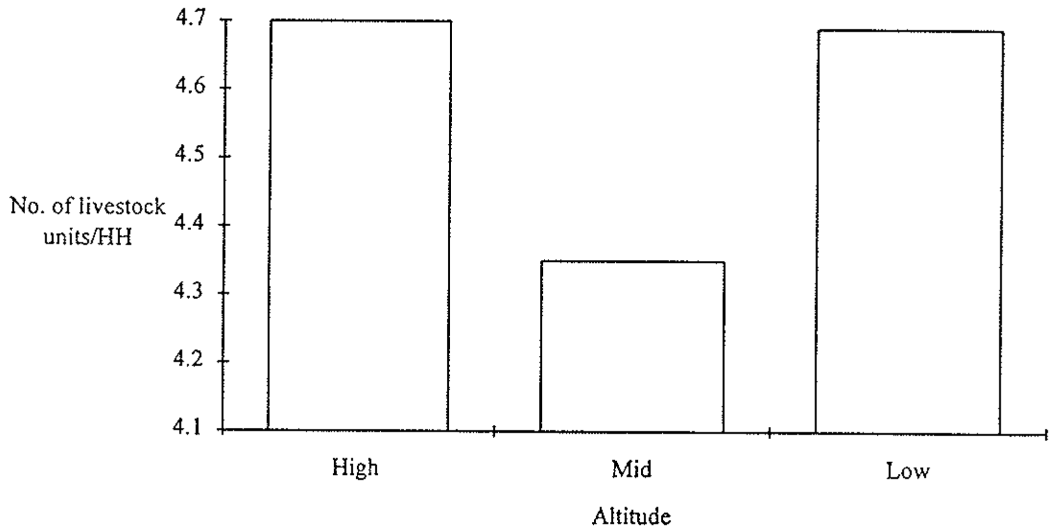


Figure 5.9 Number of livestock units/household by agro-ecological zone

There is a significant relationship between livestock numbers and trend of soil fertility, with households reporting a fertility decline on *bari* land having fewer and decreasing number of livestock ($p=0.07$). This may reflect the important role of FYM/compost in soil fertility management on *bari* land. There is no significant relationship between livestock numbers and changes in soil fertility on *khet* land and hypothesis 1 is accepted.

There are two dimensions to any change in the livestock system; a decline in total numbers and change in management practices. Numbers of livestock have decreased over the last 10-15 years. Farmers attribute this to a decline in the availability of labour; livestock were traditionally looked after by children, who now attend school.

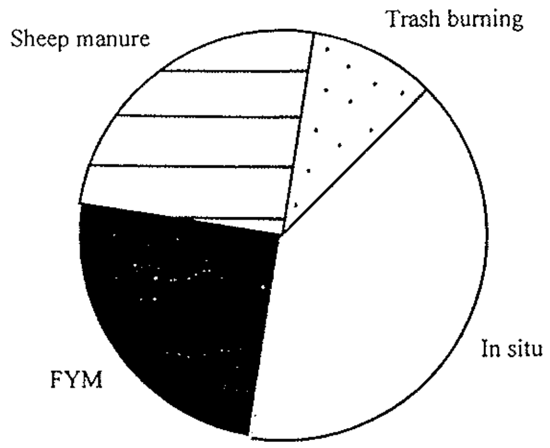
[9] the number of livestock units was calculated using the conversion rates for cattle, buffalo, goats and sheep given in Rajbhandry et al., 1994

It was previously assumed that there was a positive correlation between livestock numbers and altitude, but the results of this study do no support this. This may be attributable to the choice of high altitude villages; a shortage of labour and out-migration have particularly affected livestock numbers in Tanchok and Landruk. However, it could also be the case that high hill areas have suffered serious declines in livestock numbers over the past 10-15 years as compared to lower altitudes.

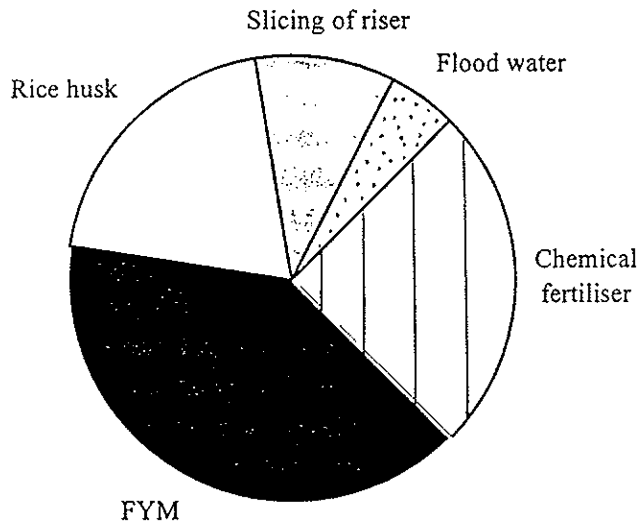
The decline in total livestock numbers and the shortage of labour has facilitated the shift towards more intensive management systems. In terms of FYM/compost, this can be regarded as a beneficial change due to the improvement in manure retrieval rates. In this study, the numbers of stall-fed animals were found to be more important than any absolute change in the livestock population. A significantly ($p=0.001$) higher numbers of farmers were found to practice stall feeding at lower altitudes than high altitudes. Not only have high altitudes suffered from the highest rate of decline in livestock numbers, it also has a lower number of households practising stall feeding. However this may be counterbalanced by the still popular, though declining, practice of in-situ manuring. No significant differences in the effect livestock keeping practices on fertility trend on *khet* and *bari* land were observed.

The strength of the link between crop and livestock components with respect to soil fertility management is stronger in high as compared to low altitudes (Figure 5.10).

In Landruk (high altitude) farmers depend almost entirely on livestock inputs (FYM/compost, sheep manure and in-situ manuring). At lower altitudes there are alternative nutrient sources. For example, in Hyanja; chemical fertilisers have substituted for declining livestock numbers (Figure 5.10). This suggests that changes in the livestock system may have had a more serious impact on soil fertility in high altitudes.



Landruk (*khet/bari*)



Hyanja (*khet*)

Figure 5.10 Contribution of livestock to soil fertility management in high (Landruk) and low (Hyanja) altitudes

In conclusion, hypotheses 1 is accepted on the basis of the relationship between livestock numbers and fertility trend. However, the survey revealed no positive impact of stall feeding on soil fertility and hypothesis 2 is not accepted.

(iii) Erosion

Hypothesis: Erosion issues are perceived as a greater problem by researchers and academics than by farmers

Erosion issues have a high profile in Nepal and many papers and reports have highlighted the potential effect of erosion on soil fertility. In this study, erosion was perceived by a large number of farmers to be a direct cause of declining soil fertility (Figures 5.6 and 5.7). When farmers were asked about the problem directly, 80% reported a soil erosion problem, which included all respondents in high altitudes. The problem is considered more serious on *bari* land. However, a substantial number of farmers reported it is a problem on both *khet* and *bari* land (35%) or on *khet* alone (12.4%).

