International Centre for Integrated
Mountain Development

THE LAND, THE FARMER, AND THE FUTURE

A Soil Fertility Management Strategy for Nepal

Brian Carson

ICIMOD OCCASIONAL PAPER NO. 21

Kathmandu, NEPAL
1992

No. 1 **EROSION AND SEDIMENTATION PROCESSES IN THE NEPALESE HIMALAYA**
Brian Carson
August 1985.

No. 2 **INTEGRATED RURAL DEVELOPMENT PROJECTS IN NEPAL: A REVIEW**
Bharat B. Pradhan
December 1985.

No. 3 **SUSTAINING UPLAND RESOURCES: PEOPLE'S PARTICIPATION IN WATERSHED MANAGEMENT**
Anis Dani and J.G. Campbell
July 1986.

No. 4 **DECENTRALIZED ENERGY PLANNING AND MANAGEMENT FOR THE HINDU KUSH-HIMALAYA**
Deepak Bajracharya
September 1986.

No. 5 **GLACIAL LAKE OUTBURST FLOODS AND RISK ENGINEERING IN THE HIMALAYA**
Jack D. Ives
November 1986.

No. 6 **OPERATIONAL EXPERIENCES IN FOREST MANAGEMENT DEVELOPMENT IN THE HILLS OF NEPAL**
G.B. Applegate and D.A. Gilmour
January 1987.

No. 7 **FORESTRY-FARMING LINKAGES IN THE MOUNTAINS**
T.B.S. Mahat
March 1987.

No. 8 **ROAD CONSTRUCTION IN THE NEPAL HIMALAYA: THE EXPERIENCE FROM THE LAMOSANGU-JIRI PROJECT**
Urs Schaffner
March 1987.

No. 9 **MOUNTAIN ENVIRONMENTAL MANAGEMENT IN THE ARUN RIVER BASIN OF NEPAL**
John R. Dunsmore
December 1988.

No. 10 **HILL AGRICULTURE AND THE WIDER MARKET ECONOMY: TRANSFORMATION PROCESSES AND EXPERIENCE OF THE BAGMATI ZONE IN NEPAL**
Mahesh Banskota
May 1989.

No. 11 **HIGHLAND-LOWLAND INTERACTIONS IN THE GANGES-BRAHMAPUTRA RIVER BASIN: A REVIEW OF PUBLISHED LITERATURE**
L. A. Bruijnzeel and C. N. Bremmer
July 1989.

No. 12 **MICRO-LEVEL ENVIRONMENTAL MANAGEMENT: OBSERVATIONS ON PUBLIC AND PRIVATE RESPONSES IN KAKANI PANCHAYAT**
Saroj K. Basnyet
June 1989.

No. 13 **CASE STUDY ON MOUNTAIN ENVIRONMENTAL MANAGEMENT: NYEMO COUNTY (TIBET)**
Zhang Rongzu
August 1989.

No. 14 **NATURAL RESOURCE MANAGEMENT IN THE MOUNTAIN ENVIRONMENT: EXPERIENCES FROM THE DOON VALLEY, INDIA**
Jayanta Bandyopadhyay
August 1989.

No. 15 **LANDSLIDE MANAGEMENT IN THE MOUNTAIN AREAS OF CHINA**
Li Tianchi
October 1990.

No. 16 MINI- AND MICRO-HYDROPOWER IN NEPAL
Jean-Marion Aitken, G. Cromwell, and G. Wishart
December 1991.

No. 17 **AGROFORESTRY IN MOUNTAIN AREAS OF THE HINDU KUSH-HIMALAYAN REGION**
Jeannette Denholm
August 1991.

The Land, The Farmer, and The Future

A Soil Fertility Management Strategy for Nepal

Brian Carson

ICIMOD OCCASIONAL PAPER No. 21

Published by
International Centre for Integrated Mountain Development
Kathmandu, Nepal

Cover photograph: Left : The Land
Top Right : The Farmer
Bottom Right : The Future
(All Courtesy of T. Partap).

Plates without acknowledgements are all the work of the author.

Published by

International Centre for Integrated Mountain Development
G.P.O. Box 3226,
Kathmandu, Nepal

ISBN 92-9115-046-0

Typesetting at ICIMOD Publications' Unit

Foreword

This paper on soil fertility management puts the problem of declining soil fertility in Nepal within the context of the economic, demographic, and geological perspective. In doing so, the author has produced an extremely useful text that will be of immense value to policy-makers and development practitioners working not only in Nepal but also in other similar environments.

The importance of the author's perspective stems from the nature of the problems facing the farmers of Nepal. Human and livestock populations exceed the carrying capacity of the subsistence farming economy, and economic necessity has led to seasonal, and even permanent, out-migration. The traditional subsistence farming system is static and labour intensive. Soil fertility maintenance measures, which require additional time, money, or risk, are not feasible for the subsistence farmer. By and large, the new techniques introduced during the preceding decades have ceased to bring about any meaningful gains.

Nepal's farmers will be faced with a decline in productivity against the background of increasing population pressure until small farmers engage in commercial, market-led agriculture. There is no doubt that also, with or without a directive policy for the commercialisation of agriculture, this change has begun to take place and the trend will continue. It is within the context of this transition that the soil fertility strategy presented in this document was formulated.

The author has drawn on his work experiences in Nepal to present an in-depth evaluation and perspective on the land and the farmer and has provided a soil fertility strategy for the future. The manuscript was first prepared for USAID, Nepal, and the present version, in the ICIMOD Occasional Paper series, is published under the auspices of ICIMOD's Mountain Farming Systems' (MFS) Programme.

Both organisations share the author's continuing concern for the degradation of available land resources in a region for which agriculture is the dominant sector of the economy, and it is within this context of shared concerns that the paper is now being published as a joint USAID/ICIMOD publication. We have no doubt that this work will be of considerable use to policy-makers, government planners, and development experts who are involved in the formulation of soil fertility strategies. It is hoped that, in the long run, the ultimate benefit will accrue to the farmers themselves, for it is they who can claim to be the most concerned of all.

K.C. Kammerer
Director
USAID, Nepal

E. F. Tacke
Director General
ICIMOD

Acknowledgements

This paper is a compilation of the research findings and observations of the author based on 6 years' work and travel within Nepal over a 14 year period. The author thanks the USAID for providing him with the opportunity to put these ideas on paper and, in particular, Chuck Strickland and Rob Thurston for their enthusiastic support throughout the paper's development. Thanks are also due to ICIMOD, particularly its Farming Systems' group, for reviewing the manuscript and making useful suggestions.

The formal and informal nurturing by my colleagues in Nepal, America, Europe, and Canada were essential to the development of this present level of understanding. Any credit to new ideas must be shared among them, while I alone am responsible for any errors and omissions.

Finally, to the farmers of Nepal, I salute your ability to manage the lands as you do, in the face of tremendous odds. I thank you for the patience and humour you have shown me over the past decade as I struggled to understand your ways. Namaste.

Brian Carson

Table of Contents

TABLES

FIGURES

I. Introduction

Nepal is at a critical point in her history. The population is increasing at a rapid rate and, in spite of the agrarian nature of the country and the Government's commitment to supporting it, there is increasing concern that agricultural production is declining. Many researchers and, indeed, even the farmers themselves believe that the soils are not as fertile as they once were and that the agricultural soils of the country are being degraded. Pressure on the remaining forests for fodder, firewood, litter, and timber is unrelenting and the present rates of extraction of forest resources often exceed the forest's ability to produce them. Biodiversity is declining and the ecological condition is destabilising (Banskota and Jodha 1992). There is also concern that chemical fertilizer, as used in Nepal, does not appear to be conducive to sustainable management. Farmers, and even researchers, at the major wheat research station at Parwanipur, are reporting serious declines in yield after only 10 years of intensive fertilizer use. A recent workshop on soil fertility in the Middle Mountains of Nepal warned of serious acidity problems looming on the horizon, and there was a general consensus that the management of organic matter in Nepalese soils, by and large, was inadequate and seemingly unsustainable. Within the Ministry of Agriculture there are raging debates on the future role of chemical fertilizers in Nepalese agriculture. To all of this, there is a constant, nagging perception that Nepal is undergoing a process of desertification as a result of rampant deforestation and subsequent erosion. Based on this scenario, nothing short of a miracle will save the country from becoming a mountainous Sahara Desert.

There are, indeed, many problems with Nepalese agriculture, in general, and with the management of soil fertility in particular. However, it is this author's contention that much of the apprehension and confusion that appears in the media is based on a basic misunderstanding of the Nepalese landscape and the farming systems that are now in place.

Soil fertility means different things to different people, but, in the context of this report, it includes all the physical and chemical properties of the soil that influence the productivity of the land resource. The dynamics of geomorphic and pedogenetic processes influencing soil fertility are investigated, as these help to establish a baseline for measuring the sustainability of the soil resource. Opportunities for the improvement of soil fertility management are considered within the context of present socioeconomic conditions. Only technologies that have been successfully implemented, or have shown considerable promise within the Himalayan region, are recommended. Finally, strategies for developing meaningful soil fertility and sustainability programmes are formulated within the present institutional and political framework.

A major gap exists within the soil science field itself when attempting to understand the complex issues of fertility management in Nepal. The tendency has been to focus on the soil itself and to ignore the dynamics of soil management in mountain farming systems. This omission has led to an unjustified focus on the inorganic components of the soil system based on laboratory analyses and experimental plot-based fertilizer trials. The organic system (surprisingly, considering its present importance) has been largely ignored. This focus on chemical fertilizers has resulted in an unbalanced overview of Nepal's soil fertility situation, particularly for the mountain regions. More importantly, this focus has not been conducive towards providing a clear vision for overcoming the present trends towards increasing soil degradation.

This work has been carried out on a contract agreement basis, RFQ-NEPAL-91-027, between USAID and the consultant awarded in August 1991. The primary task of the assignment was to develop a soil fertility strategy for Nepal which addresses the present trends of declining crop yields and the deteriorating soil fertility status of agricultural soils.

Virtually all agricultural workers agree that poor soil fertility is one of the major constraints facing farmers in Nepal, but there has been no concerted effort to characterise the soils, study indigenous fertility management, and determine why farmers are not managing their lands as well as they might.

The study is divided into four main chapters: the land - a brief treatise on the characteristics of the Himalayan landscape; the farmer - a discussion on production systems and how the farmer manages the fertility of the soil; the future - which provides a perspective on opportunities to induce positive changes within traditional soil fertility management systems. In the fifth chapter, recommendations are given that will assist the Government in formulating their agricultural development programmes and suggestions are given concerning how the donor might assist in that process. The final chapter is a brief summary of the areas covered by the paper as a whole.

II. The Land

In any discussion of soil fertility, particularly when one is concerned about long-term sustainability issues, an understanding of the land and soil resources is imperative. The Nepalese farmer is working within a dynamic geomorphic system, and the characteristics and performance of soils must be considered within that framework.

The Nepalese Landscape

The landscape of Nepal is the result of the ongoing collision between two massive continental plates - that of India to the south and Asia to the north. The land surface itself is extremely dynamic. The *Terai* is being subducted at the rate of more than 4 cm a year. A new, massive frontal uplift sheet has recently developed some kilometres away from the Siwalik front, resulting in an unprecedented erosional landscape on the otherwise featureless *Terai*. The main Himalayan chain, including Mount Everest, is considered to be still rising at an exceptionally high rate. Major breaks in the plates occur at the Main Boundary Fault and Main Central Thrust that straddle the whole country from east to west. Active transverse faulting can be found everywhere with many examples of shearing of recently deposited alluvium. This violent, tectonic movement creates unparalleled geomorphic activity. Landslides, debris torrents, and floods are every day features and result in a very high rate of natural erosion. The Nepalese farmer has learned to live with a degree of uncertainty that would be unacceptable to European farmers. Over time, the farmer has developed agricultural systems that require relentless maintenance and a highly developed sense of risk management, in order to survive normal and accelerated geomorphic events. The constant exposure and mixing of subsoils and parent rock provide for fresh exposure of certain minerals that would otherwise leach away. Soil fertility management must be considered within the context of this greater geomorphic dynamism.

Nepal is made up of 14,748 sq.km. of land, which is readily subdivided into 5 major physiographic regions: including the *Terai*, Siwaliks, Middle Mountains, High Mountains, and the High Himalayas. Not surprisingly, boundaries between these major physiographic regions correspond to the major faults and thrust plains of the ancient, now crumpled, Indian plate. These regions have distinct bedrock, geological, climatic, and hydrological characteristics; so soils and land use within these zones are significantly different. Based on traditional perceptions of land types in Nepal, with modifications by Nelson (1980) and later the Land Resource Mapping Project (LRMP 1986), these regions are now used in major planning exercises within the National Planning Commission. A brief description of the Physiographic Regions of Nepal is provided below.

The Terai

The *Terai* Region comprises 14 per cent of the land area of Nepal (2,122 sq. km.). It is made up exclusively of recent and post-pleistocene alluvial deposits forming a vast piedmont plain adjacent to the main Himalayan range. Elevations range from 60 to 330 metres, with slope gradients of 0.2 to 1 per cent. The land is flat, with the exception of minor local relief caused by river action and, in a few areas, recent, active, tectonic uplifting. The *Terai* Region is subdivided into 3 units based on alluvial history: active, recent, and older alluvium.

Making up 1.3 per cent of the land of Nepal, the active alluvial plains are flooded, or have been flooded, on a frequent basis (less than every 10 years), and the soils are generally coarse, highly porous, and lack significant weathering. Given the risk of monsoon inundation, these areas are usually managed in a less intensive manner, including grazing and low risk perennial crop production-including *Dalbergia sissoo* and, more traditionally, the pigeon pea.

The recent alluvial plains of the *Terai* make up over 7.9 per cent of the total land area of Nepal and could be considered the "bread basket" of Nepal. Soils are stable, water tables are never far from the surface (particularly during the monsoon), and the natural tendency for water to pond facilitates rice production. Virtually all of these soils are already in agricultural production.

The older alluvium, making up 4.9 per cent of the land area of Nepal, is made up of soils that are not subject to ponding as the slope gradients are higher and, in many cases, the soils are of a coarser texture. Areas of local uplifting, caused by the emergence of a new Siwalik plate some kilometres south of the present Siwalik front, are common, particularly in the western *Terai* where local relief as much as any other factor has discouraged settlement. Otherwise, government zoning for forestry and lack of readily accessible groundwater, or surface water, presently limit cultivation on much of these lands.

The *Terai* Physiographic Region is still considered to be the last frontier of Nepal, in spite of the fact that most of the best lands have already been settled. A year round growing season, good soils, availability of irrigation water, a relatively well-developed infrastructure, and easy access to the major markets of India suggest an optimistic future for agriculture. There are, however, some serious constraints centred around a population dominated by traditional landlord-tenant relationships, as a result of which the will to develop a more dynamic and productive agricultural system is lacking. Large landlords find investment in agriculture unattractive compared to other options: small farmers without assured tenure and a feudal crop-sharing arrangement see any investment beyond a bare minimum as unwise. Soil fertility management here, although much more closely bound to chemical fertilizers than in the hill regions of Nepal, still depends to some extent on livestock manures. Farmers, in areas where Sal forests are still to be found nearby, make active use of these forests for firewood and, to a lesser extent, fodder. Where fuelwood is absent, farmers are using dried livestock manure for cooking fuel and the lack of compost use on their soils is becoming increasingly serious. In the future, the agricultural system in the Nepalese *Terai* will undoubtedly increasingly benefit from experience gained in adjacent areas in India where some of the management problems now coming up in Nepal have long ago been solved.

The Siwaliks

The Siwaliks account for 1879 sq. km., or approximately 12.7 per cent of the land area of Nepal. Relief of less than 300 metres is common and rarely exceeds 1,000 metres in any watershed. Within the mountainous landscapes of the Siwaliks, slopes are generally too steep or unstable and soils too shallow to support any type of agriculture. The Siwalik Ranges are made up of relatively complex interbedding of Tertiary conglomerates, sandstones, siltstones, and mudstones of varying degrees of consolidation and form a very rugged and sometimes broken and gullied terrain. Local differences in rock type are often responsible for the tremendous variability in vegetation cover in the Siwaliks. Unfortunately, these differences are often not recognised by planners. Bedrock types that can only support scrub-type vegetation are viewed as areas that have been seriously degraded by man. The extensive shale areas north east of Lahan show inherently poor conditions for forest growth - man has had little effect on the apparent degradation. Conversely, the north facing slopes of gently, northern dipping sandstones support highly productive, mixed tropical hardwood forests that could conceivably be managed in a much more intensive manner. It is unfortunate that all of the lands in the Siwalik ranges have been lumped together as a single management unit. This lumping has resulted in many lost opportunities for effective use of resources. Large blocks of land have been included in Protection Forest Areas when they could support sustained selective logging. Conversely, many areas within the drought-prone shales have low forestry potential, and well-intended rehabilitation programmes repeatedly fail, if reclamation goals are set beyond the inherent capability of the land. Geomorphic instability within the Siwalik mountains has resulted in extremely expensive road construction and maintenance costs. Road closures caused by landslips frequently occur in the monsoon, particularly in the mudstone and shale areas.

Agriculturally, the most important areas within the Siwaliks are the Dun valleys where virtually all of the presently cultivated land is found. All Dun valleys (originally lake basins dammed as a result of tectonic uplifting of the Siwaliks to the south) have distinct features based largely on the characteristics of the watershed that served the prehistoric basins. For example, the Dang Valley and the upland areas of the Chitwan Valley were deposited by adjacent small local watersheds over 20,000 years ago. Now, those same small watersheds do not provide enough irrigation water to service the agricultural lands found downslope. Conversely, the Deukhuri and the lowland areas of the Chitwan were, and still are, strongly influenced by major rivers and have significant areas of alluvial soils with great potential for surface and groundwater development. The Surkhet Dun, while similar to the Dang in formation, has only been drained in recent geological time. The poorly drained, unweathered soils on the south side of the valley reflect their youth. Because the soils of the Duns are so variable, agricultural workers should be discriminating when determining research and extension domains.

Before 1960, these basin areas were sparsely populated by the indigenous Tharus, as malaria kept the hill people from settling there permanently. In the last 30 years, the Chitwan, Dang-Deukhuri, and Surkhet valleys have undergone tremendous change in land use and land tenure. There are still opportunities for agronomic innovation where the pioneer spirit is evident, particularly in the Chitwan. The negative effects of a rigid caste system are least felt in the Dun areas, because farmers have left their original homesteads behind and, along with them, they have left behind old ideas that prohibit more appropriate land management. As in the *Terai*, serious land tenure issues, particularly in the Dang and Surkhet areas, make introducing agricultural innovations difficult.

The Middle Mountains

The Middle Mountains make up 4,350 sq. km. or 29.5 per cent of the land area of Nepal. Relief of up to 1,000 metres is common between valley bottom and adjacent hill top, while maximum relief of 2,000 metres occurs throughout the Mahabharat Lekh - which runs the length of the southern boundary of the Middle Mountain Region. Bedrock is predominately phyllite and various degrees of metamorphosed schist with interbedding of quartzite. Isolated exposures of limestone, granite, shale, and other rocks also occur - a result of extensive long-distance thrusting of native rock from areas to the far north. For example, bedrock on the top of Phulchowki, on the south side of the Kathmandu Valley, appears to have been "pushed" via an ancient tectonic thrust plate from areas in the High Himalayas to the north. Most of these rocks are of Pre-cambrian age and are usually highly fractured due to the tremendous tectonic thrusting that has occurred in the distant geological past. Unlike in the Siwaliks to the south, where agriculture is restricted to the basin soils, most of the cultivation occurs on the moderately sloping phyllitic landscapes. Slopes are more gentle than in the Siwaliks, and a significant portion of the sloping hills is cultivated under relatively sophisticated terrace systems. The majority of the Nepalese population traditionally lived in the Middle Mountains because the soils are suited to terracing, the climate in most of the area permits two croppings per year, and the forest was well suited to meeting most of the villagers' household needs. Kathmandu Valley is an anomaly in the Middle Mountains, because of its gentle slopes and deep lacustrine soils at 1,200 metres' elevation. This fact is of importance when determining the extension domains of the central research stations of Khumaltar and Kirtipur.

Brahmins, Chetris, and occupational castes tend to occupy the lower elevations while *Tamangs, Magars, Gurungs*, and other hill tribes are more common at higher elevations (Plate 1). *Newars* traditionally inhabited the Kathmandu Valley and the adjacent areas of Banepa, Palung, and Tistung.

Land ownership tends to be more equitable in the Middle Mountains than in the Duns or in the *Terai*; however, holding size is very small with a significant portion of the population owning less than 1/2 ha of land. Any one farmer may own 5 or 6 separate plots, including both irrigated and rainfed land; in part to reduce the risk of catastrophic flooding of alluvial lands or landslide destruction of his uplands.

The forests of the Middle Mountains are extremely heavily exploited for fodder, firewood, litter, and timber collection. There are few examples of unexploited forests in the region and the increasing pressure of the local population is making ever-increasing demands on these forests. Unfortunately, the management of these forests does not match the generally excellent management of the adjacent agricultural lands. Lack of tenure or assured right of harvest has severely dampened the Nepalese farmer's enthusiasm for managing these forests in a more intensive manner. Low stocking rates of undesirable species and a virtual absence of care in management of the grass and browse species are two serious aspects of local management. Given the importance of these forests in providing the nutrients and energy to run the agricultural systems of the Middle Mountains, better management of these lands will be a theme repeated throughout this study.

The High Mountains

The High Mountain Region comprises roughly 2,899 sq. km., 19 per cent of the land area of Nepal. Relief in the order of 2,000 metres is common, so the range of tropical to cool temperate conditions can occur within the same valley. Bedrock is dominated by more competent phyllites, mica schists, and other more highly metamorphosed sedimentary rocks. Areas of gently sloping land are much less common than in the Middle Mountains because the rocks are less easily weathered and river cutting is more intense. Deep "V"-shaped valleys are common throughout the region. Many of the most intensively cultivated lands occur on landslide runout material that occurs adjacent to the valley bottoms. At higher elevations remnants of glacial till provide the basis for soils suited to cultivated agriculture. The High Mountain Region (with the exception of areas accessed by the proposed lead-zinc mine on the south slopes of Ganesh Himal and the area bisected by the Kodari highway) is isolated-with an average of 3 to 5 days' walk to a road head. As might be expected, this strongly influences the types of farming system that are found. Farmers are closely tied to subsistence production.

Individual production pockets tend to be self-sufficient, and cash cropping is not common. Region-wide populations are much lower than in the Middle Mountains; but, on a per cultivated hectare basis, overall densities are similar.

Forests in the High Mountains tend to be in much better condition than in the Middle Mountains, largely because the pressure from the local population is much less severe. Many of the forest areas are actually too far from the population centres to be accessed easily. There are, however, areas of local forest resource mismanagement with problems similar to those in the Middle Mountains.

The High Himalayan Region

The High Himalayas make up 3,447 sq. km. or 23.7 per cent of the land area of Nepal. Bedrock is predominantly more competent rock that forms very steep, rugged terrain. Relief can be over 3,000 metres. Most of the area below 4,300 metres is in natural forest. Whereas on the south side of the Himalayas this forest may be lush, being in an area of high rainfall, dry forest types and even grassland steppes occur in the rain shadow behind the main mountain ranges.

The area has a very low permanent population because of lack of cultivable land and cold winter conditions. Where local climate permits and irrigation water is available, small but dense pockets of population occur. Potatoes, millet, and naked barley have been the mainstay of production, but, with the increased importance of tourism in these areas, there is a growing interest in horticultural crops. Monsoon grazing of livestock and collection of forest plants for medicine are the major uses of the region. Isolation, with 3 to 8 day walks to the nearest market, strongly influences the type of farming system found here. In the future, an ever-increasing use of the area by tourists can be expected and this will play a major role in the management of agricultural lands in the High Himalayan Region.

Characteristics of Nepalese Soils

The confusion in the literature regarding natural resource degradation and the significance of soil fertility decline in Nepal is based, at least in part, on an ignorance of the soils and their properties. The extreme variability in soils and their properties is a result of differences in the major soil-forming factors: parent material, climate, geomorphic stability, and the types of organism that are living on its surface. The significance of these soil-forming factors is described in Annex 1. An acknowledgement of this variability is the first stage in developing appropriate soil fertility management strategies for the country. This section introduces the most important physical and chemical characteristics of Nepalese soils and indicates their significance for management techniques.

Physical Characteristics

Physical characteristics are those that influence energy and water flows through the soil. While often not considered strictly within a soil fertility framework, physical soil characteristics cannot be separated when attempting to understand farmer management of soils for production. Inexperienced researchers tend to analyse soils for chemical fertility problems when the constraints to production are a result of adverse physical conditions, particularly those related to water management. There appear to be many instances in which a farmer applies compost as much for its influence on the soil-water regime as for its nutrient content.

Texture. Soil texture refers to the relative portions of sand, silt, and clay in the soil. When all three constituents are present in the right proportions, the soil is called a loam. Nepalese soils are most often developed from micaceous parent material (phyllites, schists, gneisses, granites), and consequently most soils contain a high portion of mica. Loams and sandy loams are by far the most common soil texture throughout the hill regions on both the sloping lands and the alluvial terraces. They are well regarded by the farmer because of the ease with which they can be ploughed on upland fields regardless of moisture conditions. Loams have a good water-holding capacity and provide optimum aeration for plant roots. Infiltration rates tend to be higher than the normal rainfall intensities that occur in most areas in Nepal, so surface erosion is usually not severe.

Finer textured soils (i.e., those with a higher clay content) result from sediment deposition in quiet water, and/or intense weathering, and are much less common. Such soils require special consideration when tilling as the soils are too hard to plough with cattle-drawn ploughs when dry land ploughing results in large unworkable clods if ploughed too wet. Erosion, particularly by gullying, can be serious when local relief is high. The fine-textured red soils of many of the ancient terraces along major river systems and in the Dun valleys suffer from such erosion. Occasionally, the bedrock materials of the Siwalik mudstones break down to a fine-textured material. These fine-textured sloping soils are extremely unstable and virtually impossible to farm. Nepalese farmers rate clay soils as the most difficult to work. However, the perception of their value differs considerably depending upon whether one is responsible for tillage operations (as are most tenant farmers) or entitled to a portion of the yield (as is the case for landlords). Those who have travelled or worked in Gulmi or Salyan are familiar with the strongly sloping terraces and red, fine-textured soils used in upland maize production. Farmers have learned not to attempt to terrace these soils as the fine textures are not conducive to good drainage without a strong surface slope. Maize root systems are suppressed by poor internal drainage, and slopes tend to fail *en masse* if terracing is attempted.

The puddling requirement of the rice fields and the use of standing water places excessively high demands on many irrigation systems developed to service coarse-textured alluvial soils. Most of the irrigated hill soils are loamy by nature but, over the years, have developed a plough pan at about 10 cm below the surface. Where internal drainage rates are high and plough pans are not well developed, irrigation duties are exceptionally high.

Soil Stoniness. Stony land is hard to till. The water-holding capacity is lowered in proportion to the amount of stones present and a fine seed bed cannot be prepared. Most soils formed directly over competent bedrock are stony. Commonly, bedrock in the Middle Mountain Region has well-defined fracture planes and the colluvial churning mixes the stones plucked from the bedrock throughout the profile. While large areas of the *Terai* and the Dun valleys are stone free, stoniness is a common feature of areas draining the conglomerate, rock-dominated watersheds found in the Siwaliks. Initially the whole of the Bhabar Region of Nepal was thought to be very stony, but this fallacy was based actually on repeated observations of the same area adjacent to Amlekhgunj where conglomerate Siwalik rock is found to the north.

Because phyllitic bedrock is so variable with respect to competence and degree of fracturing, stoniness is quite variable throughout the Middle Mountains. Terrace riser cutting commonly occurs on the stone-free phyllitic soils of the Middle Mountains. Higher up in the Himalayas, where rock becomes harder and weathering less intense, soils are found to be increasingly stony.

Root crops are difficult to grow and harvesting can be difficult. A common observation of agronomists and soil scientists is that the excessively stony soils of Nepal hill areas are a sign of infertility and there is a tendency to consider the soils to be much worse than their actual productivity indicates. While stoniness is an important management feature, it is not as detrimental to soil productivity as commonly inferred. Stones up to 25 per cent of the soil volume do not seriously affect plant growth, but, they can significantly reduce surface soil erosion by protecting the soil surface. Where heat retention of soils is critical at higher altitudes; a stony soil can absorb and hold more heat during the day, slowly releasing it at night when frost might otherwise occur. Stones have been used by many farmers to make terrace risers, drop structures for drains, and irrigation canals.

Soil Depth. Soil depth refers to the thickness of unconsolidated soil material found above bedrock (or other restricting layers) and is a critical factor affecting the management of the soil. About a 50 cm thickness of soil material is required to support rainfed crop production. Soils shallower than this are considered to be marginal and are usually reserved for grazing and forestry uses. Soils in the *Terai* and in the Dun valleys of the Siwaliks are deep and support a range of agricultural activities. The exception to this is where high water tables restrict aeration and limit the vigour and/or type of vegetation that can be grown. Fortunately these soils are well suited to rice production (Plate 2).

