Components of Integrated Plant Nutrient Management for Nepal

Proceedings of a Workshop
11-17 Falgun 2056
(23-29 February 2000)

Ministry of Agriculture and Co-operatives
Department of Agriculture
Crop Development Directorate
Soil Testing and Service Section, STSS
Harihar Bhawan, Lalitpur, Nepal

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Components of Integrated Plant Nutrient Management for Nepal.
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Foreword

Nepal is an agricultural country. Livelihood of more than 80% of the people depend on agriculture. Soil fertility is a key resource for maintaining and improving agricultural production. A fertile soil can contribute greatly to increase food and cash crop production and to improve peoples' livelihoods. Poor soil management is an important cause for low agricultural production, in particular in the hill areas of Nepal.

The Department of Agriculture has recognized the need to combine all available options for better soil management into an overall concept of Integrated Plant Nutrient Systems (IPNS), sometimes also referred to as Integrated Plant Nutrient Management (IPNM) or Integrated Soil Fertility Management (ISFM). This requires the development of the IPNS concept, the training of staff in governmental and non-governmental organizations on the topic and the promotion of IPNS at the farm level. It can best be achieved in a joint effort among partners of research and extension in Nepal.

The Soil Testing and Service Section (STSS) is a focal point on behalf of the Department of Agriculture for the national planning, execution and monitoring of soil management programmes. It is also a Resource Organization to and a leading partner in the Sustainable Soil Management Programme (SSMP), which supports governmental and non-governmental organizations across the hills of Nepal in the promotion of improved soil management practices at the farm level. These proceedings form part of this joint effort between STSS and SSMP in providing information and educational material on soil management to many organizations. I am pleased to present this book and I am sure it will be a valuable source of information for further concept development and capacity building on "Integrated Plant Nutrient Systems" in Nepal.

My special thanks go to the then Agriculture Minister, Mr. Chakra Prasad Bastola, the then Joint Secretary, Mr. T.B. Shrestha, and the Joint Secretary, Mr. Suresh K. Verma, for their valuable support and suggestions at the end of the workshop and after the workshop. Thanks are also due to STSS for organizing and coordinating this workshop and all resource persons who contributed to the discussions in the workshop and to these proceedings. The financial support of the Swiss Agency for Development and Cooperation (SDC) through SSMP is especially appreciated.

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Current Fertility Status of Nepal and IPNS

S.N. Jaishy, Soil Testing and Service Section, DoA

1 Organizational setup

Soil management service in Nepal was started 1958. After the separation of Nepal Agriculture Research Council (NARC) from the Department of Agriculture (DOA) in 1992, the research mandate has been separated from the extension mandate. Previously established soil testing laboratories were from there on working for research tasks under NARC. Subsequently, for development work, five regional and one central soil testing laboratories have been established under the DOA. Currently Regional Soil Testing Laboratories (RSTLs) Jhumka, Trishuli, Khairenitar, Khajura and Dhanagadhi are providing soil management services to the farmers in their respective regions.

2 Agricultural situation

Crop production and population have increased almost at parallel during the last 25 years. Crop production increased by 79% and population by 83 %. Similarly the cultivated land area increased by 62%. The increasing of crop production is mostly due to the increment of land use intensity and expansion of land use. Almost all the marginal land has now been taken into cultivation and there is lesser chance to expand it in the future. It is realized that the soil fertility is deteriorating every year. So, improvement of soil productivity is the only way to fill the gap between the crop production and its demand.

3 Past experience of crop production

In the past Nepal was food exporter. It had also the highest yields in comparison to other South Asian countries. But now it has turned into a net importer. One of the main reasons is declining soil fertility of the cultivated land. To overcome the food crisis of the country, the improvement of soil fertility certainly plays an important role.

The main reasons for soil fertility decline are as follow:

- Acidification of soil: Mostly middle mountain and Eastern Nepal's soilz are acidic due to parent materials (sand stone, silt stone, quartzite) and use of acidifying fertilizers.
- Soil Erosion/ vulnerability: Mostly high hills, hills, upland and marginal land have high rate of soil erosion.
- Micro-nutrient deficiency: Visible of hunger signs in paddy (zinc) and cole and root crops (boron). Hidden hunger is also affecting the production of cereals, vegetable, and fruits crops.
- Siltation problems: Seti River irrigated area and Narayani irrigation sector command area is more prone to siltation.
- Non-agricultural land degradation: Degradation of forest and marginal land is wide spread.
- Crop intensification: Multi cropping in a year with high nutrient extraction.
- Mono-cropping: Limited crops in the field a for long period (e.g. paddy-wheat systems)
- Low quality fertilizer: A serious problem is faced by farmers due to introduction of low quality fertilizers in the country and due to the liberalization of fertilizer import policy.
- Deficient fertilizer use: Unbalance and inadequate use of manure and fertilizer
- Environmental pollution: Due to the uncontrolled and unbalanced use of chemical fertilizer and pesticide, in particular on high value crops (e.g. vegetable).
- Deficient use of swampy land: The management of swampy land is very poor
- Specific problems of red soil: Low pH and low phosphorus availability

4 Current soil fertility status of Nepal

Very few samples have been analyzed and compiled to know the fertility status of Nepal. Thus, we cannot say the precise soil fertility status of Nepal. However, available data provide information on the general trend

of soil fertility. The status of Organic matter (OM), Nitrogen (N), Phosphorus (P_2O_5), Potassium (K_2O), and soil reaction (pH) are presented in tables 1-8.

Table 1. General summary of the current soil fertility status of Nepal (in % of samples under different categories as explained under Table 2).

Nutrients	Low	Medium	High	Total samples analyzed
Organic matter(OM)	62	33	5	7520
Nitrogen (N)	48	41	11	9872
Available phosphorus(P_2O_5)	35.33	23.33	41.34	8942
Available potassium (K_2O)	27	33	40	9522

Table 2 .The soil analysis result is categorized as low, medium and high as indicated below

Nutrients / Characteristic	Low	Medium	High
O.M (%)	<2.5	2.5-5.0	>5
N (%)	<0.1	0.1-0.2	>0.2
P_2O_5 kg/ha	<30	31-55	>55
K_2O kg/ha	<110	111-280	>280
Soil reaction (pH)	Acidic	Neutral	Alkaline
	<6.0	6-7.5	>7.5

Table 3. Status of soil reaction in Nepa (% of samples in each rank)l

pH / rank	Acidic	Neutral	Alkaline	Total samples analyzed
Status of soil reaction	57	30	13	9959

Table 4. Region wise soil nitrogen status (% of samples in each rank)

Region / rank	Low	Medium	High	Total samples analyzed
Eastern Development Region	60	33	8	1766
Central Development Region	38	54	8	1605
Western Development Region	33	54	13	2752
Mid-western Development Region	53	29	18	2220
Far-western Development Region	66	29	5	1484

Table 5. Status of organic matter in the soil (% of samples in each rank).

Region/ rank	Low	Medium	High	Total samples analyzed
Eastern Development Region	78	18	4	977
Central Development Region	50.5	45	4.5	1105
Western Development Region	43	49	8	2600
Mid-western Development Region	72	24	4	1504
Far-western Development Region	82	17	1	1334

Table 6. Status of available phosphorus in soil (% of samples in each rank)

Region/ rank	Low	Medium	High	Total samples analyzed
Eastern Development Region	22.4	17.1	60.5	1764
Central Development Region	23.2	27.5	49.3	1384
Western Development Region	34	22	44	2180
Mid-western Development Region	49	25	26	2440
Far-western Development Region	44	26	30	1174

Table7. Status of available potassium in soil (% of samples in each rank).

Region/ rank	Low	Medium	High	Total samples analyzed
Eastern Development Region	28	41	31	1765
Central Development Region	23	34	43	1357
Western Development Region	6	33	61	2736
Mid-western Development Region	63	16	21	2323
Far-western Development Region	7	52	41	1341

Table 8. Status of soil reaction in soil (% of samples in rank)

Region/ rank	Low	Medium	High	Total samples analyzed
Eastern Development Region	68	16	16	1754
Central Development Region	75	22	3	1600
Western Development Region	65	34	1	2730
Mid-western Development Region	38	38	24	2531
Far-western Development Region	40	32	28	1344

5 Integrated Plant Nutrients System (IPNS)

Integrated Plant Nutrient System is a process of using all the possible combinations of manure (locally available) and chemical fertilizer in a judicious amount along with scientific soil and crop management that can provide the balanced dose of plant nutrients as much as the plant needs with least effect on the environment.

Nepalese farmers are using both organic as well as inorganic fertilizers but not in required amount and balanced dose. The Soil Testing and Service Section (STSS) had done studies on organic manure in Tanahun, Kaski, Parbat, Chitawan, Dhankuta, Kathmandu, Nawalparasi, Dang, Kailali, Sankhuwasabha, and Sarlahi districts. It found that most of the farmers were using 2.5-3.5 t/ha of organic manure and between 15 kg N/ha in Sankhuwasabha and 276 kg N/ha (30kg of urea per ropani) in Kathamandu. Non of the farmers used potassium fertilizer in study area.

Such variation for chemical fertilizer application is due to the availability situation, farmers purchasing capacity, transportation facility, and amount of organic manure preparation, irrigation facility and type of grower (high in potato, vegetables, low in cereals). Such type of crop management and fertilizer application practices are not satisfactory for plant nutrients as well as environment The nutrient content in 3 tones of FYM is roughly estimated to contain 12kg nitrogen, 6kg of phosphorus, and 25 kg of potassium. This amount of nutrients from organic manure is not sufficient.

There are several cropping systems in Nepal and their management practices are also differing. Maize /finger millet system, maize-wheat system, rice-wheat-maize system, require high amounts of manure and/or fertilizer due to the removal of a high dose of nutrients from the soil.

Legume based cropping systems add atmospheric nitrogen and make the soil healthy. They can be maintained with less amount of compost/fertilizer. In-situ manuring through relay green manure under maize for subsequent rice is an example for the use of legumes in cropping system. These are able to maintain the soil fertility with a low amount of manure or fertilizer.

There are several traditional practices used by the Nepalese farmers for the maintenance of the soil fertility. Use of FYM/compost, chemical fertilizer, terracing, slicing the bond and the walls of the terrace riser, leaf and in situ green manuring, bringing first spring flood water into the field, oil cake, shifting herds for in-situ manuring, use of legume as a sole crop, or as a mixed crop, use of weeds in the same field or as an animal bedding for compost, use of crop residues, crop rotation, mulching, use of forest soil, use of mobile toilet, burning of waste, collection of leaf litter, use of short fallow, animal urine as a top dressing etc are

traditional soil fertility management practices. These practices will also contribute to IPNS. Along with the traditional practices and FYM/compost a judicial use of chemical fertilizer will make an integrated plant nutrients system in Nepal.

5.1 IPNS model development

5.1.1 Objectives of model development

- Conserve fertility status of soil in a sustainable way.
- Increase availability of soil nutrients.
- Increase fertilizer use efficiency
- Reduce pollution of soil and water body
- Increase productivity and sustainability of agricultural production

5.1.2 Points to consider:

Soil properties:

a. Soil texture .
b. Soil reaction
c. Water holding capacity
d. Nutrient dynamics
e. Buffering capacity.
f. Available nutrient status

Agronomic practices:

a. Cropping system. e.g. mono cropping
b. Intensive cultivation
c. Nutrients Dynamic.
d. Input supply (High input agriculture and Low input agriculture)
e. Time and method of O.M./ fertilizer application.
f. Irrigation.

Climatic condition

a. Rainfall intensity,
b. Rainfall distribution,
c. Temperature at soil surface

Nutrients use efficiency

a. Yield potential and target yield
b. Kinetics of nutrients uptake: The lowest nutrient concentration at which plants take up nutrients is zero. It is called the threshold nutrient concentration. The threshold nutrient concentrations of different crops/var. are different. The plants with low threshold nutrient concentrations are more efficient than these with higher threshold nutrient concentrations under nutrient stress.
c- Rhizosphere effect: Plants have the ability to change the environment around their root to increase the availability of essential nutrients and avoid the excessive uptake of toxic element.

5.2 Environmental consideration.

Depending upon the availability of organic materials/wastes the following combination of organic materials with chemical fertilizer can be used for sustainable higher agricultural production:

1. FYM + chemical fertilizer
2. Compost + chemical fertilizer
3. Green manure + chemical fertilizer
4. Poultry manure + chemical fertilizer
5. Crop residue + chemical fertilizer
6. Cake + chemical fertilizer
7. Bio fertilizer + chemical fertilizer

If chemical fertilizers are not available increased amount of organic manure may be used. Urine application and green manure can also replace N-chemical fertilizers.

6 Existing activities in extension

6.1 Program and activities of STSS

The programs being conducted by STSS are:

- Supervision, monitoring, follow up of soil analysis and management activities at the regional labs.
- Green manuring and bio-fertilizer activities conducted at district level.
- Soil campaign activities.
- Study and report making on :
  - a. Use of compost at farmers' level
  - b. Micronutrient deficiency surveys
  - c. Soil survey and land evaluation programs
  - d. Fertility mapping and its use for soil services.
- Soil fertility and microbiology programs.
- Monitoring soil fertility situation in the country.
- Soil test and recommendation programs
- Soil analysis in the laboratories, based on systematic sampling techniques and recommendation of fertilizers based on test results.
- Help soil analytical work in the District Agriculture Development Offices by using soil-testing kit.
- Soil analysis for soil problem identification and recommendation for correction
- Promote soil SIBIR (campaign) and MATO SAPTAH in quantitative and qualitative basis to provide field level soil services.

6.2 Programs being launched by the Regional Soil Laboratories.

- Soil analysis and fertilizer recommendation
- Monitoring and supervision of soil fertility related activities conducted by DADOs
- Soil analysis and manure recommendation conducted by DADOs
- Study on micronutrient deficiency problems
- Preparation of soil fertility maps in co-ordination with STSS
- Conduct soil campaign in district
- Services on soil management
- One-day training to farmers in co-ordination with DADOs.
- Publication of Annual Report and Study Reports.

6.3 Activities launched by DADO:

Demonstration on:

- Manure and fertilizers
- Micro nutrient fertilizer (mostly zinc in paddy and boron in vegetable)
- Green manure
- Bacterial fertilizer
- Agricultural lime demonstration
- Composting
- Mini kit demonstration
- Technology transfer activities e.g. training on soil fertility management for officers JT/JTA and farmers
- Soil campaign
- Exhibition
- Farmer tours
- Farmers day

7 Conclusion

The declining trend in soil fertility poses a real challenge to agricultural scientists and policy maker to think over the problem. If timely measures will not be taken, the problems may aggravate with total collapse of the national economy. Moreover the increasing trend in population growth, bringing marginal land under cultivation to feed the growing population has diluted the impact of advancement in agricultural technology. It is realized that although the chemical fertilizer is indispensable to increase agricultural production, the sole application of chemical fertilizer may have negative impact on soil fertility and environment on the long term. Therefore, scientists around the world advocate for sustainable agricultural production the judicious application of all available organic resources in combination with chemical fertilizer.

IPNS is a worldwide concept. It is essential to develop a model of IPNS to popularize this program in the farmer's field. IPNS is not a new technology itself. Plenty of work has already been done on the utilization of organic manure/compost and other organic waste as an alternative way for supplying nutrients. However, the lack of a specific model for particular crops and cropping systems is the main constraint to the implementation of the IPNS concept at the field level. Therefore, to make IPNS successful in the Nepalese context, the following points should be taken into consideration:

- Continue technology generation at NARC and make results available to extension personal.
- Develop a training curriculum on IPNS (Subject included in the training curriculum).
- Develop specific IPNS model for particular cropping system/crops.
- Effective dissemination of approved technology of IPNS by ADOs and other organizations
- Create awareness among farmers for long term effect of chemical fertilizers and/or organic manure in soil fertility and environment

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Soil Survey in Agricultural Extension

S. N. Mandal, Soil Testing and Service Section, DoA

1 Introduction

The high population growth and poor performance of the agricultural sector during the last two decades has turned Nepal from being a net food exporter to a net importer in recent years. Agricultural Perspective Plan (APP) has set the target of accelerating agricultural growth by 2 percentage points, from about 3 per annum to 5 percent per annum.

Sound fertility management has been identified as an important component of the strategy for agricultural growth in the plan. Additionally soil loss is another challenge to Nepalese agriculture. Thus, agricultural extension faces great challenges.

The agriculture sector needs proper conservation of agricultural land and nearly double biological yields on existing farm land to meet food need that will also double in the next quarter century. To help meet this challenge, there is a great need for information, means and organization. Information especially for soils, its existing situation, potential for its improvement and location specific suitable methods for improvement are important to address the problems experienced by the scientists and farmers. So, the need of the "Soil Survey and Fertility Mapping Program") is realized and taken under the policy of STSS to achieve the following objectives.

2 Objectives

- To gather and organize soil information to assist in decision making, pocket selection and fertilizer recommendation.
- To avoid individual plot based soil analysis and fertilizer recommendation.
- Long term evaluation and monitoring the impact of soil fertility management.
- Mapping of an area in need of agriculture lime.
- To establish a soil database.

3 National Priority, The Agricultural Prospective Plan (APP) and Pocket Package Strategy (PPS)

From the onset of the 9th Plan, a 20 year APP has been put into practice with the following objectives:

- Accelerating growth rate through increased factor productivity.
- Transforming the subsistence agriculture into a commercial through diversification production on comparative advantage.
- Expanding opportunities for overall economic transformation by fulfilling the precondition of agricultural development.
- Alleviating poverty through accelerated growth of agriculture and generated employment opportunities.
- Identifying immediate short-term and long-term strategy for preparing periodic plan and programmes.

4 Existing operational schedule of Pocket Package Program (PPP)

The implementation of the PPP begins with the identification of pocket areas of an appropriate size for program implementation and evaluation as shown in Fig.1. Here pocket profile preparation is based on physical facilities such as road network, irrigation facilities, market facilities, electricity facilities etc, but the information about land quality is not sufficient to support the sound profile preparation. Thus baseline data regarding land quality is realized important for sound profile preparation and the responsibility is taken by STSS.

Fig.1 Steps in Pocket Package Program Implementation

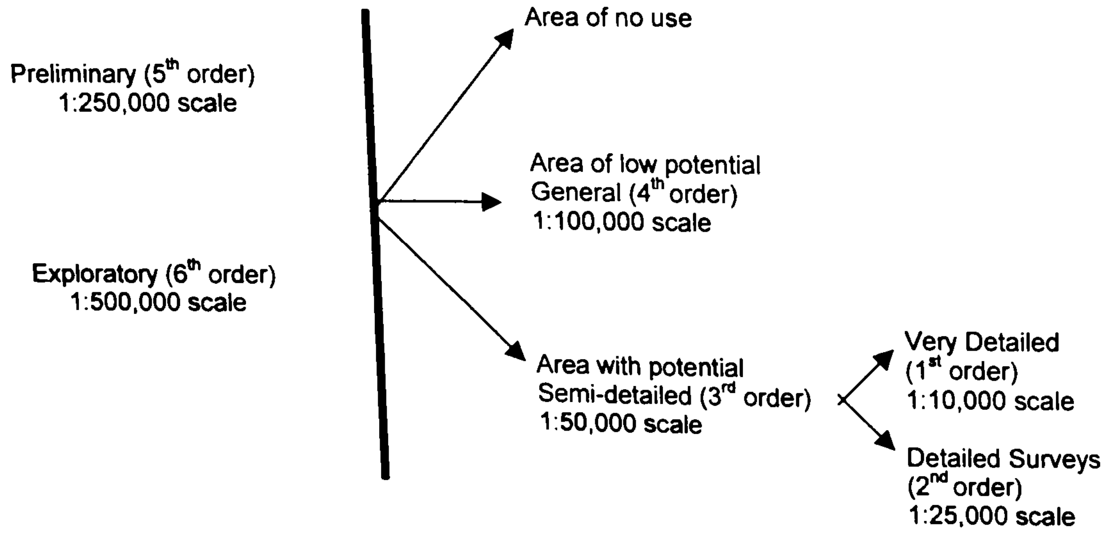
SN.	Steps	Time	Action and coordination required	Responsibility
1.	Pocket identification	Magh	DIO is to provide irrigated and potential irrigated area	ADO, SMS, ASC DIO, farmers
2.	Pocket profile preparation and baseline data collection	Poush	Formate to be developed and filled	ADO, SMS, ASC
3.	Group formation	Falgun	Call meeting of farmers and elect from group	JT/JTAs lead by
4.	Problem and opportunity identification		SMS conduct problem census and solving process	Multidisciplinary team of SMS, ASC staff, researchers
5.	Priority setting	Poush	Set priority of the problems	"
6.	Program formulation and approval	Magh	Get commitment from line agencies for inputs supply, get approval from District Assembly	ASC/ADO/SMS DIO/AIC/ADB etc.
7.	Program implementation	Sarawan/ Ashad	Prepare calender of program implementation	JT/JTAs
8.	Review/follow evaluation	Mangsir/ Chaitra	Present output or progress of pocket at review meeting	ADO/SMS/ASC Staffs

Source: Dr. H.Dahal and P.B.Shakya, 1998

5 How soil survey activities is conducted in STSS

What type, methods and techniques are required to carry out the soil survey actually depends on the information needed by the users and also availability of the basic data. The types refer to the level (scale) at which the information is to be collected, e.g. exploratory, reconnaissance, semi-detail, and detail (see Fig 2).