The majority of farmers attributed the problem to high rainfall (78%). Other important factors were wind erosion (16%), steep land (16%) and the loose nature of the soil (10%). More detailed group discussions revealed other causes of soil erosion on *khet* land. Firstly, rodents burrowing into terrace risers in the winter lead to their collapse in the monsoon season. Secondly, floods (particularly at the beginning of the rainy season) wash away soils (contrary to the theory that they deposit fertile sediments). The problem has increased in recent years in some villages due to deforestation in the upper catchment. A further reason given by farmers is the significant losses of *khet* land (as compared to *bari* land) occurring as a result of landslides. The resource maps drawn by villagers of Landruk, Arman and Naya Tola, (Appendix 5) highlight the loss of *khet* land to landslides. The saturated nature of *khet* land soil was given by farmers as the explanation for the higher risk of landslides in these areas.

One of the more specific objectives of this study was to investigate the reasons behind the large outward sloping terraces found in the Palpa and Kimchor parts of the RCA. It is certainly not a lack of awareness of erosion issues which accounts for the failure of farmers to construct level terraces that are familiar in most of the middle hills. Over 90% of farmers in Deorali and Naya Tola, reported soil erosion to be a reason for declining soil fertility. Group discussions revealed several explanations for the practice. Larger terraces were constructed in the past to save on land taxes. Although farmers are increasingly aware of the risks of erosion, a decline in rainfall in recent years has brought about a corresponding decline in the degree of the problem and farmers see less need for level terraces. The low rainfall of the Tansen area (<1500m pa) may result in less serious erosion rates than in other mid hill areas, where the failure to construct level terrace would have a more devastating effect. Farmers place emphasis on the timing and intensity of rainfall, together with the existing moisture content of the soil in assessing the risks of erosion. Frequent light showers (*sim sim paani*) are less threatening than more sudden heavy downpours which sometimes occur at the beginning of the monsoon. Other reasons given for large terraces are for ease of ploughing and their importance as a prestige symbol.

It is the loss of soil nutrients which is the primary concern of the farmer. However if soil management maintains a balance whereby eroded nutrients are replaced annually, the devastating effects of soil erosion on soil productivity may be avoided. Compost application and livestock numbers are above average in the two Tansen villages.

In other areas of Nepal, outward sloping terraces have been related to soil type, being particularly associated with red soil, similar to those in the Tansen villages. Given the high clay content of these soils, particularly in the subsoil, farmers make outward sloping terraces to aid runoff and slow infiltration of rainfall which reduces the dangers of slumping.

In summary, farmers stressed the seriousness of the problem of erosion, identifying it as a major cause of declining soil fertility. The wealth of knowledge revealed and the lively debates that surrounded this topic during informal group discussions, emphasised the importance of the erosion issue. The hypothesis is therefore rejected.

(iv) Ethnic group

Hypothesis Trends in soil fertility differ between ethnic groups, as a result of variations in both the biophysical and socioeconomic environments

There are differences in the biophysical and socioeconomic environments of ethnic groups in the hills of Nepal. The most apparent of these is the significant relationship between ethnic group and altitude ($p=0.001$), with Bhramin/Chetris usually found in lower altitudes, where opportunities for agricultural development are more favourable. Tibetan/Burmo groups live at higher altitudes, whilst occupational groups are distributed throughout the hills, often living on the margins of villages. In addition to biophysical influences, socio-cultural factors such as access to resources, differences in livestock keeping practices and the practice of tenant farming among the occupational groups are also thought to have an influence on soil fertility.

There is a significant difference ($p=0.001$) in the incidence of declining soil fertility among ethnic groups. A higher proportion of Gurung/Magar communities, who dominated the mid and high altitude survey villages, reported declines in soil fertility. Slightly more Occupational castes than expected reported declining soil fertility on *bari* land.

In summary, the hypothesis is accepted. However, at the same time it is difficult to relate differences in soil fertility trends to particular socioeconomic influences. The reasons given by the different ethnic groups to account for changes in soil fertility, when controlling for altitude were similar.

(v) Land holding/Labour availability

Hypothesis 1 Fragmentation of landholdings and long distances to fields have a negative impact on soil fertility.

Hypothesis 2 Soil fertility problems are more serious in households with small or large landholdings. This is related to either a lack of resources (in poor households), or a shortage of resources/unit area (in richer households).

Hypothesis 3 Declining soil fertility is linked to a shortage of labour at key periods

The first two hypotheses were investigated using three parameters; total land size, fragmentation (number of parcels) and distance to fields, whilst holding altitude constant as a control variable. No significant relationship was found between any of the variables and soil fertility trend and hypotheses one and two are rejected.

Fertility management systems in the hills are labour intensive, relying on manpower to transfer the resources between the 3 spheres of production; forest, livestock and crop land. The availability of labour therefore determines the strength of the links these spheres, and thus the flow of nutrients within the farming system. Labour availability and total livestock units are significantly related, with higher numbers of animals kept where there is greater availability of labour ($p=0.001$).

The majority of households (63%) reported a decline in availability of both hired and household labour due to schooling of children, out migration (particularly in the high hills) and other opportunities (such as tourism in Landruk, small businesses/urban employment in Hyanja and Chambas). This has resulted in a weakening of links between the three spheres of production. Informal discussions revealed that the contribution of children in herding animals and collecting fodder and leaf litters has been reduced and the burden of these activities has, to some extent, shifted to women. To what this extent this has upset the balance between the three components can be illustrated by the rate of decline in livestock numbers and increasing reliance on private land tree resources (Table 5.3).

However, despite these implications, there was no significant relationship between soil fertility trend and total labour availability per household[10] or total labour:total land ratio and hypothesis 3 is rejected.

(vi) Land tenancy

Hypothesis Declining soil fertility is a problem on tenant land due to less intensive management and a lower levels of inputs

The relationship between security of tenure and soil fertility has been reported in Nepal by Tamang (1991). A lack of security and short term planning horizons mean that tenant farmers are unwilling to invest in fertilising resources. Tenant farmers often have different objectives with an emphasis on the maximisation of production. In addition, tenant land is usually poorer in quality and often located at the village margins. A confounding factor is the lack of resources available to tenant farmers. In the survey, the majority of tenant farmers belonged to the two lowest wealth categories; category three (46%), categories two and three (89%).

[10] Total labour per household was calculated using the following formula;
Full-time males + full-time females + 0.5(full-time children) +
0.5 (part time males + part time females + 0.5 (part time children)).