Within the Siwalik hills, 20 degree slopes appear to be the upper limit on which cultivation can occur - a result of the shallow soils that are naturally found on steeper gradients. Within the Middle and High Mountains, slopes up to 30 degrees are generally deep enough (greater than 1 m deep) to support arable agriculture when terraced. As soil depth and slope gradient are so closely linked, land use planners are often interested in determining slope cut-offs above which cultivation would not be permitted. This approach to land management has many pitfalls and leads to potentially serious misjudgments on how land should best be managed.

Soil Structure. Soil structure describes how individual soil particles are arranged within a soil. Good structure is extremely important for proper root growth, for good water management, and to resist the effects of rainfall erosion. Soil structure breaks down as organic matter levels drop. Soil organic matter levels have declined throughout the rainfed, cultivated uplands of Nepal, as scarce compost resources are increasingly being diverted to the irrigated lands. In many cases, farmers are using compost as a physical amendment to enhance soil structure as much as for nutrient additions. Recommendations for compost management, based on fertilizing value alone, reflect a lack of understanding of the soil's physical constraints.

Soil Horizons. Soil horizons are the natural or man-made layers that occur in most soils and provide important information on geomorphic stability and past management. Certain horizons provide diagnostic criteria for classification of the soil into internationally recognised systems such as Soil Taxonomy. (A description of the major soils of Nepal is provided in Annex 2.) The primary purpose of a classification system is to permit the transfer of specific management information about a particular soil from one geographical area to the other. The soil horizons of most Nepalese landscapes of Nepal are surprisingly underdeveloped; a result of the dynamic, geomorphic nature of the area which is constantly changing the soil surface. The most important soil horizons are described here.

1. Topsoil

The surface soil in its natural state is dark coloured, has high organic matter levels, and the best soil structure. This layer is the most fertile within a soil and so supports the major feeding roots of most vegetation. This topsoil layer is quickly degraded by poor management. Ploughing tends to increase the rate of oxidation of organic matter, and, without organic matter additions, the soil structure breaks down. If the soil surface is unprotected during intense rainfall, surface erosion quickly removes the topsoil. Topsoil degradation and loss are possibly the most serious processes affecting sustainability of farming systems in the mountain regions of Nepal, so keeping topsoil in place is central to better soil fertility management.

2. Subsoil

The subsoil is the horizon immediately below the topsoil and usually contains much less organic matter, nitrogen, phosphorous, and other essential plant nutrients than the topsoil. Pedologists have differentiated many different types of subsoil depending on whether the horizon is enriched with clay, iron oxide, or humus or impoverished by leaching. Soil structure tends to be massive and less conducive to plant feeder root penetration. Plant roots exploit this layer to provide support to the plant and to provide water that has percolated beyond the reach of feeder roots in the topsoil. As topsoil erosion proceeds, this horizon is increasingly depended upon to nurture agricultural crops, which it can only do with increasing fertilizer or compost additions. Agroforestry systems are important for the management of Nepalese soils in that they provide an opportunity to better exploit water and nutrients that have leached from the surface into the subsurface layers.

3. Saprolite

Saprolites are strongly weathered, rotten rock with some of the original rock structure still apparent. They are usually extremely infertile and have poor water-retention characteristics. In many of the more marginal agricultural landscapes throughout the mountain regions, saprolitic materials can be found at, or near, the surface. Where this occurs, it should be recognised that severe erosion has taken place and that land rehabilitation will require significant investment and sufficient time. The strongly weathered feldspar granites are commonly almost pure white and are recognised by farmers as the most impoverished soils. Without heavy compost additions, crops cannot be produced on any of these saprolitic materials. Fortunately, certain pioneer species such as alder (*Alnus nepalensis*) thrive on severely disturbed sites.

Chemical Characteristics

Chemical properties of soils are closely tied to overall soil fertility. However, a strong and dangerous western bias considers fertilizers and the maintenance of soil fertility to be synonymous. Many of the original tests for nutrient availability within soils are tied to chemical extraction methods that were developed for soils receiving high chemical fertilizer inputs. These laboratory tests do not adequately reflect the productivity of soils for which fertility management is dominated by compost additions. Soils shown by sophisticated laboratory procedures to be severely deficient in one or more nutrients often produce a satisfactory crop without special fertilizer additions. Soil fertility management specialists in Nepal have been in the untenable position of working with artificial chemical fertilizer-based management and western style analytical procedures within a system that is largely based on organic soil management. There has been little appreciation of indigenous soil fertility management techniques used by the farmer. Major chemical characteristics include those described in the following passages.

Soil pH. Possibly one of the most important but, at the same time, least understood characteristics of soil chemistry management is that associated with the soils' reaction, i.e., its relative acidity or alkaline nature. Strongly acidic soils are common in Nepal because of the predominance of coarse-textured, acid-forming parent materials and the high effective rainfall which selectively removes bases from the soil. Natural pH readings range from as low as 4.0 in Abies forests on the wet southern slopes of the main Himalayan range to 8.0 for calcareous active river sediments in the Siwaliks and the *Terai*. Soil pH is an important chemical characteristic because it determines the availability of many other plant nutrients and toxic elements. The average, cultivated upland soil in Nepal has a pH of around 5.4 (LRMP 1986) which is not limiting to agricultural production. However, severe acidity problems have begun to show up in the eastern and central hill districts. The average pH for the whole Jhikhu Khola Watershed, just east of Kathmandu Valley, was 4.8 (Schreier et al. 1991). The pH problem in this watershed may be considered representative of areas with cash cropping opportunities provided by good access to the Kathmandu markets. In these areas, the natural soil acidity is aggravated by the relatively heavy use of chemical nitrogen fertilizer and the tendency for government projects to reforest with pine trees. Pine tree plantations, unlike the original hardwood forests, are not efficient base recyclers and the pine needles produce fairly strong organic acids that accelerate leaching of bases from the soil. Traditionally, amelioration of soil acidity has depended on maintaining high rates of organic matter additions through compost use to buffer the soil. With fodder shortages and labour constraints, compost is no longer available in the quantities nor qualities required to buffer the excess acidity.

The agricultural research station at Bhairahawa, after only ten years of consistent chemical fertilizer use, has found heavily acidic soils on a number of fertilizer trial plots. Yields on these soils have decreased significantly. Where heavy applications of compost are not feasible and green manures are not used, the only alternative for managing severely acid soils is to apply crushed limestone. Where pH levels have dropped below 4.5, depending on the soil's exchange capacity, rates of 2 to 4 tons of limestone per ha are prescribed to restore the soil to a more acceptable pH. Unless local lime sources are available, it is unlikely that remote villages will ever be able to use crushed limestone as part of their soil fertility management strategy. For this reason, soil acidification caused by chemical fertilizers is potentially a much more serious problem in the less accessible agricultural production pockets of Nepal. Any policy to increase chemical fertilizer use in remote areas (such as the fertilizer transport subsidy) should consider the possible negative effects of acidifying soils in areas without reasonable access to liming materials.

Because of the complex lithology, diversity of forest types, range in amount and type of chemical fertilizer used, variability of compost management, and the differing water chemistry of irrigation waters, variability of soil acidity can be quite high - even between fields on two adjacent farms. Generalised regional, district, *ilaka*, or village level pH levels, determined by single samples, should not be considered reliable. Given the ease with which field pH measurements can be taken, recommendations involving pH management should be carried out only as a result of on site field investigations.

Nitrogen. Nitrogen is the single most important element influencing the yield of traditional farming systems in Nepal and has been given considerable attention by agronomists and soil scientists. Nitrogen is different from other major soil nutrients in that atmospheric nitrogen can be locally fixed and added to the nutrient pool. Trees, such as *Alnus* and *Acacia*, and crops, such as lentils and soya beans, are used extensively for their nitrogen-fixing ability. Through appropriate crop rotations and better management of off-farm resources, considerably more nitrogen could be fixed locally. In traditional farming systems, nitrogen and livestock waste management are synonymous. The vast majority of agricultural production in Nepal is dependant on organic nitrogen production, and this method of supply will be of paramount importance in the foreseeable future.

Over 68,000 tons of urea, 13,000 tons of ammonium sulphate, and 80,000 tons of NP complex were imported into Nepal in 1989, accounting for over 95 per cent of the total of chemical fertilizer used (Crown Agents 1991).

Laboratory analyses of nitrogen levels in farmers' fields always show deficiencies and a significant crop response to nitrogen fertilizers is almost universal when it is first used. In the last 10 years, there has been an increasing awareness that, while the initial response to fertilizers is almost always favourable, long-term chemical fertilizer use without modifications in overall fertility management is not sustainable. Mismanaged use of the manufactured nitrogenous fertilizers can lead to breakdown of soil structure, increasing soil acidification, deficiencies in other macro- and micro-elements, and drastic reduction in yields. However, the problem is not whether nitrogen fertilizers are good or bad, as often debated among agricultural workers, but how to promote an overall fertility management technology that will ensure optimum levels of sustainable production within the present economic framework.

Phosphorous. Phosphorous is the second most important element of significance to the agricultural soils of Nepal. Base levels of phosphorous in the soil are invariably low and, after nitrogen, phosphorous is most often restricting to plant growth. As with nitrogen, most of the phosphorous in traditional fertility management is supplied via the compost and livestock manures. Unlike nitrogen, phosphorous is either available or absent from the soil. It cannot be produced locally. If soils are deficient, phosphorous must be added to the soil. Forest and grazing lands, through grass and fodder production, feed livestock which in turn provide manures to sustain the phosphorous levels required for agricultural production. Without these sources to replace the losses from the nutrient pool, phosphorous levels would continually decline to the point that profitable agriculture would no longer be possible.

In 1989, 40,000 tons of NP complex (8,000 tons of elemental phosphorous) was imported as chemical fertilizer. At the traditional low levels of production, phosphorous deficiencies are usually not apparent. With increasing nitrogen use and higher yields, phosphorous soon becomes limiting to crop production. With increasing use of nitrogen, whether biologically fixed or imported from outside Nepal, phosphorous will become an increasingly deficient element. Its role in future fertilizer management strategies is critical.

Potassium. While potassium is a major element required for plant growth, Nepalese soils are generally endowed with high base levels of potassium and major deficiencies are not readily observed. Sherchan et al. (1991) considered that until phosphorous deficiencies are met, chemical potassium fertilizer will not be required. Only with increasing intensity of production of certain horticultural crops (such as potatoes and bananas), and higher targetted yields, will potassium become a significant constraint to production.

Calcium, Magnesium, and Sulphur. As yet there is little indication that calcium, magnesium, or sulphur are limiting to plant growth in Nepalese soils. It is anticipated that with increasing use of the major elements through chemical fertilizers, these minor elements will commence to be increasingly deficient in Nepalese soils and supplements will be required. At present compost is providing all these elements that plants need.

Micronutrients. If compost fertilizers are provided in adequate amounts, the micronutrient elements rarely become deficient. However, with the increasing shortage of compost, the introduction of plantation and orchard systems, and the lack of use of compost materials, micronutrient deficiencies are increasingly being recognised. It is generally more instructive to think of the soils as being mismanaged rather than deficient in micronutrients. To date, micronutrient deficencies (including zinc, iron, manganese including zinc, iron, manganese, copper, molybdenum, and boron) have been reported in both agricultural and forest soils. Horticultural crops (in particular apple and citrus trees) have been known to respond to a foliar spray containing combinations of micronutrients at a number of locations in Nepal. In the Western Development Region at Lumle, molybdenum was shown to significantly increase yields of grain crops when added in small amounts directly to the seed. As more work is done on micronutrients, many more deficiencies (including zinc, iron, manganese, copper, molybdenum, and boron) pertaining to specific crops will be recognised. Given the nature of the problem it is recommended that foliar analysis be used rather than soil sample analysis, because what the plant roots are in contact with may or may not relate to what the plant actually can take up.

Organic Matter. While organic matter is considered here as a component of the soil, it has a far reaching effect on many aspects affecting soil management and sustainability. Organic matter plays a dominant role in nitrogen supply and, to a lesser extent, in phosphorous, sulphur minor, and micronutrient supply. Higher soil organic matter levels improve infiltration rates and water-holding capacity. This, in turn, has a positive effect on reducing surface runoff and limiting soil erosion. Organic matter can ameliorate the negative effect of low pH, as well as problems caused by having too coarse or too fine a texture. Additions of organic matter will increase the cation exchange capacity, break up surface crusts, improve the tillage after ploughing, serve as a mulch to cushion soil from high intensity rainfall, and provide a substrate in which micro-organisms can maintain high activity, thus releasing nutrients tied up in the mineral soil. The amount of organic matter in a soil is dependent on the ecological zone in which it occurs, as well as on the land use and management of the soil. Levels of organic matter on cultivated soils below 2,000 metres range from 0.5 to 3 per cent and average just under 1 per cent. Forest soils tend to be 1 or 2 per cent higher. Above 2,000 metres, climatic and vegetation changes are quite dramatic, and the soil organic matter content increases by 2 to 3 per cent for both agricultural and forest soils. This is because decomposition rates are lower and litter production is higher in the less disturbed, cool temperate forests. Because of their cooler temperatures and wetter conditions, north facing slopes have higher organic matter levels than south facing slopes. Areas under natural forest have considerably higher organic matter levels than those cleared for cultivation. Newly-opened forested areas in the *Terai* may have levels of 4 or 5 per cent organic matter on initial clearing; but, generally, after a few years of cultivation, the levels have dropped to less than 2 per cent.

Organic matter quality, which is crucial from the perspective of plant productivity, is, as yet, poorly understood - particularly with respect to Nepalese soil fertility management. This will be covered later in the discussion on fertility management.

III. The Farmer

Since the advent of man and his agricultural systems there has been a tremendous change in the Nepalese landscape. If one were to fly over the country, one could not help but be impressed with the pervading influence of man on the environment. Tremendous terrace systems, clustered villages, an intricate network of roads and pathways, and an ominous reduction of area under forest. There are many farmers wresting a living out of the land. Far too many! The common perception is that man has taken too much. Indeed, the land has been squeezed dry and the environment has been seriously and irreversibly degraded. The farmer can no longer maintain soil fertility because the land has nothing more to offer. So the story goes.

While this theory makes for profound seminars, it fails to squarely address the real problem and does not provide an insight into the potential solutions. The problems are a result of bad management and solutions are based on encouraging more enlightened management, if there is a will to do so. What is happening in Nepal now has happened before; periods of growth and development are followed by periods of stagnation and crowding. Malthus has been proven wrong before, primarily because production systems are not static. Nepal is at another critical point in her history with many options to make changes for the better or for the worse. A brief look at Nepal's carrying capacity from a historical perspective provides a framework with which to project the future.

The Carrying Capacity of the Nepalese Landscape

Planners and development workers alike have long been interested in the concept of carrying capacity. How many persons can be supported by the land? At what point will the system break down and productivity stagnate, or plummet, resulting in economic and social upheaval? Is the present agricultural system in Nepal sustainable? and, if not, what can be done to make it sustainable? There are no simple answers to these questions, as biological carrying capacity is a function of management of components of the system and the definition of the boundaries that you assign to it. Unlike natural ecosystems, man has the ability to radically alter nutrient and energy flows as well as to expand the sphere of influence of a given ecosystem. He can import chemical fertilizer - he can earn money outside his village - he can move to the city and take an industrial or service job. While the traditional subsistence farmer of Nepal once could be virtually isolated and maintain a sustainable agricultural system, this no longer appears to be the case. Politics, socioeconomics, and, lastly, management practices are actively changing in response to many local and outside pressures.

Local, regional, national, and international movements of goods and services make the concept of the closed ecosystem inappropriate for most of the Nepalese farmers of today. The majority of Nepalese farmers receive a significant portion of their cash income from outside the subsistence realm. The growth rates of major urban centres like Birgunj, Pokhara, and Kathmandu exceed 8 per cent, whereas remote village populations remain virtually static through out-migration. Nepalese farmers are looking, and will increasingly look, beyond traditional enterprises to support their households. Possibly one of the better ways to address the future possibilities is to look briefly at the progression of land management from a historical perspective.

Pre-man

At this stage the country was in a state of dynamic equilibrium. Natural resources were being manipulated by the climate, geology, and biotic resources. Although there were earthquakes, floods, landslides, and fires, they were natural.

Hunter/Gatherer

This stage developed from pre-pliocene times. Man's influence on nature was restricted to temporary changes in animal and plant populations. Populations were maintained at a very low level and impact on the environment was minimal.

Shifting Cultivator

With the introduction of grain crops, such as millet, thousands of years ago, man began a simple form of cultivation in Nepal. Forest areas were cut down and burned. Seeds where dibbled or scattered on the soil and domestication of some animals began. When weeds became noxious or the soil fertility of his fields dropped, the farmer cleared another patch of forest and repeated the process. Populations initially rose and the carrying capacity of the landscape was much greater than during the hunter/gatherer stage. It is assumed that this method of sustenance did not proceed too long before some forms of more permanent agriculture arrived from Mongolian influences to the north and from Aryan influences to the south. In Nepal, some remnants of shifting cultivation are still practised by a few *Chepang* and *Magar* groups in the Mahabharat Lekh and by *Rais*, *Limbus*, and *Sherpas* in the upper Arun Basin. While this system had the potential to be destroyed through overpopulation, more permanent forms of agriculture were usually adopted.

Permanent Subsistence Agriculture

With the advent of rice cultivation and the later introduction of maize (around the 15th century), the traditional agricultural cropping patterns developed more or less as we see them today in the more remote regions. This system was almost entirely subsistence oriented with very little movement of goods or services in or out of the agricultural production centres. Salt and iron were the only provisions regularly acquired from the outside. These were traded for a number of local products. Forests were used for timber, firewood, and fodder and, initially at least, there was little need to develop a sophisticated management system of either the forest or grazing lands as the total demand for forest products was low compared to the resources available. Free grazing of livestock was the rule on fallowed agricultural land and forest land (Regmi 1971).

Since 1950-The Panchayat Era

After the end of autocratic Rana rule, new ideas began to flood into the country. Among these were the need for public education, public health services, use of improved agricultural production methods, and the desire for a Government that was committed to development of the country. The most important change for Nepal as a whole was the rapid increase in population. The most significant change to agriculture was undoubtedly the introduction of winter wheat that fit nicely into the rice-fallow and maize-fallow systems. As the population continued to increase, the demands on fodder resources expanded rapidly. Fields that were traditionally fallow in the winter had been used to graze livestock and *in situ* manuring was instrumental for maintaining the fertility of the crop land. In this newly evolved system, demand for compost increased at the same time as the area available for fodder production decreased. Consequently, the farmer had to substantially increase his exploitation of the forest resources to an historically unprecedented level, particularly to harvest fodder.

Unfortunately for Nepal, this was the time when forests were nationalised. Rather than encouraging the farmers to develop appropriate forest management systems, it severely suppressed innovative local management. The common story is that the Nepalese farmer went wild, cutting down every tree in sight. This is highly unlikely. The damage to the forests was most likely due to an increased demand for forest products and a decreased interest in their management. Lands with assured tenure and in private hands are very well managed. Conversely, public lands, particularly those over which the forest department has control, have been severely degraded by poor management.

There are other signs of change within the system: men are increasingly looking to off-farm employment to support their family, women are more and more making the decisions and carrying out major farm activities, urban areas are receiving an influx of villagers, and educated sons are leaving the farm with parental blessings, with no intention of returning. The present system, as with previous systems, had a set "carrying capacity" which has been exceeded. However, changes are ongoing and will continue to occur to correct present stresses in the system. The question is, to what degree can the Government of Nepal orchestrate changes for the collective good of the people of Nepal? The production systems of the farmer are described in this chapter and specific soil fertility management practices are discussed. A brief look at the farmer's socioeconomic and institutional environment then provides the basis on which a soil fertility management strategy is developed.

Production Systems

The landscape of Nepal is a managed landscape. The majority of land is used for arable agriculture, livestock grazing, or forestry. By understanding how man currently manages these production systems, one is in a better position to understand the environmental situation and, more particularly, how soil fertility is being maintained and whether the system is sustainable (Schroeder 1985).

When assessing the overall sustainability of an agricultural system, it is useful to look at nutrient levels and flow between the different production systems. There is a high degree of interdependence between cultivation, grazing, and forestry. It is virtually impossible to adjust one aspect of the fertility flows without affecting the others. Nepalese farmers are usually active in all five production systems on a day to day basis. Unlike the classic sectorial approach used in Europe and America to define and upgrade their production systems (agriculture, forestry, livestock, fisheries, etc), Nepalese farming communities and individual farms are highly integrated. Productivity of one production system has direct bearing on the productivity of the others (Mahat 1987 and Yadav 1992). Without forest there are severe constraints on cattle, without cattle there is no compost, without compost there is no cultivated land, and without cultivated land there is no grain. It is a highly appropriate saying of the late King Mahendra "*Hamro dhaan, haariyo baan*" (Our wealth is in our forests).

What is going on in one production system has a direct bearing on the other four. Any sectorial approach to soil management must recognise and build around this fact. In Table 1 the major production types and their extent are given.

Table 1: Relative Proportions of Production Systems* in each Physiographic Region

(In percentage)

Physiographic Region	Irrigated Rice	Rainfed Cultivation	Home** Garden	Grazing, Shrub & Degraded Forest	Closed Forest	Other***	Total Area ('OOO) ha
Terai	50%	6%		6%	26%	12%	2110
Siwaliks	7%	5%		16%	68%	4%	1886
Middle Mountains	7%	15%		54%	22%	2%	4443
High Mountains	1%	6%		45%	40%	8%	2959
High Himalaya		0.2%		31%	2%	67%	3349

* The totals are gross areas taken from LRMP 1986. Actual total areas are somewhat less.

** Area proportional to the population. There are over 3.5 million households in Nepal and the average home garden might cover 25 square metres. Over the whole country this would account for 9,000 ha of production.

*** Snow, ice, rock.

The five major traditional production systems are described here in relation to fertility management. These production systems are found in each of the Tropical, Subtropical, Warm Temperate, and Cool Temperate Agroecological Zones (see Annex 3). While overall management considerations for a given production system are similar regardless of the zone, the species, varieties, and cropping calendars are different.

Irrigated Rice Land (Khet)

According to the Irrigation Master Plan (HMG/N 1989) over 923,000 ha of Nepal's cultivated land is irrigated, at least on a supplementary basis, during the monsoon. This amounts to over 35 per cent of the total cropping area of Nepal. From this total, over 594,000 ha occur in the *Terai*, 84,000 ha in the Siwaliks, 218,000 ha in the Middle Mountains, and 26,000 ha in the High Mountains.

Under the present traditional agricultural system, rice is grown wherever arable lands below 1,800 metres can be serviced by irrigation water. Rice is the most prestigious grain crop in the country and farmers measure their wealth according to the amount and type of *Khet* they own. As an example of this sense of importance of *Khet*, when asked what they would do with windfall cash, both men and women within the Jhikhu Khola watershed indicated they would purchase more *Khet* (Kennedy et al. 1991). This is a universal sentiment in Nepal. Rice trades for 2 to 3 times the price of any other grain and it forms an important component of many religious and festive events. A traditional village greeting asks, literally, if the subject has eaten rice, when the intention is more like "How are you?".

In the traditional land taxation act, the classification focuses primarily on irrigation water availability throughout the year, as it assumes that water is the major constraint facing agricultural production. Irrigation water is essential for most rice production in the country.

According to government statistics, between 1980 and 1990 the national average yield for rice rose from 1,949 kg/ha/yr to 2,366 kg/ha/yr, with a range of from 800 to 7,000 kg/ha/yr.

With a rice yield of 2,500 kg/ha/yr, nutrient removal would be roughly 30 kg of nitrogen, 15 kg of phosphorous, and 45 kg of potassium from each hectare of land.[1]

While rice is the dominant crop and grows throughout a significant portion of the monsoon season, a number of different cropping patterns occur with the rice production. Some of these are given below.

Cropping Pattern	% of Total Rice Land
Rice-Fallow	31
Rice-Cereal*	32
Rice-Winter Crop	10
Maize-Rice	8
Other Patterns	19

* mostly winter wheat (after LRMP 1986)

Reasons for choosing a particular cropping pattern are varied, but elevation, water availability, availability of chemical fertilizer and compost, natural soil drainage conditions, local climate, and land tenure are the dominant factors influencing the farmer's choice.

Rice cultivation is unique and the rules of tillage and fertility management are quite distinct from upland soil management. Rice soils must be puddled in preparation for planting. In this process, the soil structure is destroyed, oxygen is removed from the rooting zone, and a dense impervious plough plan is encouraged. During the rice growing period, water is kept on the surface as much as possible. While these conditions are highly undesirable for upland crops, rice thrives (Plate 3).

There are a great many advantages to this seemingly inhospitable soil climate, and the rice plant is able to capitalise on them.

- Under anaerobic conditions, no matter what the original soil acidity, the pH is neutralised and toxic elements, such as iron and aluminum, if originally present, become unavailable.
- At the same time, neutralizing the pH permits important soil nutrients, such as phosphorous, that are strongly bound in most soils to become more readily available.
- Sediment-laden irrigation water in the monsoon season, while considered a problem in advanced countries, acts to fertilize the soil and bring in nitrogen, phosphorous, and organic matter.
- Standing water in rice fields inhibits terrestrial weed growth, while at the same time encouraging the growth of azolla and blue green algae, both nitrogen-fixing species .
- Surface soils are not subject to the kinetic energy of intense rainfall as they are protected by the water. Surface erosion is negligible.

From the above it can be understood why, in the recent past, the traditional rice farmer did not need to rely heavily on fertilizer (compost or chemical) at the low levels of productivity of the common rice-fallow system. In fact, in spite of the importance given to rice as a dominant crop, farmers did not actively seek to fertilize it- although some nutrients were supplied by free-grazing animals. Rather, they devoted their scarce compost resources to upland crops and maize, for which response to compost was readily observable. This sheds new light on the importance of rice in the Nepalese hill-farming system. Rice was preferred, in part at least, because it was able to produce a reasonable crop on a sustainable basis without draining the farmer's limited compost supply. This was a major soil fertility

1. This includes straw removal from the field, which is the normal practice. A considerable portion of these nutrients do find their way back into the system through compost production, etc.

management strategy for the hill areas and most of the *Terai* before 1960.[2]

For irrigated land under the landlord-tenant arrangement, rice is the principal sharecrop, whereas winter crops, being only recently introduced, are not systematically included in the rent agreement. As winter cash crops become more important, major changes in tenancy agreements are expected. In general, wealthy farmers tend to have more irrigated land in proportion to their total landholdings than do poorer farmers.

Villagers have been diligent in developing water sources for irrigation in spite of apparently insurmountable obstacles. Some of the irrigation canals cross major obstacles and have been constructed and maintained at great local expense. The Nepalese hill farmer has already developed all the easier irrigation water sources. Those left undeveloped present considerably greater challenges in construction and maintenance and generally involve resource levels beyond those available in the village.

On many so-called rice soils in the hills, irrigation duty is very high, often exceeding 5 litres per second per hectare.[3] Percolation of this excessive water is terribly wasteful and has a negative effect on the soil. Hard won soluble nutrients, in particular nitrogen and potassium, are being rapidly leached from the system. When irrigation water lacks calcium, the acidification of the irrigated soils is accelerated.

Ongoing periodic, catastrophic soil degradation is occurring on the alluvial and alluvial/colluvial soils throughout the Himalayas, particularly in the Siwalik and Middle Mountain Physiographic Region. Debris torrents issuing out of unstable drainage systems are resulting in waves of destruction of *khet* near the rivers *(bogor khet)*. Farmers in Nepal, over the years, have learned to live with these destructive forces and have developed effective methods of land reclamation. Low lying alluvial terraces and alluvial/colluvial fans which now support lush rice and winter crops have usually, in the recent or distant past, been reclaimed from unproductive gravel and boulder beds brought down as catastrophic debris torrents. As discussed by Carson (1985) and Bruijnzeel and Bremmer (1989), these processes are most often the result of natural erosion and only rarely a direct consequence of deforestation. An economist trying to determine the value of irrigated land, in the mind of the Nepalese hill farmer at least, should look at the labour cost of reclamation of these devastated lands.

Given the dynamic geomorphic nature of most Nepalese river systems, it is rarely recommended to invest heavily in engineered structures to protect low lying rice land from exceptional flooding because such efforts are rarely cost effective. Gabions are a reasonable short-term solution for protecting valuable engineering structures and, to some extent, highly productive alluvial terraces, if the erosive power of the river can be effectively dispersed.

Chemical fertilization is generally carried out on irrigated lands where cash cropping is possible. Chemical fertilizer use can reduce the intense pressure already felt on the scarce compost resources available to the villager. Fertilizers are not so harmful to irrigated land, because of the buffering effect of sediment-laden (and often calcium rich) irrigation waters.[4] In the more accessible agricultural production pockets of the *Terai* and along the north-south trunk roads, some of the rice and wheat are used as cash crops, and so the farmer is able to purchase the required inputs. This, in turn, opens up other possibilities for promoting changes to the fertility management of the soils.

With the rapid acceptance of winter wheat and other intensifications of the cropping system on irrigated lands, the nutrient requirements of *khet* have increased dramatically. Chemical fertilizers and compost are being used in ever-increasing amounts in response to the needs of the winter crop and to take advantage of the higher yielding varieties of wheat and rice.

While puddling is beneficial to the rice crop, the massive structure, impenetrable plough pan, uncertain soil reaction, and questionable nutrient availability left behind when the rice is harvested have a strong negative effect on the winter crop. For these reasons, farmers are required to use as much compost as is available in an attempt to ameliorate these negative soil conditions for the following crop. This intensification of *khet* production has a serious effect on

2. This generalisation does not apply to the Kathmandu Valley in which a very different agricultural system has evolved based on the *Newari* farmers working the lacustrine-based soils.