Figure 2. Example: Survey of increasing detail accommpany the various stages

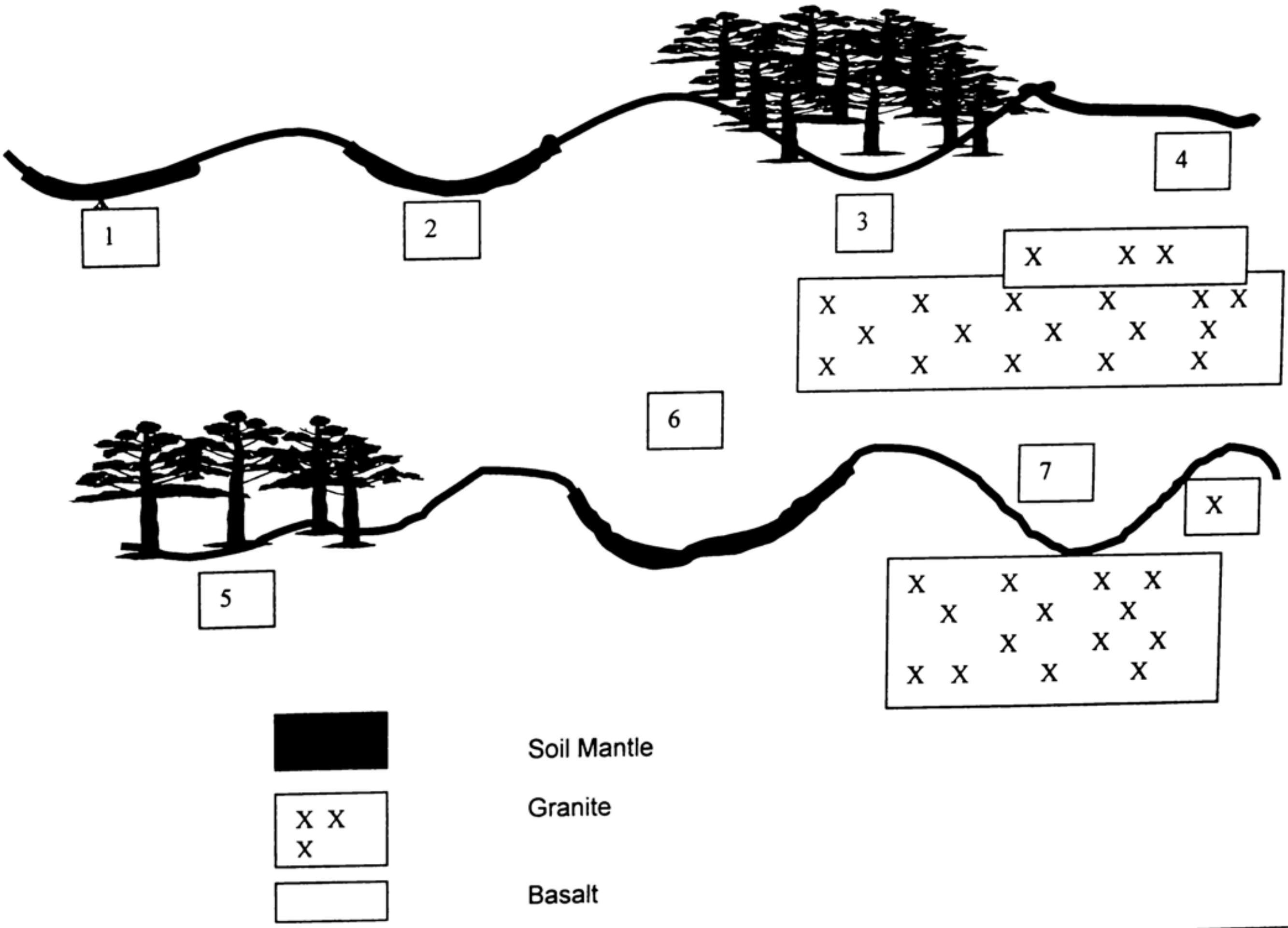


It is feasible to begin with a small scale survey (for example at 1:250,000) to select from that overall area for a more detailed survey at semi-detailed level (1:50,000).

Here for our purpose, we are conducting reconnaissance type of survey collecting sample from control grid method, photo-interpretation survey (reasoning in office and field) and 'Active' Field Survey (reasoning in the field, see example in Figure 3).

Figure 3. Example of 'Active Field Survey':

A soil surveyor studies the thickness of the A-horizon in the concave parts of the relief in the order 1-7. While doing so he formulates hypotheses on the origional of the thick A-horizons, which he encounters. Now information leads to adaptation of his model during the survey until it fits all cases encountered.



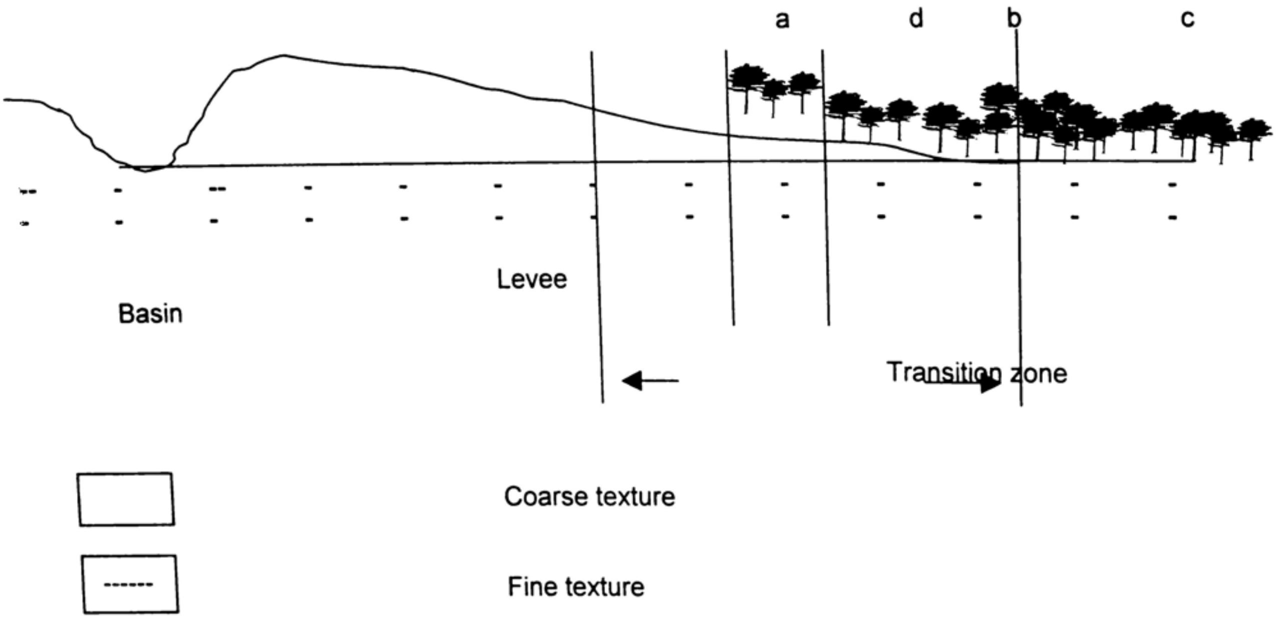
Observation	Hypothesis
1, 2	The thick horizon in the depressions is a local formation (locally formed organic matter is conserved in the soil due to poorer drainage condition).
3	The hypothesis is changed since it is found that the thick A-horizon is absent in depression in forested areas. It is assumed now that the thick A-horizons have formed due to local accumulation of organic material derived from erosion of the unprotected slopes.
4	Confirms hypothesis 3.
5	Confirms hypothesis 3.
6	Confirms hypothesis 3.
7	Seems to contradict hypothesis 3 which remains valid for the basalt landscape only. In the granite area both forested and unforested depressions have thin A-horizons. On the basis of this last hypothesis a prediction of the occurrence of thick A-horizons can be made for all concavities in the landscape on the basis of the presence/obsence of the natural vegetation on the surrounding slopes and provided that the parent material is known (granite/basalt). This prediction can either be made on the basis of airphoto-interpretation or by observation of the relief in the field.

Source: G.W.W. Elbersen, 1991.

Finally, the soil boundaries are established by the application of generic approach to soil mapping and the physiographic approach to delineate zones of homogenity (Figure 4).

Figure 4. Example of the considerations that may play a role in representing a "diffuse" soil boundary

The coarse texture materials of a levee gradually wedge out over a basin. In the rather wide transitional zone, a soil boundary must be positioned. A "normal" solution would be to place it in the middle (b). If for the levee a perticular interest exists in a crop that can not stand waterlogging, (a) would be a better position. If a levee unit has to be shown on a map of 1:500,000 the boundary has to be placed in (c) to make this cartographically possible. If a surface characteristic is present (in this case e.g. vegetation) that relates to the boundary levee/basin, the line may be placed according to this characteristic (d).



The overall process of soil fertility mapping in STSS can be summarized in an Action Sequence as follows:

Action Sequence:

Input				Output
	Pre- field	Fieldwork	Post- field	
Identification	***Preparation***	***Implementation***	***Production***	***Evaluation***

Activities done in each step:

Input Identification: Collection of APs, District Map, Land Use Maps, Land System Maps and Topo Maps.
Pre-field preparation: AP interpretation survey and estimation of representative sample sites.
Fieldwork implementation: Active field survey and collection of representative soil samples.
Post-field production: Correction of mapping units based on AP interpretation survey and active field survey.
Output evaluation: Production of final fertility maps.

6 Output

Soil survey activities conducted by STSS are not very old. They started from the FY 2053/054 with the preparation of soil reaction and soil fertility maps. In the FY 2053/054 soil reaction map of north-eastern parts of Jhapa, northen parts of Baktapur and Kanchanpur, and soil fertility maps (including pH level, Nitrogen

level, Phosphorus level and Potash level) were produced manually based on systematic soil sampling, collection and analysis of representative soil samples. District map, aerial photos of 1:50,000 scale and LRMP land system maps (1986) of 1:50,000 scale were used as source maps. Soil reaction maps of Jhapa and Bhaktapur were produced at 1:50,000 scale, whereas soil reaction and soil fertility maps of Kanchanpur were produced at 1:250,000 scale.

Similarly, in FY 2054/055, soil fertility maps (pH, N, P and K level) of Nuwakot, Bardiya and Kailali were produced manually at 1:250,000 scale. In the last FY 2055/056, soil fertility maps of Sunsari (including pH, OM, N, P and K level) were produced using GIS technology. In the FY 2056/057, STSS has targeted to produce soil fertility maps of Parbat district.

7 Purpose of soil survey:

General and secific purposes of soil surveys can be described as follows:

General purpose

1. Link soil map and its legend to the natural process which are mainly responsible for the soil pattern
2. Transfer of knowledge
3. Soil maps provides basis for interpretative class

Special purpose

1. Agricultural LUT (irrigation) (LUT= Land Use Type)
2. Engineering LUT (constr.work)
3. Earth science

General-purpose maps show the intrinsic properties of the soils, while on single purpose maps a single soil factor is emphasized. (Example: soil capability maps under soil acidity maps).

8 Users of soil fertility maps

The following users for soil maps can be identified:

1. Soil Scientists	Scientific, transfer of knowledge
2. DADO	Fertility management of district soils
3. Agroforester	Rainfed, irrigated and other land usesmarginal land for forestry.
4. Planning	Agricultural planning
5. DSCO	Soil Conservation planning in the district

9 Soil Survey Technique

Soil survey is carried out mainly in two ways;

(i) Active Field Survy (reasoning in field itself)

(ii) Photo-interpretation Survey (reasoning in office and field)

Areas with low potential are caried out at small scale surveys. The focus is on economically important land where detailed/semi-detailed surveys are carried out. If soil surveys are carried out with in the framwork of a national plan small scale surveys should procede large scale surveys in a logical order.

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Soil Survey and Its Importance in Soil Fertility Management for Agriculture in Nepal

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1. Introduction

Up to 99 percent of the food and fiber of the world comes from soils. It simply shows how important soils are for both animals and plants. In fact soils form the basis of eco-systems. Since soils are the nonrenewable natural resource base of any country and its formation is very slow requiring centuries or millennia to form even 2.5 cm of soil, special care must be taken in harnessing this important resource base.

In the past agricultural practices and other human activities with regards to the harnessing of the soils have not been sound and efficient. Consequently the world has already experienced increasing soil erosion and other forms of degradation. This certainly is the result of lack of knowledge and disregard for the ecology and rhythm of plants, animals and soils.

As elsewhere in the world Nepal is also experiencing increasing soil degradation in the form of erosion and other forms of degradation. As a result despite so many years of efforts, the agricultural productivity growth rate in Nepal has been slow. In certain cases, it has even shown a decreasing trend.

The world including Nepal seemed to have realized (though lately) the mistake made in the past with regards to the management of this important natural resource. And now with this realization, efforts are being taken to soundly and efficiently use this nonrenewable resource and maintain and sustain its productivity.

This present workshop is also an indication of the realization of the importance of sustainable management of soils in Nepal. The focus is rightly mainly on sound and efficient management of soils for increased productivity in order to meet the demands of the ever-growing population. To achieve this, it is necessary to have a sound understanding of different types of soils that occur in Nepal including their extent and distribution and their capability by taking other biotic as well as abiotic factors into account, including socioeconomic aspects.

2. Factors for soil surveys

While assessing soil properties for efficient fertility management, soil associated physiography, land systems, climatic factors and farming systems need to be taken into consideration.

2.1 Physiography

The physiography of Nepal is broadly divided into five zones.

- Tarai
- Siwaliks
- Middle Mountain
- High Mountain
- High Himalayas

2.2 Climate

Climatically, Nepal can be divided into five zones.

Temperature zone	Altitude	Mean annual temperature C°	Temperature regime
Sub-tropical	< 1000 m	20 – 24	Hyperthermic
Warm temperate	1000 – 2000 m	15 – 20	Thermic
Cool temperate	2000 – 3000 m	10 – 15	Mesic
Alpine	3000 – 4000 m	3 – 10	Cryic-frigid
Arctic	> 4000 m	< 3	Pergelic

2.3 Moisture regime

Based on moisture availability, five moisture regimes can be recognized in Nepal.

- Arid
- Semi-arid
- Sub humid
- Humid
- Per humid

2.4 Farming systems

A broad grouping of farming systems for Nepal can be done as follows:

- Upper tarai farming systems
- Main tarai farming systems
- Valley floor cultivation
- Hill slope cultivation
  - Rice based farming systems in the level terraces
  - Maize based farming systems in the sloping terraces

2.5 Thematic base maps used for conducting soil surveys

The following thematic maps may be used for supporting soil surveys:

- Topographic maps
- Aerial photographs
- Land systems maps
- Land utilization maps

Importance of GIS in Soil Fertility Management

S. N. Mandal, Soil Testing and Service Section, DoA

1 Introduction

In developing countries including Nepal, increased agricultural products and productivity are a matter of great urgency due to a rapid increase in population and need for the improvement in the standards of living. In our country, the greatest challenge for agriculture is to sustain agricultural production under adverse soil and climatic conditions.

Unfavorable agriculture environment includes low soil fertility and rain-fed conditions. Farmers can not afford to use enough fertilizers and agricultural chemicals due to their unavailability and economic limitations. Therefore, it is essential to develop agricultural technologies, which may permit a more efficient use the local organic resources or maximize useful functions of plants and micro- organisms, based on the characteristics of soils, climate and socio-economic conditions.

Recently many attempts have been made to increase food production in our country giving more emphasis on land coverage, use of agricultural chemicals and increased cropping intensity. These led to a degradation of agricultural environments and caused environmental problems such as soil degradation, expansion of agricultural land, overgrazing, unscientific use of chemicals and deforestation.

Sustainable agricultural technologies compatible with environmental preservation should therefore, be developed based on the analysis of the mechanisms of the material cycling in the agro- ecosystem. On the other hand, agriculture is practiced under various natural and social environments in our country. Therefore, it is essential to analyze the actual situations and to characterize environmental resources to develop agriculture that is compatible with environmental conservation. However, geographical information on land, its fertility and environmental resources is lacking.

Geographical Information Systems (GIS) are now expected to become an effective tool for analysis and evaluation of soil fertility and for an understanding of temporal changes in the agricultural environment.

2 Activities of STSS

The Soil Testing & Service Section (STSS) under the Department of Agriculture (DOA) is responsible for carrying out the following tasks:

- Soil and land resources survey
- Land evaluation and land suitability studies
- Soil fertility evaluation and studies
- Soil management. conservation and extension services
- Soil analysis, soil data interpretation and recommendation in the national level.

To conduct all of these activities, the use of mapping is an inevitable tool. It helps input, preservation, management and retrieval of all related data in geographical parameters.

For an effective execution of the above mentioned tasks, the climate, land use, geology, geomorphology, hydrology, forest and bio-diversity related information (either in primary or secondary form) are valuable input.

2 Use, scope and limitations of RS/GIS use

The above mentioned tasks and responsibilities of STSS clarify the use and scope of RS/GIS techniques. STSS is a new organization established with meager manpower and physical facilities. Therefore, land resource survey and mapping activities of STSS have been undertaken in a small scale.

It is based on aerial photographs and other base maps. It has not an easy access for satellite acquired information, because of the fact that Remote Sensing & GIS is a new field in itself. Scientists working here are from diverse background and do not have formal training in their respective field. They need training, further degree and job experience on Remote Sensing and GIS to use this technology.

A clear strategy of DOA and a good coordination established between related sectors (forest, meteorology, etc.) might help the organization for an easy acquisition of such data.

3 Present facilities with STSS

Hardware		Software
Pentium Computer	2	Windows 95
Local Computer	1	Word 97
Digitizer (24 x 36)	1	Exel 97
Color Printer	2	ARC/INFO one set
Dot Matrix Printer	1	ARCVIEW 3.1 one set
CD ROM Drive	2	Spatial Analyst one set
UPS	3	Image Analyst one set

4 Output

STSS has started soil survey and activities from FY 2053/054. However, because of the lack of GIS software at this time, the fertility maps of small parts of Jhapa, Baktapur, Bardiya and Kailali were produced manually based on aerial photos, district maps and field survey. From last year, when STSS was equipped with GIS facilities (Digitizer, Arc/info and ArcView programs), fertility maps (showing pH, OM, P and K level) of Kanchanpur and Sunsari districts were produced using those tools.

5 Possible collaboration

The main problem in the natural resources management sector is a 'lack of effective coordination'. This is mentioned in terms of technical exchange and exploitation. Such cooperation between various sectors would be improved if a user's friendly central data base system were established. On the other hand, a collaborative approach between the related sectors should help an easy access to remotely sensed data. In this regard, an independent body in the government of Nepal should be established that could help easy acquisition of packet of processed RS-data.

6 Vision / Mission

1. *Application of Agro-ecological zoning (AEZ) and GIS tools for land us planning, food security strategy development and land vulnerability assessment.*

Two of the most powerful and advanced development tools introduced in recent years are agro-ecological zoning and participatory land use planning. The agro-ecological zoning in this context is used as one of the first steps in natural resource management and environmental planning. Today, it became an urgent need to imagine the adaptation of agricultural techniques or environmental monitoring at any level. There are no absolute agro-ecological zonings, rather they are defined according to specific requirements and needs. The GIS, if successfully structured, allows realizing a great number of zoning options on the same territory; a number of specific zonings can be performed at a given scale.

2. *An agro-ecological zoning for whom and for what purpose?*

AEZ may be applied entirely different under different ecological and socio-economical conditions depending on land cover, land use, the national development priority, the policy setting and institutions handling resources conservation and management. In densely populated area where land use patterns are particularly diversified and land occupation by human is highly intensified, the AEZ might start from a socio-

economical point of view and zoning may be based on land use, land cover and socio-economical factors influencing production and production changes. In such a case the zoning can be useful to assess the degree of pressure on land resources i.e. land use and land cover changes due to policies and market trends.