Tenant farmers were well represented in the sample. Over 27% of households (predominantly occupational castes) rented land, with the majority of these also cultivating private land. In 80% of cases, tenants supplied their own FYM/compost. However, there was no significant difference in the soil fertility trends reported by owner and tenant farmers. The majority of tenant farmers said there was no difference in the management practices of rented and owned land. There maybe several explanations for this. Firstly, as reported by LARC (1994), occupational groups have lower cropping intensities as compared to wealthier farmers. Secondly, as was clear from group discussions, given their low food sufficient status, tenant farmers aim to maximise production, and this is not possible without good soil management. Their long term future also depends on access to rented land, as there is little opportunity to purchase additional property. More informal group discussion did suggest that management inputs was not as intensive on rented land. In Chambas, in a rare case of the landlord supplying FYM/compost, the degree of management depended on the cooperation of the landlord. Failure to keep his end of the deal, results in tenant farmers applying chemical fertilisers secretly during the night. Based on these findings, the hypothesis is rejected.

The initial aim of the survey was also to assess the effect of different tenant agreements on soil fertility. However there was not enough variation in tenant agreements. For a large majority of tenants, the length of tenancy is left open, production of all crops is divided 50:50 tenant:owner and the tenant supplies the FYM/compost. An interesting trend in the high altitude villages of Tanchok and Landruk is the move towards contract agreements, as a result of increasing out-migration of households.

(vii) Farmer category

Hypothesis Declining soil fertility is a problem more common amongst poorer households

To some extent, the influence of resource factors such as land, labour and capital can be considered in a more integrated way through the medium of farmer category. The link between wealth status of farmers and land/soil degradation was discussed by Blaikie and Brookman (1987). Blaikie and Bookman argued that declines in soil fertility are closely related to decisions made by farmers, with regard to soil management, which are in turn dictated by the resources available. He established a link between poor farmers with few resources, often cultivating marginal lands and degradation of the soil resource. However, results from the EIS showed the opposite to be true for the LARC command area. The perceived trend of increasing soil fertility was greatest among poor households and occupational cast groups. Within the richer group, 64% reported decreasing or constant soil fertility as compared to poorer households, where 77% reported an increase in soil fertility (LARC, 1994).

This study used food sufficiency as an indicator of wealth, dividing households into three categories. The majority of households interviewed had sufficient food for less than 6 months. The proportion of farmers interviewed in the different wealth categories and the resources available to farmers are given in Table 5.4 and show significant differences (p=0.01) in availability of all resources, except labour.

Table 5.4 Important farm resources of food sufficiency categories

Food sufficiency category	%	*khet:bari* ration	Land *ropani*/hh	Able manpower	FYM/ *ropani*	Total livestock units	Rented in land	
		mean	mean	mean	mean	mean	yes	no
1. >12 months	22	1.86	23.00	3.31	17.40	5.11	15	101
2. 6-12 months	38	2.21	13.40	3.30	26.00	4.42	59	140
3. < 6 months	40	1.16	8.55	3.02	27.50	3.60	64	143
Average		1.81	13.7	3.20	24.60	4.26	138	384

There was a significant difference with respect to fertility trend on *bari* land, with 54% and 40% of category three households, reporting increasing or unchanged soil fertility respectively. Although, resources are less abundant for category three households, land area is smaller and resources are spread less thinly, as indicated by the FYM/ropani value (Table 5.4). There were no differences in the reasons given by the different categories to account for declining soil fertility. The hypothesis is therefore rejected.

5.5 Combined analysis of factors

Any change in soil fertility is a symptom of wider changes in the farming system as a whole. No one factor acts in isolation to influence trend in soil fertility.

In the previous section, the effects of biophysical, socioeconomic and institutional factors were considered in isolation. The discrete analysis of factors affecting soil fertility status showed some expected correlations between altitude, accessibility, total land area and soil fertility trend, but failed to show the significance of other factors such as land size, labour availability, and livestock management. The effect of these factors maybe masked by higher level influences; of these altitude springs immediately to mind.

The objective of this section is therefore to determine which of the underlying factors are most important in affecting soil fertility trend. Logistic regression can be used to directly estimate the probability of an event occurring. In this case it estimates the probability of declining soil fertility and identifies the key factors or variables which affect the probability of such a decline. Two models were constructed for *bari* and *khet* land. Linear regression requires a binary dependent variable and as the main interest is the chances of a perceived fertility decline, answers of no change or increasing soil fertility were treated as one category; not declining. This also improved the structure of the sample with the frequencies for the dependent variable shown in Table 5.5.

Table 5.5 Frequencies of soil fertility trend responses

Dependent variable	Categories yes	no
Declining soil fertility on *khet*	232	147
Declining soil fertility on *bari*	345	168

The forward stepwise method was used for entry of the independent variables into the equation and the criterion for determining which variables were removed from the model was the likelihood ratio. The following independent variables were used to construct the model; household category, ethnic group, sex of respondent, total household labour, total land holding, tenancy arrangement, livestock management[11], livestock index[12], total compost to area of *bari* ratio, total compost to area of *khet* ratio, *khet:bari* ratio, forest index[13], forest ratio, total livestock units/hh, accessability, agro-ecological zone, total compost production/yr/hh, rainfall, aspect and market availability. For the categorical variables, the indicator variable or reference category was set as 1. Thus the reference category for market was good, for rain was high, for aspect was NE, for agro-ecological zone was high hills, for ethnic group was Brahmin/Chetri and for farmer category was wealthy. Villages were grouped according to the parameters given in Figure 4.3.

(i) Model Number 1: Declining soil fertility on khet land

The model developed to predict the probability of soil fertility decline on *khet* land would classify 70% of responses correctly. Details of the model are given in Table 5.6.