3. In Pokhara, the irrigation scheme using water diverted from the Seti River has found irrigation requirements in excess of 10 litres per second per hectare.

4. When large amounts of chemical fertilizer are being added to soils that are already strongly acidic, and the irrigation water lacks dissolved calcium, soil acidification does occur. In America, fertilizer use can increase the soil organic matter by the additional yield of crop residue which is usually ploughed into the soil. In Nepal, because farmers usually harvest all parts of the crop, this benefit is not realised from chemical fertilizer.

other components of the village land production system. The scarce nutrients made available through compost, that were traditionally reserved for the upland soils, are now also required on the rice soils to meet the requirements of the winter crop.

New ways of increasing nutrient flow, particularly nitrogen and phosphorous, to the *khet* will be instrumental in any overall fertility management strategy. It will have to involve a reassessment of nutrient foraging, particularly of grazing and forestry lands, and recognise the trade-offs with importation of nutrients from outside the closed village system.

Rainfed Cultivated Land (Pakho or *Bari)*

Rainfed cultivated land *(pakho* or *bari*) accounts for 1,717,000 ha (64%) of the cultivated land in Nepal (HMG/N 1989). Of this total, over 61 per cent of the *bari* and *pakho* occur in the Middle Mountain Region. Maize is the dominant crop and is grown on 81 per cent of the rainfed land in the country, usually relayed or followed by a cereal crop, pulse, or mustard.

According to recently released agricultural statistics (HMG/N 1990), over the last 20 years average national yields of maize have dropped from 1,869 kg/ha/yr in 1970 to 1,599 kg/ha/yr today. Millet and barley yields have remained almost the same over the period at 1,162 kg/ha/yr. The largest increase in grain yields has been with wheat. In 1990 the average yield was 1,415 kg/ha/yr; a 67 per cent increase over the 20 year period. If these data are reasonably accurate[5] the inescapable conclusion is that farmers are diverting more fertility resources to rice and wheat production on irrigated land to the exclusion of maize, millet, and barley production on rainfed land. There are many indicators that this is indeed happening and that the result is the apparent "decline" in soil fertility (Plate 4).

Using the above-mentioned average yields for 1990, the maize crop at 1,599 kg would remove 75 kg of nitrogen, 25 kg of phosphorous, and 50 kg of potassium.[6] Wheat, with a yield of 1,415 kg, would remove 35 kg of nitrogen, 15 kg of phosphorous, and 30 kg of potassium. These amounts are generally replaced by compost additions each year.

The majority of Nepalese hill farmers own and manage rainfed cultivated land for their primary source of food grains. In the hills the vast majority of this *bari* is terraced on slopes between 15 and 25 degrees. On such slopes, individual terraces are small, commonly to 3 metres wide and 3 to 15 metres long. A farmer usually owns 4 or 5 plots of such land which are not contiguous. The concern over catastrophic destruction of the land and/or crops makes the farmer wary of depending on all his land resources from one small area. Resource-poor farmers own proportionally more *bari* than *khet*, and the *bari* they do own is of poorer quality. Decline in soil fertility is most strongly felt on the marginal *bari* owned by the poorer farmers.

The fertility management of rainfed lands has evolved very differently from that of irrigated lands. In the early stages, a shifting cultivation system was in place. The farmers relied on long fallow periods with natural vegetation to recondition soil exhausted by cultivation. As the upland agricultural system developed and livestock became increasingly integrated into the farming system, the fields became permanent and compost (via cattle grazing and fodder collection from the adjacent forest lands) supplied the nutrient requirements for upland cultivation. Nepalese farmers traditionally used between 10 and 20 tons of compost per hectare of rainfed land. As previously mentioned, increased use of winter wheat, pulses, and cash crops on the *khet* has diverted compost away from rainfed lands. Given the great increase in requirements for compost to meet the relatively new winter crop requirements, an unprecedented scarcity of compost has developed. Typically, in upland crop production, the farmer has chosen to forgo production on his most distant rainfed fields, because his compost resources are most economically spread on the fields nearer home. The traditional fertility management system is under considerable strain, the evidence can be seen everywhere with the abandonment of once productive cultivated rainfed land. As a conservative estimate, between 10 and 20 per cent of the rainfed cultivated lands of Nepal are temporarily fallowed or abandoned these days, primarily because of the lack of fertilizing material for their land.

Farmers are increasingly planting multipurpose trees on their own *bari*. In the last 30 years, Gilmore (1991) found a 300 per cent increase in the number of trees on private lands. Gilmore concluded that the farmers, responding to local

5. There is always considerable doubt when assessing government-produced data for trends and this type of analysis has been consciously avoided during the development of this paper. However, in this case, the reduction in yields is obviously not fulfilling desired government projections and may be realistic.

6. Phosphorous and Potassium as oxides.

forest product shortages, have decided that the increase in production of fodder and firewood more than compensates them for the small loss of grain caused by the shading effect of the trees. To this, it must be added that those same *bari* had very little alternative use, given the severe compost scarcity in the area.

The lack of land per se is not the major constraint to increasing grain production on rainfed lands in the hills. There is a persistent and misleading myth, strongly adhered to in Nepal, that farmers are universally expanding their cultivation areas to meet food needs. Increased cultivation of *bari* has only occurred in response to an increase in urban markets - which, to date has only affected a relatively small strip of land around the Kathmandu Valley.

Chemical fertilizers play a significant role in maintaining the fertility of these soils. With the exception of the *Terai sal* forests, the only other area where active clearing of forests is taking place (seemingly for cultivation) is where cadastral surveys are to be carried out. Only cleared land can be deeded land, so the farmer tries to expand his holdings by clearing and ploughing land even though he is perfectly aware it cannot be maintained in its cleared form.

It is on the marginalised *bari* that the majority of agriculturally-induced soil degradation is occurring. Poor crop stands with inadequate compost additions are prone to serious erosion as the fields become increasingly marginalised. As soil fertility declines, harvests become scantier and rates of erosion increase. Eventually, poor fertility management and surface soil erosion reduce productivity to such an extent that the farmer gives up on the piece of land, at least temporarily.

Home Garden

Around many homesteads in Nepal, the farmer manages a small garden. At its simplest, a few red peppers, some garlic, and local greens might be grown in a small patch near the compost pile. Perennial crops may include a few horticultural or agroforestry tree species. Around some of the major urban centres of Nepal, kitchen gardens have expanded to become significant commercial enterprises supplying high value goods to the market place.

Many opportunities are made available to greatly increase production, primarily because of the proximity of the kitchen garden to the homestead. Waste water from the kitchen can be used to start seedlings or irrigate annual crops; proximity to the animal stalls ensures a high rate of compost production; the pilfering of high value horticultural crops is reduced; and intensive weeding and other agronomic practices are conveniently carried out. For crops for which ripening time is variable, the proximity to the home makes for efficient and timely harvesting. Night soil, although not systematically used, does enrich the soils around the homestead.

Given the above, it is not surprising that the kitchen garden, though small in total area, is an important part of the overall production system and has successfully been used as an entry point into the enhanced productivity of the farming system. Those technologies that are particularly successful in the home garden can be replicated on farmers' lands outside what was traditionally perceived as the home garden. This appears to have been the method for the spontaneous expansion of mandarin orange production in many hill regions.

The Horticultural Master Plan (ADB 1991) stressed that the most important constraint to increasing kitchen garden production was the lack of markets for most horticultural products. Surprisingly, farmers themselves are not keen on consuming fruits and vegetables, and, at the same time, the markets in which they can be sold are not well developed.

According to the Master Plan for Horticultural Development (ADB 1991), the Nepalese on average consume only 28 kg of vegetables and 7 kg of fruit annually- which is very low compared to other Asian countries. This is why horticultural crop markets are so poorly developed within Nepal.

Livestock Production

Livestock production is an integral part of the farming system. Milk products, meat, and leather are produced for consumption by the homestead and market. The farmer's fields are ploughed by oxen and his lands are fertilized by livestock manures. Most of the nutrient movements between all five production systems are facilitated by cattle, buffalo, goats, and sheep. Virtually all lands are grazed to some degree at some time in the year and the heavily grazed areas are responsible for much of the environmental degradation of village lands. The Land Resource Mapping Project (1986) roughly calculated livestock fodder requirements, proportioning agricultural and forest sources. These are presented in Table 2.

Table 2: Proportional Fodder Demands from Crop Waste and Forest Lands

	Livestock Units Per ha	Total TDN* t/ha	*TDN From Farm t/ha	TDN From Forest t/ha	Dry Matter From Forest t/ha
High Mountain	6.1	6.7	1.7	5.0	20.0
Middle Mountain	4.5	5.9	2.4	2.6	12.9
Terai	3.4	3.8	3.2	0.6	1.5

LRMP 1986

*TDN - Total Digestible Nutrients

From this table it is readily apparent that, as one goes higher into the hills, there is an increasing demand on the forest to meet fodder needs. In the Middle Mountains, 52 per cent of livestock feed comes from the forest. It is this forest-based fodder resource that supplies the nutrients for agricultural production to make up for the nutrients leaking from the system.

Fodder deficiencies, severely aggravated in the pre-monsoon, are seen as a primary constraint to enhancing livestock production. While farmers have a number of strategies to deal with the shortages (including planting trees on private land and timing the lactations of milch buffalo to avoid the fodder shortage period), there are still many opportunities to increase value-added production even if the total number of livestock are reduced.

Most villagers, particularly the poorer ones, are totally dependant on grazing lands to meet their animals' grazing needs and must exploit them heavily. Concurrent with this heavy exploitation is an almost complete lack of any management to enhance the future production of the site. Many of the grazing areas, particularly those found near the village, are actually no more than resting sites where the non-productive livestock are gathered to pass time, out of harm's way. While grazed soils are not exposed by the plough, severe trampling, particularly during the monsoon, compacts the soil, reducing the soil's infiltration rate to the point that even moderately intense rainfall results in serious runoff and soil erosion. Rates of erosion in excess of 200 tons per ha per year are common on grazing lands in areas below 1,000 metres. As one moves higher on to the mountain slopes and rainfall intensities drop, so does the erosion damage. On high elevation grazing land or "*kharka*", snowmelt does cause some severe gullying. However, in general, heavy grazing pressure in many of the higher elevation production pockets does not degrade the soil resource as it does in tropical areas.

While the physical effect of the livestock trampling the surface soil is the most detrimental aspect of free grazing, the selective destruction of good fodder plants by livestock gradually alters the plant community. Over time, the palatable species are lost and one is left with much less useful species such as *Artemisia*, *Eupatorium*, and *Berberis*.

Free grazing of livestock is the single most serious cause of marginalisation of agricultural and forestry lands and changes are required to make this land use productive and sustainable.

Fire is a management tool used extensively throughout most of the forested areas of Nepal to encourage a flush of green vegetation, especially when livestock feed is desperately needed at the end of the dry season. Farmers are usually reluctant to discuss their burning practices with outsiders, because the act is strongly discouraged by the forest department. Nevertheless, farmers have good reason to burn and will continue to burn until there are changes in the tenurial arrangements of the so-called common lands or National Forests.

Livestock herd management itself is also a critical issue, with large herds of cattle seemingly required to maintain both strong, healthy bullocks and an adequate breeding stock to maintain the herd. Livestock ownership is virtually universal among the traditional farmers of the hills. Cattle are owned by all farmers. Richer farmers tend to own a few buffalo, while the poorer farmers raise goats. Generally, it is considered that to support one hectare of crop land, 6 livestock units are required. Not surprisingly, Nepal has the highest livestock densities per cultivated hectare in the world (Plate 5).

The apparent inability to cull the lower quality cattle forces a large number of scrub animals on to the common lands. This, in turn, causes tremendous damage to the vegetation and soil. It is often countered that these animals are essential to produce manure to meet the farmers' compost needs, and that the manure resource alone justifies the predominance of non-productive animals in the system. Quite the reverse is true. As long as these animals are in the system, the farmer is not motivated to look at more environmentally sound cropping systems, involving fodder legume rotations, horticultural perennial crops, and more intensive forest and grazing land management. Fortunately, farmers themselves are not as rigid as some of the cultural anthropologists studying them and have developed many ways of reducing cattle herd size. As more productive (and profitable) livestock are employed, the problems will sort themselves out.

With no restriction on grazing animals, manures cannot be selectively used on lands of the farmer's choice. Initial interest in fodder legume production requires an interest on the part of the farmer to feed higher quality fodder to livestock that in turn provide nutritious food and/or cash to the farmer. The difficulty of protecting fruit trees and off-season vegetables from free-grazing livestock, at present, severely dampens the farmer's enthusiasm for this type of production. Finally, it has been recognised that the regenerating capacity of severely degraded Nepalese forests is tremendous - once the ever present free grazing animals are removed. For all of these reasons, free grazing must be recognised as a major contributor to land degradation and, at the same time, a major obstacle to upgrading soil fertility management (Plate 6).

Forestry Production

At present over 6,306,700 ha of forest land exist in Nepal. This accounts for over 43 per cent of the total land area. Wherever population pressure is high - for example, in the Middle Mountains - these forest areas are heavily utilised for firewood, fodder, litter, and timber. Where use is intense, the forests are heavily thinned, lopped, and grazed in the understorey. The materials that are removed from the forest contain energy and nutrients, which, to a large degree, maintain the fertility of the hill agricultural system. Unfortunately, as in the grazing areas, lack of assured tenure has severely restricted interest in improved management of forest areas.

Leaves and twigs make up the litter that generally covers most forest floors and they are extensively used as bedding and in compost. Litter collection can seriously alter the forest floor hydrology and leave the soil surface open to high rates of surface soil erosion. The constant one-way flow of nutrients from forest soils will also have some negative long-term effect on the soil's chemistry. However, the significance of nutrient removal in the geomorphologically active, forested slopes of Nepal, where new material is always coming to the surface, is not clear (Plate 7).

Grazing within the forest is also common and the negative effects are the same as for grassland and brush areas. Burning, however, introduces the additional hazard of possibly setting a crown fire which destroys forest resources critical for supporting the overall farming system.

Even taking the most optimistic projections of developing government-run plantations, Nield (1986) found that forests were still being degraded around three times faster than they were being planted. To give the government attempts at plantations even less cause for optimism, it is recognised that over 75 per cent of the trees that have been planted are pine, a tree that acidifies the soil and is of almost no value to the local farmer in fodder production, for which his greatest need is felt.

As with grazing land, the biggest obstacle to better management of the forests is the lack of some form of assured tenure to the villager. Community forestry and lease-hold forestry provide two options that are central to the enhancement of fodder production and, through livestock, increase fertility of agricultural soils. While community forests appear to be able to manage tree production, there are no clear successes with the management of high quality fodder trees and improved grasses on community lands. Private initiative and private ownership are required before most farmers will be willing to invest in planting and maintaining higher value produce. Where villagers have unofficially divided up the forest land among individuals, high levels of management have been noted.

Traditional Soil Fertility Management

Until recently there has been little interest on the part of agricultural researchers in investigating the indigenous soil fertility practices of Nepalese hill farmers. It was assumed that the uneducated farmers were ignorant of how to manage soil fertility. Tamang (1991) strongly refutes this and points to many examples of innovative management by the small hill farmer in the face of numerous constraints. Agricultural scientists have been slow to understand the complexity of traditional soil fertility management and consequently have been unable to substantially improve traditional management systems. For the Nepalese hill farmer, managing soil fertility has been essential to his survival. It is not surprising that many sophisticated and labour-intensive methods have been developed over the years to maintain soil productivity (Shrestha and Katwal 1992). A summary of nutrient flows of a typical Middle Mountain farming system is presented in Figure 1. Some of the more common methods are described below.

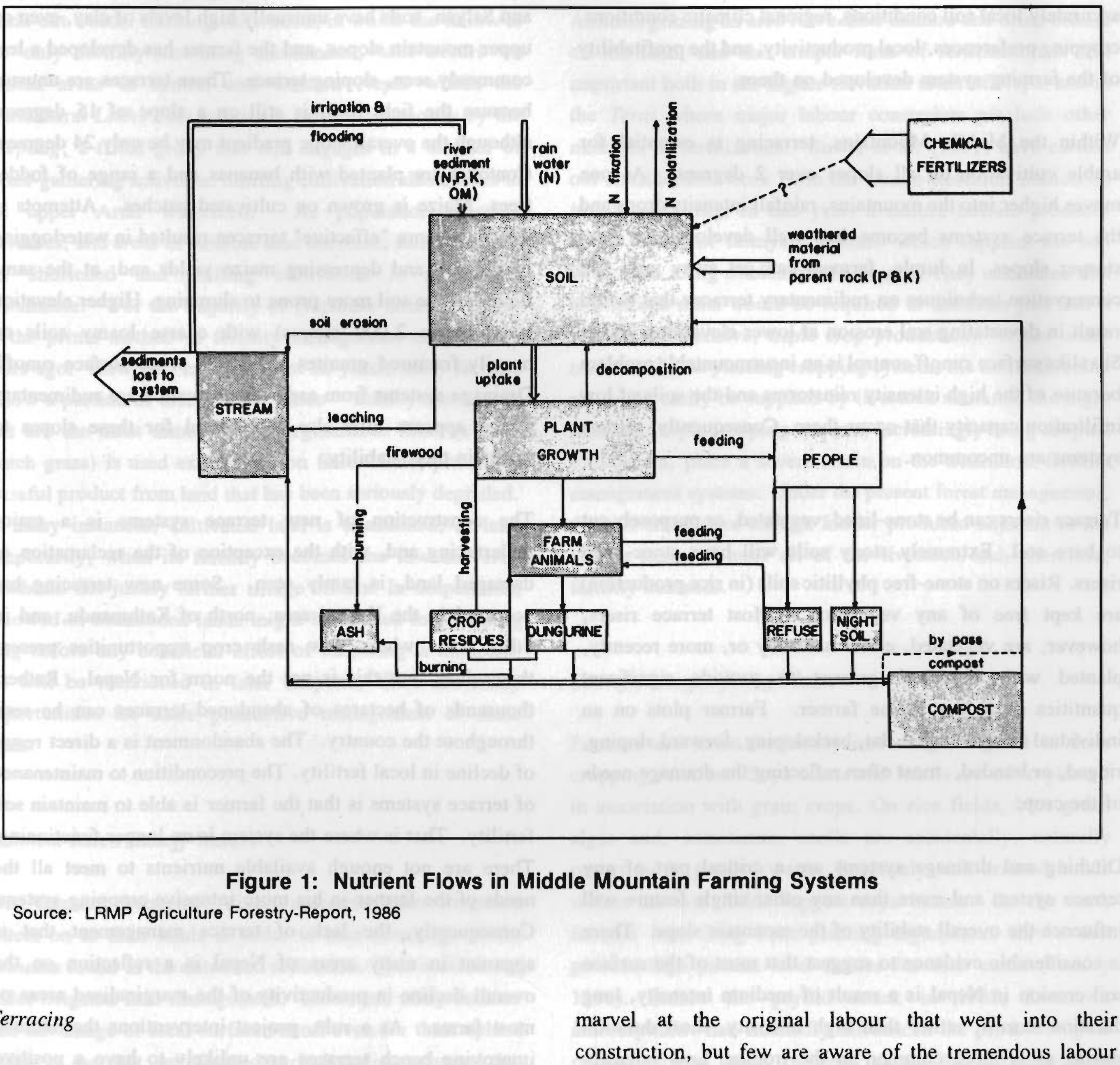


Figure 1: Nutrient Flows in Middle Mountain Farming Systems

Source: LRMP Agriculture Forestry-Report, 1986

Terracing

Terraces are a critical aspect of upland management in Nepal, primarily because of their ability to substantially reduce erosion and, secondly, to make tillage and other agronomic practices much easier to carry out. Very early in the development of stable, permanent agriculture in Nepal, farmers recognised the value of terraces as the major precondition for the maintenance of soil fertility. The existing bench terrace systems found in Nepal are a trademark of the Nepalese farmers' determination to maintain their agricultural systems. Many casual observers marvel at the original labour that went into their construction, but few are aware of the tremendous labour that is associated with maintaining bench terraces on the unstable mountain terrain of Nepal (Plate 8).

There are a great number of terrace types in Nepal, each reflecting the physical and socioeconomic attributes of the village lands on which they occur. Irrigated rice terraces are flat and bunded, rainfed terraces tend to be gently outward or sideways sloping so as to join terraces at different levels. Different production systems within different climatic zones in Nepal support distinct terrace forms. Terraces can range from perfectly groomed, flat fields with substantial, vertical rock-lined risers to a simple row of banana trees and a small pile of stones cast off the field along the contour of an otherwise uniform slope. Most rainfed terraces fall somewhere in between, with a gently outward sloping run (2 to 5 degrees) and a strongly sloping riser (60 to 75 degrees). Regardless of their surface form, they generally reflect accurately local soil conditions, regional climatic conditions, cropping preferences, local productivity, and the profitability of the farming system developed on them.

Within the Middle Mountains, terracing is essential for arable cultivation on all slopes over 2 degrees. As one moves higher into the mountains, rainfall intensity drops and the terrace systems become less well developed on ever steeper slopes. In Jumla, farmers can get away with soil conservation techniques on rudimentary terraces that would result in devastating soil erosion at lower elevations. In the Siwaliks surface runoff control is an insurmountable problem because of the high intensity rainstorms and the soils of low infiltration capacity that occur there. Consequently, terrace systems are uncommon.

Terrace risers can be stone-lined, vegetated, or purposely cut to bare soil. Extremely stony soils will have stone-lined risers. Risers on stone-free phyllitic soils (in rice production) are kept free of any vegetation. Most terrace risers, however, are vegetated, either naturally or, more recently, planted with improved grasses to provide significant quantities of fodder to the farmer. Farmer plots on an individual terrace can be flat, backsloping, forward sloping, ridged, or bunded, most often reflecting the drainage needs of the crop.

Ditching and drainage systems are a critical part of any terrace system and more than any other single feature will influence the overall stability of the mountain slope. There is considerable evidence to suggest that most of the surface soil erosion in Nepal is a result of medium intensity, long duration storms, rather than high intensity, short duration storms as is more common in the tropics. Low intensity rainfall may not have sufficient energy to break up soil structure but, if surface runoff is concentrated and not properly controlled, soil loss from these channelised areas can be severe. Recent work in the Bagmati Watershed Project has emphasised the importance of surface water control to overall slope stability. By the simple diversion of concentrated runoff water into stable channels, they have been able to stabilise previously active landslide areas and whole terrace systems.

Areas with high intensity rainfall and low soil infiltration rates are virtually unterraceable. The lower the elevation and the greater the clay content of the soil, the greater will be the hazard. The marls and mudstones of the Siwaliks are an example of land that cannot be safely terraced. Attempts that have been made have resulted in whole slopes being washed away with the monsoon rains. In areas of Tansen, Gulmi, and Salyan, soils have unusually high levels of clay, even on upper mountain slopes, and the farmer has developed a less commonly seen, sloping terrace. These terraces are unusual because the field itself is still on a slope of 15 degrees, although the overall slope gradient may be only 24 degrees. Contours are planted with bananas and a range of fodder trees. Maize is grown on cultivated patches. Attempts to introduce more "effective" terraces resulted in waterlogging of the soil and depressing maize yields and, at the same time, left the soil more prone to slumping. Higher elevation sites (above 2,000 metres) with coarse loamy soils on heavily fractured granites have little or no surface runoff. Drainage systems from areas of cultivation are rudimentary and it appears little else is required for these slopes to maintain their stability.

The construction of new terrace systems is a major undertaking and, with the exception of the reclamation of damaged land, is rarely seen. Some new terracing has occurred in the Kąkani area, north of Kathmandu, and in other areas where new cash crop opportunities present themselves; but this is not the norm for Nepal. Rather, thousands of hectares of abandoned terraces can be seen throughout the country. The abandonment is a direct result of decline in local fertility. The precondition to maintenance of terrace systems is that the farmer is able to maintain soil fertility. That is where the system is no longer functioning. There are not enough available nutrients to meet all the needs of the farmer in his more intensive cropping system. Consequently, the lack of terrace management that is apparent in many areas of Nepal is a reflection on the overall decline in productivity of the marginalised areas of most farms. As a rule, project interventions that include improving bench terraces are unlikely to have a positive effect, unless the productivity and profitability of the overall farming system is improved at the same time.

Fallow

Most soils, given a break from crop production, will have their fertility renewed to some degree. The period of time in fallow and the choice of vegetation used during the fallow period will enhance fertility when cultivation is again taken up. Fertility alone is only one aspect of rejuvenation during fallow. Noxious weeds, impossible to remove in some of the marginally productive soils, can be eliminated, given a long enough fallow period with the right species. Weeding, by normal tillage methods, may be impossible on excessively stony soils, whereas the proper bush fallow can effectively shade out weeds. Shifting cultivation, in which the fallow is the only fertility-sustaining mechanism, still occurs on limited areas in central and western Nepal within the Mahabharat *Lekh*. This activity is carried out mostly by the *Chepang*, a tribal group that still engages in a number of forest-gathering activities. Shifting cultivation also occurs in the upper Arun watershed. As population pressure increases, and areas of suitable land decrease, fallow periods are shortened and shifting cultivation is no longer sustainable. For the majority of Nepalese farmers, fallow as the prime method of fertility management ended many years ago. However, as of the past 20 years, many farmers fallow a portion of their upland fields - usually those lands that are the most remote and marginalised. *Khar* (a local thatch grass) is used extensively on fallow land, producing a useful product from land that has been seriously degraded. In many instances, cultivated land is abandoned, at least temporarily, when its fertility becomes too low and crop yields do not justify further tillage efforts. In desperation, fallowed or abandoned lands might be opened for cropping long before any beneficial effect of fallowing is obvious. As will be mentioned in later chapters, there are many opportunities for more productive management of these lands.

Sediment-laden Runoff Waters

Rice farmers frequently divert sediment-laden irrigation waters on to their lands in order to take advantage of the nutrients found in the entrained sediments. This is discussed under irrigated land management. However, many farmers take advantage of local surface runoff even for their upland crops. In the past, uninformed agriculturalists assumed that the ditch structures, often found above agricultural land were purely to protect the farmland from heavy surface runoff. Local interceptor ditches on the upper side of the terraced fields not only collected heavily sediment-laden water, but also diverted it to individual fields of the farmer's choice. Irrigation and fertilizer benefits are both realised from this activity. While there is not a lot of cultivation in the Siwalik hills themselves, water and nutrient runoff, harvested from the hills during intense rains, is important to production on the alluvial terraces below. A portion of the *bari* throughout Nepal does receive a little channelised water whenever the farmer finds manageable water upslope.

In Situ Manuring

Animals grazing an area leave their manure and urine behind on the land, and this simple form of fertilization is still important both in the higher elevation areas of Nepal and in the *Terai* where major labour constraints preclude other methods of fertilization. Suwal et al. (1991) have carried out considerable work from the Lumle Research Station on *in situ* manuring. In one year, a mature buffalo produces about 4 tons of farmyard manure which supplies the soil with 10 to 13 kg of elemental nitrogen. They calculated that 6 livestock units would be required to maintain just half a hectare of intensive, triple crop production. While under traditional, low yielding cropping systems the nutrients could relatively easily be supplied by livestock manures, the high-intensity, triple cropping systems, increasingly being adopted by farmers, place a severe strain on the traditional fertility management systems. Under the present forest management, there is simply not enough fodder produced adjacent to the village lands to meet all of the livestock and, therefore, fertility demands.

Use of Nitrogen-fixing Plants

Farmers are more frequently including a legume in their cropping rotation. Soya beans and lentils are often planted in association with grain crops. On rice fields, blue green algae and, sometimes, azolla are accidentally, naturally occurring in ponded water. Relatively well-drained bunds within the rice fields support soya beans. On the *bari*, farmers have long been planting leguminous shrubs that provide high protein level fodder for their cattle (Pandey 1991). Before the psyllid attack in 1988, *Leaucena leucocephala* had markedly influenced the productivity of rainfed terrace lands. In many cases, the nitrogen-fixing species provided high quality fodder for the production of more profitable livestock, which in turn increased the productivity of the overall system.

Green Manuring

Subedi (1989) has carried out considerable investigations on the traditional use of green manuring by local farmers and considers it to play an integral role in the farmer's overall fertility management strategies. Green manures are used extensively in nursery seed bed preparation in many parts of Nepal. Many common, locally available species, such as *Artemesia vulgaris*, *Vigna umbellata*, *Sespania sp*, *Cassia toda*, *Albizzia sp* and a number of grasses, are used traditionally by Nepalese farmers. The role of these green manures is three-fold. First, to provide nutrients needed by the crop; secondly, to improve the physical condition of the soil by using them as a mulch or by incorporating them into the soil; and, thirdly, to protect newly sown seeds and seedlings from birds and insects through both their physical and chemical effects. It is recognised that the materials used for green manure usually have little or no value for fodder and become green manure by default. In many cases, better management of the adjacent non-agricultural lands for fodder could produce a higher value commodity than these green manure species.

Terrace Riser Slicing

Wherever stone-free, terraces on soft, deeply weathered phyllites occur, the farmer, as part of his overall terrace management system, slices 1 or 2 cm from the terrace riser and deposits it on the field below. The farmer does this to control weeds on the terrace that will compete with his rice crop, control rodents that have dug into the terrace, and also to provide small, but significant, amounts of organic matter to the field below. It is surprising to non-specialists to see just how quickly these terrace systems actually disintegrate if this high level of management is not kept up. Within one or two seasons, the terraces are often hard to identify.