The AEZ approach is flexible and can be applied at different scale. AEZ permits the development of various kinds of applications. The approach lends itself to the application of GIS, a function of which is enabling the rapid integration of spatial information of maps and related (non spatial) attribute information. AEZ can be regarded as a restricted set of core applications, leading to an assessment of land suitability and potential productivity of land, which are defined, designed and implemented according to actual need. The essential elements of the core applications common to most AEZ studies-comprise of:

- Land resource inventory
- Inventory of land utilization types and production systems
- Land suitability evaluation

Outputs of core applications including maps showing agro-climatic zones, problem soil areas, land suitability, potential crop areas, yield and production. Such information provides a basis for advanced applications such as land degradation assessment. The productivity results are recorded for each AEZ cell or land unit and constitute an entry point for many advanced applications, such as land vulnerability assessment.

Of course land vulnerability requires more data and information than usually available in the AEZ land resources database. Besides the data on land cover and land use, data like irrigation resource, incidence of natural hazards, pests and diseases, floods, agricultural inputs, population, markets etc. will also be needed. Developing countries like China, Bangladesh and Kenya have also built the foundation for the application of AEZ as a decision support system in several projection models.

7 GIS as AEZ tool

GIS has different display functions, including three-dimensional resources. In the past manual integration of the maps was limited essentially to place one slide to another and in the final analysis it was an arithmetical operation of addition and subtraction. Today, starting from data organization in a GIS project, two or more maps can be related through the most distinct logical and mathematical functions.

As GIS incorporates data with different features and types of representation. It is useful to differentiate at least two types of representation, the Victoria one (such as maps, for example) and the raster (such as image, for example). The existence of multiple data presentation promotes the use of the system indifferent ways. Thanks to the GIS, the same numerical and cartographic database can be differently articulated and easily processed in dynamic and permanent interactions.

GIS allows to build decision support systems to examine thoroughly an integrated analysis of development trends based on space and time dynamics and the sustainability of production patterns. The type of land use can be compared both in cartographic and digital form with the natural resource production involved.

These process structured in GIS allow a cartographic and numerical comparison between the fertility loss and replacement of fertility. Scenarios concerning land use changes and their consequences on the national/regional agricultural sustainability produced by changes in price, credit and commercial policy, are also becoming the object of new simulation methods based on the use of GIS in new decision support systems.

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GIS in Agricultural Research and NARC Experience

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1. What is GIS?

"A Geographic Information System (GIS) is a computer-assisted system for the acquisition, storage, analysis and display of geographic data." Today, a variety of software tools are available to assist this activity, e.g. Arc/Info, Arc view, IDRISI and ILWIS. They are generally called GIS.

GIS has been designed to help us answer two types of questions:

1. What happens in a particular *place?*
2. *Where* does a particular thing happen?

Both of these are questions about spatial information, they are asking about where things are. Any business, which needs to ask questions of this type, and this day probably does, uses a GIS.

2. The philosophy of GIS

GIS has had an enormous impact on virtually every field that manages and analyses spatially distributed data. For those who are unfamiliar with the technology, it is easy to see it as a magic box. The speed, consistency and precision with which it operates are truly impressive, and its strong graphic character is hard to resist. However, to experienced analysts, the philosophy of GIS is quite different. With experience, GIS becomes simply an extension of one's own analytical thinking. The system has no inherent answers, only those of the analyst. It is a tool, just like statistics is a tool. It is a tool for thought.

Investing in GIS requires more than an investment in hardware and software. Indeed, in many instances this is the least issue of concern. Most would also recognize that a substantial investment needs to be placed in the development of the database. However, one of the least recognized and most important investments is in the analysts who will use the system. The system and the analyst cannot be separated - one is simply an extension of the other. In addition, the process of incorporating GIS capabilities into an institution requires an investment in long-term and organization-wide education and training.

In many ways, learning GIS involves learning to think - learning to think about patterns, about space and about processes that act in space. As you learn about specific procedures, they will often be encountered in the context of specific examples. In addition, they will often have names that suggest their typical application. But resist the temptation to categorize these routines. Most procedures have many more general applications and can be used in many novel and innovative ways. Explore! What you will learn goes far beyond what this or any software package can provide.

3. GIS in Agriculture Research

For agricultural planners and decision makers, accurate and up to date information about agricultural resources (land use, soil, climate, crops) are needed. Such information can be managed in GIS environment. GIS is a special form of computerised database management systems. GIS couples the attribute component (the value or category identifier) of datum with its geographic component in a much more powerful fashion than does a simple database system. The geographical position component of the data enables the researcher using GIS to combine in analysis quite diverse data-sets by linking individual datum from each data set through their common position in space.

The attribute components of each data set may be conceptually quite different from each other, e.g. language spoken by the population of an area and maize yield by district. However, since both data sets have a locational component, one can incorporate both in the analysis, e.g. determine average maize yield for each language group of a nation. Of course, as the example demonstrates, whether the analysis is of any use is entirely a different question.

Geographic Information Systems should be of particular interest to agricultural researchers simply because most of phenomena with which we deal has a strong spatial component. Variations in the subjects of interest to us are tied to spatial distribution of a wide range of elements, e.g. fertilizer response in soils, pathogen distributions, rainfall patterns, market access, cropping systems and so on. The interactions between these elements and how that interaction may relate to our research topic can be captured through the use of GIS. To use a GIS, one requires digital maps of the elements of interest for the area of interest. For example, we have maps of soils, agro-climatic zones, boundaries of districts, natural regions, elevation, land use and land cover, and various climatic variables such as rainfall, temperature and potential evapotranspiration.

As agricultural scientists we must conduct our research in full recognition of the limits imposed and opportunities provided by spatial variability in all of the components of agricultural production. If we do so, the work we do and technologies and information we provide to farmers will be much more sound. GIS provides a means of managing and incorporating spatial factors into our work. It is not a tool only for experts. It is within the capacities of most of us to acquire, learn and use GIS effectively.

The application of GIS tools is increasing day by day in many fields. Agricultural research scientists have also applied the GIS tool for their research work. Many international and national agricultural research organizations have their own GIS facilities and using this tool for the agricultural research. Some examples of GIS application in agriculture is given below:

- GIS is used in the management of crop yields
- Monitoring crop rotation and land use changes over time
- Land or crop suitability analysis and mapping
- Soil survey and mapping
- Agro-ecological zonation
- Projecting soil loss for individual farms or entire agricultural regions.
- Crop modeling and yield estimation
- Irrigation management of the crop fields

4. GIS in NARC

In 1995, the GIS lab was established in the Soil Science Division of NARC. The lab is equipped with three PC computers, one AO size Calcomp digitizer and one 24" HP Design jet color plotter. The software used in the GIS is Arc/Info 3.4D, Arc view 3.1, IDRISI win 2, WWIS 2.1 and other supporting software's e.g. Dbase, Excel, Minitab. So far, a limited amount of work has been done from this lab. We apply the GIS technique to monitor the land use changes and natural resource assessment in the small watershed area that is called Sundi Khola watershed in Kavre district.

Another application of GIS is in the management of natural resources of Rupandehi district. We have done a soil survey in this district and prepared different layers of maps e.g. land use, geo-pedological, river, roads, VDC, soil pH, Organic matter, Nitrogen, Phosphorus and Potash. We are also prepared the database of climate for agro-ecological zone map preparation.

We have also applied the GIS tool to analyze and map time series data of fertilizer use and crop production in Nepal. In this study, we use the different years of the Central Bureau of Statistics (CBS) and Agriculture Input Corporation (AIC) data to correlate the crop yield with the use of fertilizer.

5. Constraints and Limitations

Despite technological advancement of GIS, their dramatically declining costs and improved user-friendly software, the potential benefits of GIS have not been fully exploited. The use of GIS must involve awareness of the limitations of not only the available data but also the understanding of environmental processes and technology in use. There are such other limiting factors as data standardization, data access and exchange, deficient institutional framework, complex topography, and lack of trained manpower.

Procedures for Soil Sampling and Analysis

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1 Introduction

Soil testing is a chemical method of determining the nutrient supplying capacity of a soil. Soil analysis is done to know the total nutrients as well as available nutrients content in the soil.

2 Major objective of soil analysis

- To find out the fertility status of a soil.
- To determine the manure's and fertilizer dose for a particular crops and particular area or field.
- To know the soil reaction status (i.e. pH) and recommended the amount of soil amendment e.g. lime for acidic soil and gypsum for alkaline soil.
- To build up soil fertility status of the area where the soil fertility status is low.

3 Pre - steps of soil analysis

To get quality result from a given sample, much care must be taken. Use of appropriate sampling techniques, appropriate tools, demarcation of sampling area, drying, grinding etc are the major pre steps of soil analysis.

4 Sampling tools

A Spade or augers (post hole, screw) and probes (Soil tube), tray, measuring tape, information sheet, cloth and polythene bags, permanent marker or pencil etc are essential sampling tools.

5 Soil sampling

The first step of soil analysis is to collect soil samples. Soil sampling means collecting soil from a field for analytical determination. This is an easiest process but needs a lot of care for a good result. Reliable and representative soil sampling should be done.

For reliable sampling, appropriate tools of uniform size and equal volume should be used. Before sampling, the sampling area should be demarcated. This demarcation can be done by using various indicators e.g. appearance, slope, drainage, soil type, soil color, past treatment, soil fertility and productivity, cropping pattern, etc.

Take the auger or give a 'V' shaped cut up to a depth of 15 cm with a spade or Khurpee Take an about 4cm thick uniform slice of soil. This cutting must be parallel to the 'V' shaped cut. Similarly, take 6-8 random sample spots for a small plot and 15 to 20 sample spots for bigger plots in a clean tray. Mix them well and make a composite sample. If the amount of soil collected is more than 1kg, reduce it by quartering. Put the collected sample in a plastic or cloth bag. Label each sample with a detailed information.

6 Number of spots for a composite sample

How much sub samples should be collected for a composite sample is a major question on sampling because it should be done according to the objective. Generally 15- 20 sub- samples are collected from a 5 ha field or a portion of a field. According to Wayne. E. Sabbe, the following sub-sample for the following objectives are suggested:

Element	Number of sub-samples
Phosphorus (P)	25 sub-samples
Potassium (K)	5 sub-samples
Nitrate nitrogen	15 sub-samples

7 Area to be covered

Depending upon the uniformity of a field, soil color, fertility and productivity of a soil, a few ropani to more than 160-ropanies area can be separated for sampling.

8 Depth of the sampling

Generally soil samples are collected from the plow depth (15-20cm) but depth of sampling varies according the objective of the soil analysis.

Table 1 . Recommended sampling depth depending on objectives

Objective of the sampling	Sampling depth
For salt affected soil	0-10 cm
For pasture development	0-2 cm
For zero tillage	0-2 cm
For Nitrate and sulfate test	0-30 and 30-60 cm
For moisture determination	up to moisture control section 20-60 cm in case of loam.
For orchard plantation	up to150-200 cm
For standard soil surveys	from typical profile from different horizon up to the parent materials
For shallow rooted crops	0-9" depth
For deep-rooted crop	0-6" depth, collect the one composite sample from each pit 6-12" depth, collect the second composite sample from each pit 12-24" depth collect the third composite sample from each pit 24-36" depth collect the fourth composite sample from each pit

9 Time of sampling

Samples can be collected anytime but the field should be in rest. If the crops are growing but samples are needed to verify the deficiency symptoms, then take the sample between the rows. Do not sample from unusual spot. Avoid the sampling from recently fertilized plot, old bound, marshy spots, compost pile and other non-representative location.

Best time for sampling and analysis is just before seeding and transplanting the crops or plants. It is therefore concluded that sampling should be done at any time when the field is in rest and soil condition permits to sample.

10 Frequency of sampling

Generally 3 years intervals are advised to samples, but in reality it is also depend upon the cropping intensity, soil types and other factors.

11 Drying the samples

Do not dry soil in sun or artificial heating with a stove or furnace. If it is essential that temperature does not exceed 35^{0} c and maintain the relative humidity between 30-70%

12 Grinding and sieving

Grind the aggregate particle only, not the primary particles and store them in a polyethylene bottle with good labeling. For determination of organic matter, Calcium carbonate, other chemical analysis use 0.2-mm sieve. If the samples are to be used for the estimation of micronutrients, use the brass sieve. For general purpose use 2mm sieve.

13 Storage of soil samples

Always keep the identity of soil samples. Soil samples in the store must be in dry condition.

14 Methodology for soil analysis

A. pH analysis

- pH is determined by pH meter (1:1 or 1:2 soil water ratio).
- The Colorimetric method by using organic dyestuffs is good for field-tests. (Universal indicator, litmus paper & soil testing kit box)

B. Nitrogen analysis

- Total nitrogen analysis by Kjeldahl method.
- Available Nitrogen by Kjeldahl method using potassium permanganate
- Nitrogen is calculated by dividing Organic Matter by 20.
- Soil testing kit box (Diphenylamine test) can be used in field test.

C. Available phosphorus

- Olsen Method using Olsen extracting 0.5N $NaHCO_3$ at pH 8.5 (suitable to neutral to alkaline soil)
- Bray and Kurtz No 1 (Using 0.03n NH_4F, 0.025N HCl extracting) for acidic soil.
- Kit box is used for available phosphorus in the field test.

Note: Mechail No 1 extracting (0.05 Molar HCL + 0.025 Molar H2SO4) is also popular in acidic soil for available phosphorus.

D. Available potassium

- 1N Ammonium acetate at pH 7 in lab test.
- For field test - soil testing kit box.

Note: In some places optimum K test is calculated by using formula (Optimum K soil test lb. k/ acre = 220 + (5*CEC).

E. Organic Carbon

- Walkey-Black titration method

F. Boron Test

- Hot water extracting (Modified Berger and Truog method).

G. Zinc, Iron, Manganese, and Copper Test

- Extracts used are AAAC, EDTA, DTPA and 0.1N HCL.

H. Molybdenum Test

Extracts used are AAAC EDTA

15 Interpretation of soil analysis data

The ratings used by STSS for the interpretation of soil analysis data are presented in Table 2 to 4.

Table 2. Organic matter rating (in %)

Criteria	Terai	Hill
Very low	<0.75	<1
Low	0.75-1.5	1.0-2.5
Medium	1.5-3.0	2.5-5.0
High	3.0-5.0	5.0-10
Very high	>5.0	>10

Table 3. Rating of nutrient content from soil analysis result

Nutrient and method	Nepal rating					FAO rating (N in % and others in mg/l (P&K)				
	V .low	Low	Med.	High	V. high	V .low	Low	Med.	High	V. high
N % (Total)	<0.05 Hill <0.03 Terai	0.05-0.1 Hill 0.03-0.07 Terai	0.1-0.2 Hill 0.07-0.15 Terai	0.2-0.4 Hill 0.15-0.25 Terai	>0.4 Hill >0.25 Terai	<0.045	0.045-0.09	0.09-0.17	0.17-0.32	>0.32
P_2O_5 Kg/ ha NaHCO3	<10 Hill <11.2 Terai	10-30 Hill 11.2-28 Terai	30-55 Hill 28-56 Terai	55-110 Hill 56-112 Terai	>110 Hill >112 Terai	<2.5	2.5-8	8-25	25-80	>80
K_2O Kg/ ha CH_3COONH_4	<55 Hill <56 Terai	55-110 Hill 56-112 Terai	110-280 Hill 112-280 Terai	280-500 Hill 280-504 Terai	>500 Hill >540 Terai	<50	50-140	140-370	370-1000	>1000
Ca CH_3COONH_4						<380	380-1150	1150-3500	3500-10000	>10000
Mg CH_3COONH_4						<50	50-160	160-480	480-1500	>1500
B Hot water, Soil						<.015	0.15-0.35	0.35-0.8	0.8-2	>2
Cu AAAC-EDTA						<0.7	0.7-2	2-6	6-18	>18
Fe AAAC-EDTA						<30	30-75	75-200	200-500	>500
Mn AAAC-EDTA						<23	23-90	90-360	360-1400	>1400
Mn DTPA						<4	4-14	14-50	50-170	>170
Mo AAAC-EDTA						<0.003	0.003-0.014	0.014-0.065	0.065-0.3	>0.3
Zn AAAC-EDTA						<0.5	0.5-1.5	1.5-5	5-15	>15
Zn DTPA						<0.2	0.2-0.7	0.7-2.4	2.4-8.0	>8.0

Note: AAAC= Acid ammonium acetate, EDTA = Ethylenediaminetetracetic acid, DTPA = Diethylenetriamine pentacetic acid

Table 4. Rating for pH

Criteria	Range	Remark
Extremely acid	< 4.5	Characteristic of soil in humid regions
Strongly acid	4.5 - 5.2	Where annual rain fall is very high
Moderately acid	5.3 - 5.9	Characteristic of many red and lateritic soils
Lightly acid	6.0 - 6.5	Indicating deficiency of Ca & low percentage of base saturation.
Nearly neutral	6.6 - 7.0	Suitable for many agricultural crops
Slightly alkaline	7.1 - 7.5	Crops like rice and Lucerne can tolerate pH beyond 8.0 - 8.3.
Moderately alkaline	7.6 - 8.3	Crops like rice and Lucerne can tolerate pH beyond 8.0 - 8.3.
Strongly alkaline	8.4 - 9.0	Characteristic of highly alkaline soil requiring reclamation measures
Extremely alkaline	> 9.0	Characteristic of highly alkaline soil requiring reclamation measures

16 APP Concept

The Agriculture Perspective Plan (APP) is a 20-year planning for agricultural development. Pocket-package strategy is the action plan, which started with the very beginning of APP. It is also the core activity for the running 5-year agricultural development plan. Identification of feasible technological package and its application in suitable pockets based on available resources is the main theme of the Pocket-package strategy.

Overall the APP has identified different types of production systems in hills and flat plains, e.g.

(1) 'Demand driven' Production systems of less accessible hills and mountains: Agricultural development is supported by the use of available fertilizer and the improvement of their traditional integrated system of agriculture, livestock and forest.

(2) 'Technology driven' green revolution type development has been emphasized for the Terai and in the easily accessible valleys of Nepal by supporting increasing chemical fertilization and mass scale of green manuring along with bio-fertilizer use.

The implementation requires the following focus:

- Identification and introduction of soil fertility management program in the production pockets that are interesting for the farmer and which have long term beneficial effects.
- Formulation of location specific soil management programs to enhance agricultural productivity and tied-up with package production program.
- Soil management programs with a focus on the small farmers, which contribute more in Nepalese agriculture. In this connection, special programs need to be run for sustainable soil fertility management based on the study of location specific needs and opportunities.
- Promotion of Integrated Plant Nutrient System (IPNS) technologies to the farmers on sound environmental ground and with a maximum use local resources on a sustainable basis. This includes the activities of green manuring, compost/ FYM management, use of micronutrients, use of fertilizers and development of alternative source of fertilizer as cultivation of fertilizer crops and management of slurry from biogas plants.
- Carry out necessary surveys for soil inventory creation, fertility evaluation, land use monitoring and feasibility analysis to help program planning, execution, monitoring and identification of location specific soil service needs.

17 Concept of soil management services in IXth Plan

The 9th plan sets the following priorities in the context of soil fertility management:

- Improve the System of manure and fertilizer use.
- Capacity building of Soil labs as per the needs.
- Tied-up soil management program with extension activities, and compulsory soil testing and fertilizer recommendation as specified as a priority in implementation of package production program

The programs being currently conducted by STSS and Regional soil testing laboratories are soil analysis in labs and fields (Campaign). DADOs collect soil samples and send to the labs for analysis. Many soil-testing kits are not in action.

18 Suggestions

Given the exiting manpower, soil analysis work cannot properly be done. More posts for soil science should be created and responsibilities should be provided in the district level. Manpower development should be done in laboratories level, DADO level and farmers level. Structural reform from fertilizer unit to STSS,

RSTL and DADO is essential because existing structure can not achieve the national need for soil fertility investigation and fertilizer recommendation.

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Need and Practice of Quality Control of Fertilizer in Nepal.

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1 Introduction

Fertilizer is a major input to increase crop production. Its application rate is low in Nepal in comparison to other developing countries (31kg/ha). There is no fertilizer industry in the country, thus we depend entirely on import. The import of fertilizer was started since 2009 in a small amount (100mt of Ammonium Sulfate). Now, the demand is high and supply was not sufficient to fulfil demand.

The requirement of fertilizer during the 9th five year Plan period (2054/55 to 2058/59) is estimated to be 506205 tons of Nitrogen, 16312 tons of Phosphorus and 10546 tons of Potassium. Until November 1997 fertilizer trading was fully dependent on the Agricultural Input Corporation(AIC). Since than the policy has been changed to liberalization of the fertilizer trade. Now several private form are involved in fertilizer trade. Now there is no subsidy in fertilizer import and distribution. Under the monitoring and evaluation division of MoA, a Fertilizer Unit (FU) has been established for the management of fertilizer import, distribution, quality control, collection of national and international price and policy development.

The new policy of HMG/N on fertilizer import includes.