[11] livestock management variable was calculated using the following values (stallfed=1, semiextensive=2, goth=3, mixed=4)

[12] the livestock index was calculated as follows (livestock units*management practice)

[13] the forest index was calculated by summing the following variables:
influence of community forestry on fodder and litter availability (increasing =3, no change =2, decreasing =1),
sufficient fodder (yes =2, no =1)
change in number of private trees (increasing =3, same =2, decreasing =1)
change in the availability of fodder/litter resources (increase =3, no change =2, decrease=1)

Table 5.6 Variables remaining in the model for declining soil fertility on *khet* land

Variable		Regression coefficients	R value	Significance
Wealth category			0.0762	0.0476
medium	(2)	-0.6037	-0.0514	0.0859
poor	(3)	-0.9932	-0.1051	0.0146
Forest index		-0.2909	-0.0975	0.0199
Total compost :land ratio		-0.0221	-0.0954	0.0217
Market			0.1624	0.0012
medium	(2)	1.9865	0.1405	0.0026
poor	(3)	2.6411	0.1784	0.0002
Rain			0.1893	0.0002
medium	(2)	-2.3662	-0.1737	0.0003
low	(3)	-0.8026	-0.0311	0.1256
Agroecozone			0.1330	0.0056
mid	(2)	-1.9550	-0.1521	0.0013
low	(3)	-0.1960	0.0000	0.7224
Constant		2.7101	-	0.0172

The R value gives a measure of the partial correlation between the dependent variable and each of the independent variables. The highest correlation is between rainfall and changing soil fertility, with declining soil fertility on *khet* land being associated with low rainfall. There is a high positive correlation between market availability and change in soil fertility, indicating that as access to markets becomes more limited, the chances of a decrease in soil fertility on *khet* land increase. Households belonging to category three, all other circumstances being equal, have a lower probability of a decline in soil fertility. A larger forest index and higher application of compost/ropani also reduce the chances of declining soil fertility.

The model can be more clearly illustrated, using the example of two households in Chambas and Tanchok.

For a wealth category 1 household in Chambas, situated in the low hills (agroecozone 3), with medium rainfall (group 2), a good market (group 1), a forest index of 4, and a total compost to land ratio of 20, the probability of a soil fertility decline is given by the equation:

$$\frac{1}{1+e^{-Z}}$$

where $Z = 2.7101 - 0.2909(4) - 0.0221(20) - 2.3662(1) - 0.01960(2) = -1.6537$

Thus the probability of declining soil fertility would be:

$$\frac{1}{1+e^{-Z}} = 0.16$$

For a category 3 household in Kimchor at high altitude (agroecozone 1), with medium rainfall (group 2), a poor market (group 3), a forest index of 8, and a total compost to land ratio of 20, the probability of soil fertility decline on *khet* land is as follows;

$$Z = 2.7101 - 0.9932(2) - 0.2909(8) - 0.0221(20) - 2.3662(1) + 2.6411(2) = 0.8705$$

The probability of declining soil fertility would be:

$$\frac{1}{1+e^{-Z}} = 0.70$$

Thus the probability of declining soil fertility is far greater for a household in Kimchor, which is located far from market facilities. Better forest resources (forest index of 8) fail to compensate for disadvantages arising from poor market access and altitude.

(ii) Model number 2: Declining soil fertility on bari land

The model developed to predict the probability of soil fertility decline on *bari* land would classify 76% of responses correctly. Details of the model are given in Table 5.7.

Table 5.7 Variables remaining in the model for declining soil fertility on *bari* land

Variable	Regression coefficients	R value	Significance
Wealth category		0.0890	0.0352
medium (2)	-0.8785	-0.0914	0.0278
poor (3)	-1.0860	-0.1075	0.0149
Total compost: *bari* land	-0.0149	-0.1099	0.0134
Forest index	-0.3498	-0.1171	0.0098
Market		0.1841	0.0004
medium(2)	2.1465	0.1604	0.0010
poor (3)	2.6171	0.1969	0.0001
Rainfall		0.1303	0.0075
medium (2)	-1.0255	-0.0469	0.0973
low (3)	1.3898	0.1126	0.0120
Agroeco zone		0.1788	0.0006
mid (2)	-2.5051	-0.1941	0.0001
low (3)	-0.8244	0.0000	0.2050
Constant	3.4891		0.0051

The variables remaining are similar to those for *khet* land, with total compost to land ratio being replaced by total compost to *bari* land ratio. Once again market access is a key factor affecting the probability of a soil fertility decline The replacement of total compost to land area, with the total compost to area of *bari* land ratio indicates the greater importance of FYM/compost in soil fertility management on *bari* land.

Access to markets is important in both models. Returning to Figures 5.2 and 5.3, it is clear that villages clustered around the decreasing plot are inaccessible, with few market facilities and/or at high altitudes; villages such as Arman, Kimchor, Khalte, Landruk and Tanchok. More accessible villages noticeably Hyanja, Bahrphirke and Chambas are located closer to the increasing/same plot.

In conclusion, the key factors affecting soil fertility change are similar for both *khet* and *bari*. These factors are the key factors affecting soil fertility and thus consideration of them is crucial in the development of any research strategy.

6 SOIL FERTILITY MANAGEMENT

Indigenous soil fertility management practices have been well documented in previous works (Sthapit *et al.*, 1988; Subedi *et al.*, 1989). Households generally adopt an integrated approach with differences in the importance of practices according to land type (Figure 5.4).

6.1 Changes in fertility management

Soil fertility management practices have changed over the years in response to changes in the socioeconomic, biophysical and institutional environment. To investigate these changes farmers were asked to show the contributions of different management practices to maintaining soil fertility on *khet* and *bari* land, both now and in the past (Appendix 5). One farmer in the group was given 20 maize grits to distribute amongst the practices according to their importance. Other members of the group then adjusted the grits until a consensus was reached. Figures 6.1 and 6.2 show the diagrams constructed in Pang and Talbari, which illustrate the main changes encountered during the survey.

	Present		10-15 years before	
	khet	*bari*	*khet*	*bari*
FYM/compost	10	12	11	20
Chem. fertiliser	0	0	1	0
Asuro/mulch	0	0	3	0
Oil cakes	8	8	2	0
Leaf litter	0	0	3	0
Green manures	2	0	0	0

Reconstructed from a diagram made by a group of farmers in Pang (Appendix 5)

Figure 6.1 The contribution of different management practices to soil fertility maintenance of *khet* and *bari* land in Pang

Pang is a classic example of a low hill village with almost no forest, undergoing hardship during the protection stage of community forestry. The diagram constructed for *khet* land illustrates the move away from integrated management systems where the nutrient system is characterised by a relatively expensive levels of inputs and a high efficiency of internal resource use, to one relying on 2/3 major practices, and high dependency on external inputs. Declines are most notable in the practices of in-situ manuring, green manuring, fallowing and cultivation of legumes. In accessible areas such as Pang, these have been replaced to some extent with the use of chemical fertilisers, however this is not a viable option for more remote areas. It is striking that the negative effect of chemical fertilisers was mentioned by over 75% of farmers to be the prime reason for declining soil fertility.