Compost

Compost[7] is by far the most important soil additive used by Nepalese farmers to manage fertility. Next to virtually every house in the hills a compost pile will be found. The compost is made up of animal manures, forest litter, and agricultural and household waste, including ash from cooking fires. A sign of ultimate desperation for the local farmer is the selling of his compost pile, as it is well recognised that his next crop is solely dependant on that compost. Reported rates of compost use range from 0 to 58 tons per hectare but are most commonly between 0 and 23 tons per hectare for rice crops and 20 to 28 tons per hectare for maize crops (Suwal et al. 1991). The Lumle group has carried out significant investigations on traditional compost use. Their work will be of increasing importance in the future. There are many criticisms of the local farmers' management of compost, but this is quite likely based on incomplete knowledge of the farmers' opportunities and constraints. Excess nitrogen volatilisation and potassium leaching are seen as the major problems of traditional compost management and will be discussed later.

Chemical Fertilizer Use

Chemical fertilizers are increasingly being used by Nepalese farmers, as they intensify their cropping systems and expect greater yields on a per hectare basis. Recently, the Nepal Fertilizer Sector Management Study (Crown Agents 1991) calculated that 12 per cent of the present grain crop yield in Nepal was a direct result of chemical fertilizer use. In 1980, over 22,000 tons of elemental nutrients were imported as chemical fertilizer. By 1990 this had increased to over 56,000 tons (HMG/N 1990). Sherchan (1991), after exhaustive studies on composite maize varieties, found that a fertilizer mix of 40 to 50 kg of nitrogen, 30 to 40 kg phosphorous, and 10 tons of farmyard manure was profitable and attractive to the hill farmers in the Pakhribas area. In the same study, he found that local rice varieties did not respond well to fertilizer additions and were uneconomical at any application rate. In general, nitrogen and phosphorous fertilizers have consistently shown a favourable response to a wide variety of introduced species; and to a lesser extent to local species. Potassium, on the other hand, only occasionally shows a response with traditional cropping patterns.

Farmers, particularly in areas with good access and with marketing opportunities, are using chemical fertilizer. A candid interview with farmers carried out by Tamang (1991) in the Jhikhu Khola watershed nicely sums up the farmer's viewpoint. Farmers liked chemical fertilizer because:

- it was now possible to cultivate soils throughout the year;
- crop yields had increased greatly - even the non-productive white soils could grow maize; and
- cash made available from selling surplus crops was important for running the household.

7. Compost here is used to mean any combination of livestock manure, animal bedding, agricultural crop remains, ash, and kitchen refuge that is stored in a pile by the home and carried to the field as needed or when time is available. Lumle researchers use the term farmyard manure (FYM) rather than compost because the material is often not well composted.

On the other hand farmers did not like fertilizer because:

- it makes the soil hard and difficult to plough;
- it reduces the moisture-retention capacity of the soil, increasing drought hazard for upland crops;
- yields of some crops were now declining after a period of high production; and
- farmers were increasingly at the mercy of fertilizer traders who were unable to supply to the farmer in a timely or cost-effective manner.

While the trends towards increased fertilizer consumption are clear, there is also a growing realization that fertilizers alone do not provide a complete fertility management package. Grain yields at the Bhairahawa Agricultural Farm showed significant declines when nitrogen fertilizer was used exclusively over a ten year period. Declines, although less drastic, were also observed when nitrogen and phosphorous were used together. When a "complete" NPK fertilizer was used, yields were better but not as good as when organic matter in the form of farmyard manure was applied alone. Although it should have been apparent from the start, it is now recognised that an important synergistic response occurs when the right proportions of chemical and organic fertilizer are used. There is a role for both organic and inorganic fertilizers in Nepal and the polarisation of interest groups to make either/or choices is counter to sensible soil fertility management.

Erosion and Fertility Management

Rainfall erosion acts to remove the most fertile surface soil and leave behind a less fertile subsoil. If the soil surface is maintained in a bare state, as occurs in marginal, rainfed cultivation or heavily grazed areas, each rainfall event has an opportunity to remove soil, either by direct kinetic energy or, as is more likely, by the erosive force of channelised surface runoff. Soil erosion, more than any other single factor, is responsible for the increased marginalisation of peripheral agricultural and forest lands.

Generalists and specialists alike often assume a direct correlation between deforestation and erosion - "the more natural forests are used and degraded, the greater will be the degradation of Nepal's soil resource". The surprising fact is that there is virtually no evidence to support this view. Lopping branches and cutting down trees have relatively little effect on the soil hydrological properties that influence erosion. In many situations, a grassland and a good forest are equally able to protect the soil. However, a growing body of literature suggests that increased marginalisation of rainfed agriculture and the increased pressure of low quality livestock on grazing lands are the primary causes of erosion (Gilmore 1991 and Wymann 1991).

There is an ongoing attempt to equate this form of soil erosion with downstream sedimentation and infer that changes in land management will automatically lead to significant changes in the sediment loads of major river systems. With the exception of small, isolated watersheds, data to support this theory are scarce. However, a casual study of the major river systems of the Himalayas will demonstrate that natural, geological forces are resulting in the vast majority of sediment within the river system. Better land management cannot be expected to result in improved river flow characteristics, but better land management is required to sustain the Nepalese hill farmer.

Throughout the hill regions of Nepal, particularly at lower elevations where rainfall intensity is highest, erosion is a major contributor to the decline of soil fertility. In Table 3 estimated soil and nutrient losses are given for major production systems of Nepal below 1,000m.

The Socioeconomic Condition of the Nepalese Farmer

When addressing the overall soil fertility situation, there has been an unfortunate reliance on strict biophysical analysis (even though inadequate) and an inexplicable exclusion of socioeconomic analysis. The net result is experimentation, and even demonstration, on how to improve soil fertility that has little relevance to the local farmer's situation.

In the final analysis, the farmer's social and economic setting will dictate if, or how, she might adopt interventions from the outside. Where socioeconomic information has been collected, it has often remained unused when developing the soil fertility programme. The few "successes" of government and donor-driven crop productivity enhancement programmes were often a result of enrichment of the rich farmer and further impoverishment of the poor farmer. Some of the recent block production programmes in the *Terai*, associated with irrigation, have increased overall productivity but only at the expense of the small farmer who, for many reasons, is unable to take advantage of the offered technologies and credit and his situation further deteriorates.

Table 3: Estimated Nutrient Loss by Rainfall Erosion Associated with Different Production Systems*

	Irrigated Rice Terrace	Rainfed Bench Terrace	Rainfed Marginal Land	Grazing (Degraded)	Forest (Good)
Soil Loss Depth mm	0	0.4	1.0	8.0	0
Soil Loss t/ha/yr	0	5.0	20.0	100.0	0
Organic Matter Loss kg/ha/yr	0	75.0	300.0	1500.0	0
Nitrogen Loss kg/ha/yr	0	3.8	15.0	75	0
Phosphorous Loss kg/ha/yr	0	5.0	20.0	100	0
Potassium Loss kg/ha/yr	0	10.0	40.0	200	0

(modified from Carson 1985)

* Calculated based on a topsoil with the following analyses:

Organic Matter	1.5 %
Nitrogen	0.075 %
Phosphorous	0.1 %
Potassium	0.2 %
Bulk Density	1.3 g/cm^3

Although these tables are based on inadequate field erosion measurements, the results can be considered to be good approximations of the overall situation. There are a number of important points to consider and these have been given in the following points.

1. Irrigated rice fields are not eroding. In many irrigated rice systems there is actually a net gain of soil through sediment additions from diverted monsoon runoff.

2. The well-managed bench terrace systems have rates of soil loss that can be relatively easily maintained by normal compost additions.

3. It is on the marginal agricultural lands that nutrients are being progressively depleted. Under such management, topsoil quality will decline (and productivity with it) to such an extent that the farmer will abandon the plot of land.

4. On heavily grazed land, the erosion is even more serious, although the total area impacted in this manner is actually small.

A soil fertility management strategy must address marginal agricultural land management and grazing as focus points for enhancement.

Severely eroded, overgrazed sites (Plate 9) are common throughout Nepal and make a lasting impression on government officials and donors alike. Such sites are used in photo essays to justify swift, expensive, and usually unsuccessful remedial action through a wide range of government and consultant-originated ideas. Land degradation is a symptom of existing socioeconomic conditions and, as a result of only attacking the symptoms, requires infinite resources to fuel non-sustainable development. Many of the "Hot Spots" identified by nationally-based inventory and subsequently used to determine priorities for soil conservation fall into such a category. Official government projects, largely funded by foreign aid, throughout the whole of Nepal have repeatedly attempted, without success, to improve specific tracts of degraded land through direct intervention by using fencing and hired guards to stop grazing, fires, and other village activities that damage the soil. Unfortunately, when the project has run its course, the land quickly returns to its initial, degraded state because the underlying cause for overgrazing or promoting burning has not been addressed.

In the same light, while chemical fertilizer use may result in increased yields, it is only sustainable if using fertilizer is economically viable. It is generally conceded that chemical fertilizer will increase yields "significantly". This has captured the imagination of agricultural planners who have been given the task of increasing Nepal's agricultural production. In reality, for many small hill farmers in Nepal, available cash would be much more wisely employed to service debt rather than investing in the marginal returns to fertilizer. Big, wealthy landlords in the *Terai* also have much more profitable ventures than reinvesting in subsistence-oriented agriculture on their own land. Contrary to the "official" line, the farmer would be irrational if he adopted fertilizer use and not "ignorant" or "stupid" as he is commonly claimed to be. A closer look at the farmer's decision-making processes is required.

Indigenous Farming System

The key to developing more productive and sustainable agricultural systems in the future depends on an in-depth analysis of what is going on at present (Gill 1991). Farmers make decisions based on the opportunities and constraints they face on a day to day basis. If one is to develop more appropriate innovations for the future, it is essential to understand the relevant aspects of the farmers' socioeconomic environment as it influences the biophysical environment today. The farmer has successfully integrated a wide number of activities, including rainfed and irrigated cultivation, livestock management, gathering products from the forest, marketing of specialised crops, etc. However, the scientific disciplines of agriculture and forestry, which have done so much to advance production in the West, have failed to become a significant force in raising the production of Nepalese hill farmer. The farmer's present decisions on how to manage the soil resource provide the basis for developing more productive and sustainable soil management in Nepal (Shrestha and Katwal 1992). If the farmer is reluctant to use chemical fertilizer, his reasons are going to be central to an overall analysis for developing fertility strategies. If a farmer refuses to use compost in an officially prescribed way, an understanding of the farmer's concerns will be the first step in developing more appropriate compost management.

Farmers' Motivation

An understanding of the farmer's motivation sets the ground rules with which to develop a tactical approach to enhancing soil fertility. Farmers are interested in the results of soil fertility, not soil fertility per se. The present management of village land resources makes tremendous nutrient and energy demands on the locally available land resources. Fodder, litter, firewood, timber, and food are harvested from the local environment, some with careful husbandry, others with apparent reckless abandon. More productive and intensive agricultural systems extract more, not only out of the land but also from the local farmer, in the form of labour. Over the last 40 years there has been an ever-increasing need for more productive agricultural systems to support the increasing local population. Running concurrently with this is the impoverishment and abandonment of marginal lands as farmers run out of fertilizing material, labour, and capital to service them (Jodha 1992). There comes a critical point, however, at which the combination of increased labour and fertility requirements are not able to compete with alternative employment outside the agricultural production sector. Investments off the farm are more lucrative than investments on the farm. Out-migration and off-farm employment have become significant forces influencing a farmer's decision on if, and what, to farm.

It is of significance that virtually all small farmers wish their sons to get a good education and the farmer will make great sacrifices to that end. However, the farmer's motivation is not for the son to learn how to manage the farm better but, rather, for the son to escape from the farm so that he will possibly not have to work so hard.

Virtually all farmers are able to agree on one point. They do not have enough cash and their present overall farming system cannot provide the cash they need. Unless the farm becomes more profitable and returns to labour increase instead of decrease, as has been happening in the last 30 years, the farmer is strongly motivated to quit the farm. Because of the fertility constraints discussed in this paper, it appears that cash crop production is the only significant approach towards the increasing profitability of the system. It is only by an increase in the profitability of the system that the farmer will be motivated to manage his soils in a more productive and sustainable manner.

Target Farmer

When discussing agricultural research priorities and what technology should be extended to enhance fertility management, the answers will be very different depending on whether the client is a rich or poor farmer. In the past, many programmes began with the generalised premise that Nepal is desperately poor and as a group the farmers are also poor. Equitability issues were rarely considered and programmes were based on the view that lead farmers would provide the focal point for development. Not surprisingly, lead farmers are invariably the wealthier farmers and what is relevant extension material for them may well not be for the poor farmer. In order to address the national soil fertility management problems, it is imperative that the inequities of natural resource control be considered. The differences in the characteristics of wealthy and poor farmers are considerable and are summarised below.

In general, wealthy farmers have:

- large landholdings (>1 hectare per household),
- a larger portion of better-quality lands,
- a greater portion of irrigated rice lands,
- rice (and, to a lesser extent, maize) as their most important grain crop,
- a greater number as well as more productive livestock,
- enough rainfed land for them to produce their own firewood and fodder needs on their private lands without collecting from forest areas,
- capital resources to invest,
- little interest in agriculture - many other investment opportunities in the village prove to be more lucrative, including money lending, truck transport, and trade,
- the ability to hire labourers to fulfill agricultural duties, including livestock maintenance,
- indentured labourers and tenants working their land,
- children with a higher education level,
- political power, and
- they are of a higher caste,

At the other end of the spectrum, poor farmers have

- small landholdings (> 1/2 hectare per household),
- poorer quality land,
- a greater portion of the marginal, rainfed upland fields,
- a reliance on maize, but millet and buckwheat are important grain crops,
- fewer, as well as less productive, livestock-often they look after the wealthier farmer's livestock,
- to get most firewood and fodder needs from communal lands rather than private lands and to a large extent are responsible for the exploitive management of marginal lands,
- debts and are cash-starved generally,
- to perform their own labour,
- children with fewer education opportunities,
- no political power, and
- they are of a lower caste.

Both groups of farmers are intimately in tune with their own environment and the opportunities and constraints that they face. They are rational in the decisions that they make. Although Nepalese farmers have a strong cultural heritage, this fact rarely creates an insurmountable obstacle to development. When targetting recipients of any development programme, the above check list indicates what type of innovations might be considered appropriate. Communal grazing lands and marginal rainfed lands are the domain of the poor. Research and extension on improvements for upland crops will have much more relevance for the small farmer. Meeting the needs of the poor farmer must be one of the primary goals of donor-driven development projects, not only on compassionate grounds but also because most of the serious environmental degradation is a direct result of his/her activities.

Extension

Adoption of new soil fertility management practices by the Nepalese hill farmer depends on criteria that extension agencies and research efforts for one reason or another have failed to address.[8]

In general, extension workers are not motivated. If they are motivated, they lack a clear understanding of the farmer's agricultural system. If they also understand the agricultural system, the technologies that they are entrusted to extend are irrelevant to the needs of the farmer. Finally, where there exist a few models of successful extension, the inability to "scale-up" any extension activity appears to be a severe limitation. Unquestionably, there is tremendous opportunity for improvement of extension within the Government and by non-government organisations (NGOs), but it is predicated on a strong client orientation and based on local interest rather than Central Government targets.

8. Individual agriculturalists in Nepal are intimately aware of the problems as can be seen from the papers presented in seminars, but the nature of their employment and the structure within which they work often stifles a farmer-oriented approach.

Appropriate Extension Messages

Bunch (1982) used a check list of "appropriateness" in judging the merits of new technologies for the small, resource poor farmer. To ensure success, a new technology should:

- meet with the felt needs of the villagers,
- increase productivity, quality, and/or profitability of the overall farming system significantly,
- be able to demonstrate success rapidly,
- utilise resources that are readily available to the small farmer,
- assume a low or at least an acceptable level of risk,
- be labour rather than capital intensive, and
- be simple.

Most workers recognise that productivity must be increased significantly to be of interest to the small farmer. However, there is a misunderstanding of the word significant. What might be statistically significant to science may well not be significant to the farmer and vice versa. Qualities that have been considered insignificant by the researcher (such as straw yield in rice breeding) may be a critical component of a farming system. Increasing rice grain yields at the expense of straw may be unacceptable. In the area of soil fertility, it is well recognised that high yielding varieties have greater fertility requirements which may or may not be possible for a farmer to manage in a particular farming system. In normal risk management, anything new involves risks. The farmer must be convinced that the new technology is worth the risk. Where only small changes are required, small incremental gains are acceptable. However, with extension recommendations involving unfamiliar crops or with the complete revamping of whole cropping systems, productivity increases of 70 per cent might be required to interest the farmer.

Dependence on Local Resources

The more remote a production pocket is from roads and outside markets, the greater is the reliance on local landscape for nutrient and energy needs. The better the access to the production pocket and the more sophisticated the market, the greater is the dependence on outside forces. When considering the changes required to make agricultural production sustainable, the planner must weigh the advantages and disadvantages of the self reliance of a community versus interdependence of local, regional, and international communities. If fertilizer transport subsidies are not sustainable, do not encourage them, because in the future the farmer may be dependent on a resource that at some point will not be available.

The Institutional Environment

Government institutions have the potential to strongly influence how a farmer uses his land. The Ministry of Agriculture's mandate is to lead the way in research and extension on agricultural problems; the Agricultural Inputs' Corporation supplies improved seed, fertilizer, and pesticides; and the Agricultural Development Bank provides loans to farmers and agro-businessmen. The Department of Roads has a critical role to play in opening up remote areas to agricultural inputs from the outside and providing an opportunity for moving produce to the markets outside the previous "market-shed". Customs and Excise departments strongly influence agro-entrepreneurs in their interest (or disinterest) to invest in agricultural enterprise. For all of the development attempts made, few government (or donor) initiatives have had any lasting positive effect on the small farmer.

Forestry, as we have seen, has a critical role to play in the nutrient cycling of traditional agricultural systems; although this is not reflected in the operation of the present Ministry of Forests. The Forestry Ministry and the Ministry of Agriculture have little in common and they jealously guard what they consider to be their domain. This is most strikingly reflected in the concrete marking pillars that the Forest Department has been using to mark out and distinctly separate the domain of the forest from that of agriculture in many village areas of Nepal. Considering traditional land management in Nepal, these imposed boundaries are not only meaningless but result in pointless hardship where the forestry administration is able to impose its regulations. The small Nepalese hill farmer is dependant on forest lands to maintain the productivity of his overall farming system (Yadav 1992). And yet, the Forestry Department is heavily biased towards timber production and has generally seen the farmer as an encroacher and common thief on forestry-administered government lands. The control of their access to and removal of farmers from forest land has dominated the Forestry Department's philosophy and actions up until the present. Great efforts are being made, particularly by donors, through projects such as the Nepal-Australia Forestry Project, to reverse this attitude, but change has been slow. Until recently, the role of the Department of

Agriculture was meeting targetted goals of agricultural production while Forestry Department activities have been centred around achieving targetted goals for plantation and protection through the services of forest guards. As in all bureaucracies, walls are built up between the various institutions, effectively preventing any beneficial cooperation. In Nepal the word "agroforestry" is shunned by both the departments of Forestry and Agriculture and is carefully avoided in official correspondence. Even within the ministries themselves, antagonisms exist that preclude cooperation leading to more relevant extension programmes (Plate 10). As discussed later, the special role of fodder, livestock, and compost in the overall soil fertility management strategy makes it essential that government agencies orchestrate their work more closely if they are to provide an effective service.

Many land resource studies in Nepal, including the Land Resource Mapping Project (1986), have investigated resource allocation and concluded that only if the Central Government divested power and authority to private enterprise and the farmers themselves could significant improvements in natural resource management be made.

The Central Government has embraced the concept of grass roots' development, in theory, but now must put it into practice. There is an ongoing, donor-driven push to accelerate the decentralisation process and divest power to lower levels of government and, ultimately, the people themselves. The Forestry, Irrigation, Livestock, and Horticultural Master Plans (HMG/N 1988, HMG/N 1989, HMG/N n.d., ADB 1991) (some of which are still in a preliminary stage) have all been remarkably consistent in stressing the facilitating role of the Government to empower local resource management. Herein lies an unexcelled opportunity for positive change, particularly given the recent changes in Nepal's Government.

The "bottom up" approach to development is based on the premise of villagers becoming empowered, making their own decisions about what they want, and cajoling the bureaucracy to provide the services that they require. Although the recent changes in the Government are encouraging, it is hard to see how these two opposing philosophies can be reconciled. Until the small farmer is understood and becomes, for the bureaucracy, the client who demands service, rather than the humble recipient at the end of a long and tenuous bureaucratic chain of command, the Government and donors have little to offer towards sustainable management of village lands.

While the elected Government has changed, the bureaucracy was, and to a large degree still is, based on the autocratic and rigid hierarchical structure of the Rana Regime. In this dawning of democracy in Nepal, possibly one of the most important issues to be resolved is to put politicians firmly in control of the bureaucracy, while at the same time ensuring that politicians are sensitive to the needs of their constituents. Along with this, local representation and a local tax base are also necessary to facilitate local management of local resources.

The strengths and weaknesses of the various insti-tutions have been closely investigated by many reports (Jodha et al. 1992) and it is not the purpose of this study to echo their findings. In brief, there have been many attempts to strengthen institutions, none of which have succeeded. Until the concerted philosophies and goals of the institutions are appropriate, no amount of strengthening will improve the life of the small farmer.

IV. The Future

The Government must consider many aspects outside the realm of soil fertility when promoting productive and sustainable agricultural systems. Under the previous government regime, the production system stagnated. Historically, the development of Nepal's resources has experienced a slow progression towards increasing carrying capacity. Periods of stagnation and lack of major change occurred along with spurts of expansion. While there is tremendous uncertainty about Nepal's future in this period of stagnation, and although there are many indicators that the overall situation is deteriorating, there is also considerable opportunity for promoting positive change.

A concerted effort will be required on the part of the Government to facilitate the necessary changes. Minor or even major shuffling of the various government agencies will likely, as in the past, make no difference to the development effort. A new philosophical approach is required. The "top down" system of management has failed to satisfy the basic needs of the people. Government control has stifled, rather than encouraged, private enterprise on the farm and in industry. Culturally, Bista (1991) portrays a convincing and pessimistic outlook for the future given the fatalistic outlook of the elite who hold the seat of power. However, the mere recognition of these problems is a positive step towards finding solutions. The increased awareness of local user groups and the rapid proliferation of NGOs are strong indicators of the willingness on the part of the Nepalese people to lead in privately induced development. It is hoped that the newly-formed democratic government, and the bureaucrats under it, can govern and administer the nation based on the collective will of the citizens of Nepal. Without that commitment, there is little reason to expect positive change.

Opportunities for Enhancing Soil Fertility

There are many excellent management practices now being carried out by the small farmer. However, technical improvements are still possible on many fronts of soil fertility management. Only when these technical improvements are translated into increased productivity and profitability will the farmer be willing or able to accept them.

In the previous chapter the management of nutrients within the traditional farming system in Nepal was discussed. This chapter will suggest ways in which to manage nutrient flows both to be sustainable and to optimise returns to the farmer.

Reduce Loss of Nutrients from the System

Possibly the most cost-effective method for improving the overall soil fertility status in Nepal is to reduce the losses that occur in the system. Potentially valuable resources are being converted into someone else's problem as sediment clogging, irrigation canals, high groundwater nitrate levels, and downstream pollution. Erosion seriously degrades the soil resource. Excessive leaching of over-irrigated soils, volatilisation of nitrogenous materials, burning of organic matter, and mishandling of human wastes are all lost opportunities. Reducing losses of nutrients by changes in management of the above provides the most direct, and possibly greatest, return on investment to the farmer.

Reduce Surface Erosion. Loss of topsoil by surface soil erosion is recognised as one of the most serious problems facing the small, resource poor farmer in the hill regions of Nepal. Increased degradation of already marginalised upland soils results in the loss of soil nutrients. A loss of only 1mm of topsoil (a minimum that would occur) on marginalised uplands can be translated into the loss of 10 kg of nitrogen, 7 kg of phosphorous, and 15 kg of potassium per ha.[9] Farmers are most concerned about soil erosion because they recognise that the compost or fertilizer that they have just added is literally washed away by rainfall erosion. There is increasing evidence that the classical method of predicting soil erosion may not provide a useful model for the terraced landscapes of Nepal. As discussed in Annex 3, rainfall intensities are relatively low and soil infiltration capacities relatively high throughout the Middle Mountains of Nepal, but erosion is still occurring. It appears that the

9. Assuming a soil with an organic matter level of 1.5 %, nitrogen level of .075%, phosphorous level of .05 %, and a potassium level of .1 %.

management of surface drainage and storm runoff above and within terrace systems is critical for the management of soil erosion.

Regardless of whether the method employed to reduce surface erosion is by increasing rainfall interception of the soil or safe removal of runoff water from slopes, either will have a strong positive effect on regional soil fertility. Consequently, soil conservation techniques are crucial in an overall soil fertility strategy for Nepal. Fortunately, most good agronomic and forestry practices also have the benefit of enhancing soil fertility, productivity, and sustainability at the same time.

The driving force for conservation should be that it is in the farmer's short and long-term interest to do so. Soil conservation for conservation's sake alone will be of little or no interest to the small farmer. For this reason, the western-based idea of a soil conservation driven project is misdirected within the Nepalese context. The end product must be measured in produce and money. A sustainable, productive landscape is a result of, not a condition for, economic well-being.

Reduce Amount of Irrigation Water Used on Pervious Soils. Excessive soluble nutrients are lost through deep leaching of pervious irrigated soils, any method used to reduce water loss will preserve soluble soil nutrients including nitrates and potassium. Unused water can be redirected to expand the area under irrigation. The most obvious way to reduce consumption of water is to irrigate crops other than rice on the coarse-textured soils. Irrigation duties for maize may be less than 1/5 the requirement for puddled rice.

Reduce Volatilisation of Nutrients from the System. Nitrogen losses through volatilisation can be significant and any methods to reduce such losses should be considered. Major nitrogen losses occur during compost production and incorporation into farmers' fields. Present studies being undertaken by researchers at Lumle will bring new understanding into an area long ignored by agronomists.

Some of the biggest volatilisation losses occur through the burning of grasslands and brush forests. Whenever burning of any type occurs, nutrients, including nitrogen and sulphur, are lost into the atmosphere. Organic matter, which is so critical to the whole production system, is lost when burning occurs to enhance pre-monsoon grazing. The management of the coarse, high carbon/nitrogen ratio organic material on grazing and forest lands is critical and will have to involve integration of agriculture, livestock, and forestry activities.

Reduce the Loss of Nutrients from Night Soil. The present misuse of human waste is a serious nutrient drain on Nepalese agriculture. The nutrients lost to agricultural production through the indiscriminate disposal of human wastes are in excess of all of the chemical fertilizer now imported into the country. The average household produces 28 kg of nitrogen, 4 kg of phosphorous, and 8 kg of potassium as organic waste and, through lack of care, a significant portion of these nutrients are ineffectively lost to the system. If only 50 per cent of the nutrients are recycled on to farmland (by chance or design), this would result in an additional 70,000 tons[10] of elemental nutrients available for production systems. (At present, Nepal only imports 50,000 tons of elemental nitrogen, phosphorous, and potassium.)

Hill farmers use nearby fields, grazing areas, and pathways for eliminating body wastes, but the process is one of chance whether the nutrients will be recycled. The *Newars* of Kathmandu Valley, before the days of chemical fertilizer, made extensive use of night soil in market gardening. Now the *Jyapu* farmers find it more convenient to use chemical fertilizer and most of Kathmandu and Patan's human wastes foul the holy Bagmati River, or even worse, the streets. Some toilet designs already exist that use little water and can safely convert waste into fertilizing material but as yet they have not been given the priority they deserve. At present, only the *Sherpas* of eastern Nepal actively use human waste in compost for their agricultural soils.

While present sensibilities may preclude such intensive use of night soil for orthodox high caste Hindus in Nepal, temporary latrine pits adjacent to the homestead in rural areas can be used productively for perennial tree establishment. Where farmers have already adopted this simple technique, the fertilizing value of their own waste becomes much more apparent and the farmers begin to experiment themselves. This would be the first step in getting the Nepalese farmer to recognise night soil as an important resource to be managed rather than squandered.

The simple separation of human wastes from potential water supplies would do more for the development of Nepal than

10. This figure is based on very rough calculations and is only meant to indicate the order of magnitude of the problem (and opportunity).

any other single innovation yet attempted in Nepal. Greatly reduced child mortality and lowered child and adult morbidity would be a direct result of a successful sanitation programme. From the farmer's nutritional point of view, the increased ability to absorb nutrients as they pass through his/her stomach would be more beneficial than all agricultural improvements developed over the last 20 years. Implementation of a sanitation/fertility recovery programme affects the "sensibilities" of many and as such would be unpopular. However, a serious Government will have to become more serious about sanitation, sooner or later.

Develop Alternative Fuels to Dung in the *Terai* and in the Dun Valleys. The loss of livestock manure that is burned for cooking purposes is an increasingly serious drain on agricultural production for poor farmers. While the ash is returned to the land it does not contain nearly the amount of nitrogen it would if used as compost. The physical effect on soil structure and the buffering effect on low pHs are two important reasons for using more compost on the *Terai* soils. Fast growing tree species now being planted on marginal lands in the *Terai* provide considerable opportunities for improving this situation and should be encouraged.