- Free entity of fertilizer
- Keeping the AIC and private sectors in equal footing
- Termination subsidy for all kind of fertilizers
- Essential commodity (Control) act1961has included fertilizer in the list of essential commodities.
- Promulgation of the fertilizer (control) order 1999
- Deregulation of fertilizer prices at wholesale and retail levels
- General fund for agricultural development (23 districts of high hills are benefited for transportation facilities)
- Removal of uniform national price for fertilizers

2 Major problems faced by liberalization of fertilizers

Sub-standard fertilizers is frequently entered in the country from India particularly in the Terai region. Results from samples collected by various sources were analyzed and the result are shown in Table 1.

Table 1: Result of fertilizer analysis

S.N.	Fertilizer	No of samples	Total N %	Total P_2O_5 %	Potassium K_2O%	Standard Nutrients		
						N	P_2O_5	K_2O
1	Urea	28	41-46		-	46	0	0
2	DAP	17	14-18	5.5-46	-	18	46	0
3	DAP 10-10-10	1	10	8.7	-	10	10	10
4	DAP 10-10-10	4	2.65-10	8.7-11.5	-	10	10	10
5	DAP	1	0.44	46	-	18	46	0
6	DAP	1	11.1	11.3	-	18	46	0
7	DAP	1	14.0	5.5	-	18	46	0
8	Unknown	1	22.6	-	-			
9	Ammonium Sulphate	4	19.7-21	-	-	21	0	0
10	Single Super Phosphate	3	0	16	-	0	16	0

Name of the fertilizers: Godabari, Hariyali, Suphala, IFFCO etc ; Potassium content was not analyzed.

3 The removal of subsidy and problem of price variation.

The greatest problem is price equality, because the prices of AIC and the private sectors are not same. Within the country the fertilizer price of AIC is lower than private sectors. The price between India and Nepal is also not equal. It is because, India still subsidies on fertilizer. The fertilizer price rate of India is lower than in Nepal.

4 Steps taken by MOA for quality control

The Ministry of Agriculture has taken the following steps for the regulation of quality fertilizer in Nepal:

- Development of Fertilizer (control) order 2055
- Developed the procedure for chemical analysis of fertilizer
- Trained some soil scientists for fertilizer analysis
- Appointed the fertilizer Inspectors in each district for quality control
- Many workshops and interaction programs had been conducted for the awareness
- Promoted the soil analysis laboratory of Jhumka for Fertilizer Analysis Lab for quality control

5 Constraints

- Lack of physical facility for fertilizer analysis in all regions
- Lack of trained manpower in all labs
- Open border easy to take and sent
- No fertilizer and blending factory for fertilizer supplying Nepal
- Lack of awareness with farmers for quality fertilizers
- Purchasing capacity of farmers are too low, so they will search for cheaper fertilizer
- Imbalance in use of chemical fertilizers

6 Suggestion

Fertilizer is a key factor for crop production, without which we will not be able to maintain the crop productivity. It should be given proper attention. Good quality control mechanism should be developed. Regular monitoring and awareness should be created. The distribution of fertilizer material by the wholesaler and retailer should cover the whole country. Manpower for the Fertilizer Unit should be increased and proper by trained staff should be in place. The workload should be shared by MOA, DOA, STSS, RSTLS, and DADO.

7 Reference

9th five-year plan of Nepal

Indigenous Agricultural Land and Soil Classifications[1]

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1 Overview

The indigenous knowledge of rural farmers in the Himalayas regarding soil classification and management has been transferred verbally over many centuries. This knowledge can often be applied within socio-economic and spatial boundaries of a society or ethnic group. It has been preserved. communicated and used to overcome problems related to agricultural land management and production activities. A number of projects have been carried out to document indigenous management techniques (Gill, 1991; Tamang, 1991), but indigenous agricultural land and soil classification systems have not been documented in any depth, and few details are available for use in developing an integrated approach to soil management problems. Documentation of how farmers perceive and classify soil types can improve communication between technical personnel and farmers. Integration of knowledge developed by farmers over centuries, combined with modem science, can bring about positive changes in the implementation and design of development programs that could provide innovative and useful insights to modern research and extension activities. It is hoped that this documentation of indigenous knowledge on agricultural land and soil classification systems in the Jhikhu Khola Middle Mountain Watershed can serve as a prototype for regional and national centres interested in applying indigenous knowledge for improving management scenarios of small scale production systems by incorporating new scientific technology into the existing knowledge at the grass root level.

Given the intricate and sophisticated terraced agricultural systems, which have been under agricultural use for centuries, the need to document the indigenous system has become more and more apparent. The socioeconomic surveys provided a good forum for documentation of some of the indigenous classification systems. The information provided by the 200 farmers who participated in the soil fertility survey in the Bela-Bhimsenthan study area was used to document the local system. It also provided an opportunity to calibrate the system using laboratory analysis of the soils. The following is a first attempt at documenting the indigenous soil and land classification scheme in the Jhikhu Khoia.

2 Indigenous classification of soil and agricultural land

Farmers have a systematic criteria for distinguishing soils according to landform position, which are based on slope, elevation, and drainage. Top soil colour, texture and terrace type are the most dominant criteria for local land classification and soil fertility management. The farmers also use broad climatic regimes to differentiate climatic conditions. These are based on elevation and aspect, which relate to temperature, and which is in turn one of the most important factors influencing the choice of crops to be used In the rotation sequence, crop production and length of the growing season. The broad classes, with their native vegetation types, are illustrated in Table 1.

Table 1. Indigenous climatic regimes

Climatic Regimes	Altitude (m)	Mean Annual Air Temp. (degree C)	Dominant Forests
Awal	< 1200	20 – 25	*Shorea robusta, Pinus roxburghii*
Kchard	1200 – 1600	15 – 20	*Pinus roxburghii*, mixed broad leaf forest
Lekh	1600 – 2200	1 - 10	Oak (*Quercus*) mixed forest

[1] Previously published in: Schreier, H., B.P. Shah and S. Brown. 1995. Challenges in Mountain Resource Management in Nepal. ICIMOD / IDRC / UBC.

2.1 Khet and Bari land classification

Irrigated khet and rainfed bari terraces are classified according to landform position and slope. The classification system developed by the farmers forms the basis for land management and agronomic cultural practices. Tables 2 and 3 list the terminology used by the farmers for classifying the khet and bari lands in the Jhikhu Khola watershed and provide information on terrace types and the management limitations of khet and bari lands. The farmers have adjusted the terrace system to the different sites by changing the size and height of the riser and the width of the terrace to obtain maximum stability, drainage and performance. These classes are well recognized by the local farmers and reflect their experience and adjustment to environmental conditions.

Table 2. Local khet land classification.

Names	Landform Position	Slope degree	Terrace Type	Management Limitations
Bagar khet	Valley bottom, floodplain	1-3°	Pata < 1m terrace risers	Prone to frequent flooding
Khola khet	Stream banks, stream terraces	5-10°	Gara < 1m terrace risers	Stream bank erosion
Sim khet	Head hollows, foot slopes of colluvial slopes, spring or seepage areas	3-10°	Gara/pata < 1m terrace risers	Poor drainage, high water table during monsoon
Ghol khet	Valley floor depressional	1-3°	Pata/gara < 1m terrace risers	Poor drainage, high water table during monsoon
Khadi Daldale khet	Valley floor swamp	1-3°	Pata/gara < 1m terrace risers	Poor drainage, high water table
Gairi khet	Valley floor, intermediate terraces or foot slopes	1-3°	Pata/gara < 1m terrace risers	Imperfectly drained, high water table during monsoon
Tari khet	Old river terrace/fans (TARS)	1-5°	Pata/gara < 1m terrace risers	Irrigation water, low fertility status, prone to surface wash and gullying
Pakho/Tari khet	Ridge tops/fan	1-5°	Pata/gara < 1m terrace risers	Irrigation water, low fertility status, prone to surface wash and gullying
Ghara khet	Moderately/gently sloping hillside (colluvial slopes)	10-15°	Gara < 1m terrace risers	Low terrace maintenance cost and surface erosion problems
Kanle khet	Steeply sloping hillside	15-25°	Kanle > 1m terrace risers	High terrace risers, high terrace maintenance, severer surface erosion
Phagata khet	Steeply sloping hillside	25-30°	Kanle > 1m terrace risers, short narrow terraces	High terrace risers, bullocks cannot be used for ploughing, high terrace maintenance cost, severe surface erosion
Surke khet	Very steep hillside	>30°	Kanle > 1m terrace risers, long narrow terraces	High terrace risers, bullocks cannot be used for ploughing, high terrace maintenance cost, severe surface erosion

Table 3. Local bari land classification.

Name	Landform Position	Slope (degree)	Terrace Type	Management Limitations
Tar (Pata) bari	River terraces (Tars) fans, ridge tops	1-5	Pata < 1m terrace risers, wide sloping terraces	Low fertility status, surface wash and gullying, moisture deficiency
Pata bari	Moderately sloping hillside	10-20	Pata > 1m terrace risers, sloping terraces	Severe surface erosion and mass wasting with slope disturbance
Ghar bari	Gently sloping hillside, FANS, TARS accordant ridge tops	5-10	Pata < 1m terrace risers, wide sloping terraces	Surface wash and gullying
Kanle bari	Moderately to steeply sloping hillside	20-25	Kanle > 1.5m terrace risers, sloping or nearly level terraces	High surface erosion and mass wasting with slope disturbance, high soil fertility requirement
Surke bari	Strongly sloping hillside	25-30	Kanle > 1.5m terrace risers, sloping terraces, long narrow terraces	High surface erosion and mass wasting with slope disturbance, narrow terraces, bullocks cannot be used, low fertility status, marginal areas
Khoriya bari	Strongly sloping hillside	25-30	Kanle > 1.5 m terrace risers, sloping terraces, long narrow terraces	High surface erosion and mass wasting with slope disturbance, narrow terraces, bullocks cannot be used, low fertility status, marginal areas
Khar bari	Moderately to strongly sloping hillside	20-30	Kanle > 1.5m terrace risers, sloping terraces, long narrow terraces	Marginal areas for thatch grass producing
Karalo bari	Gently sloping hillside, FAN	5-10	Pata > 1m terrace risers, wide sloping terraces	Surface wash, gullying low fertility status
Gagrine bari	Gently to moderately sloping colluvial slope	5-20	Pata > 1m terrace risers, sloping or level terraces	Severe surface erosion and mass wasting with slope disturbance, coarse gravelly terraced, high leaching and infiltration capacities

3 Indigenous soil classification system

Farmers have a distinct and systematic criteria for soil classification. Soil are differentiated on the basis of colour, topsoil texture, depth and consistency. These factors, in combination with slope provide information on infiltration, drainage, soil moisture retention capacity, organic matter content and stability.

3.1 Soil colour

Soil colour can be used as a key distinguishing criteria by farmers. Some of the colour differences relate to the age of the soil, the origin or parent material, and the carbon content. The major topsoil colours used by the farmers to differentiate soils are shown in Table 4 alongside the scientific classification.

The colour categories noted by the farmers are a partial indication of organic matter content in the soil. At higher carbon content the soil colours are usually darker, the moisture content and cation-holding

capacity are higher, and the structural stability of soil aggregates is greater. In addition, the very old soils in Nepal are deeply weathered and contain significant portions of Fe and Al. The former gives rise to the red soils which have a significant portion of kaolinite and distinct physical properties. Because of the long leaching processes, the red soils are generally low in phosphorus.

Table 4. Local soil colour classification system

Local Colour Classification	Munsell Soil Colour Chart
Kalo (black)	10 YR 3/1-4/1 - dark greyish brown-very dark greyish brown
Rato (red)	2.5 YR 4/6-5/6 – red
Haluka rato mato (light red)	5 YR 5/6-6/6 – yellowish red-reddish yellow
Khairo mato (brown)	7.5 YR 4/2-5/2 – brown-dark brown
Phusro (grey)	10 YR 5/1-5/2 – grey-greyish brown
Kharani mato (light grey)	7.5 YR 7/10 YR 7/7 – light grey
Jogi mato (yellow)	10 YR 6/6-7/6-8/8 – brownish yellow-yellow

3.2 Texture

Among the most important physical properties of soils considered by farmers is soil texture. Soil texture involves the size of individual particles and arrangement of soil particles into groups or aggregates. These properties determine nutrient supplying ability of soil solids and the supply of water and air necessary for plant root development activities. The size of particles in mineral soil (texture) is not readily subject to change, and remains constant. The farmers are aware of the.fact that the texture of a given soil can be changed only by mixing it with another soil of different textural class. Farmers incorporate large quantities of sand and sill through irrigation water to improve the physical properties of red day soils for potato cultivation. The textural classes differentiated by farmers in the field are listed in Table 5 below and their equivalent USDA soil texture classes are also provided. The farmer's textural classifications are used primarily for crop selection and soil management. Heavy textured (chimte) soils require higher labour inputs than light textured (domat) soils for ploughing and other agronomic activities. Moisture content in relation to texture is also used as an index for workability of the soil.

Table 5. Indigenous terms for texture classification.

Local Name	USDA Texture Class
Pango	silty loam/silt
Balaute	sand
Domat	loam
Balaute Domat	sandy loam
Balaute Chimte	sandy clay loam
Domat Chimte	clay loam
Chime	clay
Gagren	gravelly
Masino	fine
Chimte	very fine (clay) soil

3.3 Soil depth

Soil depth has been one of the most important criteria used by farmers in selecting land for farming. Deep soils (gahiro) generally have higher moisture-retention capacities than shallow ones. Shallow soils restrict the penetration of plant roots and affect the soil's moisture retention capacity. Deep soils (>1 m depth) do not restrict the distribution of roots in the soil profile and plants are able to absorb a considerable proportion of their moisture requirement from the soil layers. Farmers prefer soils with a good rooting depth of more than one metre, and are aware of the factors governing the uptake of nutrients and use of soil moisture by plants.

3.4 Soil Consistency

Soil consistency has important significance for soil tillage and land management systems. Farmers do not have many distinguishing criteria but know that wet red claysoils are sticky and slippery while sandy soils are non-sticky and non-slippery. "Rato mato chiplo bato" a term used to note that red soils are slippery has significance to farmers in that these soils have poor infiltration capacities. Major local terms used for classifying consistency are provided in Table 6. The terms used for classifying soil consistency may be simple, but are meaningful and easily understood by farmers for management practices.

Table 6. Soil consistency classes and scientific equivalents.

Local	USDA	Soil Texture
Chipplo (chyap-chyape)	Sticky, plastic	Clay (fine)
Khasro	Loose, non-sticky, non-plastic	Sands (coarse)
Lasailo	Slightly sticky, slightly plastic	Loams (medium)

4 Relationship between indigenous classification and soil nutrients

A set of 200 soil samples were available to compare the indigenous classification with the scientifically measured results. First, the differences in the soil colour classes recognized by the farmers were compared, and secondly the land classification and terrace systems favoured by the farmers were compared against the Inherited soil chemical conditions.

4.1 Comparison between indigenous soil colour classes and soil chemical conditions

All soil samples were sorted into three broad colour classes well recognized by the local farmers. The chemical properties of the soils failing into the three classes were then analyzed and compared. As was shown in a previous paper by Shah et al. (1995), elevation, parent material and land use all affect the soil composition. A stratification based on elevation (~ 1 200m,> 1 *200m)* and agricultural land use (irrigated vs. rainfed) was made before separating soil colour. The results, shown in Table 7, indicate that significant differences could be discerned in a number of cases. The dark greyish soils usually have the best pH in all high elevation sites while the light grey-yellowish class had the lowest pH, in all sites regardless of use. In contrast available phosphorus values were consistently lower in all red soils. All light grey to yellow soils had the lowest cation exchange capacity and exchangeable Ca content. This reveals that the farmers are well aware of the unique differences between soil colour and its associated properties. The chemical variables displayed in Table 7 are to a great extent related to inherent differences in soil parent materials but the impact of management is also evident.

4.2 Comparison between indigenous agricultural land classes and soil chemical conditions

The *200* soil samples originating from the Bela-Bhimsenthan test area were sorted according to the twelve indigenous khet and bari classes and the results were compared statistically for a number of nutrients. The indigenous land categories listed in Tables 3 and 4 were grouped into three categories: very desirable sites, moderate sites, and poor sites for crop production.

Table 7. Comparison between indigenous soil colour classification and soil chemical conditions.

Soil Colour	Munsell Soil Colour Class	Land Use	Elevation (m)	pH	Avail. P (mg/kg)	Cation Exch. Capacity (meq/100g)	Exch. Ca (cmol/kg)
Dark greyish	10 YR 3	khet	> 1200	5.8	19.6	14.8	10.1
Red-reddish yellow	2.5 YR 5-6 5 YR 5-6	khet	> 1200	5.4	5.6	12.3	5.1
Light grey-yellow	7.5 YR 4-7 10 YR 5-7	khet	> 1200	5.0	28.2	9.4	4.4
Dark greyish	10 YR 3	khet	< 1200	5.1	84.3	6.2	2.5
Red-reddish yellow	2.5 YR 5-6 5 YR 5-6	khet	< 1200	5.6	10.8	13.8	5.8
Light grey-yellow	7.5 YR 4-7 10 YR 5-7	khet	< 1200	4.8	34.4	9.1	3.9
Dark greyish	10 YR 3	bari	> 1200	5.2	36.6	10.9	5.6
Red-reddish yellow	2.5 YR 5-6 5 YR 5-6	bari	> 1200	4.9	13.3	14.3	4.1
Light grey-yellow	2.5 YR 5-6 5 YR 5-6	bari	> 1200	4.7	37.1	7.9	3.2
Dark greyish	10 YR 3	bari	< 1200	4.7	14.1	12.1	3.5
Red-reddish yellow	2.5 YR 5-6 5 YR 5-6	bari	< 1200	4.8	7.2	12.4	3.1
Light grey-yellow	7.5 YR 4-7 10 YR 5-7	bari	< 1200	4.6	18.1	8.6	2.8

We then sorted all soil samples according to these three classes and determined the relationships or differences in selective soil nutrient conditions (Table 8). The best differentiation was found in terms of cation exchange capacity and exchangeable Mg and, to a lesser extent, in exchangeable K. Most of these are at least in part related to differences in parent materials.

Table 8. Possible relationships between indigenous soil classification and soil chemical conditions.

Land Use	Indigenous Names	Quality	CEC (cmol/kg)	Exch. Mg (cmol/kg)	Exch. K (cmol/kg)
Khet	Ghol, Gairi, Gara	Most desirable	8.6-14	1.4-2.2	0.15-0.35
Khet	Kanle, Phagata, Surke	Moderate	10-12	0.95-1.49	0.17-0.25
Khet	Bagar, Khola, Sim, Khadi Daldale, Tari, Pakho/Pata Tari	Least desirable	9-11	0.7-1.3	0.1-0.21
Bari	Pata, Ghar	Most desirable	10-12.1	1.5-1.8	0.3-0.4
Bari	Tar Pata, Surke	Moderate	9-12.7	1.2-1.5	0.3-0.5
Bari	Kanle, Khoriya, Khar, Karalo, Gagrine	Least desirable	6-10.1	1.1-1.2	0.11-0.3

Although there is some overlap in the range of conditions the separation between classes is sufficient to suggest that there is a reasonable relationship between the indigenous classification and the associated chemical conditions related to parent material. Since organic carbon is low in all soils in the watershed, the cation exchange capacity is primarily inherited from the parent material. The rate of weathering and the differences expressed in the indigenous classification is at least partially reflected in the scientific data.

Exchangeable cations are usually influenced by management particularly by the application of chemical fertilizers. Since few farmers apply lime or use potassium fertilizer, K and P also reflect inherited conditions. Variables that are more easily influenced by management (N, P, Ca, pH) did not show a significant relationship.

The calibration of the indigenous physical properties of the soils has not yet been completed but is expected to show similar trends suggesting that the experience in soil management gained by the farmer has validity and can be very useful in extension work, particularly when dealing with the introduction of new crops or alternative management methods.

5 Conclusions

This paper documented the prevailing indigenous soil and classification system used in the watershed. Farmers have vast long term experience and recognize soil and site conditions that relate to crop performance and workability. These conditions are often difficult to measure scientifically. The key features in the indigenous land classification system in the watershed are landform type, topographic setting and drainage regime. The type of terrace constructed is well adjusted to the conditions and is cognisant of slope stability, drainage regime, seepage conditions and texture.

When the indigenous land classification scheme was grouped into three types, ranging from the most to the least desirable, a good relationship was found between the quality of the land and the extent of the cation exchange capacity and selected exchangeable cations, particularly those that are not readily affected by fertilizer and manure management.

The soil classification system used by the farmers is based on soil colour, texture, consistency and depth. Most of the indigenous classes can readily be converted into the commonly used scientific classification schemes. These conversion tables facilitate communication between the subsistence farmers and the scientifically trained extension personnel. More documentation and calibration is needed, particularly in the area of physical properties and soil performance in terms of biomass production. Additional research is needed to better document the indigenous knowledge on soil workability, soil performance and soil quality, all of which are notoriously difficult to measure scientifically. These are the most fruitful research directions since the potential benefits are great, particularly when new management techniques and new crops are being introduced into the indigenous farming system.