	Present		10-15 years ago	
	khet	*bari*	*khet*	*bari*
FYM/compost	7	8	8	6
Chem. fert	4	4	2	3
Terrace slicing	3	2	2	2
Mulches	0	1	0	4
Floodwater	1	0	3	0
In-situ manuring	4	5	5	5
Trash burning	1	0	0	0

Reconstructed from a diagram made by a group of farmers in Talbari (Appendix 5)

Figure 6.2 The contribution of different management practices to soil fertility maintenance of *khet* and *bari* land in Talbari

In Talbari, a days walk from the road head, soil fertility management still retains its integrated nature. Seven different practices contribute to maintaining soil fertility and there have been few changes over the last 10-15 years. Of particular interest in Hyanja was the noticeable contribution of rice husks in maintaining soil fertility (Figure 5.11). Unfilled grains of rice are burnt in the field after winnowing, the fine rice bran is fed to livestock and the coarse husk is put in the FYM/compost pit. Rice husk is traditionally applied to crops such as ginger and turmeric or used a bedding material for goats and poultry. Application directly to crop land is questionable in terms of providing nutrients, as rice husk is carbonaceous and poor in nitrogen. However, there may be other reasons for its use, such as the improvement of soil texture and structure.

The main features to emerge from the diagrams constructed in all villages are an increase in the relative importance of FYM, a decline in in-situ manuring, the introduction of chemical fertilisers and a decline in traditional practices such as trash burning, use of green manures and mulches. However, these changes are not evident for all villages. Accessibility to roads and markets and/or altitude seem to be the main factors influencing the degree of change.

6.2 Farmyard manure

Farm yard manure has remained the primary source of nutrients in all villages, however its relative importance varies (Figure 6.3).

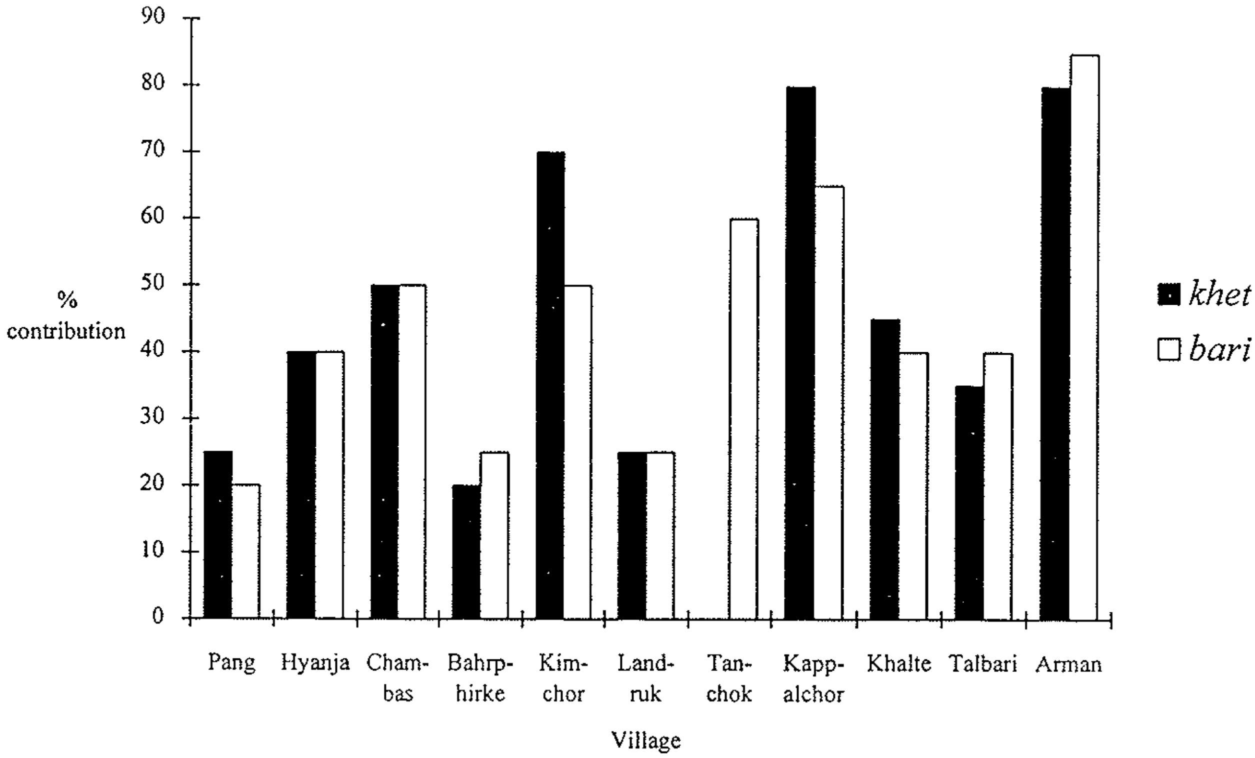


Figure 6.3 The proportion of nutrients contributed by FYM/compost

In Pang, Hyanja, Chambas and Bahrphirke, chemical fertilisers are an important supplementary source of nutrients. In high altitude villages such as Landruk and Tanchok, in-situ manuring, migratory sheep herds are important. FYM/compost forms only part of an integrated management strategy in the less accessible areas of Talbari and Khalte. The proportion of plant residues in the manure was reported to have decreased in most villages due to the depletion of forest resources, shortage of labour for leaf litter collection (traditionally a children's job) and the use of crop residues as fodder, not as bedding. Paradoxically in Kimchor and Tanchok, the collection of leaf litter is a strategy adopted by farmers to compensate for declining manure output. The two mid altitude villages of Arman and Kapalchaur rely almost entirely on FYM/compost.

Carson (1992) reported that in many areas farmers were diverting their FYM resources to *khet* land due to increased cropping intensities. However whilst the redistribution of FYM/compost is a more common feature of low altitudes, the majority of households (62%) in this study reported no change in the patterns of distribution of FYM between *khet* and *bari*. What remains crucial is the balance between supply and demand of FYM (Figure 6.4).

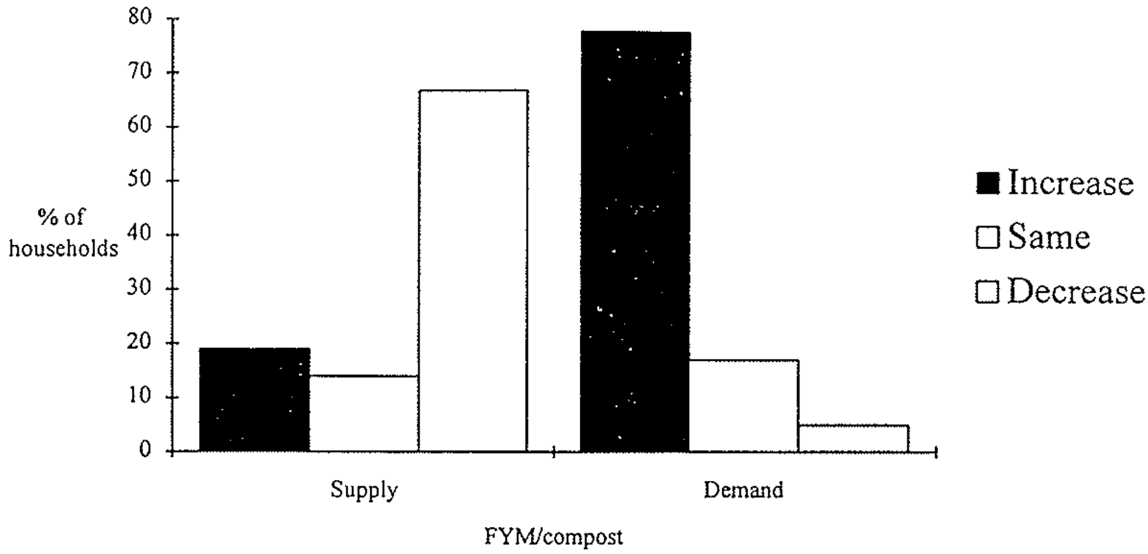


Figure 6.4 **Proportion of households reporting a change in supply and demand of FYM/compost**