Improve the Efficiency of Nutrient Use

The nutrients that are now within the village fertility management system have the ability to be used in many different ways for a wide variety of crops. A number of techniques can be used to enhance the efficiency of these nutrients.

Improve the Quality of Compost. Compost is the single most important soil fertilizing material in Nepal and the improvement of its management would have significant spinoffs for agriculture. Before the quality of compost can be improved, it will be essential to dramatically improve the resource scientist's understanding of its physical and chemical nature, how the farmer makes it? and what role compost plays in soil amelioration? It is apparent that many of the recommendations regarding compost management are made with little or no field-tested, scientific justification. A "theoretically" correct, yet probably inappropriate, recommendation is that farmers should not let their compost dry out before incorporation because nitrogen is lost through volatilisation. Such analyses without attention to the farmer's management system also make results less extendable. If the labour needed to bring the compost to the field is the major constraint, it makes good sense to let the compost dry out so that more can be brought to the field with each journey. Likewise, it is also "theoretically" correct to assume that incorporation of distributed compost, once spread on the field, is essential. Again, this assumes that nitrogen is the primary constraint. Maybe it is not. The compost may be acting as a mulch to protect the soil from surface rainfall erosion. On certain sites the net effect of a surface mulch in reducing erosion may be much greater than a "timely" incorporated compost. These are just two examples of an incredible research vacuum that is hindering concerted efforts to improve the farmers' present fertility management systems. At Lumle ongoing experimental work with compost use under farm conditions provides a critical new look at the process of compost improvement. Subedi et al. (1989) found that wet application and immediate incorporation of compost improved yield in some cases and not in others. Laboratory analyses of soil fertility did not always reflect the actual productivity of crops grown on those soils. Subedi indicated that more study is required in order to understand the complex interactions of compost management.

A clearer terminology of compost quality is desperately required for agronomists and soil scientists so that they can begin to address overall fertility management within the system. It is almost useless to record that a certain number of baskets (*dokos*) of compost have been added to a field and assume that tells one all one needs to know about fertility management. If the compost is made from pine needles and a minimum of dried goat manure, it will differ tremendously from well-rotted compost made with oak forest floor litter, ash, buffalo manure, and urine. Agronomists and soil scientists must cooperate to understand how and why compost is being used and only then enter the more serious domain of making recommendations for improvements.

Increase Quantity of Compost. Quantity of compost is another critical issue. Given the tremendous increase in demand for compost, as discussed in the preceding chapters, changes within the system will be required to ensure that compost quantity is increased. Increased production of high quality fodder will be central to this goal. Better management of fodder production systems and the livestock feed will ultimately be required. Systems of compost distribution and location of livestock stalls relative to the farmlands will have to be modified to reduce the labour associated with the increased compost production.

Maximise Returns on Compost Use. Understanding how farmers manage their compost resources may provide more insight into the overall productivity constraints of village lands. The present proportioning of compost by a farmer on his lands should provide useful information on how the farmer allots scarce resources. The higher the value of the crop being fertilized with the compost, the greater the returns of a given fertilizing unit. Rather than land itself being considered as the primary constraint to increasing production, it might be more appropriate to think of compost as the primary constraint. Instead of discussing yields in terms of tons per hectare, it might make more sense to discuss yields in terms of productivity or profitability per unit of fertilizer and/or compost required. This would be closer to the real constraints facing many hill farmers.

Reduce Labour Associated with Compost Distribution. Labour constraints are usually associated with the management of compost resources. Reducing the requirement for labour will in effect improve the allocation of compost resources. Developing higher quality compost, reducing weight and/or bulk of compost, and possibly producing compost where it will be used, by moving the livestock stalls to the field, are all changes that could be considered. With the increasing production of fodder on *bari* there will be a much stronger incentive to feed the animals on the site rather than carrying fodder between field and household and then carrying the compost produced back to the same field. In many areas of Nepal, farmers move livestock from homesteads to fields at markedly different elevations to take advantage of a crop by-product or forestry species that can be fed to livestock from a nearby source. The resulting manure or compost is then used on the nearest appropriate field with a minimum of labour expended.

Increase the Use of More Valuable Perennial Crops. Crops that can be productive and which exploit deep soil nutrients and water can give a new lease to mountain agriculture. The five major land use types - irrigated land, rainfed land, kitchen garden, grazing land, and forest land - have a potential to support a wide range of perennial crops. From a strictly ecological point of view, solutions involving perennial crops are excellent, but there are a number of constraints that must be overcome before the farmer can become enthusiastic. To ensure that the new crop provides some regular cash income for the small farmer is of primary importance.

Use Crop Varieties with Low Nutrient Requirements. Riley (1991) has strongly recommended that the great diversity of traditional varieties and landraces of major grain crops be preserved; in part to take advantage of their different soil nutrient requirements. The present extension trend to replace all local varieties with a single improved variety will have a very negative impact should chemical fertilizers become scarce. Local varieties have the ability to produce low, but stable, yields under adverse soil fertility conditions.

Encourage More Extensive Use of Mulches. Mulches have considerable potential for protecting soil surfaces from erosion, enhancing soil moisture, and reducing weeds and are already used by farmers for a number of crops under different conditions. Mulching materials and ways to incorporate them into existing farming systems should be a major focus of research agronomists, particularly where high rates of erosion are identified (such as in off-season potato production). Many of the waste weed species, if harvested at the right time, can provide a weed-free, protective mulch. Initially *Artemisia* (*tite pate*) and *Eupatorium* (*banmara*) should be considered. Other non-vegetative mulches, such as stones, wood ash, or rice husk, can be useful to ameliorate undesirable soil characteristics also.

Facilitate Production/Conversion of Nutrients to a More Useable Form

If nutrients can be made or converted into a more useable form on site, rather than imported from the outside, there are obvious advantages to remote hill farmers.

Introduce Green Manures-cum-Fodder Species into the Farming System. While there are already a great number of leguminous and non-leguminous trees, shrubs, and plants within the Nepalese agricultural system, there is potential for considerable improvement. This is particularly so on marginal agricultural plots. Subedi (1989) studied a number of green manuring plants that were being used by farmers for different purposes and provides a qualitative assessment of their value. A large number were used in the nursery establishment of rice and to a lesser extent millet. At present very little green manuring is done on *bari* anywhere in Nepal. The ideal fodder tree must grow rapidly and have high quality fodder that is available during the months of March, April, and May when all other sources of feed are absent. It must coppice well and be able to survive the rigours of survival on a terrace riser. In their work in Bahunipati, World Neighbours (1991) found that the coppice height of trees used for green manure and fodder was critical to successful adoption by farmers. If trees were too low, free-grazing goats would strip them, if they were too high, grain crop yields were suppressed by the shading.

Cultivated green manure-cum-fodder must provide either high quality livestock feed and/or an edible seed and, at the same time, not compete with other crops that are currently producing satisfactorily. In some instances, the addition of the green manure crop does not require major increases in labour. There are a number of such species in Nepal that meet these criteria, and these should be the focus of on farm research-cum-demonstration plots. Some of the ongoing work of World Neighbours (1991) with introduced and local legume species has been very promising. Sun hemp, velvet bean, jack bean, and pigeon pea have all found 'niche' within marginal rainfed terrace systems and have obvious advantages for farmers (Plate 11).

<u>Research Inoculation of Micorrhizal/Azotobacter to Improve Performance of Plant Root Systems.</u> Many plants have associations with fungi and bacteria that are of benefit to both. While work on micorrhiza and azotobacter has been carried out under experimental conditions, results are not yet conclusive. On agricultural plots, yield increases have often been insignificant but possibly all of the important parameters affecting yield were not understood. There is an increasing need to research the use of soil inoculum to assess how important it is for production.

Bring Fertilizer in from Outside the System.

If the village has something to offer to an outside market, whether an agricultural commodity or even labour, there is the opportunity of importing and paying for nutrients that originate outside the village. Chemical fertilizers have the potential to play an important role in enhancing overall soil fertility and greatly boosting the agricultural production within certain farming systems. Obviously, changes in the way fertilizer is used will be required to avoid some of the potentially serious problems that can arise.

<u>Promote Proper Use of Chemical Fertilizers</u>. It has been well demonstrated that the yields of the major grain crops can be significantly increased with judicious and timely applications of chemical fertilizer. The best response to fertilizers is elicited through the use of improved seed varieties and by paying careful attention to cultural practices, including watering and plant stand densities. Unfortunately, there is a lot of confusion in Nepal regarding the pros and cons of fertilizer use, and this confusion has begun to be reflected in misdirected government programmes.

Experimentation on fertilizer use should be focussed on maximising the marginal return to increased fertilizer use. Although nitrogen, and to a lesser extent phosphorous, responses are documented for most crops on most soils, this, in itself, is no cause for the extension of chemical fertilizer use. In many cases, farmer practices have not been used for the control, and so the results may have little significance to the small farmer. Sometimes trials compared the use of chemical fertilizer and the use of no fertilizer whatsoever, ignoring the fact that the farmer was already using between 5 and 20 tons of compost for his crops. Lack of compost use (or proper documenting of its quality) in any fertility trial makes it extremely difficult to interpret the results.

Many farmers, particularly in the Kathmandu area, have been complaining about the lack of continued response to fertilizer, and some farmers are actually reporting a reduction in yield after as short a period as five years. Urea appears to be the main fertilizer of concern to the farmer. In some cases, such as at Rampur in Chitwan, repeated nitrogen fertilizer use, without proper organic matter management, has seriously degraded the physical and chemical properties of the soils on the station. Soil acidification, exacerbated by chemical nitrogen fertilizers, appears to be a major problem in Nepal in the more accessible areas of the Central and Eastern hills. In areas of increasing soil acidity, sources of limestone will have to be found and processed for use as a regular soil amendment.

The government research thrusts for maximising yields are rarely meaningful to the Nepalese farmer. Economic justification is required concurrently with the trials to show that chemical fertilizers not only increase yields but also increase income. At present, it is obvious that subsistence farmers are not interested in using scarce cash to buy fertilizer for use on subsistence grain crops, in spite of the apparent returns on investment.

Regardless of the nature of the farm, soil organic matter management will be increasingly important to farmers using chemical fertilizer.

<u>Increase the Availability of Chemical Fertilizers</u>. The current sporadic availability of fertilizer supplies is severely hampering those farmers wishing to use chemical fertilizer on their cash crops. Until this problem is resolved, the production potential of many commercially-oriented farmers will be severely curtailed. The Government must adopt a policy that assures that farmers who want fertilizer can get it when they need it. It appears that only by putting distribution in the hands of private traders will significant

improvements be made (Crown Agents 1991). Given Nepal's present and projected financial situation, fertilizer prices must reflect true costs. Subsidies will only further cripple the economy and give an artificially low substitution value for local compost-based fertilizers. The net result could delay the development of more sustainable soil resources.

At present all chemical fertilizer is imported. Nitrogen fertilizer in the form of urea may eventually be produced in Nepal if a major source of hydropower is developed. Phosphorous poses a potentially more serious problem for the future. Even if leguminous crops and factories can supply nitrogen, phosphorous will become increasingly deficient in production systems. All phosphorous fertilizer is imported, although low grade phosphate deposits do occur in the country (Pradhananga 1986). Researchers must determine if there is any way in which local, low analysis phosphates can be used. Limestone for reducing acidity is increasingly being recognised as critical in many areas of Nepal. Local sources of limestone will have to be exploited within agricultural pocket areas, as the amounts required to treat acidic soils are too bulky to transport over long distances (Plate 12).

A Soil Fertility Management Strategy for Nepal

In previous chapters, the physical, socioeconomic, and institutional backgrounds to soil fertility management have been discussed. Specific recommendations for technical innovations have been given. However, the lack of technical solutions is rarely the major obstacle to accelerating agricultural development. A soil fertility management strategy must be based on a holistic outlook and integrate many seemingly unrelated components that directly or indirectly influence soil fertility management. These components are discussed below.

Develop a Strategy Based on Increasing the Productivity and Profitability of the Farming System

There have been major shortcomings in developing sustainable soil management programmes of both government and donor-driven projects. While maintaining soil fertility and long-term sustainability are worthwhile goals, programmes to address soil management issues must be tied intimately with soil productivity and profitability. There is nothing particularly attractive to farmers about developing long-term sustainability strategies when their primary concern is with day to day survival.

A farmer making good returns on his investment of labour or capital will be encouraged to manage the soils as required to keep productivity up. On the other hand, farmers working marginal lands and receiving little return for their labour will become discouraged and lose interest in working the land. Outsiders' attempts to "make the soil better" without a clear economic motivation for doing so are bound to yield disappointing results. Donor-driven extension is rarely sustainable. Concern over the laboratory soil sample analyses that indicate very low levels of nitrogen, phosphorous, and organic matter and low pH does not, in itself, help to formulate a strategy for soil fertility management. The key to any successful soil management strategy must be tied to increased productivity and returns on investments in labour, money, land, or fertilizing material-whichever resource is considered to be scarce by the farmer.

Many projects have fallen into the trap of enticing farmers to adopt what are considered by professionals to be appropriate soil management techniques. When the project enticement ends, whether it be through free fertilizer, food for work, or money, the farmer reverts to his pre-project activities and recreates his pre-project problems. A recent review by the Rapti Project in the Midwestern Development Region concluded that the farmer was making the right decision to ignore extension messages, provided by the line agencies, as they would not benefit by adopting them. It was not that the messages were "wrong" but that they did not match the farmers' problems. In a wide range of rural development projects in Nepal, there have been attempts to construct "improved" bench terraces on farmers' marginal lands, promote surplus horticultural production, encourage fertilizer use at highly subsidised prices, and force protection of overgrazed lands without providing alternatives. These are all examples of well-meaning but inappropriate extension activities. Any programme to improve soil fertility must understand the Nepalese farmer and his socioeconomic and physical environment.

Recognise that Market-driven Forces Are an Essential Component for Extracting the Subsistence Farmer from His Present Plight

The traditional subsistence agricultural system no longer offers the farmer sufficient returns on his labour to motivate him to adopt new innovations. However, wherever clear market indications are present, the Nepalese farmer is quick to produce for those markets and, in doing so, provide the opportunity to begin to manage his land in a more productive and profitable manner. It is only after this marketing opportunity occurs that the farmer will show enthusiasm for enhancing the fertility of his soil on a sustained basis. This market-led force appears to be the key required to motivate the farmer to put his farm in order. Knowingly or otherwise, most of the successful agricultural development projects that have occurred in Nepal were hinged on the presence of this market force (Banskota 1989).

Recognise What Are the Scarce Resources

A primary step is the identification of scarce resources. Many independent surveys of Nepalese farmers have been carried out within farm households and, with regard to the perceived limitations, farmers are surprisingly consistent. These limitations include those covered below.

Water. Invariably the major perceived limitation to increasing production is lack of water. Farmers universally recognise the possibilities of increased production by using more irrigation water, not only for the value of the water alone but also for the value of the dissolved and suspended nutrients that have made irrigated land more fertile in areas where nutrient resources are scarce. However, it is also recognised that harnessing new irrigation water sources in the settled hill regions of Nepal can be extremely expensive and beyond the ability of the unorganised small farmer. Possible improvements to existing irrigation systems include lining canals to increase water delivery and reduce slope instability, improving the efficiency of water use on site and, in some cases, using alternative, highly profitable, but less water-demanding, crops. In any of these improvements, the local user groups' intimate involvement seems crucial to the success of such programmes.

Irrigation is not the only way to increase the amount of water available to crops. Soils can be managed to increase substantially the efficiency of rain interception and soil water-holding capacity. Many of the characteristics of a fertile soil are as much related to their physical as chemical conditions. Substantial increases in productivity are possible by better management of soil water even without irrigation. This is most closely tied to organic matter management.

Land. The second scarcity most often considered by the small farmer is the land resource itself. Small hill farmers, on average, own 0.4 ha of cultivated land, with which they must support 5 people. However, large land-holders, particularly in the *Terai* and in the Dun valleys, can own huge tracts of land that are worked by tenants. Redistribution of lands from the large holders to the landless and smallholders is a major political issue and was heavily exploited by candidates in the 1991 election. However, while land resource tenures strongly affect land management, a report of this nature cannot predicate a land management strategy assuming significant changes in land reform. Agricultural planners and politicians alike are constantly referring to this land hunger that forces increasing cultivation on to marginal and grazing lands. Given the large areas of abandoned rainfed land in the remote hill areas, it must again be stressed that lack of soil fertility, rather than land scarcity itself, restricts local level production. Clearing, ploughing, and sowing seed on infertile soil is not a profitable venture.

Labour. Household surveys invariably point to severe labour shortages in agricultural production systems for both subsistence and commercial production. Cropping calendars point to periods of extreme work loads, particularly burdensome for the women who tend to work much longer hours than men. In many cases, the farmer is attracted to off-farm occupations because the returns to farm labour are so low. Techniques of increased fodder production and better compost utilisation can obviously increase soil fertility; but, it is essential that the returns to their labour justify the more intensive management.

Capital. Every farmer interviewed will discuss the lack of money as a serious constraint to production. Not only are small farmers broke, but they are also in debt and any cash they have is used to service debt. Real interest rates on loans are often as high as 60 per cent from private lenders. Loans from public institutions are not much different after one takes into account the various hidden costs. Given the risk factor, it is easy to understand why capital is a scarce commodity, particularly for investment in agriculture.

Fertilizing Material. This brings us to the fifth most commonly mentioned scarcity regarding natural resources and that is fertilizing material - compost, manure, and chemical fertilizer. Soil fertility is probably the single most important limitation to increasing productivity that farmers can actually directly modify on an individual basis. Changes in management techniques that affect the uptake, transfer, and utilisation of soil nutrients alone can make marked changes in the soil fertility of village lands.

A farmer will only adopt a soil management or conservation technique if he can see some increase in returns for the commodity that he feels is scarce. Labour saving or cash saving may be more critical than promoting productivity increases at any cost. Sustainability issues must follow or, at best, be concurrent with increasing returns on investment. A farmer will not forgo a maize crop to plant green manure on marginal uplands because he is told it is good for the soil. When yields drop to a certain level, the farmer is forced to look at alternatives for managing that land. Intercropping a green manure that is also a good fodder species may increase the maize crop yield, reduce erosion, and produce a high quality fodder. Providing this enhanced fodder resource can be connected into enhanced livestock production; this combination can provide the entry point to village development. Successful development programmes throughout Nepal have been based on this simple innovation (World Neighbours 1991).

Oddly enough, virtually all research analyses of productivity look at yields on a per unit land area basis. Some traditional farmers consider the return on seed sown to be the most meaningful measure of productivity. Land scarcity in itself is not the major constraint to production where significant areas of fallowed or abandoned fields occur. In such cases, alternative units should be used to determine productivity. Yields per unit of compost and/or fertilizer or yields per unit of labour are possibly more relevant to the farmer than yields per hectare. For instance, it may be relevant to describe yields in kilogrammes of grain per particular quantity and quality of compost. Looking at farmer practices, some of the farmers' apparently irrational behaviour may suddenly seem more rational! Recognising the scarce resource and developing trials based on those units should have a far-reaching effect on agricultural research and how it is conducted.

Develop a Strategy that Includes the Effect of Accessibility on Fertility Management

The distance from a road and/or market will strongly influence the degree to which chemical fertilizer can be used versus the need for reliance on forest and grazing land for nutrient replenishment. Clearly, different programme emphases might be required to improve fertility for remote regions of Nepal compared to areas with good road access. To a large degree, the "Green Revolution" has been concentrated on the *Terai* and in the readily accessible interior valleys of Nepal. Areas more than a few hours' walk from road heads are unable to adopt fertilizer recommendations that have been assumed to be appropriate. The planner must not only consider the cost of the movement of fertilizer in, bút, in the absence of local markets, the cost of also moving the crop out. This often sheds new light on the feasibility of chemical fertilizer. The infrastructural map, such as that developed in the Horticultural Master Plan (ADB 1991) provides a simple way of planning overall chemical fertilizer use, development strategies (Annex 3). In general, any significant movement of fertilizer beyond a one-day walk from a road is not recommended.

Develop Separate Strategies for Subsistence and Commercial Markets

Differences in commercial and subsistence demands will influence the types of crop, livestock, etc that can be considered. These differences in demand will also strongly influence fertilizing possibilities. If cash crops are not grown, long experience in Nepal shows that the farmer is reluctant to use chemical fertilizers. The recent block trials of the Fertilizer and Related Inputs Project (FRIP 1991) have reconfirmed what has been common knowledge. While tremendous increases in yield were realised, the lack of commercial outlet in the more remote block production areas left the farmer with a glut of grain that he could not sell to recoup his loan for the initial inputs. Chemical fertilizers and cash crops must be considered together, at least until agricultural household systems become more sophisticated.

Cash crop production must be market led. Without clear, well-defined markets there is no advantage to promoting crops that cannot otherwise be locally consumed. With cash crop production, the farmer has the opportunity to purchase fertilizer from the outside, and he is less dependant on the adjacent forest and grassland resources to maintain fertility. At present, commercial grain production is never far from a motorable road. Trials on timing and placement of the proper fertilizer, the crop response, and the economic significance of the response are of relevance to the commercial farmer. Timely fertilizer availability is critical to the cash crop producer. Certain cash crops, such as potatoes, ginger, and other horticultural crops, also require considerable amounts of compost, which results in competition for compost from subsistence crops. In such cases it is assumed that a portion of the cash received for the sale of the cash crops will be used for buying chemical fertilizer.

Most of the production within the hill regions is subsistence based and farmers are unwilling or unable to devote scarce cash to procurement of fertilizers. Less than 5 per cent of all fertilizer use extends beyond the immediate reach of roads and this is with subsidies that are recognised as a serious burden for the Government. The production focus in these areas and on these crops should be to increase the quantity, quality, and efficiency of use of local nutrient sources for production.

Actively Promote a "Bottom Up" Approach to Development

A wealth of experience in Nepal shows that the "bottom up" approach to development, such as that used by many NGOs, results in significant and sustainable development. The international NGOs, such as Care, Action Aid, Save the Children, United Mission to Nepal, and World Neighbours, have facilitated the farmers to make impressive production and profitability increases in otherwise seriously disadvantaged communities. User group formation and only small monetary inputs in the early stages have resulted in significant and sustainable development (Plate 13).

On the other hand, the "top down" approach that has been the primary mode of stimulating development by the Government and major donors has failed miserably in Nepal. The reasons have been made clear in a large number of reports that have examined Nepal's institutions. The Government has an important role to play in Nepal's future, and it is time to define clearly both the Government and the farmers' responsibilities. Facilitation rather than implementation should be the primary role of the Government. Entrepreneurial behaviour rather than submission should be encouraged in the farmer.

Focus on the Small Farmer

Most of the positive results of development projects have been directed towards the rich farmers. They are able to adopt new technologies much more rapidly and their adoption allows bureaucrats to meet the targets set for them. However, the client should increasingly be the small farmer, if not for compassionate reasons then because that is where most of the resource degradation is caused. Targetting the small farmer requires that the focus of research move away from irrigated rice land and high inputs of chemical fertilizer and pesticides and towards sloping rainfed land and compost. Upland, rainfed soils are the major source of production for poor Nepalese farmers. These upland areas are being seriously degraded. They do not receive development attention commensurate with their importance in solving resource-conservation problems. Better management could result in a dramatic improvement in the long-term sustainability of farming systems in the hills of Nepal. Development experiences in Nepal have shown promising opportunities for development in this area (Sharma 1992).

Build on the Indigenous Agriculture and Forestry Management System

Agricultural planners should recognise and make use of the existing techniques used by the farmer as a starting point for developing recommendation domains. While there have been recent efforts to document soil characteristics, such as laboratory analyses of nitrogen, phosphorous, potassium, and pH, the information is of little use to land managers because it can rarely be tied to the actual productivity of agricultural or forestry soils.

A better understanding of compost production, distribution, and method of incorporation into the soil is required before meaningful soil fertility programmes can be developed. Work done by the Lumle scientists in their fertility thrust is an example of the kind of research that is required to understand present soil management. Rapid Rural Appraisal (locally adopted as *Samuhik Bhraman*, literally "travelling together") is a technique that should be adopted as one of the important research tools for Nepalese agricultural scientists (Pound et al. 1992 and Chand and Thapa 1992).

Offer Proven Technologies that are Relevant to the Individual Farmer

The farming systems used in Nepal are complex. The farmer's land is heterogeneous. Individual farmer's opportunities and constraints are infinitely variable. It is highly presumptuous of agriculturalists to develop a few "packages" for everyone and assume that the small farmer will adopt them to the exclusion of his own tried and tested farming methods. Farmers have personal likes and dislikes, some are highly industrious and frugal, others are unmotivated and alcoholic. The farmer has to make his own choice on each individual technology. Extension agents can only be as successful as their message is relevant and, in most cases, the message has been irrelevant.

Think Integrated, Act with Discrete Innovations

Integrated rural development projects look perfect. On paper, in fact, they function poorly because of the problems of integrating bureaucracies that do not like to be integrated. Separated from the realities of traditional Nepalese agriculture, the work of single sector scientists has little relevance to the hill farmer. Any innovation the scientist may wish to include within a recommendation domain should be based on the work of an interdisciplinarian study team. It is important to let the farmer decide what he wants to do and let him "integrate" it within his own system. Both donors and the Government should concentrate on ensuring that relevant technology is available. The Swiss decision to focus on forest management is a positive one. Get something right and hand it over to the farmer to be worked into his own personal system.

Develop a Long-term Strategy Based on Immediate Results

Do not expect a farmer to be overly interested in any long-term fertility strategy unless it puts food on the table or money in the pocket today. Motherhood issues with global consequences will not sell ideas to the farmer. When the long-term goal is sustainable soil management, the strategy should be to introduce production technologies that are interesting to the farmer and which provide immediate results but which, at the same time, have long-term beneficial effects. Planting improved grasses at the beginning of the monsoon which can be ready for harvesting by the end of the monsoon will encourage the farmer to participate in other development ideas. While everyone knows that planting mangoes is an excellent idea, the five or six years wait before the first fruits are ready will dampen most farmer's enthusiasm.

V. Recommendations

The Government and donors interested in assisting to alleviate the serious soil fertility problems in Nepal must accept that direct intervention in technical soil fertility matters is unlikely to play a significant role in improving the overall situation. Most of the soil fertility problems recognised on the cultivated lands of Nepal are symptoms of a more serious decline in the net profitability of traditional farming systems. As populations rise, diminishing returns to agriculture make it a less attractive occupation. The following suggestions are considered to be basic requirements to reverse the dangerous trend of the increasing marginalisation of agriculture, particularly in the mountainous regions of Nepal.

Support Family Planning Programmes

More than any other single issue, the ever-increasing population is crippling the country in its attempts to advance. Any gains made by increased agricultural productivity or improved infrastructure in the past 30 years have been more than offset by the increased needs of the ever greater population (Sharma & Banskota 1992). The disequilibrium resulting in degradation of the natural resources, is a direct consequence of too many people, too few resources, and not enough flexibility in management. While there are a number of promising ways in which soil fertility and sustainability can be improved, even the total success of such programmes will mean nothing if population growth is not halted.

This said, it is also apparent that family planning follows, rather than precedes, basic improvements in household welfare. Once the basic needs of the family are met, and there is a sense of permanence in the improvements, most Nepalese families automatically actively seek to practise some form of birth control. Consequently, as in other areas of development, a definite pattern emerges in which, by choosing the appropriate entry point into village development, many seemingly unrelated aspects of development are eventually addressed. Family planning is rarely, if ever, a successful entry point to rural development but, with success in other programmes, its ultimate acceptance by the villager becomes a possibility.

Assist in Every Way to Make Markets More Accessible to Farmers

A portion of most hill farmer's income is derived from the sale of agricultural produce. Growth of commercial trade has been severely constricted by a myriad of obstacles that have hampered the farmer from taking a more active interest in cash crop production (Banskota 1989). While farmers are capable of producing a wide range of potentially suitable crops, they are unsure of preferred varieties; quality expectations; timings of planting and harvest to optimise prices, packaging, and transport requirements; advantages of bulk sales; or the role and requirements of the trader and agro-processor. Improper attention to any of these issues acts as a further constriction on the flow of produce. In fact, if the Nepalese agricultural marketing system was a heart patient, by-pass surgery would be indicated. While in many cases, Nepalese markets are in their infancy and, as such, are depressingly shallow, Indian markets are well developed and, from Nepal's perspective at least, are limitless. If a product can be grown and marketed competitively because of some comparative advantage, then radical surgery is in order to facilitate opening agriculture produce flow within the obstructed channels. The Government has a crucial role to play in this exercise. The current barriers to free trade and movement of goods could easily be removed by a Government committed to stimulating the economy. Encouragement of private enterprise, particularly for fertilizer distribution and sales, transport, storage, and agro-processing would help the farmers to improve their market scope. Market-led and producer- driven activities should be the bottom line for evaluating a programme's worth.