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Contribution of Bio-fertilizers to Integrated Plant Nutrient Management

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1. Introduction

Soil fertility in the hills of Nepal shows a declining trend mainly as a result of decreased livestock numbers, increased surface erosion, a declining natural forest resource and increased cropping intensity (Sthapit, et al, 1988; Subedi and Gurung, 1991). The problem tree for the declining soil fertility in Nepal is shown in Figure 1. Therefore, despite every effort made by the hill farmers, productivity of the major grain crops is stagnant or declining (Subedi et al., 1989b). With limited availability of more land for arable cultivation, increase in agricultural production can only be achieved by increasing the availability of plant nutrients. However, in the hill farming situation, it is difficult to meet the increased demand for plant nutrients to increase crop yields solely through the use of farmyard manure (FYM). There is a huge demand of nutrients as a result of increased cropping intensity and reduced amount of organic manures in Nepal. To meet this demand, in recent years more and more chemical fertilizers are recommended and used. Though it has been well demonstrated that the yields of major grain crops can be significantly increased with judicious and timely application of chemical fertilizer (Subedi and Gurung, 1991), wide scale use of such purchased inputs is impractical for the foreseeable future, especially in the more remote hilly areas. The use of chemical fertilizers in the hills is limited because they are costly, are not available in required amount at the right time, and in many cases, farmers are reluctant to use them because they state it spoils their land (Subedi et al., 1989b, Tamang, 1992). Further, transportation of fertilizer is very difficult in the remote hill areas, as it relies upon human porterage.

Therefore, none of the single component is enough in our context. In order to develop appropriate alternative technologies for maintaining soil fertility, efforts should be directed towards integrating different plant nutrients sources. Nepalese farmers have been using different strategies and practices for maintaining soil fertility since centuries when chemical fertilizers were not developed or used. The same approach is now called as "integrated plant nutrient management (IPNM)". For this approach, use of locally available resources, such as farmyard manure (FYM), green manure and legume crops should be encouraged wherever possible. In this paper, how green manure and legume inter-cropping can contribute to IPNM in Nepalese hill farming is highlighted.

2. Methodology

Various field studies on search and utilization of indigenous green manure, inter-cropping of legumes with cereals have been reviewed. Notable results and different aspects of these indigenous practices that contribute to IPNS are highlighted.

3. Results and discussions

3.1. Green manure

Two types of green manure i.e. cut- and-carry system from farm and forest, and in-situ green manure are used in Nepal.

3.1.1. The cut- and -carry system

Traditionally some wild plants are known to be rich sources of nitrogen, and green leaves and twigs are collected and buried in soil to add organic matter and then plant nutrients. Search of such plant species was carried out at Lumle. A list of species that are commonly used in the Western hills of Nepal are presented in Table 1

Figure 1: Problem tree showing the factors associated with the declining of soil fertility in the hills of Nepal (After Subedi, 2000)

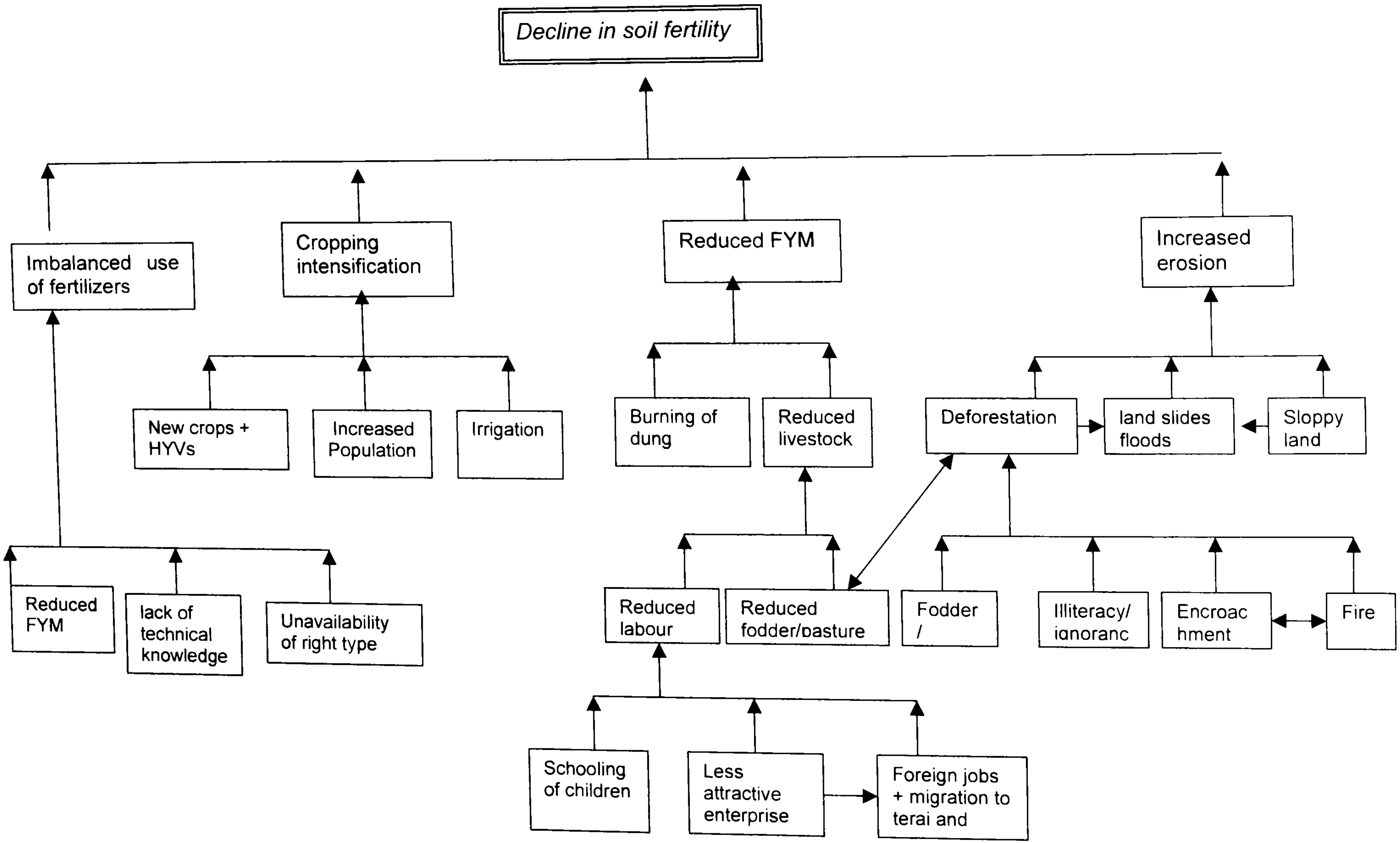

Table 1. List of different indigenous green manuring species commonly used in the Western Hills of Nepal and their nutritive values

Local Name	Latin name	Altitude limit (m)	Nutrient concentration (%)		
			N	P	K
Asuro	*Adhatoda vascia*	1300	4.30	0.88	4.49
Titepati	*Artemisia vulgaris*	2000	2.40	0.41	4.90
Bakaino	*Melia azedarach*	1500	3.24	0.19	1.76
Kalo Siris	*Albizia lebbek*	1400	2.89	0.65	2.59
Siplikan	*Crataeva uniloculari*s	1300	3.69	0.36	2.26
Padke	*Albizia spp.*	200-800	3.62	0.16	0.94
Ankhitare	*Walsura trijuga*	500-1200	2.77	0.49	2.40
Khirro	*Sapium insigne*	1300	2.70	0.79	2.89
Sajuban	*Jatropha curcas*	1000	2.76	0.32	2.27
Siamli	*Vitex negundo*	1200	2.08	0.14	2.56
Tuni	*Toona ciliata*	800-1400	2.44	0.16	0.71
Chelaune	*Schima wallichii*	400-1600	1.68	0.09	0.37
Dhokreful	*Brugmansia suaveolens*	1400	1.34	0.17	2.75
Banmara (kalo)	*Eupatorium antidysentrica*	800	2.91	0.35	2.68
Banmara (seto)	*Eupatorium adenophorum*	1800	1.34	0.17	2.75
Jhushe til	*Guizotia abyssinica*	1600	4.45	0.36	3.44
Masyang	*Vigna umbellata*	1200	2.91	0.28	1.84
Dhaincha	*Sesbania aculeata (S.bispinosa)*	1200	2.87	0.22	1.07

Source: After Subedi (1993b).

It shows that some of the species are very rich in N and K. Many of these plant species are multipurpose and can be grown in fences, along the road and in marginal lands and supply green biomass for manuring or for mulching. Conservation, evaluation and utilization of such locally available materials contribute to the total nutrient demand of intensive cropping systems.

Many of the green manuring species listed in Table 1 were also evaluated in field experiments. The comparative study of Asuro and Banmara with chemical fertilizer and farmyard manure across three locations over two seasons is presented in Table 2.

Table 2. Effect of treatments and locations on yield of rice (t/ha, ± SEd) averaged over two seasons (1991 and 1992)

Treatments	Rice yield in 3 locations in t/ha			
	Shera (1250 m)	Keware (1100 m)	Yampaphant (400 m)	Treatment Means (t/ha)
FYM/compost 10 t/ha	2.42	3.30	3.47	3.06
Chemical fertilizer NPK, 60:30:30 kg/ha	3.46	3.03	4.10	3.53
Asuro 15 t/ha	3.76	3.60	4.21	3.86 (±0.10***)
Banmara 15 t/ha	3.21	3.23 (±0.17***)	3.50	3.31
Location means (SEd, 72 df)	3.21	3.29 (±0.09***)	3.31	

Source: After Subedi (1993a)

Asuro was found to be superior to the other treatments and Banmara, considered as a problematic weed, also produced rice yield equivalent to chemical fertilizer applied at NPK 60:30:30 kg/ha and farmyard manure applied at 10 t/ha. These results show that plants like Asuro should be used widely while Banmara, which is not used for any purpose can be exploited either for green manuring or composting. This will help to suppress weeds and adds organic matter to the soil.

3.1.2 In-situ green manuring

In this system, green manuring plants, especially legume species, are grown in the field and they are slashed and incorporated in the same field where they were grown. *Sesbania spp.* is the most commonly used green manure species in Nepal. However, it has some problems e.g. latitudinal limitation, difficulty in germination and most importantly a grain crop has to be substituted in-lieu of green manure. At least 50-60 days are to be devoted to green manures to grow. In an effort to grow green manure without replacing crops from the existing system, Dhaincha and rice bean were relayed cropped with standing maize at the pre-tasselling stage.

The results of both locations over two years (1993 and 1994) showed no significant difference between the four imposed treatments for rice yield (Table 3). This agrees with the results from individual seasons and locations. However, rice grain yields were different in two years over two locations. Overall grain yield of rice was higher in 1993 season (5.61±0.08 t ha^{-1}) than in 1994 season (4.57 t ha^{-1}). Similarly, yield was higher at Rishingpatan (5.32±0.08 t ha^{-1}) than at Yampaphant (4.87 t ha^{-1}). There was a significant location x treatment interaction ($P<0.01$) as a result of significant treatment effect at Rishingpatan in 1994 season. There was no effect of the relay cropped green manure on the plant stand or on the grain yield of maize. Gurung and Serchand (1994) also observed a similar result in the eastern hills of Nepal.

Table 3. Grain yield (t/ha) and fresh straw yield (t /ha) of rice crops succeeding green manure at Yampaphant and Rishingpatan in two seasons (1993 and 1994)

Treatment	Grain yield				Straw yield			
	Yampa		R-patan		Yampa		R-patan	
	1993	1994	1993	1994	1993	1994	1993	1994
Maize/Dhaincha-rice*	4.94	4.70	6.01	4.21	6.4	7.3	7.1	7.1
Maize/Rice bean-rice	5.06	5.07	6.18	3.69	7.2	7.3	6.8	6.2
Maize-rice + Inorganic fertilizer	5.05	4.79	6.41	4.67	7.3	7.7	7.5	8.6
Maize-rice + Compost (10 t/ha)	5.10	5.05	6.38	4.39	6.6	7.4	7.2	6.8
Mean	5.03	4.90	6.25	4.24	6.9	7.5	7.2	7.2
SE (12 d.f)	0.35	0.27	0.23	0.26	0.33	0.46	0.39	0.45
P	>0.05	>0.05	>0.05	<0.05	>0.05	>0.05	>0.05	<0.001

Source: After Subedi (1998a)

3.2. Integration of legumes

Nepalese farmers grow different species of legume crops to meet their dietary requirement. At the same time, they contribute to the soil fertility through biologically fixed nitrogen and biomass recycled as animal feed. Legumes are generally grown as secondary crops and mostly inter-cropped with main crop cereals. Some of the examples of legumes inter-cropped with other crops are as follows.

3.2.1 *Inter-cropping of pea and tori with wheat*

Tikot Local variety of pea (Pisum sativum) and Lumle Tori variety of tori (Brassica campestris var. Toria) were mixed inter-cropped with Annapurna-3 of wheat at three seed rates (120:45 kg, 120:30 kg and 120: 15 kg for peas and 120: 6kg, 120:4 kg and 120:2kg of tori) at Lumle (1675 m) during the winter seasons of 1992 and 1993.

Results over the two seasons showed that the inter-cropping of wheat with pea was profitable in terms of overall grain yield, land advantage, monetary advantage, economic return and meeting dietary requirements of the subsistence farmers although the sole crop of pea gave the highest net return (Table 4). Wheat + tori inter-cropping did not perform well. For wheat + pea inter-cropping, sowing pea at 30-45 kg seed /ha was the most profitable. The contribution of biologically fixed nitrogen to soil and pea straw for livestock feed will be another advantage of this system.

Table 4. Effects of different inter cropping combinations on the grain yield (t/ha) of wheat, tori and pea at Lumle. Mean of two seasons (1992/93 and 1993/94)

Treatments (kg of seed per ha)	**Grain yield t/ha**			**LER**	**Net benefit (Rs./ha)**
	Wheat	**Tori**	**Pea**		
Sole wheat (120 kg/ha)	1.74	-	-	1.00	12720
Sole tori (8 kg/ha)	-	0.66	-	1.00	13000
Sole pea (60 kg /ha)	-	-	1.85	1.00	32000
Wheat + tori (120:6 kg/ha)	1.24	0.23	-	1.06	13170
Wheat + tori (120:4 kg/ha)	1.34	0.25	-	1.15	14420
Wheat + tori (120:2 kg/ha)	1.43	0.12	-	1.00	12590
Wheat + pea (120:45 kg/ha)	1.34	-	1.16	1.40	29500
Wheat + pea (120:30 kg/ha)	1.55	-	0.98	1.42	28240
Wheat + pea (120:15kg/ha)	1.65	-	0.40	1.17	20400
Mean	1.47	0.32	1.10	-	-
SE	0.24	0.07	0.19	-	-*
D.F.	24	12	12	-	-

Source: After Subedi (1997)

3.2.2. *Inter cropping of pea with barley*

The traditional practice of inter cropping pea with barley was verified with a formal field experiment at Lumle (1675 m) and Lopre (2200 m) during 1993 and 1994. Tikot Local pea was mixed with barley at the time of planting without any row arrangements. Bonus and Local variety were the barley varieties grown and seed rates used were 100 kg/ha for barley and 20 kg and 40 kg for pea (Table 5).

Results across two locations for two seasons showed that the barley+pea inter cropping was advantageous in terms of overall grain yield, land equivalent ratio (LER), monetary advantage and economic return and dietary provision in the subsistence farming system (Subedi, 1998b). A combination of Bonus barley and pea at 100:20 kg seed /ha enabled farmers to harvest an additional 400 kg grains per ha from peas.

Table 5. Effects of different inter cropping combinations on the grain yield (t/ha) of barley and pea at Lopre and Lumle for two years (1992/93 and 1993/94).

Treatment (kg of seed per ha for each crop)	**Lopre**				**Lumle**			
	1992/93		**1993/94**		**1992/93**		**1993/94**	
	Barley	**Pea**	**Barley**	**Pea**	**Barley**	**Pea**	**Barley**	**Pea**
Bonus barley pure stand (100 kg/ha)	2.49	-	1.89	-	3.04	-	1.77	-
Local barley pure stand (100 kg/ha)	3.39	-	0.94	-	3.98	-	2.83	-
Tikot Local pea pure stand (60 kg/ha)	-	1.30	-	0.96	-	1.76	-	1.39
Bonus+Pea (100:40 kg/ha)	2.06	0.37	1.94	0.20	3.01	0.45	1.55	0.86
Bonus+Pea (100:20 kg/ha)	2.69	0.34	2.48	0.28	3.01	0.41	1.98	0.91
Local barley+pea (100:40 kg/ha)	2.97	0.36	0.52	0.70	3.21	0.37	2.37	0.90
Local barley+pea (100:20 kg/ha)	2.35	0.29	0.70	0.47	3.39	0.27	2.59	0.43
Mean	2.66	0.50	1.41	0.52	3.27	0.65	2.18	0.90
Sed	0.35	0.41	0.25	0.20	0.35	0.23	0.18	0.24
P	<0.05	<0.01	<0.001	<0.05	>0.05	<0.05	<0.001	<0.05

Source after Subedi (1998b)

3.2.3. *Use of nitrogen fixing bacteria*

Studies on inoculation of legumes seeds with Rhizobium strains were carried out at Lumle. Soya bean (*Glycine max*) inoculated with *Rhizobium japonicum* increased its seed yield by 5-60 % (Sthapit, 1988). Similarly, inoculation of lentil (*Lens culinaris*) seed with *Rhizobium leguminosarum* increased its yield by 15 % (Table 6).

Table 6. Effect of Rhizobium inoculation on the seed yield of lentil at Lumle in 1989

Treatment	**Plants /m^2**	**Pods/plant**	**Nodules/plant**	**Grain yield (kg/ha)**
Non-inoculated	186	32.0	3.0	1143
Inoculated	218	33.0	5.0	1346
Mean	202	32.3	4.0	1245

Source: After Subedi et. al. (1989a).

4. Conclusions

Based on the observation of the problem tree for soil fertility declining in Nepal, depletion of organic matter seems to be the crucial one. The field studies and observations presented here show that there is still room to add more organic matter in the soil and increase crop productivity through integrating locally available resources. These include green manure, relay planting of green manure and inter-cropping of cereal crops with legumes. Inoculation of legumes with Rhizobium is also found to be highly beneficial. For the subsistence farming in the hills of Nepal, these technologies are found to be suitable and contribute substantially to IPNS.

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Nutrient Availability and Nutrient Use Efficiency: Basic concepts for plant nutrient management

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1. Introduction

The main objective of scientific nutrient management is to produce maximum crop yield per unit of nutrient applied in a sustainable manner with least effect on the environment. The nutrient source may be from fertilizer or from what is already in the soil. The knowledge of nutrient availability in soil and the nutrient use efficiency of plants are two major points to be considered for plant nutrient management. Therefore, the paper aims to deal about the concept of nutrient availability and nutrient use efficiency of plants and their effect in economical use of fertilizer and the best utilization of native soil nutrients to get maximum yield as part of integrated plant nutrient system (IPNS).

Nepalese agriculture is basically subsistence agriculture with organic manure as its soul and the tireless hand of farmers as the tool for agricultural production. Since the introduction of chemical fertilizer in 1960s, the use of chemical fertilizer is on an increasing trend. The average national use of chemical fertilizer on nutrient basis is about 30 kg. There is no doubt that the use of chemical fertilizer increases the production but it is a fact that the productivity of major food crops is almost constant for the last three decades. Therefore, it is time for the agriculturists to find the reason behind it.

Although crop production and productivity is a function of many factors, soil fertility status and proper nutrient management are the most important points to be considered to get maximum yield per unit area. A soil containing abundant amounts of available plant nutrient is called a fertile soil. A fertile soil is not necessarily a productive one, because crop productivity is determined by many factors. In the same field one crop or variety performs very well but other crops or varieties fail to do so. It is evident that, the ability of crop plant to uptake and utilize plant nutrients differ not only between the species but also between the different varieties of the same species.

Nutrient availability mainly depends on soil properties and the amount of manure and fertilizer applied. Nutrient use efficiency on the other hand depends on the genetic make up of the plant. Proper knowledge of nutrient availability and nutrient use efficiency not only helps to increase crop production but also to reduce the problem of environmental pollution by over-fertilization. Therefore, the soil fertility (nutrient availability) and the nutrient use efficiency of the crop plant are very important points to be considered for scientific plant nutrient management.