6.3 Chemical fertilisers

Chemical fertilisers are increasingly used by farmers, although use is highly skewed towards accessible, low altitude areas (Figure 6.5).

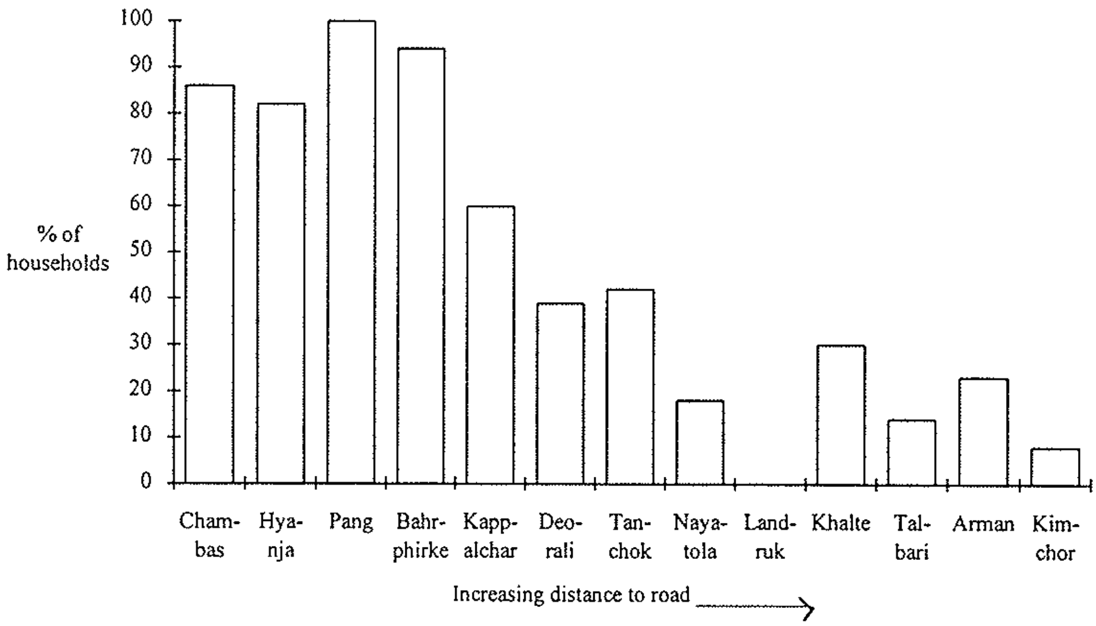


Figure 6.5 **Percentage of households in each village who used chemical fertiliser in 1994**

The incidence of chemical fertiliser use is affected both by accessibility and altitude. It is, as expected, most common in low altitude, accessible villages such as Pang, Hyanja, Chambas and Bahrphirke. Villages located further away and/or at high altitudes use little chemical fertiliser. There is also a significant relationship ($p=0.001$) between use and farmer category, with a fewer than expected number of category three households using chemical fertiliser.

6.4 Gender dimensions of soil fertility management

Gender plays a crucial role in determining labour allocation in the hills. Roles, tasks and responsibilities are affected by cultural, socioeconomic and agro-ecological divisions. The roles and responsibilities of men, women and children with respect to soil fertility management were explored using PRA techniques (Appendix 5). Farmers were first asked to list the main activities involved in maintaining soil fertility. Having listed these, they were then given 10 maize grits to indicate the contribution of labour from females, males and children to each activity. The results from Hyanja are displayed in Figure 6.6.

	Responsibility		
	Female	Male	Children
Collect leaf litter	6	1	3
Cut and carry grass	5	3	2
Clean shed	5	4	1
Turn FYM	2	8	0
Carry FYM	6	1	3
Spread FYM	5	4	1
Carry Chem.fertiliser	2	4	4
Apply Chem.fertiliser	5	5	0

Reconstructed from a diagram made by a group of farmers in Hyanja (Appendix 5)

Figure 6.6 Division of labour for soil fertility management activities

This pattern was remarkably similar across all villages, although in low altitude Brahmin communities, women generally have a lesser workload than their counterparts in high altitudes. The majority of tasks are shared by men and women, with a greater burden falling on women. Children also play a key role, particularly in the collection of leaf litters in high altitudes. It has been reported that the majority of decisions concerning crop production in the hills are made jointly and that with regard to the use (amount and kind) of traditional fertilisers, women are the dominant decision makers. However decisions regarding the amount and kind of chemical fertilisers use are made by men (Shrestha, 1989).

The increased number of children attending school has led to an increasing work burden for women, as they are responsible for the collection of fodder and leaf litter. However, the introduction of chemical fertilisers as a replacement for FYM/compost may have led to a reduction in the work load of women. The purchase and application of chemical fertilisers is primarily the responsibility of men, although women participate in many of the related activities such as carrying fertiliser from the distribution point.

Despite the variation in the responsibilities and roles of male and female farmers, there was no significant difference in the perception of soil fertility trends between men and women, nor in the reasons given to account for decreasing soil fertility.