The Government Must Learn to Carry Out its New Role as a Facilitator

There is a deeply ingrained feeling in Nepalese culture that one's relationship to the Government or "*sarkar*" is the same as that of a son to a strongly authoritarian father. It is the duty of the son to do as instructed and the duty of the father to chart his son's course. In the case of Nepal, to create the changes required, the father will have to become less authoritarian, the son more willing to step out on his own. Neither are simply done, but there is ample evidence that Nepalese society is ready to move in that direction. Just as the Government must move towards increasing facilitation of the motivated individual or group, it must move away from its heavy-handed regulatory nature. Many of the regulations that are in place stifle initiative and create inefficient and ineffective resource management. Significant changes in legislation are currently being considered by the new Government and it is assumed that significant change is in the offing. Privatisation of fertilizer distribution, decentralisation of government responsibility and authority, and giving villagers more power are all required to promote sustained village development (Plate 14).

One area where the Government can make a major contribution to Nepalese agriculture, in general, and overall soil fertility management, in particular, is in the area of research and extension. No private agency has the resources to nurture appropriate research properly and to provide for its effective extension to the widely dispersed, highly diverse Nepalese farmers. Donors should assist the Ministry of Agriculture in creating such a new system whenever possible It is strongly recommended that a National Agroecological Zone Classification System be developed for Nepal, in order to assist in the efficient management of human and financial resources associated with agricultural research and development and the effective communication of appropriate extension materials to the farmer. A framework for such a classification system is presented in Annex 3.

Encourage Local Initiatives

A great many of Nepal's resource utilisation problems would be resolved if local resource management could be based on local decision-making initiatives. In the village, there is a tendency to divide the world into two major spheres: that which is "mine" or "ours" and is managed to the best of one's ability given local constraints and that which is the Government's and is exploited with the aim of immediate gratification with no thought to sustained management. As a simple example of how this ownership works, villagers who have designed, worked, and paid for a water system themselves will also maintain it to the best of their ability. Drinking water systems "dropped" on them through some form of aid function only until the first minor thing goes wrong, at which time they never function again. When asked why someone does not fix the system, villagers will invariably say that it is not their system, it is the Government's. The same holds true for roads, forest plantations, irrigation canals, and the results of most other centrally conceived development projects. If one is serious about fostering local development, it is certain that it can only succeed if it is based on local enthusiasm. Donors, then, should assist in implanting or nurturing that local enthusiasm, while at the same time helping the Government in their role of facilitating local requests initiated from local demands. There are a number of points that should be considered when encouraging local initiative and these are given below.

A Client-oriented Extension System

Extension materials should be developed to meet the specific needs of a wide range of diverse Nepalese hill farming systems. For a specific agroecological zone, relevant, tested technologies and varieties should be made available to the farmer for him to select which, if any, are of use to him. The farmer should feel it is his right to demand service from extension agents. In the same light, it should be the extension agent's responsibility to communicate the wishes of the farmer back up the line, so that the Government can develop more relevant programmes.

A Recognition that Women Should Be a Major Focus of Most Agricultural Development Programmes

Women in Development (WID) has come to be considered an essential part of many development programmes. Given the fact that men are increasingly leaving the farm in search of more renumerative labour, it is often the women who carry out the bulk of agricultural decision making. In many cases it would be more fitting to leave out men altogether from agriculture and forestry management groups, as women generally are much more concerned about a properly run household; including child health, sanitation, cash crop production, and livestock raising. Women are usually the initiators of farm household improvements and to focus on them would be more productive than the traditional focus on men (Bajracharya et al. 1990).

Accelerating the Process of Community Forest Handover

Local management of local forests is one of the key issues in the area of village resource management. The widespread environmental degradation found on common lands is a direct result of uncertain tenure. Soil fertility decline is partially a result of the lack of management of these public lands and the poor yield of low quality fodder from these lands. If the Government is committed to promoting better forest management, it must back that commitment by an immediate and unconditional hand over of forests to the users. Any means that the donor has to assist in this process will have a strong positive effect on local development.

Assist in the Promotion of Local Political Power, Local Tax Collection, and Local Budget Preparation

Until political power both represents and is responsible to the local community, there is little real opportunity for the kind of changes that are required. Local revenue collection is also required to promote efficient local resource management. Any encouragement the donor can provide the Central Government in these areas would be important.

A Priority Entry Point for a Soil Fertility Management Strategy

Donors and government agencies appear to get lost in the seemingly insurmountable problems associated with village level development. They often respond by trying to attack too many fronts at once and rarely succeed on any. As aid agencies have found out, tangible, sustainable development is rarely nurtured by the convoluted programme action plans that traditionally go with integrated rural development programmes.

The strategy components mentioned above form the ground work for any soil fertility management strategy. Only if these are sanctioned by the Government will the Nepalese farmer become enthusiastic about participating in entrepreneurial activities. As has been repeatedly stated, only by creating this enthusiasm is there any hope of making the kind of revolutionary change required to reverse very serious land degradation. The role of the donor is to provide consistent and generous assistance to help the by-pass patient through surgery, including pre- and post-operative care. However, all of the above-mentioned strategies and actions take time. Programme officers cannot immediately produce the results that head office requires. Agricultural development needs a "kick start" by which some relatively easy and popular innovation can be successfully promoted by local institutions and enthusiastically received by a large number of small hill farmers.

To be effective, a priority entry point must be simple, clear, and able to capture the interest and imagination of natural resource planners. More importantly, it must accurately reflect the needs and aspirations of the small farmer. As far as possible, it should adopt the major technical innovations discussed in this paper and observe the major recommendations presented. It must also lead into readily implementable work plans that can conceivably be carried out by development agencies as they exist today.

The priority entry point presented here is based on a single front line of action and proper phasing. However, the potential spinoffs that may lead to solving other development problems are significant. The use of this priority entry point has already been adopted by a number of NGOs, with impressive results.

Increase the productivity of high quality fodder, which is green during the dry season, by planting nitrogen-fixing trees on marginal *bari*, and support the development of more productive and profitable livestock management systems for selected agricultural production pockets where identified markets exist.

It is recommended that this agricultural innovation be adopted as the highest priority for implementation of any agricultural development programme in the Middle and High Mountain Regions.

Rationale for Choosing a Fodder/Livestock Entry Point

The strategy is simple, but not simplistic. As a critical first entry point, it addresses the most immediate problems facing the farmer by exploiting production where Nepal has an obvious comparative advantage. No other country in the world has such a high livestock population density per hectare of cultivated land. This entry point has been tested across the country and when all of the elements were accounted for, the programme was successful. The fact that it is developing spontaneously is the best indicator that it is indeed appropriate.

Declining soil fertility is a major factor influencing the decline in the production of rainfed lands. Compost, of which animal manure is the critical component, is in increasingly short supply and any increase in horticultural cash crop production requires even greater compost resources. More, better quality compost can only be made available if livestock are stall fed with greater amounts of higher quality fodder. The major constraint to livestock production is the lack of high protein content feed, most critical during the dry season in March, April, and May. High quality animals do not thrive in this famine period. Farmers are only interested in implementing labour-intensive feeding schedules of high quality fodder for livestock that provide a significant cash return for their labours. Local breeds of milch buffaloes, goats, and pigs are presently being used in income generation. Where feed is sufficient and farmers recognise a good market, there is tremendous opportunity to increase the genetic potential of local breeds by providing a stud service and basic veterinary care for higher quality animals. However, in most village areas, fodder resources are not sufficient and, before a livestock improvement programme can be instigated, farmers must produce much greater quantities of high value fodder for the pre-monsoon period when other fodder is not available. No concern need be given to the low quality scrub cattle that are now a part of most village systems. With alternative, high quality livestock that provide significant cash returns, farmers will manage those animals in an economically rational manner. At present, there are many under-utilised, poorly-managed rainfed croplands associated with most agricultural production pockets. Privately-owned, marginalised rainfed lands provide the primary target lands for the introduction of a range of agroecologically-suited fodder species. Local nurseries would supply appropriate fodder trees, shrubs, legumes, and grasses to the farmer. Community forest lands, while they have an even greater potential, should not be the primary focus for the planting of fodder trees, shrubs, and grasses, because in most cases the individual tenurial harvesting rights are lacking and so is the motivation to manage at the level of intensity required to provide the quality and quantity of fodder needed. However, reducing pressure on forest areas, as alternative fodder sources become available, provides a positive first step to the regeneration of Nepal's forests.

It is recognised that agriculture, livestock, and forestry, as well as the existing market-led and producer-driven forces, are all integral parts required to solve the soil fertility problems of Nepal. An interdisciplinary rather than multidisciplinary approach is required. A model after the Lumle "*Samuhik Bhraman*", or rapid rural appraisal approach, should be considered an essential element. It is not enough to collect information about each sector, but specialists must recognise the opportunities and limitations of other sectors. While non-government organisations have performed well using this type of methodology, there is considerable scope for adoption by government-sponsored research and extension agents. The Rapid Rural Appraisal Team should not develop packages but should rather present a variety of technical options to the individual farmer through his user group.

Major research and extension domains should be defined to look at (among other things) high quality indigenous and exotic fodder trees, shrubs, and grasses. Fodder quality, as it relates to animal productivity research, must be heavily stressed. There has been a tremendous amount of good research on fodder in Nepal but communication of the findings has been poor. Preliminary domains must be developed to provide a vehicle for communication from areas of research to areas of extension. This will greatly ease the burden on small NGOs and even major donor-driven projects that apparently rarely communicate with each other on their successes or failures.

Staging of Interventions

<u>Stage 1</u>. Determine those production pockets where there are comparative advantages for the production of various livestock products for an identified market. The product will vary with distance from road heads and size and sophistication of markets identified. For instance, fresh milk collection points should be no further than four hours from a chilling plant. Commercial production of milk, therefore, must be restricted to areas adjacent to road heads at reasonable distances from commercial markets. More remote areas have other options, including higher value, less perishable items like ghee. Better processing methods can make unprofitable operations profitable. A system based on that developed by the Master Plan for Horticultural (ADB 1991) using Agroecological Zones and regional infrastructure is recommended. See Annex 3.

<u>Stage 2.</u> Encourage user group formation and initiate nurseries to produce desired species of fodder for livestock of preference for which markets are readily identifiable. Training programmes should be developed and possibly run by presently existing non-government agencies or the Lumle or Pakhribas Agricultural Centres. In the initial stages focus on:

- fodder tree production on private *bari*,
- fodder grass production on private terrace risers, and
- green manure-cum-fodder production on marginal *bari* or as relay crops.

Stage 3. Encourage livestock user group formation as fodder resources increase. High value crosses of desired buffalo, goat, and pig species are to be introduced into the farming system as fodder production picks up. The user group itself is to provide collateral for purchase and maintenance of breeding stock. Systems of local rotating credit can be resurrected or initiated to assist in capital accumulation.

Stage 4. Encourage the setting up of group initiatives for the improved production and marketability of their product. Cooperatives should be set up for extension and service during production, livestock disease control, product quality control, bulking, packaging, etc.

Stage 5. The direct positive spinoffs from successful initiation of the above programme are significant. These include self-imposed stall feeding, prohibition of free-grazing animals, increase in compost resources for use on cash crops, better ground cover and, hence, less erosion of marginal lands, less pressure on forest lands, increased cash resources, and, possibly the most important, a recognised channel through which other developments can proceed.

One of the most promising features of the fodder/livestock/market intervention is that by design it focuses on the small farmer and on degraded, marginalised land; two formerly elusive targets. The small farmer is poor and his actions are resulting in most of the environmental degradation that is occurring in Nepal. Providing this farmer with a means to receive cash from on-farm employment is a key to starting the process of agricultural renewal in Nepal.

Longer Term Considerations

There are a number of mid- and long-term technical soil fertility issues that should be of concern to donors and the Government. These should be included within the mandate of Nepal's agricultural research programme.

- Soil organic matter management and the role of crop residues, green manures, composts, and chemical fertilizers for different farming systems.
- Potential for incorporation of night soil in agricultural systems and positive spinoffs in areas of sanitation and public health.
- Soil acidification and the role of chemical fertilizers and different composts in the acidification process.
- Economic liming requirements of acidic soils: sources, manufacture, and distribution.
- Enhancement of chemical fertilizer use.
- Future feasibility of Nepalese hydroelectric power for nitrogen fertilizer production.
- Use of local rock phosphate deposits.

VI. Summary

The Land

The nature of the Nepalese landscape and the characteristics of the soils have been discussed, in relation to their significance for management. While, in general, the climate and soils are conducive to moderately high levels of agriculture and forestry production, it is only through careful husbandry that soil fertility can be sustained.

The Farmer

1. Soil fertility in Nepal is maintained by good soil management practices, not by the inherent properties of the soil.

2. While indigenous farmer knowledge is rich with appropriate soil management techniques, that knowledge has only recently been considered relevant in agricultural research and extension.

3. Agricultural production systems in the hills are dependant on forest resources for the maintenance of soil fertility. The past lack of consideration of the farmer's needs in forest management has been a major obstacle for developing a more productive system. The strong emphasis of the present Government towards local forest control and management is highly desirable.

4. Present constraints to production are generally seen to be scarcity of land, capital, and labour. These, in turn, strongly influence the fourth constraint - fertilizing material - whether compost or chemical fertilizer.

5. Subsistence demands can no longer be met because of increased population pressure on a currently static agricultural system. Alternative off-farm employment is becoming increasingly attractive to Nepalese farmers, as returns to labour on the farm diminish.

6. Degradation of the soil resource is a direct result of increasingly marginalised agriculture and forestry production systems practised by small farmers. An improvement in the overall environmental condition of the country must be centred on changes within the agricultural production system.

7. Maintaining good soil fertility management practices is motivated primarily by the presence of a productive and profitable agricultural system.

The Future

1. The carrying capacity in Nepal has increased in spurts throughout history, in response to major changes in production systems. The present stagnation in agricultural production can only be broken by increasing the returns to investment of the scarce resources of the farmer, whether capital, land, or labour. Participation in commercial agricultural production appears to provide such an opportunity.

2. There are many examples of Nepalese farmers reacting decisively to increase commercial production of agricultural commodities when prices are encouraging.

3. Market-led agricultural development appears to be the key to enhancing the present agricultural system. Increased profitability will have spinoffs that include a more productive and sustainable soil base.

4. A more dynamic agricultural production system will, in turn, create a local demand for agricultural inputs and extension services to meet their production goals. A real demand for fertilizers, pesticides, etc will encourage the trader. A real demand for appropriate technology will make the extension agent's job more demanding and rewarding.

Recommendations

1. **On the household and village level,** technical, socioeconomic, cultural, and political changes will help to enhance soil productivity and the overall profitability of farming systems. These changes include the measures outlined below.

   a. Family planning services, including child and maternal health care. Sustainability of any future programme for the enhancement of agriculture and the soil resource is dependant on a stable population. Reducing child mortality is the first step to acceptance of family planning.

   b. ~~A~~ client-oriented extension system in which the needs of the farmer are the focus for agricultural development technology.

   c. Increased sophistication in the understanding of markets, variety, timing of scarcity and glut, quality, packaging, and processing. In many cases, these appear to be more important than the production itself.

   d. An education system that encourages more productive and profitable agricultural production rather than flight from the village.

   e. Competitive, private rather than monopolistic, public enterprise to provide the inputs required by the farmer.

   f. Local empowerment by user group formation for the management of common resources, particularly forest lands.

   g. Gradual reduction in the traditional role of caste and elite rule as other ethnic groups begin to assert themselves.

   h. Initiation of local political power.

   i. Initiation of the local ability to collect taxes and manage a development budget.

2. **At the national level,** real decentralisation of authority and responsibility is a prerequisite for creating a healthy development atmosphere. Facilitation, rather than control, of the entrepreneur (including the small farmer) should be the guiding force in policy-making. Many of the past regulatory functions of the Government have had a strong negative effect on private initiative and thus overall development. Areas where the Central Government should strengthen its facilitating role include:

   a. transportation,
   b. communication,
   c. education, and
   d. research agriculture and forestry and a systematic means for its dissemination.

3. **The donors' role** should increasingly be seen as that of a "broker" between the "bottom up" demands of the local farmer and the "top down" policies adopted by the Government. Direct or indirect involvement in 1 or 2 form the basis for the brokerage. Specifically, the donor should fulfill the following functions.

   a. Assist the Government of Nepal to better perform its facilitating role. Assistance in developing appropriate research and extension domains for agriculture and forestry is discussed in the report.

   b. Wherever possible encourage the Government to give up its centrally conceived, target-oriented, "top down" approach to development. Assistance in the formation and empowerment of local user groups will be a critical part of the overall development.

   c. Open up, direct, or encourage more efficient marketing of agricultural products. The initial linking of producers, traders, and markets as well as streamlining the process is crucial.

   d. Align themselves more closely with the many newly-formed NGOs throughout the country. There is no substitute for the local initiative of serious community-based interest groups. Implementation of programmes can be much more effectively carried out by local non-government organisations.

4. Based on the strategy analysis, an **entry point** for improving the overall agricultural situation is

suggested. This entry point focuses on introducing high value fodder species on marginal rainfed lands, encouraging productive livestock to use the fodder, and providing enhanced market opportunities to sell animal products. This process is of primary importance for improving soil fertility management.

5. The Government should continue to investigate:

   a. the management of soil organic matter,

   b. the squandering of night soil as a fertilizer source,

   c. the enhanced use of chemical fertilizers,

   d. the problems of soil acidification,

   e. the policies for fertilizer use in remote areas, and

   f. the development of national and local fertilizer production capabilities.

Annex 1

Factors Influencing Soil Formation in Nepal

Soil fertility research in Nepal is notable for the almost complete absence of information on soil classification, genesis, or geomorphic features as they influence the soil. In this annex, soil-forming factors are considered as they relate to important management characteristics.

Soil-forming Factors

The physical and chemical characteristics that influence a soil's inherent fertility are largely based on differences in parent material, climate, stability of the land surface, and the effect of vegetation and animals on the soil. Man has had a profound effect on the soil resource over the past 500 years. A thorough understanding of soil-forming factors influencing any landscape permits a high level of predictive value on what the soil characteristics will be and how they will affect crop production. A brief discussion of the major soil-forming factors influencing Nepalese soils is provided here.

Parent Material

A wide range of parent materials occurs in Nepal and can be divided into two broad classes: a) *In Situ* Bedrock - on which soil is developed directly over native rock - and b) Transported Material - on which soil is developed over unconsolidated material that has been transported, either by water, ice, and wind and/or gravity.

In Situ Bedrock

The major rock types in Nepal include phyllites, schists, granites, limestones, quartzite, and sandstone - all in varying degrees of metamorphism. Most soils on mountain slopes are dominated by the bedrock underneath and soil properties will reflect the characteristics of the underlying bedrock to varying degrees. Water-holding capacity, cation exchange capacity, base saturation, and overall slope stability are all strongly influenced by rock type. The major rock types and their characteristics are considered below.

1. Phyllite. Phyllites or phyllitic schists are the most common bedrock material in the more populated Middle Mountains of Nepal. This rock type tends to weather rapidly, develops into moderately sloping terrain, and the soils over them tend to be relatively stable. There are many grades of phyllite, degrees of competence, and amount of fracturing and these in turn influence the physical and, to a lesser degree, chemical properties of the soil. The weathered products of phyllite generally form a deep, loamy, occasionally stone-free, solum with moderate levels of inherent soil fertility. They are used extensively in both rainfed and irrigated agriculture. Phyllite-based soils are often mistakenly considered to be much older by soil scientists unfamiliar with the terrain. Green phyllites have the peculiarity of turning brilliant red when oxidised, which results in the many red-tinged soils that occur sporadically, but commonly, throughout the Middle Mountains of Nepal. These reddish soil spots are readily observable on the Naubise-Mugling section of the Kathmandu-Pokhara highway. If these reddish soils are used for irrigated rice production, they turn yellow over one or two monsoon seasons as the iron oxides in the soil matrix are reduced.

2. Quartzite. Quartzite and quartzitic soils are also common in Nepal, particularly in the steeper landscapes of the Middle and High Mountain Regions. The soils tend to be acidic, shallow, stony, and relatively non-fertile. They are usually associated with forest uses rather than agriculture. As quartzites are generally competent rocks, when the rock formations are thick, they create steep cliff and bench-dominated terrain. However, the majority of quartzite occurs as thin layers within other rock formations and, in such cases, it modifies the characteristics of soils developed from the mother rock.

3. Granite. Granites and granodiorites are common in well-defined masses along the southern region of the Middle Mountains, and in the the High Mountains and the High Himalayan Region. Soils developed over

these rock types tend to be shallow, stony, and acid and generally do not support agriculture. The large granite massive transected by the Dandledhura road is a classic example of acidic granitic rock that will only support forestry uses. Granites in the Mahabharat are generally deeply weathered - possibly due to the greater fracturing of the bedrock caused by past tectonic movement and the greater proportion of feldspar found in the mother rock. Bedrock around the town site of Dhankuta and the horticultural station at Daman are two examples of areas with agricultural soils developed on the deeply-weathered granites. In contrast, the granites and granodiorites of the High Mountain and Himalayan regions above the Main Central Thrust tend to be relatively unweathered, possibly because of less fracturing, lower content of weatherable mineral (mainly feldspar), and the relatively recent glaciation that has removed any unconsolidated material that had formed before that event.[11] Micronutrient deficiencies frequently occur on the deeply-weathered granites throughout the country.

4. Limestone/Dolomitic Limestone. Limestones occur sporadically throughout much of Nepal, north of the Main Boundary Fault. The soils developed over them are usually shallow, stony, and loamy textured. While the pH of these soils is initially around 6, over time they are leached and tend to become red and acidic, at least on the surface. The high base saturation of subsoil in limestone and dolomitic areas makes for growing conditions that are particularly suited to leguminous trees, such as *Acacia catechu*, below 1,000m. The natural occurrence of *Acacia* is a good indicator that the soil is not acidic and that the subsoil is actually calcareous. *Leucaena leucocephalla*, a multipurpose tree used extensively in the 70s and up until 1987 (when it was attacked by the psyllid), did not perform very well in Nepal unless it was planted on calcareous or at least non-acidic soils. This, in part, explains the patchy success foresters were experiencing with *Leucaena* in the early 1980s.

5. Interbedded Tertiary Sediments. The interbedded Tertiary Sediments of the Siwalik Range are readily recognised as being strikingly different from the other bedrock formations of Nepal. Their lack of consolidation, strong interbedded nature, and extreme hydrological properties make many of the soils developed on these rock types shallow, stony, and infertile. High rates of surface erosion, a result of the intense tropical rainstorms and the many impervious layers that stop infiltration or deep percolation, are a major feature of many areas in the Siwaliks. Severe erosion occurs here even under natural forest. Certain marls and interbedded siltstones have the added hazard of being extremely unstable and subject to landsliding and slumping. Road closures on the north south corridors from the *Terai* to all hill districts are especially plagued by mass failures here. The fact that these rocks are so variable has resulted in a tremendous range of both opportunities and constraints when working in the Siwalik area, and this needs to be considered during development efforts.

Transported Materials

Most of the agricultural soils occur on materials that have been transported, at least to some degree. The resulting unconsolidated materials can be extremely coarse, as on boulder talus slopes, such as those found north of Buddhanilkantha or fine, such as in the historic lake basins of Kathmandu Valley. In general, these deep, relatively stable parent materials have a higher fertility than found in soils developed directly over bedrock, partly because of the greater mixing of a diverse range of minerals. The following are the major transported parent materials found in Nepal.

1. Alluvium. Alluvium covers 17 per cent of the whole country and consists of unconsolidated sediments resulting from active, recent, and ancient deposition of the rivers and streams of Nepal. Virtually all of the *Terai* and much of the Dun valleys are made up of alluvium that accounts for over 90 per cent of all of the alluvium found countrywide. However, within the Middle and High Mountains, the small proportion of alluvial terraces plays a critical role in the overall food security of the area. Although the soils themselves are not especially fertile, it is the proximity to irrigation water and the ongoing dissolved and particulate additions to the soil from the irrigation water that boost overall productivity. In the village, most farmers have at least a small plot consisting of 1 or 2 ropanis (.05 ha) of alluvial land as part of their holdings.

11. These granites are more competent because of less fracturing of the parent rock, their lower content of weatherable minerals (mainly feldspar), and the recent glaciation that has removed any unconsolidated material.

Within the Mountain Regions, catastrophic alluvial events, including glacial lake outburst floods and landslide dam breeches have produced the major terrace systems (*Tars*) found along the rivers today. Relatively recent downcutting through those deposits by the rivers, creates the terrace forms as we know them today.

2. Colluvium. Colluvium refers to those parent materials that have been deposited by gravity, either rapidly - as in a landslide runout deposit - or slowly by the process of soil creep. Soils developed on colluvium tend to be stony throughout the profile without clearly defined depositional horizons. They may or may not be stable. Given the steepness of the highly dissected river systems of Nepal, it is not surprising that many soils are developed on parent materials that are at least partly colluvial in nature. On the steeper mountainous landscapes, major agricultural production pockets are developed entirely on these colluvial deposits; the surrounding terrain is too steep to support any arable agriculture. The large rice-growing area west of Naubise is a classic example of a colluvial landscape - resulting from a major landslide/debris torrent issuing from the Mahabharat Range to the south.

In many instances gravity and water work together and the resultant debris flows occur throughout all of the mountainous regions. While the initial result is one of destruction, the material laid down becomes the basis for much of the productive agriculture found in the mountainous terrain of Nepal. There is considerable speculation that the current deforestation is causing the major landslides and debris torrents; but, in the majority of cases, there is no evidence to support this.

3. Glacial. Glacial materials are those that have been deposited by glacial action. In areas above 5,000 metres, this process is still going on today. The last major glaciation occurred around 10,000 years ago and strongly influenced areas in the High Himalayan and High Mountain Physiographic Region. All major valleys above 2,000 metres issuing out of the High Himalayan Region show evidence of glaciation. A classic glacial deposit is found at Lukla where the airport that services the Khumbu region is situated. The diagnostic U-shaped valleys are not apparent below 2,500 metres because the extremely high rates of downcutting of the river systems. Where these rivers cross the 1,200 metre elevation line, the mountain masses around them are experiencing the most rapid tectonic uplift of any landscape in the world. Consequently glacial deposits are often left stranded at as high as 500 metres above the present valley floor. Evidence of glacial advance down to 800 metre elevations has been observed south of Pokhara where a tremendously active glacier issuing off the south face off the Annapurna Massive has surged. This till has been covered by the much more recent glacial outburst flood (700 years B.P.) that has totally reshaped the Pokhara Valley. The importance of glaciers in fertility analyses is that unexpected physical and chemical properties of soils occur where glacial deposition has unknowingly occurred. Strongly calcareous materials, representing rocks higher in the watershed, may occur inexplicably in areas with strongly acidic bedrock.

4. Lacustrine. Lacustrine deposits are those that are laid down in relatively quiet water, thus excluding the coarser sand and rock components. While the total area of lacustrine parent materials is very small in Nepal, they are important.

The Kathmandu Valley is the largest single lacustrine deposit in Nepal and the occurrence of the fertile soils on that lacustrine has strongly influenced the development of the country. The soils developed on lacustrines are deep, fine-textured, stable, and provide an ideal medium for plant growth. Given their low topographic position, they are relatively easy to irrigate. Without this unusual soil type, the *Newari* culture would not have developed as we know it today. The *Jyapu*, the *Newari* cultivators, have an extremely rich culture and their agricultural system is an anomaly within the Himalayas. Even the use of the *kodalo* (the short-handled cultivating implement) is perfectly designed for the deep, fine-textured, stone-free lacustrine soils of the Kathmandu Valley, Banepa, and the Tistung/Palung area. The deep cultivating action of the *kodalo* permits higher productivity than is possible in the shallower soils of the adjacent hilly areas. The fact that the plough was not used in the valley[12] was likely a recognition on the part of the *Jyapu* that shallow ploughing with oxen would not optimise the production potential of the local soils.

12. There is a legend that ploughing in the Kathmandu Valley is forbidden because it would offend Lord Pashupatinath who makes his home on the Bagmati river at Pashupati.

A serious drawback to the development of the country is that most agricultural research has been carried outwithin the Kathmandu Valley on these lacustrine soils which are strikingly different from soils in the areas targetted as extension domains for research. Consequently many of the results based on trials conducted within the valley are not relevant to the farmers of the hills.

5. Aeolian Deposits

Aeolian, or wind-deposited, materials are not common in the Himalayas and, where they occur, they are usually in association with other parent materials. The most active and significant aeolian deposition is found in association with alluvial soils in the western *Terai* and in the adjacent hills, a direct result of the strong, dry winds blowing out of the Rajasthan Desert during the pre-monsoon period. While the winds carry dust into Nepal, significant fine sands and silts are picked up from the many dry river beds in the *Terai*. As many of these materials are calcareous, it is possible that this is one mechanism that explains the significantly higher pHs common throughout western Nepal.

Climate

Climate is a critical factor in the formation and resultant characteristics of the soils of Nepal. Temperature and effective precipitation strongly affect the rates of chemical and physical reactions in the soil. The wetter and hotter the climate, the greater the weathering. The most weathered soils are found in the tropical areas, while the least weathering occurs in the arid, cold regions within the High Himalayas. Although this is a well understood factor in soil development, the extremely dynamic geomorphology of the area often masks the important role of climate on the soil. Few of the soils in the tropical areas are actually strongly weathered.

A tremendous range of climatic conditions exists within the country. This is a direct result of the high relative relief and the different effect the monsoon has both regionally (from the west to the east of the country) and locally due to varied orographic effects caused by differences in the relief and orientation of mountain ranges. These differences, in turn, strongly affect the properties of the soils of Nepal. Wymann (1991) concluded that microclimate was a major determinant influencing the soil fertility indicators (organic matter content and base saturation percentage) of the upper Jhikhu Khola. Climatic differences are central to the development of the Agroecological Zones of Nepal and are discussed at length in Annex 3.