In high external input agricultural system (HEIAS), nutrient availability and use of nutrient responsive crop varieties and species is very important for getting maximum yield. But in adverse soil and resource poor farmer's condition or low external input agriculture system (LEIAS), maximum utilization of local resources and mining the native soil nutrient through use of nutrient efficient crop varieties and species is more important for sustainable production. Therefore, a good knowledge about the concept of nutrient availability and nutrient use efficiency is essential for effective plant nutrient management for high production and low environmental pollution.

2. Nutrient availability

Nutrient availability may be defined as *the ease with which nutrient elements are available to crop plants from soil or other nutrient media*. It is a relative term and does not give any idea about the total quantity of the nutrient that is available to crop plants during crop growth or over a period of time. Therefore, the term bioavailability is used to indicate the amount of nutrient that is actually available to crop plants during crop growth. The bioavailability of nutrients to crop plants depends upon the following factors.

(1) Quantity (extractability):

The portion of the nutrient element that can be taken up by crop plants during crop growth. The period is usually determined by laboratory soil tests using different extractants. It gives the general idea of the fertility status of soils and is known as the quantity factor.

2. Mobility (spatial availability):

Before the nutrient element is taken up by plants, it must move to the surface of the roots. The movement of nutrients to root surface may be brought by three different mechanisms.

- Root interception
- Mass flow
- Diffusion

In case of nutrients with high solubility in water, mass flow alone can supply all the requirements of crop plants, for example calcium, magnesium, sulfur and boron. However, in case of nutrients with low and very low solubility in water, diffusion plays an important role to bring the nutrient elements to the surface of the root. Root interception although not very important, also plays an important role in the transportation of some nutrients like iron, zinc potassium and phosphorus (Table1).

Table 1. Nutrient demand of a maize crop with a yield of 9.5 ton/ha and estimates of nutrient availability from soil by different mechanisms

Nutrients	**Demand kg/ha**	**Amount supplied by kg/ha**			**Remarks**
		Interception	Mass flow	Diffusion	
K	195	4	35	156	Barber 1984
N	190	2	150	38	
P	40	1	2	37	
Mg	45	15	100	0	
Ca	38	66	165	0	Barber and Olsen 1968
S	22	1	21	0	
Cu	0.1	0	0.4	0.01	
Zn	0.3	0.1	0.1	0.1	
Fe	1.9	0.7	1.0	0.2	
Mn	0.3	0.0	0.4	0.1	
B	0.2	0.0	0.7	0.02	
Mo	0.01	0.0	0.02	0.001	

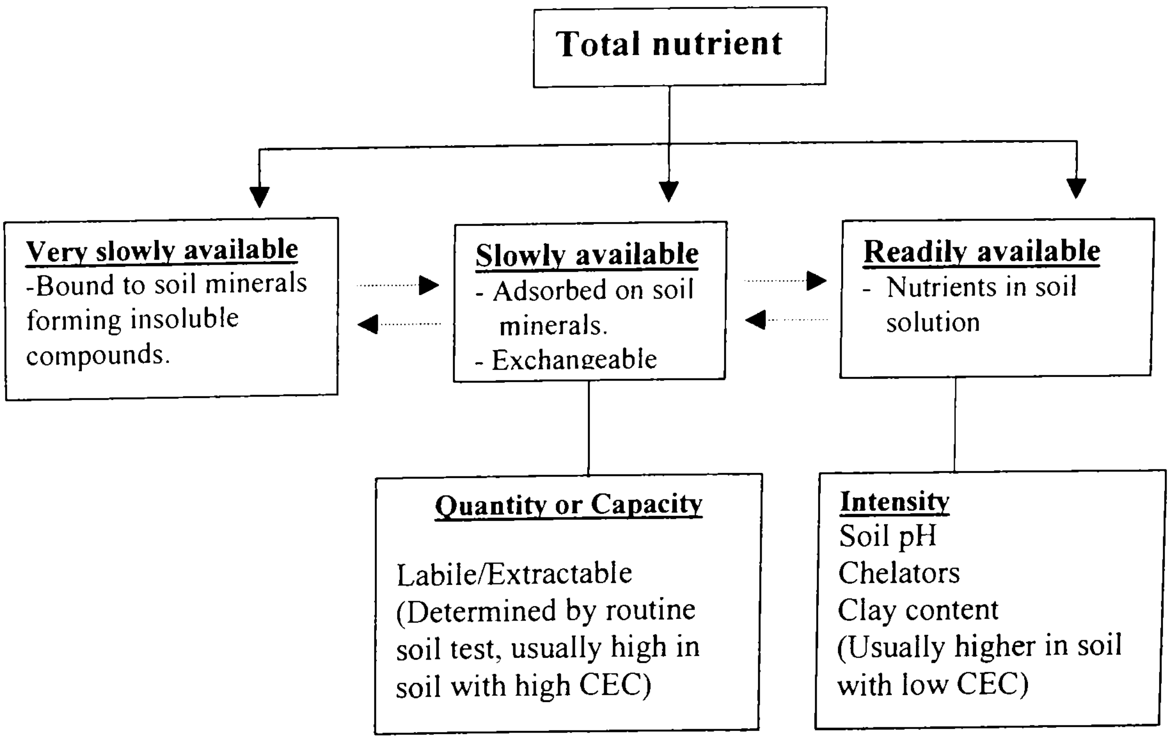
2.1 Total and available nutrients in the soil

Soil is composed of various minerals and compounds. The total amount of particular elements in the soil is always much higher than requirement of crop plants but often plants suffer from nutrient deficiency. This is due to the fact that only a very small fraction of any element present in soil is available to crop plants.

For example a soil containing 0.1% total nitrogen contains about 2000 kg of total nitrogen per hectare of furrow slice. However this soil is categorized as a nitrogen deficient soil because most of the N is in the organic form which becomes available to crop plant only after mineralization. On the basis of ease with which it is available to crop plants, the nutrient element present in soil can be grouped into three categories (Figure1). They are as follows:

1. Readily available (solution phase)
2. Slowly available (exchangeable)
3. Very slowly available (in the form of rocks and minerals).

Figure 1. Nutrients in different pools and bioavailability (Marschner, 1993).



2.2 Factors affecting nutrient availability

The nutrient availability to crop plants mainly depends on soil properties as follow.

2.2.1. Total nutrient content of soil

In general the higher the total nutrient content in the soil the higher is the availability to crop plants. However it is not universal in all conditions. For example the nitrogen availability is directly proportional to the total nitrogen content in soil but in case of phosphorus and other nutrients with low mobility in soils, the available nutrient content is more important than the total content from the viewpoint of plant nutrition.

2.2.2 Moisture content in soil

Plants absorb nutrients from the soil solution. As already discussed, the effective diffusion of different nutrients in soils depends mainly on soil moisture and has a great effect on nutrient availability to plants. The soil moisture plays an important role in nutrient availability in various ways as follows:

- Increases the mobility of nutrient element
- Changes the oxidation-reduction potential in soil, thereby changing the solubility of different compounds.
- Increases the solubility of nutrient elements

Up to a certain level, an increase in soil moisture increases the availability of nutrient elements by increasing the

effective diffusion coefficient (Table 2). However very high moisture content in soil reduces the nutrient uptake creating anaerobic condition for root respiration.

Table 2. Effect of moisture on effective diffusion coefficient of phosphorus and potassium.

Element	Initial		Final	
	Moisture %	D_e	Moisture %	D_e
Phosphorus	19	2.55×10^{-7}	33	6.4×10^{-7}
Potassium	12	0.1×10^{-13}	33	4.45×10^{-13}

Where D_e = Effective diffusion coefficient of nutrient in soil m^2s^{-1}

2.2.3. Soil pH

Soil reaction (pH) affects nutrient availability greatly. The optimum pH range for availability of different nutrients is as follows.

Nutrients	Optimum pH range
N,K,S	5.5-7.5
P	6.5-7.5
Ca, Mg	>6.5
Fe, Cu, Zn and Mn	5.5- 7.0
B	5-7
Mo	5.5-7

In addition to modifying nutrient availability, soil pH also has great effect in microbial activity and modifies the nutrient availability to plants.

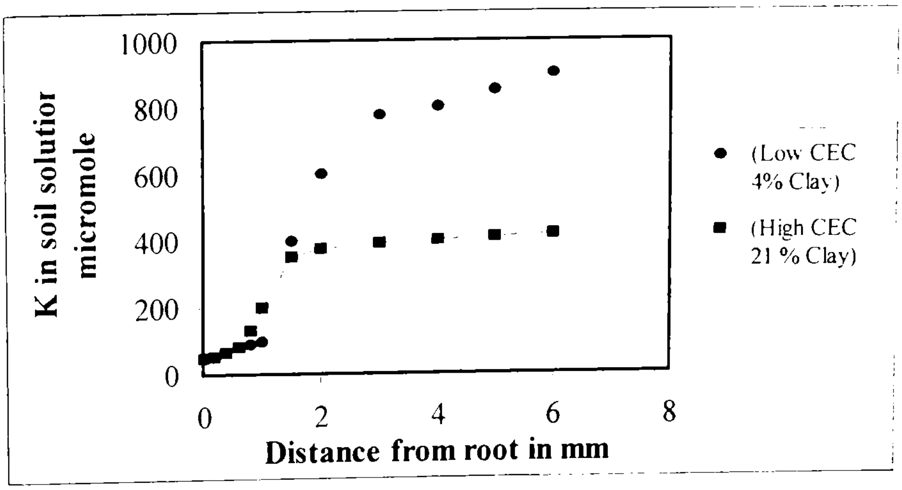
- Nitrate (NO_3) and Phosphate (PO_4) uptake is higher in slightly acidic soil. Phosphate (PO_4) uptake is highest at pH 5.6. Cation uptake is higher in neutral and slightly alkaline soil.
- Phosphorus fixation is high in very low or very high pH soil.
- Toxicity of Al, Fe, Mn, Cu and Zn may occur in very low pH soil.
- Very low pH restricts microbial growth.
- Low pH inhibits nitrification and symbiotic nitrogen fixation.

2.2.4. Soil texture and structure

Good soil structure favors root growth and extension thereby increasing the volume of soil exploited by roots for nutrient uptake. At a particular water potential, clay soils contain more water volumetrically than sandy soils. Therefore at a particular water potential, effective diffusion coefficient and availability of nutrient elements are higher in clay soils. At -33 kPa (water potential) the volumetric soil moisture in clay and sandy soil is 0.13 and 0.4 g/cm^3 and the Phosphorus uptake by plants is 200μM and 10μM, respectively.

Moreover, because of high cation exchange capacity, clay soils have more exchangeable nutrients and nutrient supplying capacity than sandy soils (Figure 2). The soil with a low CEC has a higher potassium concentration in soil solution than a soil with a high CEC. However, the relative K-depletion near the root zone is more in soils with low CEC. This indicates that the total available nutrient content is more in soil with high CEC in spite of its lower concentration in the soil solution.

Figure 2. Effect of soil type on potassium depletion in the root zone (Classen and Jungk, 1982 referred by Marschner, 1986).



2.2.5. Organic matter content

Major functions of organic matter are as follows:

- Organic matter acts as nutrient reservoir.
- It has a high water holding capacity.
- It has a high buffering capacity and helps in ameliorating acidic or alkaline soils.

Because of all these properties, a soil with high organic matter content has more available nutrient and is more productive than that with low organic matter.

2.2.6. Microbial activity

Major functions of microbial activity are as follows:

- Nutrient transformation
- Decomposition of organic matter
- Symbiotic and non-symbiotic N fixation.
- Solubilization of insoluble compounds.

The nutrient elements in soils are either bound to organic matter or in inorganic compounds and only a small fraction is readily available to crop plants. The microbes in soils help in the decomposition of organic compounds and solubilizing them. Thereby unavailable nutrients are made available to crop plants. Some symbiotic and non-symbiotic organisms help in fixing elemental nitrogen and make it available to crop plants.

2.2.7. Extra cellular enzyme activity

Soils contain various extra-cellular enzymes, which help in the break down of organic compounds and increase availability of nutrients to crop plants. A good example is the direct relationship between the availability of organic phosphorus to plants with the phosphatase enzyme activity in soil.

2.2.8. Ionic composition of soil solution

Soil solutions contain various nutrients in ionic form. The composition of ions in soil solution greatly affects the availability of nutrient elements to crop plants. Increase in iron in soil solution reduces zinc availability. Calcium reduces the availability of potassium and magnesium.

2.3. Measurement of nutrient availability:

Various techniques can be used to measure the nutrient requirements of crops as follows.

- Field plot technique.
- Soil test (Routine analysis)
- Plant analysis
- Culture technique
- Histological and Histochemical test

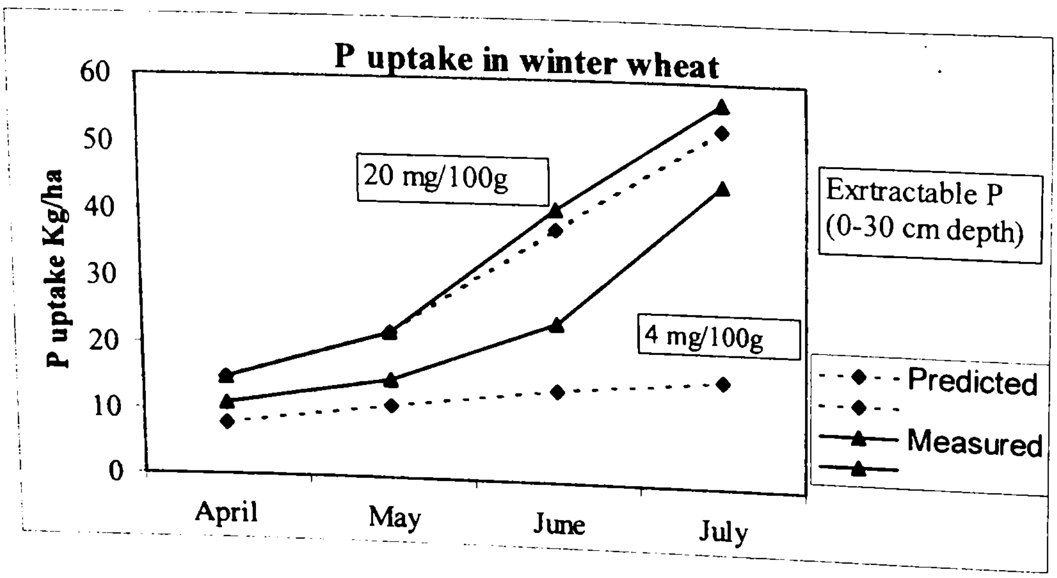
Field pot techniques give very good results about nutrient availability in soil but they take a long time and are very expensive. In general soil and plant analysis in laboratories is done to measure the nutrient status of plant and nutrient availability in soil. In most of the cases, they give very good results. However, it is always better to measure the accuracy of laboratory results.

Different methods can be used in laboratory procedures. Different extractants extract different amount of nutrients from the soil (Table 3). Under ideal condition laboratory reports closely match with the nutrient availability in soils and nutrient uptake by crop plants but under stress condition plants have the ability to uptake more nutrients from soils than predicted by laboratory analysis (Figure 3). Therefore, laboratory analysis of soils only gives a relative indication of nutrient availability, hence cannot be relied on under all circumstances.

Table 3. Content of readily available P in 40 soils extracted with various solutions (Williams and Knight, 1963)

Extraction solution	**Readily soluble P (mg/100 g air dried soil)**
Neutral NH_4F (pH7.0)	14.8
Acidic NH_4F (pH <2)	7.4
Truog H_2SO_4 + $(NH_4)SO_4$ pH 3	3.6
Acetic acid pH 2.6	2.5
NaHCO3 (pH 8.5)	2.4
Calcium Lactate (pH 3.8)	1.2

Figure 3. Phosphorus (P) uptake of winter wheat in a long term field experiment under 100 kg P/ha or without P fertilizer (after Jungk and Classen, 1989 referred by Marschner, 1986)



Culture techniques using certain microorganisms are also in practice to measure nutrient availability in soil. Growth of microorganisms in the soil sample to be tested gives very good indication about the status of nutrients under study in the given soil. But in Nepal this method is not in practice.

Nutritional disorders are generally related to typical changes in the structure of cells and their organelles. Similarly increase or decrease in the activity of certain enzymes are also related to the nutritional disorders in various plants. Therefore, histological and histochemical methods are also helpful in determining the nutrient status of plants and nutrient availability in soil. For example nitrogen (N) deficiency results in reduced nitrate reductase activity and Phosphorus deficiency increases phosphatase activity within plants and exudation of extracellular phosphatase. Similarly changes in anatomy and morphology of leaf tissue is common as a result of deficiency of copper, boron and molybdenum.

Soil test (routine analysis) is a common practice to identify the fertility status of soils and for fertilizer recommendation. Routine analysis of soil indicates the nutrient availability status of the soil. It is a qualitative measurement and does not consider the total quantity of available nutrient and nutrient dynamics in soil. Therefore, routine soil analysis alone (specially under adverse soil condition) may not be enough to measure the nutrient availability for fertilizer recommendation. Therefore, Diagnosis and Recommendation Integrated System (DRIS) has been developed taking all possible criteria (soil, plant and agronomic management) into consideration for fertilizer recommendation.

3. Nutrient use efficiency of plants

It may be defined as the ability of plants to uptake and utilize nutrients from soils and to produce economic yield per unit of nutrient applied. However, from a physiological point of view it may be defined as the ability of crop plants to produce dry matter per unit of nutrient absorbed.

In low input agriculture system, crops that are able to uptake nutrient from very low nutrient solution are called more efficient. But in high input agriculture system the crop with ability to uptake more nutrients from the media and ability to produce more economic yield per unit of nutrient absorbed are called more efficient. Therefore, in both high as well as in low input agriculture system nutrient use efficiency is very important from the viewpoint of nutrient management.

Plants have ability to adapt themselves under nutrient stress condition. The difference in the ability of plant to adapt to nutrient stress condition has been observed not only between species but also between different varieties of the same species. The mechanisms of how plants adapt themselves under different nutrient situation are given in Table 4.

*Table 4. Characteristics of strategies of wild plants in adaptation to soils with low or high nutrient availability**

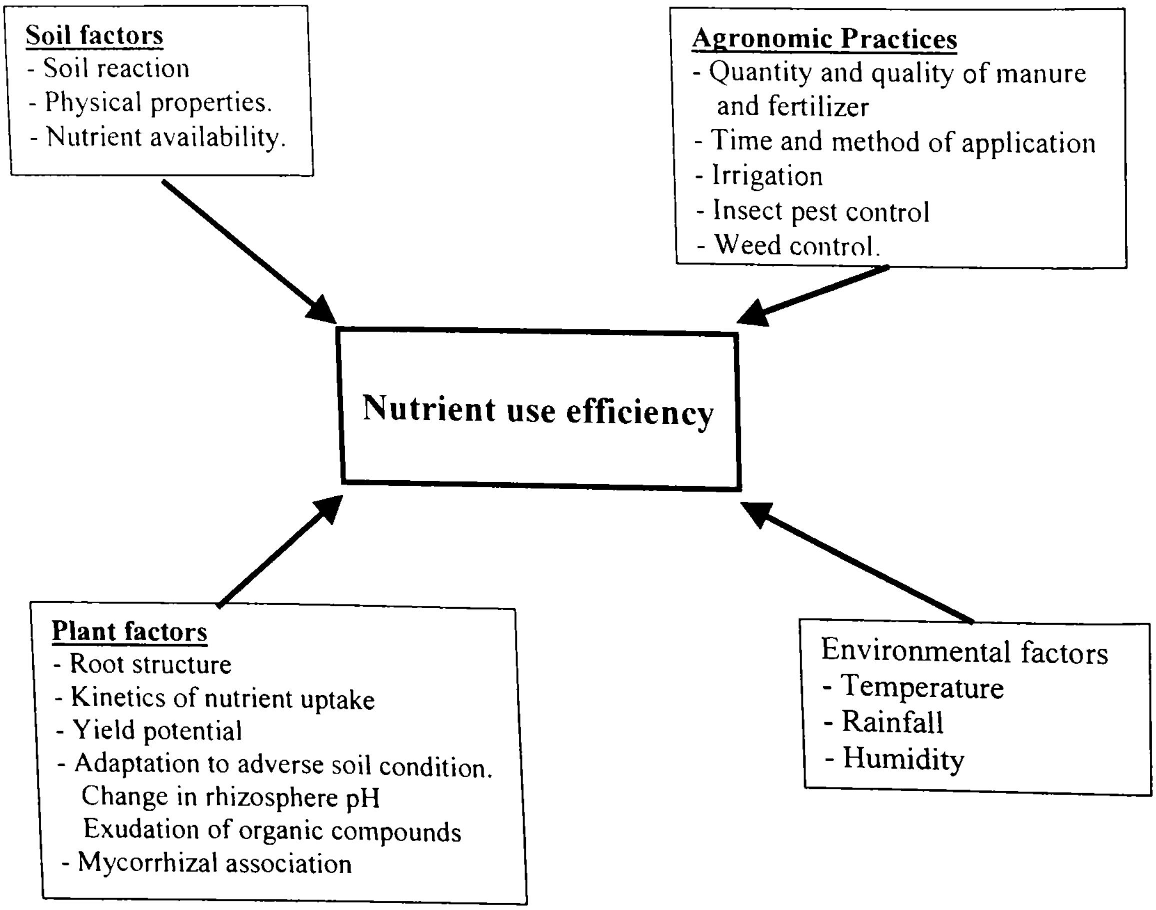
Nutrient availability	Type I (slow growers)	Type II (ruderal species)
Low (Nutrient Poor Sites)	Low nutrient uptake rate Low growth rates of root and shoot High root/shoot ratio High nutrient concentration in the tissue	Low growth rates Low nutrient storage High root/ shoot ratio
High (Nutrient rich sites)	Small growth response of roots and shoots High nutrient storage (Luxury consumption) Low nutrient use efficiency	High nutrient uptake rate High growth rate High nutrient use efficiency Decrease in root/shoot ratio

*Based on Chapin 1980, 1988

3.1. Factors affecting nutrient use efficiency

Nutrient use efficiency of plants depends on various factors (Figure 4). Although all of these factors influence the nutrient use efficiency of plants, the genetic make up of plants (plant factor) is most important among them and will be discussed in detail here.