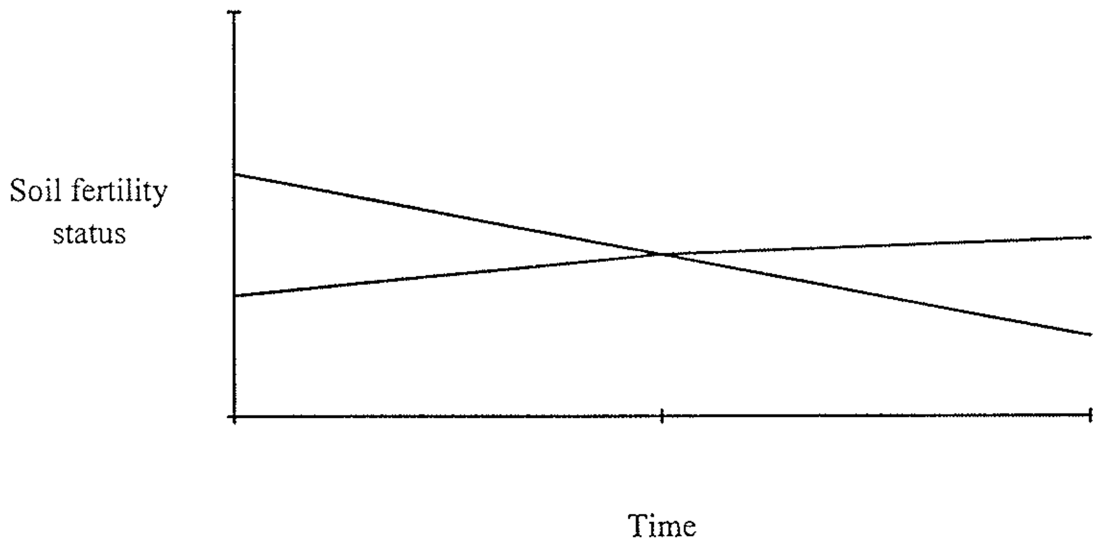
7 CONCLUSIONS

7.1 Is the problem of declining soil fertility a priority?

Declining soil fertility was identified by the majority of farmers to be a serious problem, directly contributing to declining crop productivity. However, the degree of the problem in the perception of farmers varies widely across the RCA.

There was no difference in the reported incidence of declining soil fertility on *khet* and *bari*, land, although soil analysis results in Chapter 4 revealed that the macronutrient status of *bari* land is higher. Similarly, soil analysis results showed that macronutrient status increases with altitude, whereas reported incidence of declining soil fertility was significantly greater at high altitudes. This suggests a situation whereby, soil fertility maybe a more serious problem for soil with a higher nutrient status (Figure 7.1).

Figure 7.1 Hypothetical relationship of fertility status and soil fertility



The problem for research is; should the focus be on soils of low fertility status or on soils of higher fertility status but in decreasing trend?

7.2 Factors affecting soil fertility

Biophysical factors have a strong influence on soil fertility trend. Altitude, accessability, market availability, rainfall and aspect were all shown to significantly effect the incidence of reported soil fertility decline. The worst scenario arises from a combination of high altitude, poor markets and accessability, southern aspect and low rainfall. Superimposed on these factors are socioeconomic influences such as ethnic group and farmer category. Of all of these factors, the logistic regression models showed that market availability, rainfall, altitude and farmer category were most closely linked to soil fertility decline. However, there is little researchers can do to ameliorate the impact of these factors, the key lies in taking them into account when designing a research strategy.

This report has stressed that changes in soil fertility are only a symptom of changes in the farming system or the wider environment. Among the more important of these changes seem to be the decline in livestock numbers, change in livestock keeping practices, forest degradation, development of community forestry, and changes in soil fertility management strategies of farmers. The importance of these factors was emphasised by the reasons given by farmers to account for changes in soil fertility. Declining FYM/compost and erosion were found to be the most serious problems and these are closely related to changes in the livestock and forest components of the farming system and the relationships between them. The declining ratio of compost to land area and the availability of forest resources (as measured by the forest index) were shown to significantly influence the chances of declining soil fertility on both *khet* and *bari* land in the logistic regression model.

The changes in soil fertility management systems reflect a changing balance between the three spheres of production; forest livestock and crop. In accessible areas at low altitudes, a weakening of links between forest/livestock on the one hand on crops in the other is evident. In mid and high altitudes, the traditional link between forest and cropland seems to be weakening, relying more on private land to meet fodder needs.

The logistic regression has two potential implications for research; on the issue of soil fertility research domains and on the critical issues to be addressed by research.

7.3 Soil fertility recommendation domains

This issue was first raised by Bennett (1994) who was asked to produce a framework, easily understood across disciplines, for dividing the RCA into soil fertility domains. He questioned the validity of using such terminology in the Nepal context, where inherent soil fertility or productivity of a land type with a certain soil type can only be seen as one component within the farming system.

However, this study suggests that based on the results of the logistic regression and on differences in soil fertility management systems, it maybe rational to divide the RCA in to three fertility research domains.

The first research domain is composed of low altitude accessible areas close to markets. In these areas, the traditional linkages between crops, livestock and forest have weakened. Farmers now increasingly rely on private land to meet fodder needs and there is a decline in the relative importance of FYM/compost in the nutrient management system. This decline has to some extent been compensated for by the use of chemical fertiliser as a complimentary source of nutrients (Figure 7.2).

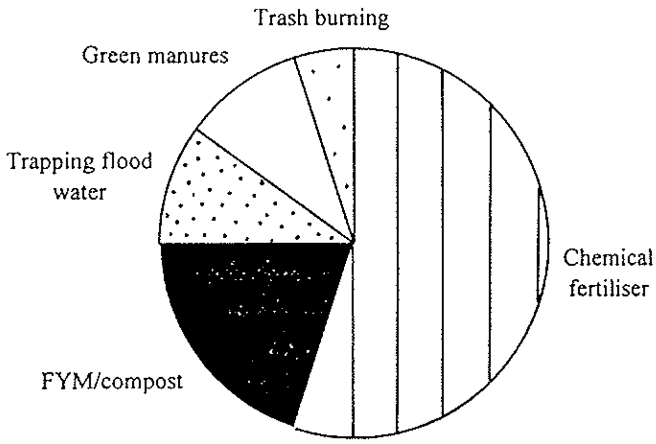


Figure 7.2 Sources of nutrients for *khet* land in Bahrphirke

In this area, the majority of the farmers in the survey reported static or increasing soil fertility; high cropping intensities, increased population pressures has been overcome through the use of external sources of nutrients. However, there are exceptions to this such as in Pang. The main problems of farmers in these areas are the negative effects associated with chemical fertiliser use which is often linked to the a corresponding decline in FYM/compost application rates.

The second research domain is composed of more inaccessible areas and/or those at mid and high altitudes. In these areas, linkages between the components of the farming system remain strong, and soil fertility maintenance is highly dependent on livestock inputs. Farmers are not in a position to substitute for the decline in FYM/compost with alternative nutrient sources, such as chemical fertilisers (Figure 7.3).