Stability of the Landscape

In a mountainous, tectonically active landscape such as that of Nepal, with its overwhelming geomorphic events, it is not surprising that the stability of a surface strongly influences the properties of the soil found there. The major soil types are classified, indirectly at least, by the stability of the alluvium or mountain slope on which they develop (Annex 2). All other factors being equal, the more stable the surface, the more developed the soil profile. This explains why the vast majority of the tropical regions, while under a strongly weathering climatic regime, do not have old, weathered soils. In most cases, the surfaces are too young, and the return period of destructive events too frequent, to permit sufficient weathering to age the soils. Landslides, debris torrents, slumps, and flooding occur, or have occurred, in the geologically recent past on most landscapes in the Himalayas of Nepal. The oldest soils of Nepal occur on the high alluvial terraces (*Tars*) of the major river systems and on uplifted fan and delta deposits of the ancient Dun basins within the Siwaliks. These landscapes have remained undisturbed for more than 20,000 years and, consequently, the landscapes are deeply weathered. At the other end of the scale, many landscapes (including those resulting from catastrophic flooding, landslide scouring of mountain slopes, and landslide deposition in valleys) have soils that are virtually unweathered.

Flora and Fauna

Although parent material, climate, and soil strongly influence the type of vegetation that can occur on any landscape, flora and fauna themselves can have a strong effect on overall soil development. Good forest cover promotes good infiltration of rainfall, greatly reducing the rate at which a soil material would otherwise erode. Extensive tree root systems can extract nutrients and water from deep within the solum and recycle substances that would otherwise be lost to vegetation by deep leaching. Certain species, such as the *chir* pine, can colonise difficult sites but, at the same time, prevent the introduction of other species. It is well recognised that conifers, in general, and pines, in particular, can significantly reduce the pH of soils that were originally in hardwood forests. This can be a problem in places where soils are already highly acidic. Oak forests, on the other hand, tend to be much better at recycling calcium and magnesium bases than pine forests.

Insects, such as ants and termites, over the years, can selectively carry fine materials to the surface, leaving the coarser materials at depth. The older alluvial terraces (*Tars*) of Nepal owe some of their characteristics to the termites that, over thousands of years, have developed deep stone, free surface layers from what were rock-strewn wastelands. The deep red soils of the ancient Marsyangdi *Tars*, above Dumre, and the Trisuli *Tars*, northwest of Kathmandu, started out essentially the same as the shallow, calcareous boulder-strewn terraces now observed in the Pokhara Valley. The difference between them is the length of time weathering and termite and ant action have had to take effect on the once similar parent materials. Man, of course, in the past 500 years has had a tremendous effect on the soils of Nepal through terracing, irrigation, fertility management, forest clearing, fire and roads, and trails and settlement construction. This is discussed at length in the main body of the report.

Annex 2

Classification of Nepal's Soil

Once a soil has been described, the next step is to classify it so that specific information regarding the soil can be communicated locally, nationally, and internationally. Nepalese farmers have long used a traditional system of soil classification based on soil colour, texture, and water regime and, within their own village, can communicate soil management information effectively (Tamang 1991)

The Government, being primarily concerned with taxation, has developed a system of classification based on the availability of irrigation water (the longer the availability of water, the greater the cropping intensity, and so the higher the taxes).

These two classification systems have not been used extensively by soil scientists in Nepal. Indigenous systems, while very useful on a local level, have different meanings for different areas and among different ethnic groups. The soil classification for taxes provides important information on how the soil is managed, but it is of little use in predicting important soil properties that influence fertility.

The dominant international soil classification system used in Nepal is **Soil Taxonomy**. The system permits identification in the field rather than in a laboratory, it is universal in that it encompasses all of the soils found in the world, and it is easy to translate into other national and international soil classification systems. The Soil Taxonomy classification is based on diagnostic horizons and their significance to soil pedogenesis. The system has been particularly useful in assessing landscape stability - an important feature of Himalayan landscapes.

When the Land Resource Mapping Project (LRMP) carried out their country-wide soil survey, they based the soil classification on Soil Taxonomy. The following summary of the major soil types of Nepal has been based largely on the work carried out by LRMP between 1980 and 1985.

Entisols

While some topsoil development is usually apparent, subsoils are unmodified. Lack of clear soil horizons is the distinguishing feature of these soils. They occur along active river ways and on steeper, less stable slopes throughout the mountain regions. Two major groups of Entisols are common in Nepal.

Fluvents

Fluvents are Entisols that have recently been deposited by river sedimentation. They tend to show little or no pedogenetic development and often exhibit strong evidence of recent sedimentation. Textures of these soils are generally coarse sandy with considerable inclusions of gravel within most of the mountain regions. The risk of flooding precludes intensive cropping on these soils and grazing and firewood collection are the dominant uses. Where irrigation water is readily available, such as in the Kathmandu Valley, along the lower terraces of the Bagmati and its tributaries, Fluvents are occasionally cultivated - although the risk of crop damage or destruction is a constant threat during the monsoon.

Orthents

Orthents are common throughout the mountainous regions of Nepal and occur in areas where slopes have recently failed. They also describe those surfaces where older soils have been seriously eroded by surface erosion and original diagnostic horizons are absent. Generally, Orthents are found on steep slopes (over 30 degrees) or where landslide runouts have been deposited. Areas on gentle slopes can quickly be reclaimed for agriculture, while steeper slopes are rapidly reinvaded by pioneer vegetation. In general, the

Himalayan landscapes have a much higher proportion of Orthents than other mountain regions of the world. This is because of the exceptionally dynamic hill slope processes that occur in the Himalayas.

Inceptisols

Inceptisols are by far the most important soil order in Nepal. Positioned on more stable landscapes than the Entisols, both agricultural and forestry uses are common on these soils. The relative stability of these landscapes permits some leaching of the topsoil and weathering of the subsoil. Three major soil groups occur in the Inceptisol Order.

Aquepts

Aquepts are relatively stable soils that are strongly affected by a high water table - at least during the monsoon season. Subsoils are under anaerobic conditions for long periods, and this inhibits most plant growth but is conducive to rice production. Depending on the depth and variation of the water table over the year, different cropping systems are possible. Those areas of the *Terai* that still have high water tables late in the fall cannot take advantage of some of the cash-cropping opportunities. Farmers tend to grow two rice crops in these areas. Aquepts are common in the lower *Terai*, in stable, low relief areas and are commonly associated with infilled back-water channels.

Ochrepts

Ochrepts include all light-coloured Inceptisols found on the well-drained, deeper parent materials both in the mountains below 1,500m (higher on south-facing slopes) and in the *Terai*. They are the single-most common soil found in the country and are extensively used for agricultural production. *Ustochrepts* with high base saturation are most prevalent in the Far-Western and Mid-Western Development regions of Nepal, where the climate is considered to be sub-humid. *Dystrochrepts* and *Udochrepts* have a lower base saturation percentage and are more acidic. They are more commonly found in Central and Eastern Nepal, where more humid conditions create stronger leaching conditions. It is in the Dystrochrepts and Udochrepts that the problems of soil acidification are most severe. *Cryochrepts* are common at elevations above 3,500 metres, on moderately sloping lands throughout the country.

Umbrepts

Umbrepts are the dark-coloured Inceptisols that usually occur above 2,000 m. (1,500 m on northern aspects). They have low base saturation and high organic matter levels in the surface soil. If organic matter is oxidised off, their natural acidity becomes limiting to the growth of many agricultural crops. *Haplumbrepts* are Umbrepts found below 3,500 m in elevation, while *Cryumbrepts* occur above 3,500 m.

Spodosols

Spodosols are rare, but are important to pedologists as they indicate a stable but strongly leaching environment. Spodosols have a strong reddish or black subsoil in which iron and organic matter have been deposited after initial leaching from the surface soil layers. They occur on stable landscapes at elevations above 3,000 metres where conifers dominate the forest. The best developed Spodosols in the country were sampled 1 km north of the old Tengboche monastery in the Khumbu area. These were *Cryorthods*.

Mollisols

Mollisols have a thick, dark, base rich, high organic matter topsoil. Mollisols have been found sporadically in the *Sal* forests of the upper *Terai* and southern exposed grassland sites in Western Nepal at higher elevations. They are formed on calcium-rich parent materials and, through rapid base recycling and/or low leaching, have maintained their high base saturation. Vegetation removal for cultivation results in the rapid oxidation of the organic matter in the surface of these soils and they are, over time, converted to Ustochrepts.

Alfisols

Alfisols are those soils with significant pedogenetic development, with obvious translocated clay in the subsoil, and a high base saturation percentage. Alfisols are common but do not make up a large percentage of the soils. They represent the most mature landscape positions throughout the sloping lands of the mountain regions and also on older alluvium. *Rhodustalfs*, the strong red soils common on ancient alluvial terraces, are among the oldest soils found in Western Nepal. They are well known to resource managers because of their tendency to crust on the surface after tillage, have problems with phosphorous fixation, and are occasionally subject to severe gullying. The extensive gullying found in Jajarkhot on the Bheri River in the Mid-Western Development Region shows the extent to which gullying and land degradation can proceed. Strong local relief, low infiltration rates, slow permeability of subsoils due to the clay accumulation, and occurrence in areas of high intensity rainfall are the dominant characteristics that result in the gullying of these soils.

Where soils do not meet the colour criteria for *Rhodic*, soils are classed as *Haplustalfs* and *Hapludalfs*. Hapludalfs are found in the area just north of Godavari on the southern edge of the ancient lake basin that once covered Kathmandu Valley.

Ultisols

Only one Ultisol of any significance occurs in Nepal - the *Rhodudult*. Its properties are identical to those of the *Rhodudalf*, except that it has a low pH and a low base saturation. These soils are restricted to the old *Tars* in Central and Eastern Nepal, and they represent the oldest, most weathered soils found in Nepal. The Jhikhu Khola, just east of Kathmandu, is set between major terrace systems of Rhodudults. These soils are important to distinguish because soil acidification rapidly occurs through use of chemical fertilizers. There is also considerable evidence that phosphorous management will be a serious problem as cropping intensity increases.

Aridisols

These are soils that are dry for more than nine months of the year. They exhibit very little in the way of weathering and usually have free calcium carbonate and other salts at, or near, the surface. Aridisols are restricted to the rain shadow areas of the main Himalayan Massive, where precipitation is less than 300 mm. The areas north of Jomosom in the Mustang area are dominated by Aridisols. With irrigation, in special microclimatic pockets, they can be productive; although the vast majority of Aridisols are covered with extensive grazing pastures at this time. Considering the extreme variability of the landscape, and the variability of land management within that landscape, broad-scale soil maps, representing regional, district,or even *ilaka* areas, have very limited application. Given the seriousness of the fertility problems and the lack of resources, Nepalese soil scientists should be encouraged to investigate the soil fertility dynamics of indigenous farming systems and develop innovations building on the present system.

Annex 3

An Outline of an Agroecological Classification for Nepal

Agricultural research should be tied to defined production pockets on relevant production problems. Any research conducted without a clear idea of where, or for who, the research is being conducted is a misuse of scarce resources. Given the tremendous variability of the soil and climate resources, recommendation domains should be developed based on a simple open-ended Agroecological Zone Classification and Infrastructural Maps such as described here.

Recommendation domains enable information to be gathered, analysed, prioritised, and transferred in an efficient manner. Information regarding agriculture, livestock, or forestry systems gained in one production pocket will have relevance to other production pockets within the designated zone. Without a systematic classification to focus improved technologies, transfer of information is haphazard. A typology forces the development scientists to look at and describe their research and demonstration areas critically in the early stages of development planning. Information characterising the recommendation domains can be as general or as specific as desired. The more information provided on agroecological and socioeconomic features, the more specific the recommended innovation can be.

Given the tremendous diversity of landscapes and climate in Nepal, it is not surprising that agricultural workers have been slow to develop a comprehensive, yet workable system for classifying agroecological zones. For such a system to be useful it must:

- reflect as nearly as possible the biophysical constraints of importance to agricultural and forestry production in Nepal;
- be simple enough to be readily adopted by the National Planning Commission as a useful tool to focus on optimum land resource development;
- use existing classification systems to the extent possible, so as not to further burden planners, politicians, and technical staff;
- delineate clearly-defined altitudinal zonations that are significant for agricultural, horticultural, and forestry production (local variations in temperature, resulting from changes in aspect, slope and air drainage, are recognised, but not mapped); and
- assist planners in providing justification for natural resource development based on the comparative advantages of specific agricultural production pockets (Carson 1992).

Inputs Required to Develop an Agroecological Zone Map

Base Maps 1:250,000 Scale

1:250,000 base maps were used to show the boundaries of development regions, major rivers, towns, roads, trails, and airports.

Land Systems' Maps from Land Resource Mapping Project (LRMP)

1:125,000 LRMP Land System Maps were reduced to 1:250,000 and the Physiographic Region Boundaries separating the *Terai*, Siwaliks, Middle Mountain, High Mountains, and High Himalayas were transferred to the base map. Soil drainage features significant to agricultural development were extracted from land systems' maps for the *Terai* Physiographic Region.

Land Utilisation Maps (LRMP)

1:125,000 LRMP Land Utilisation Maps were reduced to 1:250,000 and major blocks of cultivated land in the *Terai*, Siwaliks, Middle Mountains, High Mountains, and High Himalayan Regions were delineated. These included all areas of flat or sloping land and bench terraces. Because of the problems of landscape heterogeneity and mapping scale, these cultivated pockets actually ranged from 25 to 100 per cent cultivated. It can safely be assumed that any other land included in these map units is heavily utilised for grazing, fodder, and firewood collection. These delineated units describe the agricultural production pockets referred to in the text.

Defining Altitudinal Limits and Climatic Zones

Altitudinal breaks have been defined that are significant to Agricultural and Forestry Production. These breaks help identify and explain differences in crops, cropping patterns, planting dates, and need for supplemental irrigation. They were drafted on the 1:250,000 base map where agricultural production pockets occurred. The area delineated within these contours represents the major climatic zones significant to agricultural and forestry production (See Figure 3.1). It was difficult to find a consensus on the elevation of the lower and upper limits of any particular altitudinal zone. All of these parameters are controlled by gradient changes and, by definition, gradients do not lend themselves to being classified into discrete zones. Differences in slope, aspect, air drainage, characteristics of soil surface (per cent of stones on the surface) and cloud cover can permit a crop to grow and produce significantly above and below the defined limits. Different varieties have different elevation ranges under which they thrive. These factors could not be mapped on a 1:250,000 scale.

Defining Criteria in the Terai and Dun Valleys

In the *Terai* and Dun Valleys, a different set of criteria was used to define the agricultural production pockets. All of the *Terai* and Dun Valleys fall into the Tropical Climate Zone and are capable of producing a similar range of agricultural and forestry crops. There are, however, two major, mappable factors of significance to agricultural development. The first is that large areas of land well-suited to agricultural production are presently under forest which is protected by the Government. Although farmers are theoretically forbidden access to these forests, in practice many displaced hill farmers are illegally felling and clearing the forests at an accelerated rate. The other important biophysical differentiation was made based on soils. The active, recent and sub-recent alluvial plains are characterised by imperfectly to poorly-drained soils and are well suited to rice cultivation. This is in contrast to upland soils that are found on erosional landscapes and that are well drained. During the past, when clearing for agriculture, cultivators restricted themselves to the lowland, imperfectly-drained soils because their first choice was rice-producing lands. Regardless of the use, most agricultural areas depended heavily on adjacent forest areas, and, as forests, were cleared and converted into agricultural uses, forest products - timber, firewood, and fodder-became increasingly rare. Farmers often use livestock dung for cooking fuel and rely much more heavily on crop wastes for fodder. There is also a much greater interest in cultivating fast-growing timber species, *Dalbergia sissoo* and Eucalyptus, on private farm land. These are some of the important features of the *Terai* which are quite different from the situation in the hills. However, forest use dynamics are still important and the future use of the lowland and upland forest areas in the *Terai* and Dun valleys requires careful consideration by the Government.

Soils

The characteristics of Nepalese soils are described in Chapter II and in Annexes 1 and 2. Soil depth, texture, structure, stability, drainage, macro- and micronutrient fertility, infiltration rate, and permeability are all important when assessing the production potential of a given soil. However, the variability of the above soil characteristics is extreme on any mountain slope and attempting to define homogeneous units based on such soil properties is a futile exercise - particularly when developing maps on the scale of 1:250,000. For this reason, soil properties were not directly used when defining Agroecological Zones.

Within each mapped, physiographic region, however, one finds predictable patterns of bedrock types, saprolite characteristics, soil depth, and mineralogy. Consequently, map units reflect ranges of important soil properties. As an example, *Terai* soils are universally deep, but the water table is a restricting feature on the lower piedmont; soil depth is generally very shallow in the Siwaliks; slopes in the Middle Mountain of less than 30° usually have a minimum depth of 50 cm. There is a much smaller proportion of gently sloping land (and associated deep soils) as one moves from the Middle Mountains through to the High Himalayas. So, although it is not possible to map the extreme variability associated with any one mountain slope on the scale of 1:250,000, it is possible to at least predict the range of characteristics one might encounter. The Agricultural Production Pockets are delineated based on the present occurrence of cultivated land within that map unit. Although there is considerable variability within each pocket area, one

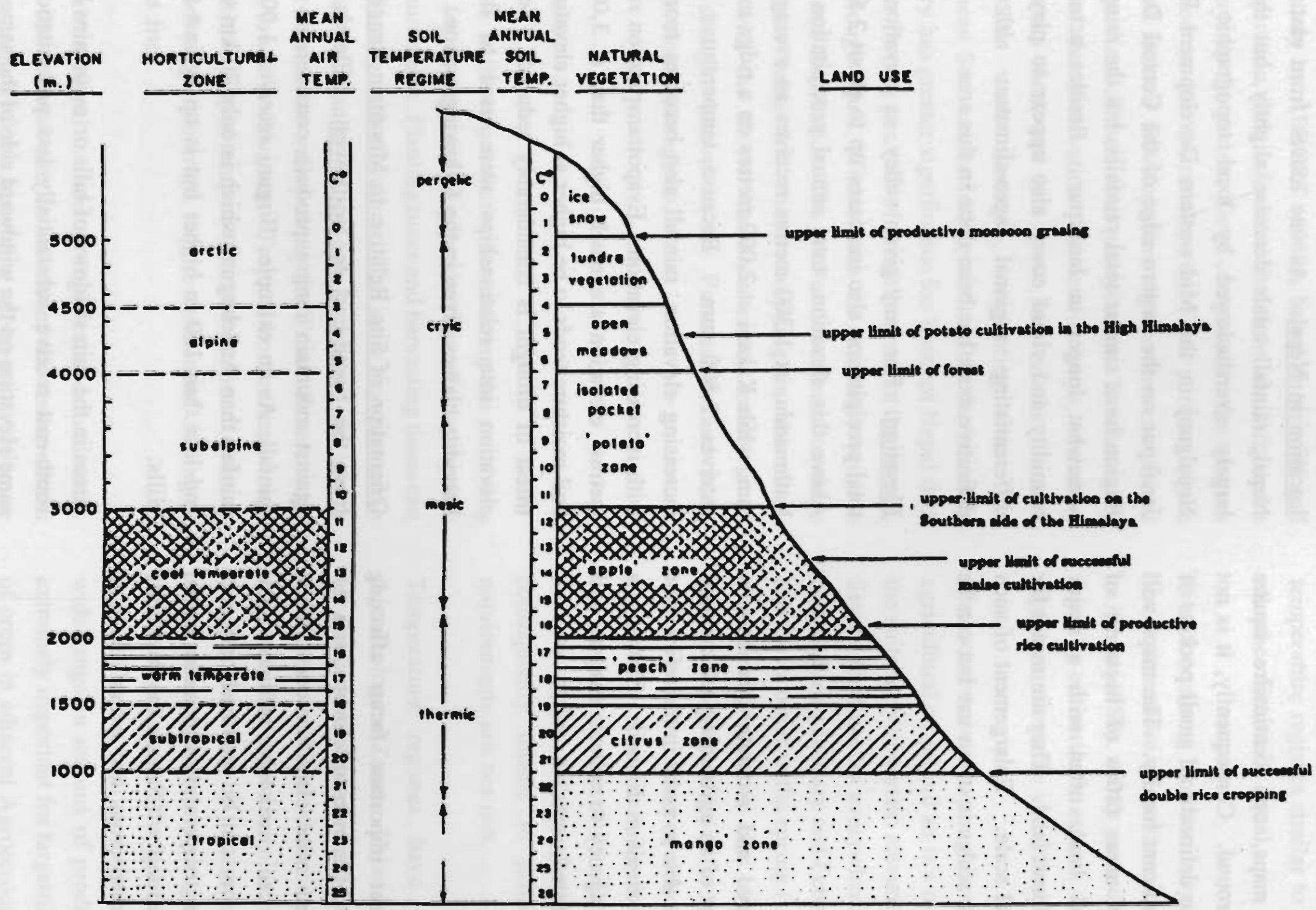


Figure 3.1: Agroecological Zones of Nepal

Source: Horticultural Master Plan, Vol. 3, 1991 can expect that, on average, at least 60 per cent of the mapped unit has soils with characteristics suitable for the production of agricultural crops.

Scale Considerations

For the 1:250,000 scale maps, one centimetre square represents 625 ha on the ground. Consequently, it is not possible or even desirable to delineate all small pockets of land use that might be significant locally. The maps will only point to large pocket areas (100s of hectares) of intensively-used agricultural land, often with a major component of heavily-used forest land. They are meant for use on a national or regional scale. Enlargement of such maps to 1:20,000 and larger scales is of no use but can be seriously misleading.

Data Base

The importance of a detailed and accurate data base is essential for the development of an agroecological zonation map. Any new data must be able to assist in the refinement of the overall research and extension domains. There is a great need for some central agency to collect, analyse, and make data available to interested users.

Climate

Climate is the single most important factor affecting agricultural production and differences in climate form the basis for the agroecological zone classification. While changes in management can markedly influence soil characteristics, climatic factors can be modified only to a small degree. Mean annual temperature and mean annual rainfall as base indicators strongly influence the suitability and performance of individual crops and overall farming systems.

Precipitation

Precipitation characteristics vary greatly from one area of Nepal to another. The total measured annual precipitation within Nepal ranges from less than 200 mm to over 5,000 mm. Local relief plays an important role in determining the amount of precipitation any area receives. Rainfall isohyet maps based on the scant number of rainfall-recording stations make extrapolation of rainfall dangerous, particularly on a regional level.

Country-wide Rainfall Distribution

Location in Nepal. As one moves from east to west in Nepal, rainfall totals decrease slightly, but this trend is largely overshadowed by local topographic variations. Nepalgunj in the Mid-western Development Region and Janakpur on the eastern edge of the Central Development Region have similar total rainfalls, but the rainy season is somewhat longer in Janakpur. Besides actual rainfall, humidity and cloud cover also appear to play a role in differentiating regional agro-climates; although little definitive work has been done in this area.

Elevation. For any given valley, as elevation increases, total precipitation also increases up to about 2,500 metres. Above this elevation, total annual precipitation decreases. Kathmandu, at 1,300 metres receives an average of 1,200 mm, while Kakani at 2,000 metres on a ridge to the north, receives 2,800 mm. Because temperatures drop with increasing elevation, rainfall also becomes more effective with increasing elevation. Evapotranspiration rates at 500 metres' elevation are much higher than at 3,000 metres. Soil moisture tends to be higher at higher elevations and the threat of drought is considerably reduced. Temperature-elevation inter-relationships were used to develop the humidity classes given in the following section.

Orientation of Site Relative to Mountain Ranges that Run from the South-East to North-west. Clouds forced up against mountain ranges produce considerable orographic rainfall. As an example, Birgunj receives 1,000 mm less rainfall than Amlekhgunj which is only 20 km to the north and less than 100 m higher but is up against the Siwalik Hills.

Areas in the rain shadows of hills or mountains lying to the south-east receive substantially less precipitation than the same elevation on the windward side of the same range. The classic example of effective blocking of rainfall is that 5,000 mm of precipitation falls on the windward side of the Annapurna Massive, whereas only 200 mm falls on the leeward side. These contrasting rainfall patterns occur to a lesser extent on all east-west trending ridges in the country.

Seasonal Rainfall Distribution. In the summer season (between May and October), 80 per cent of the annual precipitation occurs, carried by the east monsoon. While the rainy season begins in Jhapa in mid-May, it is not until two or three weeks later that Kanchanpur receives its first substantial monsoon rains. The rainy season also lasts two or three weeks longer in the east, causing significant differences in agricultural practices between Eastern and Western Nepal. A recent study by APROSC (1989), based on rainfall and evapotranspiration data, calculated that there are forty more growing days in the eastern *Terai* compared to the western *Terai*. Based on this information, the *Terai* portions of the Central and Eastern Development regions are considered humid, regardless of their total precipitation. This humidity accounts for the observation that certain crops, including coconut, areca nuts, and jute grow best on the eastern *Terai*. The west monsoon, originating from the Mediterranean Sea, carries little moisture, but the moisture it does carry has greater significance for Western Nepal than for the east. Twenty per cent of rainfall occurs in the winter, October through April. Winter rains are extremely variable in amount and distribution. The greater dependence on these erratic winter rains for winter cropping in the west, combined with the shorter monsoon rains, results in an increased drought hazard in the Far-western and Mid-western Development regions.

Temperature

Temperature is the major factor determining the suitability of an area for any type of crop production. Each crop has certain requirements. Planting times and harvesting times can vary significantly with elevation. The same rice planted in May in the Kathmandu Valley can be planted six weeks earlier just outside the valley along the Trisuli River, some 500 metres lower in elevation. Tropical horticultural crops may be sensitive to cool temperatures and intolerant to frost, whereas cool temperate crops require substantial chilling in order to set fruit.

Temperature in Nepal is most strongly related to altitude. For every 100 metres' rise in elevation, the mean annual temperature drops by 0.5°. According to Nayava (1980) over ninety per cent of the variability of mean annual temperature at recording stations in Nepal can be attributed to elevation alone.

Another factor affecting mean annual temperatures is latitude (for every 3° north of the equator, the mean annual temperature will drop by 1°C). A station at 1,000 metres' elevation in Ilam would have a mean annual temperature one degree centigrade higher than a station at 1,000 metres in Baitadi. While this would not represent a major difference when mapping the agroecological pockets on a scale of 1:250,000, it may be important when extrapolating cropping zones from the Far-western to the Eastern Region of Nepal. Apples growing in Baitadi at 1,900 metres might experience temperature regimes similar to 2,100 metres in Ilam should all other factors be equal.

Sites on strong northern aspects will have temperatures lower than those on southern aspects. In Whiteman's studies in Jumla (1980), winter ground temperatures remained below freezing on northern aspects during the day while southern aspects in the same valley had soil temperatures of +20°C.

The occurrence of spring frosts can seriously affect many agricultural crops and so is a major factor when considering the suitability of certain elevation ranges for sensitive crops. Severe frost occurs everywhere in the country above 1,500 metres during January and February. The later in the season that frosts occur in the spring (i.e., the higher the elevation), the more restrictive the successful flowering of the appropriate range of fruit tree species. Temperate fruit trees also require a certain number of chilling days for fruit production. This limits the lowest elevation at which they can be grown successfully. There are many cases of crops, such as apples, that are grown below 2,000 metres being consequently unable to produce fruit because chilling requirements are not met.

Temperature regimes have been used to define the Agroecological Zones. These zones indicate suitable pockets for production of perennial fruit trees and type and timing of agronomic crops and whole cropping systems. For vegetable crops, such as potatoes, cole crops, and tomatoes, elevation dictates when (not if) the crop can be grown successfully. As an example, potatoes are grown in the the tropical zone during the winter, in the subtropical zone in the spring and fall, and in the cool temperate zone in the summer. This wide range in seasons of production for similar crops is extremely important for targetting gaps on production cycles of crops in adjacent Agroecological Zones.

As one moves to the higher reaches of valleys within the High Himalayas, the maximum elevation at which cultivation can take place increases. For example, potatoes are an important horticultural crop that is grown successfully at 4,200 m in Solokhumbu. Such microclimates are the result of a combination of unique valley alignment, proper slope aspect, and edaphic conditions. Micro-site position becomes increasingly important as one moves to the limits of a particular horticultural crop's range.

Humidity Classes

Humidity classes have been based on the relationship between mean annual precipitation and mean annual temperature (LRMP 1986). Throughout Nepal, the higher the altitude, the cooler the temperature, and the lower the evapotranspiration. At higher altitudes, then, less rainfall is required to support lush vegetation growth and productive rainfed agriculture. In general, valley bottoms have drier climates than adjacent ridges. Where low elevation valleys project into areas of increasing relief, the valley bottoms become drier. These are described below in the following paragraphs.

Semi-arid

Semi-arid moisture regimes are deep river valleys well within the High Mountains or High Himalayan physiographic region - Thibru in the upper Karnali River valley, and Marpha in the Kali Gandaki occur in the semi-arid regions of Nepal. Juniper and cypress are often associated with these semi-arid regions. The driest areas support caragana and ponicera shrubs. Irrigation is essential for good crop production even during the summer season. Ground crops and temperate fruits do well and represent an important potential export.