Figure 4. Factors affecting nutrient use efficiency



3.1.1 Plant factors affecting nutrient use efficiency are as follows:

Yield potential

Nutrient use efficiency may be classified in two categories, efficiency in uptake, and efficiency in internal utilization. Usually high yielding varieties of crops are more efficient in nutrient utilization within plants. Therefore under high input agricultural systems and normal soil conditions these crops and varieties perform better than their low yielding counterparts. But in adverse soil conditions (soil reaction and nutrient stress), efficiency in nutrient uptake is more important than internal utilization. Under adverse soil condition traditional low yielding varieties of crops may yield better than high yielding varieties.

Kinetics of nutrient uptake

Threshold concentration: It may be defined as the lowest nutrient concentration in soil solution when the net nutrient uptake is zero. The crops and varieties with low threshold concentration are more efficient to uptake nutrient from nutrient poor soil. It is a very important criteria for selection of plants under nutrient stress condition.

Affinity parameter: It may be defined as the nutrient concentration in soil solution when the maximum nutrient uptake rate is half of the maximum uptake rate. In general the crop and varieties with low affinity parameter are more efficient in nutrient uptake under abundant nutrient supply. This parameter is more important for selection of plant under high input agriculture system.

Root structure

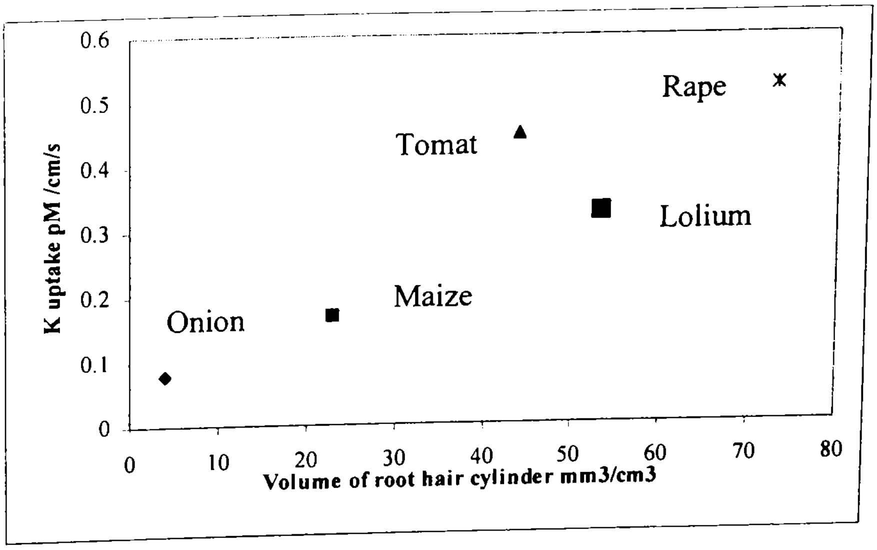
Root volume and root surface area are the two most important criteria determining the nutrient uptake rate. In general finer roots are more efficient in nutrient uptake. Decrease in root diameter increases the total root surface area per unit volume, which is directly proportional to nutrient uptake rate (Table 5).

Table 5. Estimates of proportion of soil (sandy loam) contribution to the P and K contribution of field grown maize (Fusseder and Krauss, 1986)

Root length density (cm/cm^3)	**Proportional contribution %**	
	P	K
> 2 (cm/cm^3)	20	50
< 2 (cm/cm^3)	5	12

Plants with longer roots and a higher roots to shoot ratio are more efficient under stress condition. Similarly the volume and length of root hairs has also a great effect in the nutrient uptake from soils. Root hairs are specially important in nutrient uptake under low moisture condition. In most instances the length and volume of root hairs is found to be directly related to the nutrient uptake by plants (Figure 5).

Figure 5. Rate of K uptake per unit length of root in relation to the volume of the root hair cylinder (Plants grown in silt loam soil with 21 % clay) from Jungk et.al. 1982



Adaptation to adverse soil condition.

Change in rhizosphere pH and the exudation of organic compounds are the major factors. Plants have the ability to adapt themselves under stress conditions. Changes in rhizosphere pH and exudation of different organic compounds in mobilizing the unavailable phosphorous is reported by many workers. This property is very important for selecting plants under adverse soil condition to increase the nutrient availability and nutrient uptake by plants.

3.1.2 Mycorrhizal association

Certain fungi live in association with plant roots and help in acquisition of nutrient by crop plants. Such beneficial associations have been found to be vital in tress and many other plants. Efforts have been done to exploit the fungal association with plants in nutrient management and have yielded very promising results. Therefore, isolation and inoculation of effective mycorrhizal fungi may prove to be an important tool in plant nutrient management. The effect of inoculation of vesicular arbuscular mycorrhiza (VAM) in three different grass species is presented in Table 6.

Table 6. Shoot dry weight of 3 alfalfa cultivars with or without VAM at different levels of P supply

Soil Treatment		Shoot dry weight (mg/plant)		
mg P/Kg	**+/- VAM**	**Buffalo**	**Chrokee**	**Du Puits**
0	-	22	18	32
20	-	114	235	375
80	-	2389	2058	2115
0	+	1113	1740	2177

Note: Plants were grown in P deficient soil pH 7.2 (Lambert et.al. 1980)

In all three grass species mentioned in Table 3, VAM inoculation without phosphorus application increased the total biomass production, indicating that mycorrhizal association could greatly help in phosphorus nutrition of plants.

From the above discussion it is clear that the nutrient use efficiency of plants is a very important point to be considered for plant nutrient management. There are reports that, simply by selecting crops and varieties yields can be increased to a great extent without addition of extra inputs specially under adverse soil condition (Table 7). In the Philippines an increase in rice yield from 1.8 ton to 2.7 ton per hectare was recorded from selection of efficient cultivars under different stress condition.

Table 7. Grain production of rice genotypes with different degree of adaptation to adverse chemical soil condition in farmers' field in the Philippines 1977-1988

Soil condition	No of Cultivars studied	Mean grain yield (ton/ha)		
		Farmers cultivar	**Selected cultivar**	**Advantage ton/ha**
P deficiency	336	2.2	4.9	2.7
Zn deficiency	411	1.8	4.4	2.6
Fe deficiency	89	0.9	2.8	1.9
Salinity	120	1.4	3.4	2.0
Alkalinity	103	0.8	3.4	2.6
Iron Toxicity	104	2.2	4.1	1.9
Al/Mn toxicity	44	1.2	3.0	1.8

Source: Neue et.al. 1990

4. Conclusions

There are two options to increase agricultural production, that is either by increasing the use of fertilizer and other inputs or by use of efficient cultivars that perform well even under adverse soil condition. In the twenty year

agriculture persepective plan fertilizer is one of the key component to increase agriculture production. But in a resource poor country like Nepal, increasing yield by increasing the fertilizer and other input is very difficult to realize, if not impossible in some areas. Therefore, we must look for other options to face the challenge of increasing the agricultural production and soil fertility management.

Utilization of locally available organic manures and selection of efficient crops and varieties that perform well under adverse soil condition along with the rational use of chemical fertilizer is vital for increasing the agricultural production under Nepales context.

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Concept of Integrated Plant Nutrient System and its Model for Sustainable Soil Management

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1. Introduction

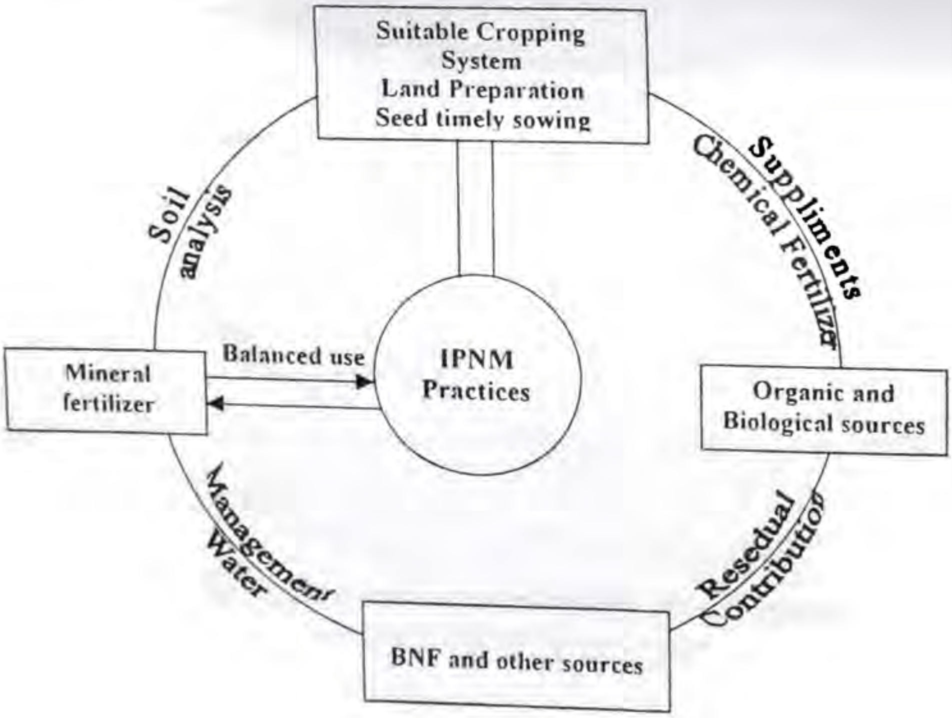
Increasing food production to meet the needs of increasing population is a major challenge facing the world today. Asia's population of 3.4 billion people constitute almost 64% of the world population. During the last 2 to 3 decades most Asian countries have been successful in increasing food production to keep pace with the increasing population. This has been achieved mainly through the use of high yielding crop varieties, improved irrigation and increased use of chemical fertilizer.

Although the use of chemical fertilizers is the quickest way of increasing crop production, it is not advisable to depend only on chemical fertilizer because of their rising cost, unavailability, and improper use. Hence a combination of mineral fertilizer all locally available organic and biological sources of plant nutrients are recommended. Such combined application of organic materials improves the physical and biological characteristics of soils by increasing water retention properties and the activity of microbial biomass. Thereby it increases the efficiency of added chemical fertilizers. As defined by FAO (1995) the basic concept of integrated plant nutrition management (IPNM) is as follows:

> *The maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity through the optimization of the benefits from all possible sources of plant nutrients in an integrated manner.*

In other words it is an appropriate combination of mineral fertilizer, organic manure, biofertilizer, crop residues, etc, with crop rotation, soil conservation and agronomic practices, including water management (Figure 1).

Figure 1. System approach to IPNM



The overall purpose of IPNM, therefore, is to supply and manage the required plant nutrients from different sources on a sustainable basis. In principle, it should embrace a total management plan, based on balance sheets within a watershed. Use of fertilizers, manure, biofertilizer, crop residues, legumes and reduction of losses such as leaching, gaseous losses of ammonia, erosion losses, crop removal, etc. must be considered. Thus, IPNM should focus on the farming system as a whole. We can also say that it is a balance between organic and inorganic fertilizers, traditional and modern technologies, and agriculture and the environment.

2. Components of integrated nutrient management

2.1 Soil Sources

Soil supplies all 16 essential plant nutrients. Most nutrients are found in organic and or fixed mineral form. Plants can meet much of its nutritional requirement from this source if managed properly. However, due to continuous and intensive cultivation the nutrient supplying capacity of soils has decreased considerably corresponding to a general decline in organic matter content of agricultural soils. Therefore, under intensive agricultural systems, special emphasis has to be given to maintaining the nutrient status of the soils and to prevent soil degradation. The soils of Nepal are generally low in organic matter and total nitrogen. They are poor in available phosphorous but have adequate levels of potassium.

2.2 Sources of nutrients and biofertilizers

Biological nitrogen fixation occurs through bacteria or Azolla in wetlands. They convert nitrogen from the air freely or in symbiosis with leguminous crops, shrubs or trees. Potential nutrient sources are as follows:

Azotobacter: Recommended for cereal crops in the higher hills in association with organic manure. Yield increases of 3-29 percent are expected. It is not useful in combination with mineral fertilizers.

Rhizobium: Recommended for pasture and grain legumes. A number of effective strains are identified and distributed. Yield increases of 10-70 percent are expected in legumes. It can have significant residual effects on soil fertility for succeeding crops. It is estimated that legumes such as soybean, chickpea, lentil derive 50-100 percent of its requirements from the atmosphere. The Division of Soil Science, NARC, distributes about 10,000 packets (200 gm each) of *Rhizobium* inoculant annually. In India, government institutions, universities and private enterprises are involved in the development of bacterial and algal biofertilizers. Efficient nitrogen-fixing strains have been developed. At present about 800 t of rhizobial biofertilizers are produced and distributed. In addition, 15 million ha or rice-land are inoculated with blue-green algae. However, these efforts are still under research and at the pilot-plant stage under the name of Bio N (Azotobacter, Azospirillum) and Nitrogplus *(Rhizobium)* (Biswas 1994).

Mycorrhiza: In Nepal, work on mycorrhizal inoculants is still at the research stage. However mycorrhizal products are commercialized in India, the Philippines and Thailand. Mycorrhizal cultures are used in cereal and vegetable crops. Mycorrhizae are associations between soil fungi and plant roots. Approximately 1267 genera of mycorrhizal fungi have been isolated. The most important species are *Glomus, Gigaspora* and *Acaulospora*.

Organic manure: A package on better methods of farmyard manure (FYM) compost preparation, storage and application is available. Also, technology for rapid composting (20-30 days) thorough the use of fungi *(Trichoderma)* is available. There is ample information on the synergistic effect of the

combined use of organic manure, fertilizers, and green manure on various crops. Responses to 5 t/ha of poultry manure, 20 t/ha of FYM/compost and 100:40:30 kg/ha of NPK fertilizer were found comparable. Improvement in quality of compost using various micro-organisms is worth exploring.

Legumes in rotation: Incorporation of legumes into the cropping system is beneficial. It is reported that legumes, at about a yield level of 1 t/ha, can provide a residual 20-40 kg/ha of N to succeeding crops. This depends on the quantity of biomass returned to the soil.

Inter cropping of maize with legumes is a common practice in the hills of Nepal. However, the introduction of high-yielding varieties of maize and the use of chemical fertilizers mean that inter cropping of legumes with maize is decreasing. In some districts, legumes are relayed with maize and, in western Nepal, relaying of lentils with rice is common.

Green manure: About 30-60 kg N/ha can be supplemented through green manuring with *Sesbania canabina* in rice crops. Several plants have been identified as potential green manures. *Azolla,* a water fern, can be used where water management is good.

Inorganic fertilizers: Ample information has been generated in fertilizer use and crop responses. Increased fertilizer efficiency through integration with organic sources, balanced use, better methods of application and soil amendments should be given priority. Fertilizer recommendations for the major crops of Nepal on the basis of crop responses and soil analysis are given in Table 1.

Table 1. Fertilizer recommendations for major crops in Nepal.

Crop and variety	**Optimum dose (kg/ha)**			**Expected yield (kg/ha)**
	N	**P_2O_5**	**K_2O**	
Rice (improved)	100	30	30	3811
Rice (local)	40	20	30	2541
Wheat (improved)	100	40	30	3287
Maize (improved)	120	50	40	3359
Barley (improved)	60	30	30	2479
Sugarcane (improved)	120	60	60	65300
Jute (improved)	60	30	40	3231

3. IPNM demonstration

3.1 Objectives:

- To develop fertilizer recommendation based on cropping systems in integrated use of mineral fertilizers with crop residues, green manures, BNF sources and organic manure for sustainable crop production in major agro-ecological zones of the country.
- To monitor the soil physical and chemical changes brought about by the incorporation of organic matter in soils on a long-term basis.
- To make an economic analysis of crop production by the integrated use of inorganic and organic sources of plant nutrients in cropping system.
- To increase fertilizer use efficiency and reduce nutrient loses.
- To promote the adoption of improved farming practices under IPNMS acceptable to farmers.

The above objectives will be met through local resources based IPNM trials and training activities.

3.2 Trials

Trials should be based on nutrient requirements of crops in specific cropping systems as shown in Table 2. Based on crop requirements, the tentative dose of nutrients required for a system can be calculated (Table 3).

Table 2. Nutrient requirements of crops for specific yield levels in a 3-year cropping system

Expected yield / Plant nutrients required	Cropping sequence						
	Rice	**Potato**	**Maize**	**Rice**	**Wheat**	**Maize**	**Potato**
Expected yield kg/ha	3	20	3	3	2	3	20
N kg/ha	50	140	72	50	56	72	140
P_2O_5 kg/ha	26	40	35	26	24	35	40
K_2O kg/ha	80	200	55	80	67	55	200

Table 3. Approximate amounts of nutrients to be applied in an IPNM trial on a 3-year cropping system.

Expected yield / Plant nutrients to apply	Cropping sequence						
	Rice	**Potato**	**Maize**	**Rice**	**Wheat**	**Maize**	**Potato**
Expected yield kg/ha	3	20	3	3	2	3	20
N kg/ha	100	140	120	100	100	120	140
P_2O_5 kg/ha	40	40	60	40	40	60	40
K_2O kg/ha	40	200	40	40	40	40	100

A nutrient-use efficiency of about 40-50% was assumed for the applied N and P in Table 3, except for potato, which often receives large amounts of organic N. For potassium, about 50% of the required amount may need to be applied, as most soils in Nepal are rich in K.

4. Recommendations

The following recommendations can be made for IPNM in Nepal:

- Improvement of composting technology
- Utilization of farmers' indigenous knowledge
- Promotion of high-value crops
- Promotion of agroforestry (fodder tree crops) and methane gas plants
- Promotion of soil and water conservation practices in agricultural lands
- Building on indigenous knowledge and skills
- Increasing farm incomes
- Reducing soil erosion
- Supporting biomass regeneration and livestock development
- Incorporating legumes into the farming system
- Increasing water availability
- Optimizing external inputs such as fertilizers
- Improving compost quality
- Exploring and promoting production of organic fertilizers on a commercial scale
- Increasing nutrient-use efficiency
- Maintaining/enhancing agricultural productivity as well as environmental stability
- Agro-ecological zone model sites should be established for farmers, participatory innovations, verifications, training and demonstration of integrated soil fertility and plant nutrition management practices

- IPNM trials/demonstrations should be designed to assess the plant nutrition balance sheet of dominant farming systems
- Farmers should be motivated and organized to promote biomass-centered, local-resource-based and regenerative soil fertility management practices in combination with mineral fertilizers

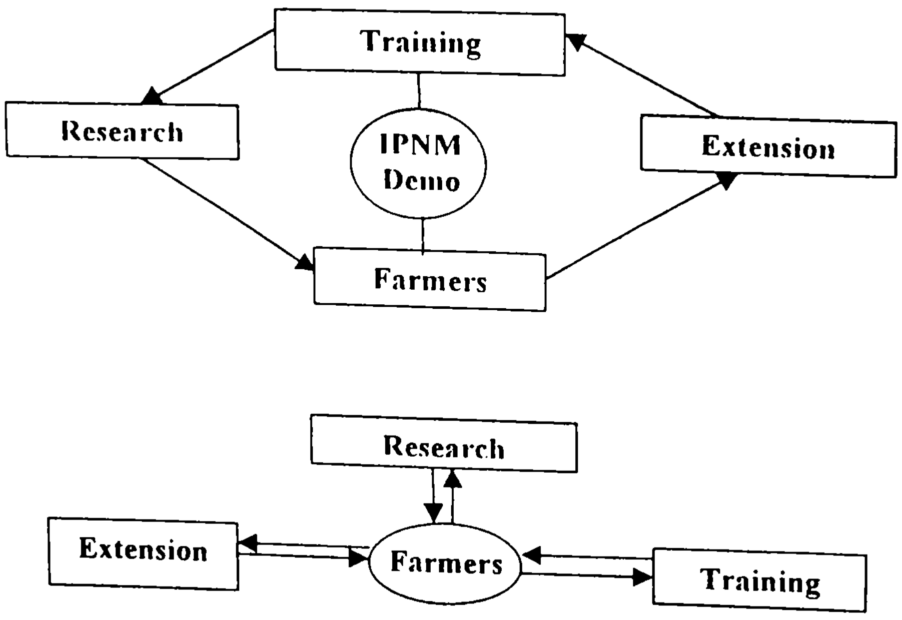
5. Conclusions

The integrated nutrient supply and management through judicious use of organic, mineral and microbial fertilizers will lead to balanced nutrient supply. The complimentary use of various sources of nutrients is advantageous as it helps to improve fertilizer use efficiency and improves the cost benefit ratio. The combined use of organic manure and bio-fertilizers with chemical fertilizer helps to maintain soil productivity and soil health even under intensive cropping systems.