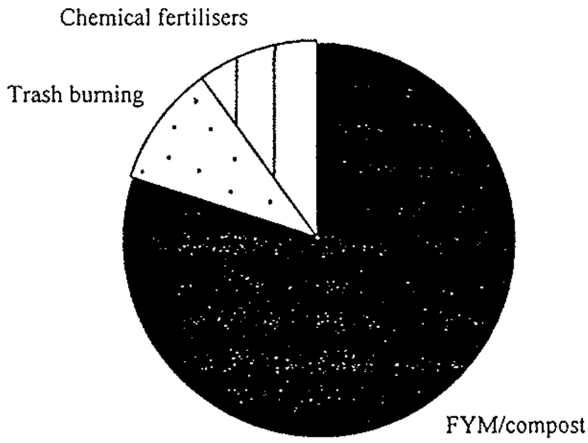


Figure 7.3 Soil fertility management on *bari* land in Kapalchaur

Soil fertility management relies on traditional practices such as in-situ manuring, trash burning and slicing of terrace risers. The main problems of these areas are degradation of the forest resource and to some extent a shortage of labour resulting from out-migration.

One of the shortcomings of this study was that the focal points did not include a site above 2000m. From a soil fertility point of view such areas are unique, with potato based cropping patterns and a unique livestock management system. Soil fertility management is dominated by in situ manuring, FYM/compost and manure from migratory sheep flocks during the winter. It is suggested that these areas form the third research domain.

Within these research domains, rainfall is an additional criteria to be considered in the selection of any research sites, with declining soil fertility a particular problem in low rainfall areas. Farmer category was also shown to significantly influence the chances of declining soil fertility and research must consider the needs and differences of farmers of different wealth status explicitly in future research activities.

The fertility research domains suggested above complement the policy proposed by the APSC (1994). The promotion of chemical fertiliser is a feature of this policy for accessible areas in the hills (APSC, 1994). HMGN has now permitted private sector involvement in the purchase and distribution of fertilisers and is heavily committed to an expansion in their use. The proposed policy therefore placed a large emphasis on the role of chemical fertilisers, recommending that integrated fertility management should form the focus of research in more accessible areas. However in less accessible areas, the role of organic matter, and investigation of organic matter dynamics should form the focus of research.

7.4 Research priorities

(i) The need for a quantitative baseline

Figure 7.1 emphasises the need for an understanding of the relative rates of decline in soil fertility across agro-ecological zones and for different land types. Further investigations are needed to establish the relative rates of change in soil fertility, so that the problem of declining soil fertility can be prioritised. This could be achieved by the relatively simple method of establishing a network of sampling sites, covering different socioeconomic and biophysical environments and analysing soil samples on an annual basis. Further work on soil characterisation and soil analysis, particularly of sub soils, is also needed to provide a substantive baseline from which research can be prioritised.

(ii) Forest resources

The availability of forest resources (measured by the forest index) was included in the logistic regression model as affecting the probability of declining soil fertility. The importance of these resources is emphasised by the significant effect of community forestry polices and private tree planting on soil fertility. However, the importance of the type of forest resources varies, as indicated by the forest ratio (a measure of the proportion of fodder/litter coming from different sources) which shows increasing reliance on off-farm forest resources at higher altitudes. Farmers' activities reflect this with the development of community forests more prominent at mid altitudes and private tree planting significantly higher at low altitudes.

Carson (1992) recommended that the entry point for a soil fertility management strategy should be an increase in the planting of high quality nitrogen fixing fodder trees, which are green during the dry season, marginal *bari* land. This study supports this recommendation in identifying the forest component as critical for soil fertility and the starting point for any improvement. However, it suggests that sites for tree planting be assessed according to variation in the forest ratio. Whilst private tree planting may be appropriate in low altitudes, the emphasis in mid/high altitudes may shift towards the restocking and improvement of forest through community management.

(iii) Farmers' strategies to maintain soil fertility

Throughout the survey area, farmers have responded in different ways to the problem of maintaining soil fertility. These include both direct approaches such as the use of chemical fertiliser and more indirect approaches such as improved forest management. Farmers' strategies to tackle declining soil fertility are active in all three spheres of production;

- forestry; through private planting, improved forest management through community forestry
- livestock; through shift to stall feeding systems, reduction in livestock numbers
- agricultural; through land abandonment, use of chemical fertiliser, rationalisation of FYM/compost

Understanding the motivation and decision making processes behind these strategies would provide a good starting point for determining future research priorities.

(iv) Soil fertility management

The main features to emerge from the diagrams constructed in all villages are an increase in the relative importance of FYM/compost, a decline in in-situ manuring, the introduction of chemical fertilisers and a decline in traditional practices such as trash burning, use of green manures and mulches. However, the degree and direction of changes is not the same for all villages. Accessibility to roads and markets and/or altitude seem to be the main factors influencing change.

FYM/compost remains the most important source of nutrients for the majority of farmers in the RCA and the importance of a greater understanding of organic matter dynamics is emphasised by Chapter 3, which concluded that the soils' organic fraction was critical in accounting for variation in important soil properties.

The role of FYM/compost and therefore the research needs vary widely across villages. For example, in accessible areas (recommendation domain one), the emphasis should be on finding the most suitable combinations of chemical fertiliser and FYM/compost for sustainable improvements in soil fertility. In less accessible areas with few markets (recommendation domains two and three), research should focus on understanding the decision making process of farmers regarding FYM/compost use; particularly the nutrient quality of different FYM/compost and details of timing and placement of manures Changes in FYM/compost practices resulting from changes in livestock management practices and practices such as incorporation of leaf litters (observed in high altitude villages of Tanchok and Kimchor) also need investigation.

Soil fertility management remains integrated in nature. Practices such as green manuring, burning of trashes and cultivation of legumes, although playing a minor role in nutrient supply, play an essential role in the dynamics of plant nutrient supply and nutrient cycling. Although maybe not warranting attention in their own right, consideration of their contribution is essential in the development of integrated nutrient management systems. For example, the promotion of appropriate FYM/compost chemical fertiliser combinations must also consider the role of these practices.

The study emphasised the important role women play in soil fertility management. Failure to address their specific needs and/or consider their implicit knowledge may have been one reason for the failure of soil fertility technologies in the past.

(v) *Reduction of losses from the system:*

There is little quantitative data on inputs and outputs to the nutrient system. Erosion represents the most potentially serious loss of nutrients, although section 3.3.1 showed that losses from erosion may be replaced by annual application of FYM/compost. Despite this, erosion was identified as a major contributing factor to declining soil fertility, particularly at mid and high altitudes (Figure 5.6). These losses of nutrients from erosion may become more crucial in the future as FYM/compost applications decline.

Farmers are acutely aware of the erosion problem and its causes, relating it directly to high intensity rainfall; loss of topsoil is recognised as the most serious issue. A participatory approach to the development of soil and water conservation technologies is fundamental to the development of socially acceptable technologies. Farmers gave many rational explanations for their failure to construct level terraces despite the awareness of nutrient losses from erosion and only a participatory approach can successfully respond to these concerns.

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