Sub-humid

The tropical regions of the Far-western, Mid-western, and Western Development regions fall into the sub-humid moisture regime. The sub-humid moisture regime is also found in sheltered valley bottoms in the rain shadow of the Mahabharat *Lekh.* Here rainfall intensities are especially high.

Jumla, situated in the High Mountains at 2,300 metres, experiences only 770 mm precipitation and so is classed as sub-humid. In these High Mountain regions, rainfed cropping is carried out, but the use of bench terrace systems is less common. Rainfall intensities are much lower and contour terracing can be employed without such serious surface erosion as in other regions. Irrigation permits dry season cropping and improves the yields of monsoon crops.

Humid

Humid moisture regimes are found in the tropical areas of the Central and Eastern Development regions as well as in most of the subtropical and warm temperate zones in the Middle Mountains. These areas are generally highly populated, and two rainfed crops with reasonable yields are expected in most years. Benefits are realised by supplemental irrigation during the dry season. Certain horticultural crops suffer from excessive humidity during the monsoon season.

Per-humid

Per-humid moisture regimes occur in areas receiving significant orographic rainfall, usually in the upper slopes of the Middle Mountains and on the southern slopes of the High Mountain Physiographic Region. Per-humid moisture regimes are expected wherever moisture-laden monsoon winds come in contact with high mountain masses.

Because of poorer agroclimatic conditions (i.e., high humidity and low radiation) these areas are not heavily populated, so settlements and precipitation records are scant. Cropping, when it occurs, is often restricted to potatoes planted on outward sloping terraces. Apple production, where it has been tested in areas such as Daman and Helambu, has serious problems because of the extreme hail hazard and the fungus disease that affects both fruit quality and tree health.

Other Factors Affecting Climatic Suitability

In addition to these moisture regimes, there are also many features that cannot be mapped on a scale of 1:250,000; but which obviously must be considered when locating sites for horticultural development. Factors affecting the microclimate include those outlined in the following paragraphs.

Aspect

All other factors being equal, southern aspects receive more radiation than northern aspects. The steeper the slopes, the more pronounced is this effect. Whiteman (1980) found that maximum fall autumn temperatures on northern aspect slopes around Jumla were at least 3°C cooler than on the southern aspect slopes. This had a profound effect on evapotranspiration and soil moisture content. It is commonly noted that on east-west oriented ridges, forests occur on the wetter, cooler north-facing slopes, while the southern facing slopes, at the same elevation, are hotter and dryer and support grass or scrub vegetation. Farmers use this knowledge to place crops in full sunshine with a good southern aspect where adequate irrigation water is available. If irrigation is not available, survival may dictate planting trees on cooler, moist north-facing sites. This has been done with apples at the Baitadi Horticultural Farm. Citrus growers in the eastern hills commonly say that mandarins must be planted on slopes facing the Himalayas; probably for the same reason. The Dhankuta Agricultural Station at Paripatle is on a strong south aspect, and consequently, irrigation is essential to ensure citrus tree growth and, production. Aspect effects are extremely important within the High Mountain and High Himalayan Valleys for all agricultural production.

Air Drainage

When crops are planted near their absolute limits for production or survival, air drainage can markedly influence the success of horticultural endeavour. Air drainage is often restricted at the bottom of deep valleys, such as those that occur throughout the High Mountains or in shallow basins including Kathmandu and the Dun Valleys. Minimum temperatures tend to fall significantly below what would otherwise be found at that elevation on normal mountain slopes and so restrict certain crop production. Kathmandu at 1,200 m, experiences more frost days than Nagarkot at 2,100 metres. This explains the anomalous findings of the Kirtipur Horticultural Research Station in Kathmandu Valley. Citrus fruits do not grow well in spite of a seemingly appropriate elevation. Fog is usually associated with areas of poor air drainage. Where one finds fog lying in valley bottoms, cooler night temperatures can be expected in the winter. This fog can have a beneficial effect on the moisture regime of crops growing at that time.

Local Winds

Winds in mountainous regions are difficult to predict but can strongly influence potential horticultural production. Afternoon winds can have a pronounced cooling effect and so influence temperatures in the area. As an example, the upper Kali Gandaki valley is subjected to severe desiccating winds daily, and windbreaks of rock fences or poplar trees are required to protect sensitive fruit trees. These same constraining winds also occur in certain valleys in Jumla and Dolpa and must be considered when planning the location of fruit orchards. More generally, very strongly gusting pre-monsoon winds occasionally occur, damaging sensitive crops throughout the country.

Frequency of Hailstorms

Although the occurrence of individual hailstorms appears as a random phenomenon, there is a correlation between per-humid moisture regimes and increased frequency of hail-storm occurrence. In general one can anticipate 2 hail belts - one along the length of the Mahabharat *Lekh* and the other on the southern slopes of the Himalayas near the border between the Middle and High Mountain Physiographic Zone. This generalisation is further complicated by the fact that in some areas (i.e., south of Pokhara), the Mahabharat *Lekh* is only a low ridge of 1,000 metres. Extremely violent updrafts occur in areas where the low Middle Mountain Regions abut the main Himalayan Front. Syangja district, in particular, is noted for frequent and severe hail storms.

Rainfall Intensity

Frequent observations of field conditions after heavy rainfall support the premise that rainfall intensity is highest in the tropical horticultural zone, moderately high in the subtropical zone, moderate in the warm temperate zone, and lowest in the cool temperate zone. Farmers working unterraced slopes at 2,400 metres in Jumla do not have to worry about soil degradation by erosion nearly as much as farmers at 800 metres on similar slopes in Dailekh. Management of intercropped species in the higher rainfall intensity zones will have to ensure that adequate surface protection is given to the soil, so as to reduce potentially severe soil erosion.

Agroecological and Infrastructural Maps

Agroecological zone and infrastructural maps provide important basic planning information for the identification of priority programmes throughout the country. These maps give the planner an opportunity to look at both markets and production pockets at the same time. After national priorities are set for overall agricultural development, agroecological maps and infrastructural maps give direction in the setting up of research and extension domains.

Research and Extension Domains

All of the collected land management information relevant to a specific recommendation domain should be organised into discrete information "portfolios". These "portfolios" will then be used as basic extension materials. As the body of information grows, so will the complexity of the classification system and the recommendation domains. An important task of the Government is to ensure that the classification is appropriate for the various zones within the different districts of Nepal. For example, if agroforestry is to become a major area of interest for enhancing soil fertility, it will be important that the suitability of local and exotic agroforestry species be tied to specific agroecological zones. To the degree possible, refinements should be made to the classification system by recognising changes in cropping patterns, natural forest boundaries, and other features.

Experimental sites must be chosen based on the information that is directly applicable to other sites within the project area. Those sites with the greatest area and largest opportunities for making improvements should be the best represented in research work. The national priority for different agroecological zones should be in proportion to their area. In brief, the Tropical, Subtropical, Warm Temperate, and Cool Temperate Agroecological Zones of Nepal represent 61, 19, 12, and 8 per cent of the arable land in the country.

Tropical, Subtropical, and Warm Temperate Humid Production Pocket Areas within the Middle and High Mountain areas appear to be underrepresented, considering the total area and importance of finding alternative farming systems for traditional hill, grain farmers. There are serious doubts about the extension of research carried out at Khumaltar and Kirtipur to anywhere outside the valley because of the unique climate and soils found there.

The Agroecological Approach provides an effective alternative for streamlining the extension service for the country. It would be based on the field worker's intimate knowledge of the land and farming systems of a particular biophysical zone rather than on being a specialist in a particular commodity or group of commodities. A Junior Technical Assistant (JTA) who has spent 10 years in the Daman area will have considerable difficulty adjusting to the agroclimatic characteristics of Mustang, even though both stations specialise in apples. On the other hand, he may have a wide range of agronomic experience valuable in other cool, temperate per-humid areas of Nepal. Stressing farming systems within the distinct Agroecological Zones provides a basis for the development of useful research and extension packages.

1. Magar woman harvesting millet, Dhading. Upland cereal grain production forms a critical part of the traditional hill agricultural system in Nepal. Unfortunately, soil fertilizing materials are becoming increasingly scarce and, within the subsistence production system, there is little opportunity to make the changes that might improve the system. Cash crop production appears to be one way to improve the soil and the farming system.

2. Putting up rice straw for winter feeding of buffalo, Chitwan. From this vantage point we see a cross-section of the country: the Siwalik Dun, the Mahabharat *Lekh* in the Middle Mountains, and the Annapurna Massive in the High Himal all within 100 km. This great diversity in landscapes and climate is reflected in the diversity of peoples and farming systems. Soil fertility management throughout the whole of the country depends to some degree on the forest; the greatest dependence is in the High Mountain Region, the least in the *Terai*.

3. Puddling rice land *(Khet)* in preparation for transplanting, Makawanpur. Rice is the preferred crop in Nepal and, wherever irrigation water is available, rice is grown. The anaerobic conditions afforded by flooded irrigation create a favourable set of chemical circumstances that permit stable, albeit low, yields of rice on a sustained basis without fertilizer addition. However, in the last 30 years, tremendous increases in the intensity of management have resulted in much higher yields and 3 crops instead of 1 crop per year. Compost and fertilizer demands are now very high, resulting in an overall scarcity of compost on the adjacent rainfed lands.

4. Abandoned rainfed land *(bari)*, Nuwakot. According to local farmers, this land had previously supported good crops of maize/millet during the time of their grandfathers. Lack of fertilizing resources (compost) had forced farmers to abandon the land. The widespread occurrence of abandoned *bari* land is testimony that scarce fertilizer resources, rather than land per se, is the major constraint facing hill farmers. There are good opportunities, however, to substantially increase production, particularly of high quality fodder trees on such sites.

5. Homestead, Kavre. The most valued livestock and the compost pile are found adjacent to most farm houses in Nepal. Tied goats and a small vegetable garden are seen in the foreground. Because of the presence of kitchen wastes, easy access to compost, the possible availability of water, and the possibility of closer supervision, the home garden is often the focus for promoting innovation. Those innovations that are deemed successful by the farmer can then be moved out on to the farmer's lands, according to his own schedule and conditions. To be acceptable to the small hill farmer, horticultural development should be focused initially within the home garden area.

6. Sheep and goats grazing, Accham. Devastation such as that seen here is relatively uncommon, although such sites are often used in photo essays to elicit sympathetic donor response. In this case, the combination of proximity to the village, high livestock populations, lack of private tenure, highly erosive red soils, and low elevation where rainfall is most intense has led to the damage viewed here. Such sites have been given the label "hot spots" and selected for extra project attention. Unfortunately, it is the processes that are important, not these small areas of devastation. Under the philosophy of the triage when treating war wounded, this land should be written off, temporarily at least. There is much more rewarding work with much greater impact on local villagers on less devastated sites.

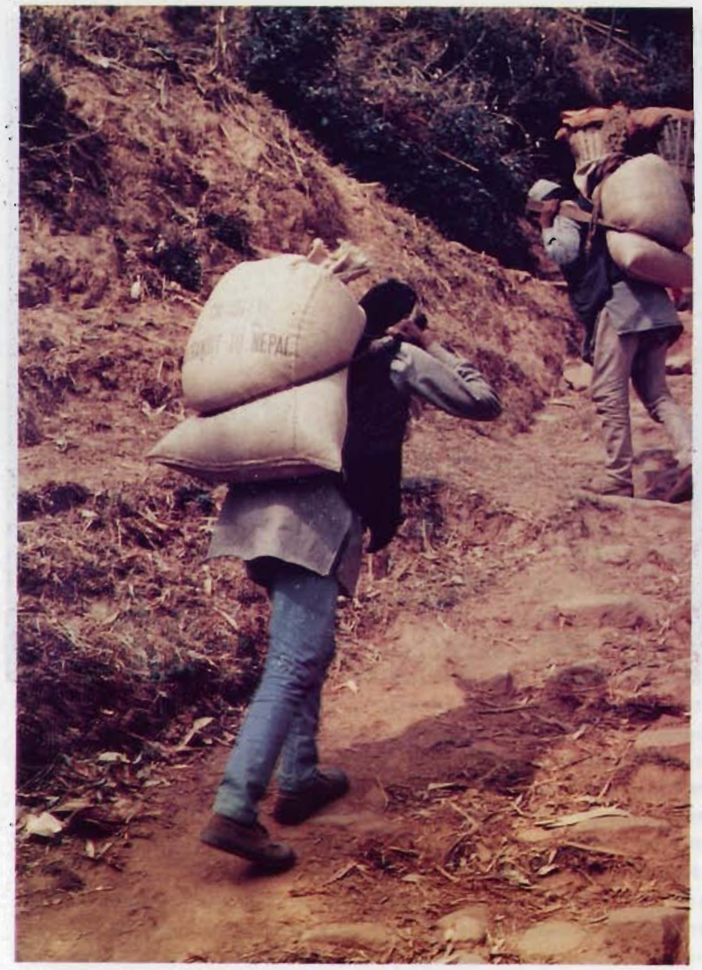
7. Sherpa girls carrying loads of forest litter back to their homes, Solokhumbu. Nepalese farmers make tremendous use of the forest. Fertility management of their agricultural land depends on the forest. Fodder (processed through livestock), litter, and ash from firewood are all used in compost to maintain the fertility of cultivated fields. Increasing pressure on forest areas for fodder and litter, without commensurate improvement in the management of the forests, is resulting in severe environmental degradation and creating severe hardship for the farmer. The net result is less compost, leading to less productive agricultural land and, finally, an increasingly strong incentive to quit the farm altogether. Because of the bureaucratic difficulties in assuring individual tenure on public or even community-managed land, privately owned *bari* appear to be a more promising target, at least initially, for enhancing high quality fodder production.

8. An extensive bench terrace system, Doti. Terrace systems are the best indicator of the health and productivity of the Nepalese farming system. Contrary to public perception, farmers are not actively clearing forest land and creating new terrace systems throughout the country. In fact, the reverse is occurring, with abandonment of large areas of terraced land. This author estimates that for every hectare of new terraced land being constructed, 1,000 hectares have been abandoned. The most common reason for abandonment is lack of fertilizing material. An anomaly occurs around the Kathmandu Valley where cash cropping opportunities have permitted the farmers to use chemical fertilizers and, thus, temporarily at least, maintain fertility. Unfortunately, most horticultural crops require more compost than grain crops, so, in the end, organic matter management is the most critical soil fertility issue for both subsistence and commercial crop production.

9. Example of severe erosion, Bardiya. Surface soil erosion is one of the most serious threats to the integrity of the marginalised agricultural and forestry lands in Nepal. Lands that have been marginalised by serious decline in soil productivity reduce the interest of the farmer in husbanding the soil in a sustainable manner. Overgrazing and the burning that must accompany grazing are the two most degrading practices on public lands. Unfortunately, the technologies are "sound" - from the point of view of the farmer, given the lack of tenure and other uncertainties that stifle any form of more productive management on these lands. It is also important for the land manager to be able to recognise the difference between man-induced, accelerated erosion and geological, natural erosion. A good rule of thumb is that, if the layman can readily observe the erosion (landslides, gulleys, debris torrents), changes in management cannot greatly improve the situation. At the same time, most of the serious, controllable erosion is going on in an unspectacular way, unobserved.

10. Landscape, Kavre. Is this a forested slope or is it an agricultural slope? While this is what planners wanted to know and is information that the Land Resource Mapping Project attempted to provide, in the end it is of no relevance to the farmer. The farmer needs the forest as much as he needs the agricultural land. The artificial separation of agriculture and forest bureaucracies has caused serious problems with integrated land management. Antagonisms between bureaucracies and, indeed, between the forester and the farmer are deep rooted and serious. Until they can be resolved in the village, rapid improvement in forest management is unlikely.

11. A farmer's experimental plot on his own *bari*, Kavre. A major thrust of World Neighbours, an international NGO, is to substantially increase the production of high quality fodder on marginalised *bari*. In this trial, velvet bean is sown after the maize and both crops are able to grow together in a sort of symbiosis. The Government, with the assistance of donors, must increasingly look for innovative solutions to the management of rainfed upland, because this is the land owned by the poorer farmers and it is these farmers who are directly or indirectly responsible for much of the environmental degradation taking place in the country. The mistake of many projects in the past was to not tie innovations in with a marketable cash crop that would motivate the farmer to adopt innovative practices. Farmers do not cherish more work or even sustainable agriculture. What they need is more money and this should be the thrust of village development programmes. No direct intervention in soil fertility can hope to succeed without a well-conceived entry point into the indigenous farming system.



12. Farmer carrying fertilizer (urea) into the village, Ramechhap. About 12% of Nepal's present grain yield is the result of chemical fertilizer additions, of which over 95% of chemical fertilizer use is within a short distance of the existing road network. Chemical fertilizers can definitely increase yields of agricultural crops, as demonstrated by many trials and the farmer's own experience. It is not so clear, however, if it is in the best interest of the farmer to invest scarce capital in agriculture versus some other off-farm venture. There is a malaise in the present subsistence-based agriculture that has prevented greater interest in producing surplus agricultural crops. The lack of clear market signals appears to be the major constraint.

13. Woman with goat, Kavre. This high-value breeding buck is owned and managed by a users' group. In a short period, impressive increases in farm income can be realised by the small farmer. Research and extension have not been looking towards the needs of the small hill farmer. The emphasis on rice and irrigation has by default excluded many of the poorer farmers who must make a living from the relatively impoverished uplands and have maize and millet for staples. However, even for these farmers, a more profitable system is required. Cash crop production must be encouraged to break the farmer away from his present downward spiral of decreasing grain yields and further decreasing soil fertility. In most situations, improved livestock, both large and small, appear to have the production qualities required to increase cash incomes without further taxing the soil base.

14. Gurung women, Lamjung. Local empowerment involves giving those who use the resource the right to manage it without interference from outside. Because of the temporary movement of men in search of jobs outside the village, women are increasingly making the decisions on how the village resources are to be managed. It is the farmers who make all the resource-utilisation decisions, whether male or female. At best, the Government can influence those decisions in a positive way by carrying out a facilitating role.

References

APROSC. "Agroecological Zones of Nepal". Draft report submitted to the National Planning Commission. Kathmandu, Nepal: APROSC, 1989.

Asian Development Bank. "Master Plan for Horticultural Development". Ministry of Agriculture. Kathmandu, Nepal: PACMAR, East Consult Ltd., 1991.

Bajracharya, D.; Banskota, M.; Cecelski, E.; Denholm, J.; and Gurung, S. *Women and the Management of Energy, Forests, and Other Resources*. Discussion Paper No. 3., Kathmandu: ICIMOD, Mountain Population and Employment Division, 1990.

Banskota, M. and Jodha, N.S. "Mountain Agricultural Development Strategies: Comparative Perspectives from the Countries of the Hindu Kush-Himalayan Countries". In *Sustainable Mountain Agriculture*, Vol 1, N.S. Jodha, M. Banskota, and T. Partap (eds). New Delhi: ICIMOD and Oxford IBH Publishing Co. Pvt. Ltd., 1992.

Banskota, M. *Hill Agriculture and the Wider Market Economy: Transformation Processes and the Experience of the Bagmati Zone in Nepal*. ICIMOD Occasional Paper No 10. Kathmandu: ICIMOD, 1989.

Bista, D. B. *Fatalism and Development: Nepal's Struggle for Modernization*. Calcutta: Orient Longman Ltd., 1991.

Bruijnzeel, L. A. and Bremmer, C.N. *Highland-Lowland Interactions in the Ganges-Brahmaputra River Basin: A Review of Published Literature*. ICIMOD Occasional Paper No. 11. Kathmandu, Nepal: ICIMOD, 1989.

Bunch, R. *Two Ears of Corn*. Oklahoma, USA: World Neighbours, 1982.

Burton, S.; Kennedy, G.; and Schreier, H. "An Analysis of Land Use Options in Chitwan, Nepal". In *Mountain Research and Development*, Vol.10, pp. 73-87, 1990.

Carson, B. *Erosion and Sedimentation Processes in the Nepalese Himalaya*. Occasional Paper No 1. Kathmandu, Nepal: ICIMOD, 1985.

Carson, B. "An Agro-ecological Zonation Approach to Agricultural Planning in Mountain Environments". In Jodha, N.S.; Banskota, M.; and Partap, T. (eds) *Sustainable Mountain Agriculture, Perspectives and Issues*. New Delhi: ICIMOD and Oxford and IBH Publishing Co. Pvt. Ltd., 1992.

Chand, S. P. and Thapa, B. "Mountain Agricultural Technology Development and Diffusion: The Pakhribas Model, Nepal". In *Sustainable Mountain Agriculture*, Jodha et al. (eds) op. cit., 1992.

Crown Agents. "Nepal Fertilizer Sector Management Study". NEP/88/042, Draft Final Report. Kathmandu, Nepal: HMG/UNDP/ADB, 1991.

Gill, G. J. "Indigenous Erosion Control Systems in the Jhikhu Khola Watershed". Winrock International, Kathmandu, Nepal. In *Workshop Proceedings, Soil Fertility and Erosion Issues in the Middle Mountains of Nepal, Jhikhu Khola Watershed*, April 22-25, 1991. Sponsored by IDRC, Kathmandu, Nepal, 1991.

Gilmore, D. A. "Trends in Forest Research and Management in the Middle Mountains of Nepal". Nepal Australia Forestry Project, Kathmandu. In *Workshop Proceedings, Soil Fertility and Erosion Issues in the Middle Mountains of Nepal, Jhikhu Khola Watershed*. Sponsored by IDRC, Kathmandu, Nepal, April 22-25, 1991.

HMG/N. "Master Plan for Irrigation Development in Nepal." Kathmandu, Nepal: Canadian Water and Energy Consultants/East Consult, 1989.

HMG/N. "Agricultural Statistics of Nepal". Unpublished data. Kathmandu: National Planning Commission, 1990.

HMG/N. "Master Plan for the Livestock Sector", unpublished.

Jodha, N. S. "Mountain Perspective and Sustainability: A Framework for Development Strategies". In *Sustainable Mountain Agriculture*, Vol I, Jodha et al. (eds) op. cit., 1992.

Jodha, N. S.; Banskota, M.; and Partap, T. "Strategies for Sustainable Mountain Agriculture: An Overview". In *Sustainable Mountain Agriculture* Vol I, Jodha et al. (eds) op. cit., 1992.

Kennedy, G; Shrestha, B; and Dunlop, C. "A Study of Farm Household Systems in the Jhikhu Khola Watershed. Kathmandu, Nepal. In *Workshop Proceedings, Soil Fertility and Erosion Issues in the Middle Mountains of Nepal, Jhikhu Khola Watershed,* Sponsored by IDRC, Kathmandu, Nepal, April 22-25, 1991.

Land Resources Mapping Project. *Land Systems, Land Utilization and Agriculture-Forestry Reports*. Ottawa, Canada: Kenting Earth Sciences Ltd., 1986.

Munch, M. 1987. Forest Degradation and Biomass Utilization in an Himalayan Foothill Village. WP-87-10. Honolulu: East West Centre, 1987.

Nayava, J. "Climates of Nepal and Their Implications for Agricultural Development". Unpublished Ph.D. Thesis. Australian National University, 1980.

Nelson, D. *A Reconnaissance Inventory of Major Ecological Land Units and Their Watershed Conditions in Nepal.* Kathmandu: Department of Soil Conservation and Watershed Management, FAO/UNDP, 1980.

Nield, R. *Land Use in Nepal: A Summary of the Land Resource Mapping Project Results* (with emphasis on forest land use). Kathmandu: Water and Energy Commission Secretariat, 1986.

Pandey, Kk. "A Simple Case of Livestock Management by the Bhardeo Community". ICIMOD, Kathmandu. In *Workshop Proceedings, Soil Fertility and Erosion Issues in the Middle Mountains of Nepal. Jhikhu Khola Watershed.* Sponsored by IDRC, Kathmandu, Nepal, April 22-25, 1991.

Pound, B.; Budathoki, K.; and Joshi, B.R. "Mountain Agricultural Technology Development and Diffusion: The Lumle Model Nepal". In *Sustainable Mountain Agriculture* Vol. II, Jodha et al. (eds) op. cit., 1992.

Pradhananga, U.B. *Present Status of Phosphorites of Nepal.* Kathmandu, Nepal: Department of Mines and Geology, 1986.

Regmi, M.C. *A Study in Nepali Economic History 1786-1846.* New Delhi: Manjusri Publishing House. 1971.

Riley, K.W. "Soil Fertility Maintenence for Crop Production in the Mid-Hills of Nepal". In *Workshop Proceedings, Soil Fertility and Erosion Issues in the Middle Mountains of Nepal, Jhikhu Khola Watershed.* Sponsored by IDRC, Kathmandu, Nepal, April 22-25, 1991.

Schreier, H.; Shah, P.B.; Kennedy, G.; Brown, S.; and Wymann, S. "Discussion of Major Issues, Research Priorities and Implementation of Research Results." In Workshop Proceedings, *Soil Fertility and Erosion Issues in the Middle Mountains of Nepal, Jhikhu Khola Watershed.* Sponsored by IDRC, Kathmandu, Nepal, April 22-25, 1991.

Schroeder, R. F. "Himalayan Subsistance Systems: Indigenous Agriculture in Rural Nepal". In *Mountain Research and Development*, Vol. 5, No 2, 1985.

Sharma, P. and Banskota, M. "Population Dynamics and Sustainable Agricultural Development in Mountain Areas". In *Sustainable Mountain Agriculture*, Vol I, Jodha et al. (eds) op. cit., 1992.

Sherchan, D.P.; Gurung, G.B.; Chand, S.P. "A Review of Current Soil Related Research Activities at Pakhribas Agricultural Centre". Kathmandu, Nepal. In *Workshop Proceedings, Soil Fertility and Erosion Issues in the Middle Mountains of Nepal, Jhikhu Khola Watershed,* Sponsored by IDRC, Kathmandu, Nepal, April 22-25, 1991.

Shrestha, S. and Katwal, B. "Farmers' Strategies in the Middle Hills of Nepal". In *Sustainable Mountain Agriculture*, Jodha et al. (eds) op. cit., 1992.

Subedi, K. D. et al. "Traditional Methods of Maintaining Soil Fertility in the Mid and High Hills of the Western Development Region", Working Paper No. 3. Pokhara: LAC, 1989.

Subedi, K. D. "The Green Manures". In *Prabidhi Sangalo*, Year 3, Vol-4, 4/91. Pokhara: LRARC, 1989.

Suwal, M. R.; Subedi, K.D.; and Gurung, G. "Soil Fertility Thrust Towards Sustainable Agriculture: Experiences of Lumle Regional Agricultural Research Centre". Pokhara, Nepal. In *Workshop Proceedings, Soil Fertility and Erosion Issues in the Middle Mountains of Nepal, Jhikhu Khola Watershed*. Sponsored by IDRC, Kathmandu, Nepal, April 22-25, 1991.

Tamang, D. "Indigenous Soil Fertility Management Systems in the Hills of Nepal". Ministry of Agriculture and Winrock International, Kathmandu. In *Workshop Proceedings, Soil Fertility and Erosion Issues in the Middle Mountains of Nepal, Jhikhu Khola Watershed.* Sponsored by IDRC, Kathmandu, Nepal, April 22-25, 1991.

World Neighbours. "Fodder Trees and Grasses". Unpublished lists and information from Tom Arens. Kathmandu: World Neighbours, 1991.

Wymann, S. Contribution to Dhulikhel Soil Fertility Workshop, 1991.

Yadav, Y. "Farming-Forestry-Livestock Linkages: A Component of Mountain Farmers' Strategies". In *Sustainable Mountain Agriculture*. Vol I, N.S. Jodha et al. (eds) op. cit., 1992.

The Author

Brian Carson has worked in Nepal as a soil scientist with Kenting Earth Sciences Ltd. and was engaged on the Land Resource Assessment Project. Subsequently he was the Project Leader for the Master Plan for Horticulture of HMG/Nepal.

Mr. Carson has a B.Sc. in Soil Science and an M.Sc. from the University of British Columbia, Canada. His M.Sc. thesis dealt with soil erosion in Timor, Indonesia, and he has worked in various developing and developed countries on projects dealing with irrigation and the survey and conservation of soils.

Founding of ICIMOD

ICIMOD is the first International Centre in the field of mountain area development. It was founded out of widespread recognition of the alarming environmental degradation of mountain habitats and the consequent increasing impoverishment of mountain communities. A coordinated and systematic effort on an international scale was deemed essential to design and implement more effective development responses based on an integrated approach to mountain development and mountain environmental management.

The establishment of the Centre is based upon an agreement between His Majesty's Government of Nepal and the United Nations Educational Scientific and Cultural Organisation (UNESCO) signed in 1981. The Centre was inaugurated by the Prime Minister of Nepal in December 1983, and began its professional activities in September 1984, with the support of its founding sponsors:

HMG Nepal, the Government of Switzerland,
the Federal Republic of Germany, and UNESCO

The Centre, located in Kathmandu, the capital of the Kingdom of Nepal, enjoys the status of an autonomous international organisation.

Participating Countries of the Hindu Kush-Himalayan Region

- Nepal
- China
- India
- Pakistan
- Bhutan
- Myanmar
- Bangladesh
- Afghanistan

INTERNATIONAL CENTRE FOR INTEGRATED MOUNTAIN DEVELOPMENT (ICIMOD)

4/80 Jawalakhel, G.P.O. Box 3226, Kathmandu, Nepal

Telephone: 525313
Facsimile: (977-1)-524509

Telex: 2439 ICIMOD NP
Cable: ICIMOD NEPAL