If is therefore, possible to increase productivity with the complimentary use of organic manure, bio-fertilizer and mineral fertilizers instead of using mineral fertilizer alone. The organic manure application also helps recycle the nutrients and corrects deficiencies of micro-nutrients.

Farmers need to be educated in the integrated use of plant nutrients. Strong collaboration between research and extension is needed to demonstrate the IPNMS technologies suitable for different agro-ecological condition (Figure 2).

Figure 2. Promotion of IPNM in a joint efforts among farmers, extension and research



Development of an Integrated Plant Nutrient System (IPNS) for Sustainable Soil Management in the Mid-hills of Nepal

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1 IPNS in research and extension

Integrated Plant Nutrient Systems (IPNS) are a reality in hillside farms as well as an ideal yet to be achieved:

- Farmers manage IPNS in their traditional farming through biomass collection, biomass-transformation in livestock systems, inter cropping, organic-inorganic fertilizer combinations and several other practices.
- Researchers define IPNS as a "goal to combine all sources of fertility enhancement and to manage the nutrient transformation and cycling processes in the most efficient way for land productivity and sustainability". IPNS is also referred to as Integrated Soil Fertility Management (ISFM).

The difference lies primarily in the following:

- Efficiency: Research quantifies nutrient flows and pools, and identifies leakage and opportunities. Farmers concentrate on input/output relationships without fine-tuning the system for IPNS-efficiency. However, they may fine-tune the system for the most efficient water-use or for the most efficient labour utilization depending on local priority.
- Biomass availability: Research and extension include biomass sources such as legumes, weed biomass or defined amounts of FYM-inputs per area of land into their recommendations. For farmers, biomass is always scarce and the use of the available biomass for soil, livestock and household compete with each other.
- Input availability: Research and extension include external inputs such as NPK-fertilizers, lime or micro-nutrients into the recommendations. However, they are accessible only in limited areas and the crop response may not pay the investment.
- Organic matter dynamics: IPNS is rooted in a conventional concept of modern agriculture, i.e. feeding the plant and balancing mineral nutrient supplies. It is only recently that soil processes and the management of organic matter have attracted equal importance for IPNS. The findings are of importance for the mid-hills. However, the methods to measure these processes and our understanding of how to balance OM-dynamics are still deficient.

Thus, we are confronted with a dilemma: Farmers in the mid-hills may be a generation behind the green revolution technology, which combined mineral fertilizers, irrigation and input-responsive crop varieties into one package. However, mid-hill farmers may be a decade ahead of science in developing locally appropriate systems of OM-management. There is no doubt that the efficiency and productivity of these systems can be improved. However, this is unlikely to be achieved through the introduction of packages of improved inputs and standard recommendations. The challenge of IPNS in the mid-hills may be stated as follows:

Develop together with farmers locally appropriate IPNS, which brings together local and new knowledge and contributes to the design of productive and sustainable land management systems.

The following are considered essential elements in the development of IPNS for the mid-hills:

(1) IPNS needs to be based on scientific evidence. However, the nature of IPNS as an integrated systems approach also exposes the limitations of trial-based research for the development of IPNS.
(2) IPNS cannot be based on standard recommendations based on soil and plant analysis. Soil analysis contributes to an understanding of the resource base, but the design of Integrated PNS requires a broader view on the overall natural resources and farming systems.
(3) The diversity of farming systems across the mid-hills is too wide and too spotty to be analyzed and adequately described by research or recommendation domains. IPNS will remain to a large degree a

concept to be promoted and a goal to be achieved. It will become reality if farmers take it into their hands. This requires a focus on enhancing farmers' knowledge on soil processes and nutrient use efficiencies.

(4) IPNS can be seen in the context of sustainable agriculture as part of ecosystem management. This implies bringing agricultural land use and management as close as possible to the natural ecosystem.

This paper tries to outline the basis for the development of IPNS for mid-hill farming systems as follows:

Chapter 2: A systems' perspective for IPNS
Chapter 3: Scientific evidence and opportunities for IPNS
Chapter 4: Example for an IPNS in the mid-hills
Chapter 5: Recommendations for action

2 Systems' perspective for IPNS

IPNS is location-specific. Characteristics of the locally prevailing farming system and the resource endowment form an integral part of IPNS.

2.1 Macro-level systems

Farming systems vary widely across the mid-hills. The differences are roughly due to three main factors:

- the underlying resource base (soil, climate, topography) varies widely,
- socio-economic conditions determine farmers' decisions between localities (e.g. market access, population density, land ownership)
- agronomic management varies by characteristics of individual farms and farm families.

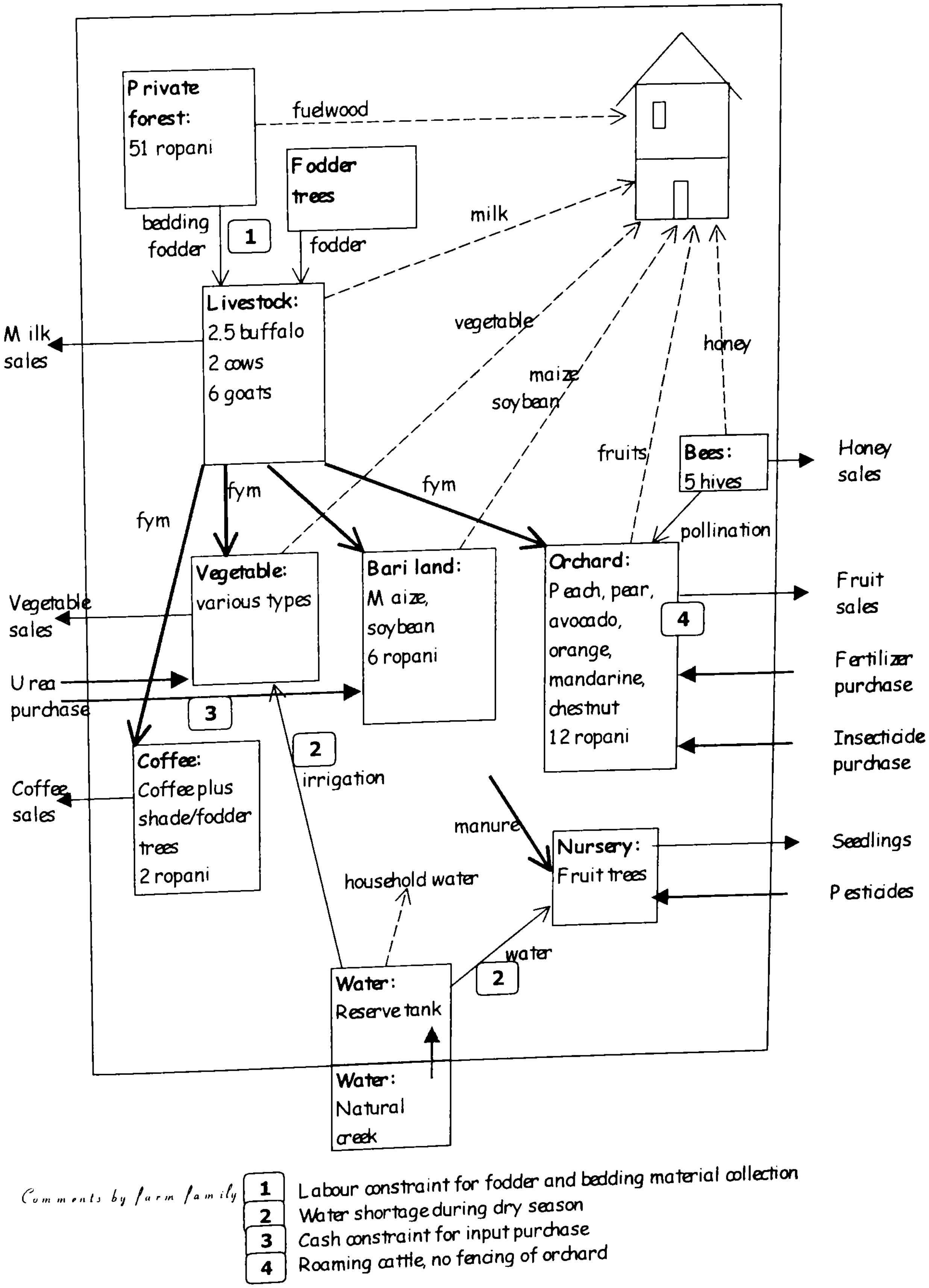
We can therefore analyze and describe systems at the macro-level based on the predominant soils, topography, climate and land-use patterns. This has been done in the Land Resources Mapping Project (LRMP) and is being developed further by a number of organizations (NARC, NPC, DWMSC, PDDP,...) including STSS for soil fertility mapping. GIS-systems facilitate this work. They contribute to the establishment of agricultural information systems, which increasingly become useful tools for policy decisions. A coordinated effort to make these different efforts compatible is urgently needed. These efforts may contribute to a macro-level targeting of different IPN-Systems to specific environments.

2.2 Micro-level systems

The underlying resource base, including soils and socio-economic conditions, determine to a certain degree the problems and opportunities of the individual farm system. However, neighboring plots may have different slope and fertility, farms differ in size and resource endowment (e.g. water access) and farmers differ in their interest and limitations. These micro-level factors determine the individual farm system and the Integrated-PNS for the farm.

Macro-tools such as GIS, soil mapping, and recommendation domains are not designed to describe the complexities of individual farm management. They may guide the decision process. Specific tools for support of decision-processes at the micro-level are needed to enhance the decision process of individual farmers towards IPNS. This is the challenge of extension. Figure 1 describes the complexity of an individual farm in Kavre district.

Figure 1. Components and inter-relationships in a farm system
Example of a moderate sized farm with good market access in Kavre district



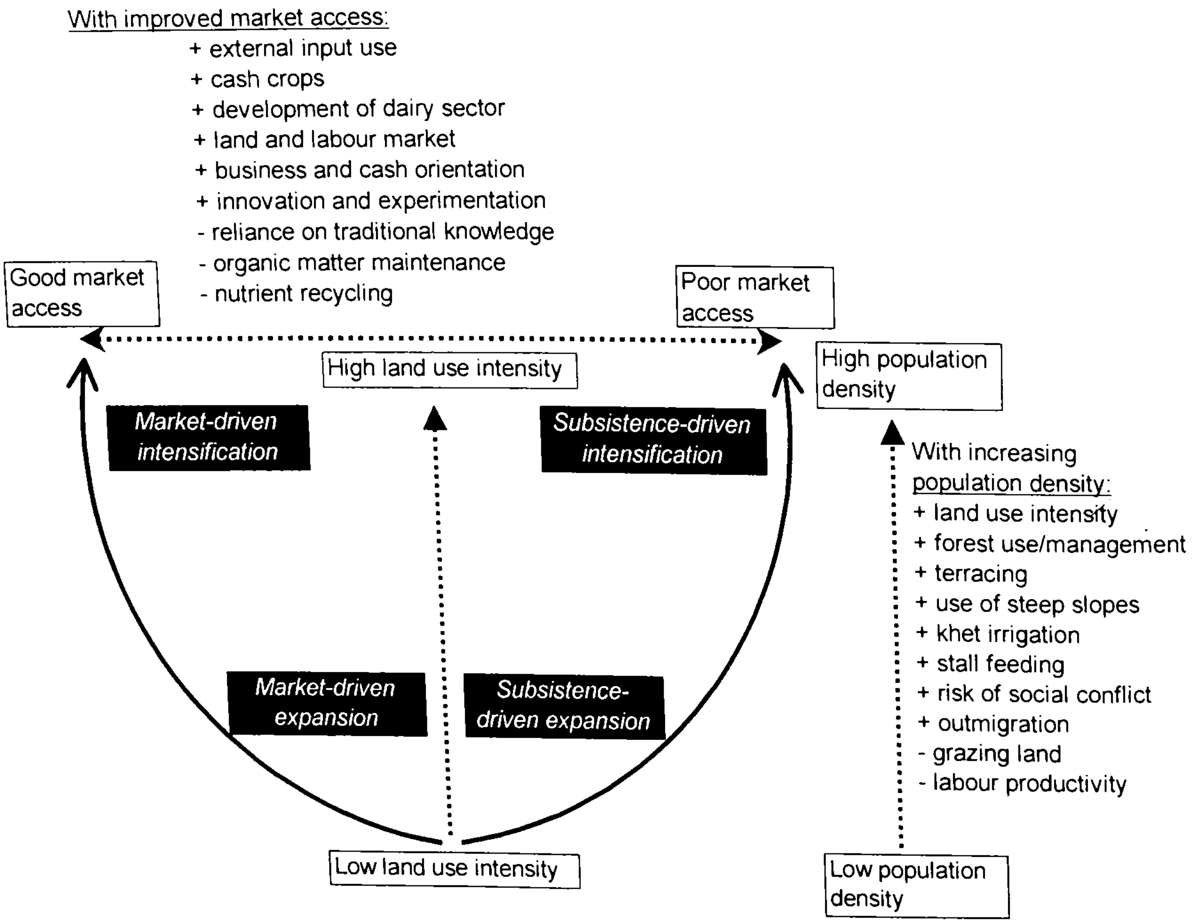
2.3 System change

Farming systems are not static. They change over time. The Agricultural Perspective Plan (APP) is a policy document for promoting change in farming systems. Thus, IPNS in the context of sustainable soil management is not only the appropriate management of present soil systems. It implies foreseeing change and putting the coming change of farming systems on a sustainable footing. We can do this only if we can predict system change and its implications.

Figure 2 shows an attempt to analyze the ongoing changes in mid-hill farming systems. All areas started some time ago at a level of low land use intensity and low population density. As population density has increased exponentially over the past decades, it is now moderate to high in most mid-hill areas.

More recently, there is an additional change towards more market-driven intensification in the mid-hills. This trend is mainly based on the expansion of the urban consumer population and the development of transport infrastructure. The APP identifies this change from population-driven to market-driven systems as a major focus of agricultural development in the country.

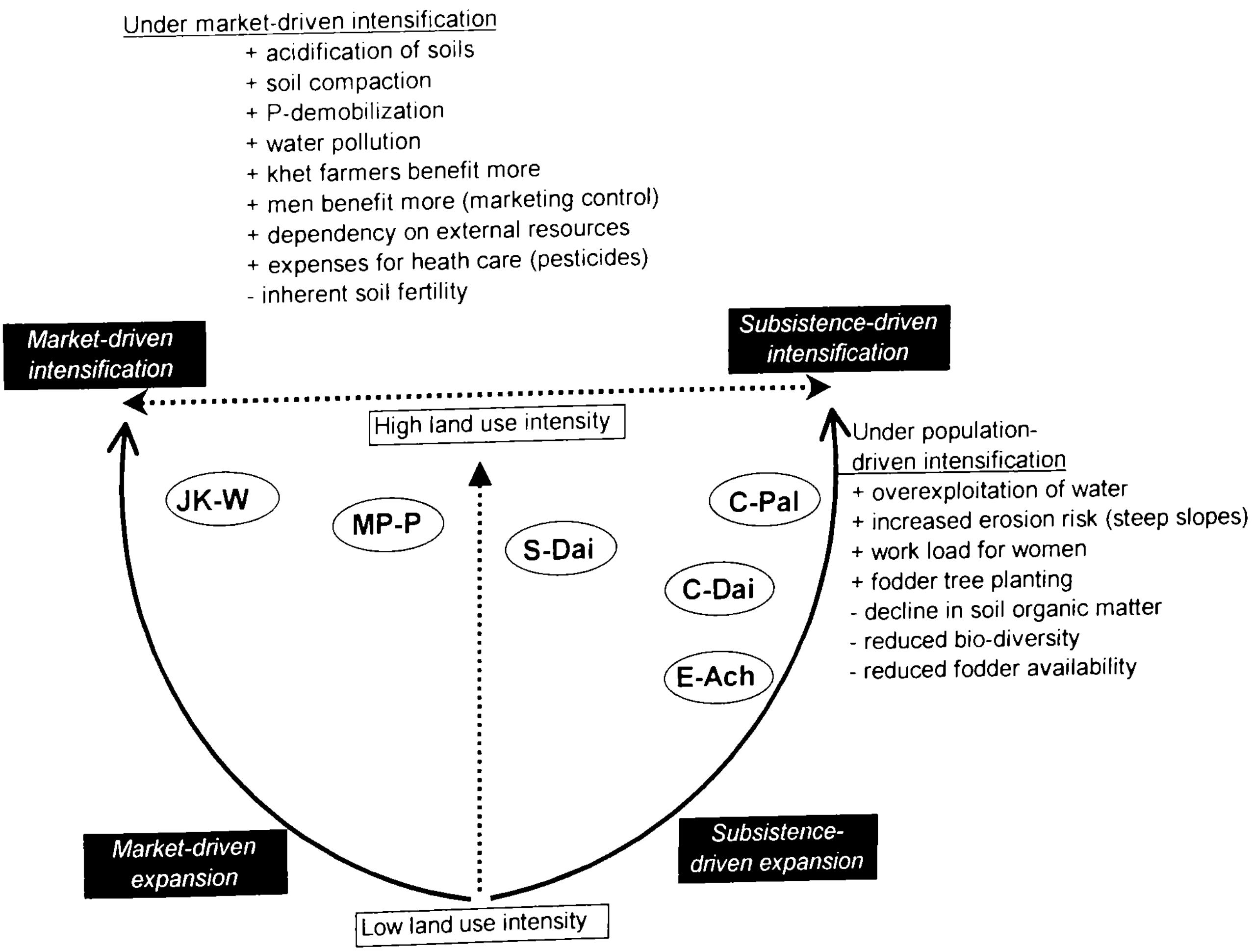
Figure 2. Changes observed in soil-related aspects as Agricultural Systems intensify in pocket areas in the mid-hills.



Source: PARDYP-ICIMOD and Helvetas, 1998, unpublished.

This change has a wide range of implications as described in Figure 3. Thus, promoting IPNS in the context of sustainable systems for the future requires, that we counterbalance now the negative impacts which the market-driven intensification might bring (e.g. water pollution, soil acidification). Soil specialists need to bring their expertise into a concerted effort for action together with district level governmental and non-governmental organizations.

Figure 3. Implications of changes observed in soil-related aspects as Agricultural Systems intensify in pocket areas in the mid-hills.



JK-W: Jhikhu Khola watershed areas with market access, Kavre
MP-P: Madan Pokhara, Palpa
S-Dai: South Dailekh areas with improving market access
C-Dai: Central Dailekh with poor market access
C-Pal: Central Palpa areas with poor market access
E-Ach: Eastern Achham areas

Source: PARDYP-ICIMOD and Helvetas, 1998; unpublished.

2.4 Conclusions on systems *(e.g. water pollution, soil acidification)*

(1) The macro-level characterization of soils in fertility maps will be most useful on a longer term if it is part of a concerted effort to describe the macro-systems. Efforts of mapping by different agencies need to be coordinated and need to be compatible. This may allow targeting specific IPNS to different areas.

(2) National policies promote the decentralization of decision taking and planning. District offices are, for example, being equipped with GIS-tools. Thus, soil maps and the ability to use the information needs to be coordinated with the respective district-level agencies. This could gradually become part of the targeting of IPNS to different areas.

(3) IPNS for sustainable agriculture needs to look into the future. Thus, the development of IPNS for evolving farming systems needs to be based on an understanding of future risks rather than on present soil conditions. The targeting of IPNS needs to take into account expected system change.

(4) Within specified target areas, we need to move away from standard recommendations towards system-specific guidance. This implies participating in and strengthening farmers' decision process rather than providing standard recommendations. This implies giving farmers options for IPNS and providing support in the testing and identification of the locally most appropriate system.

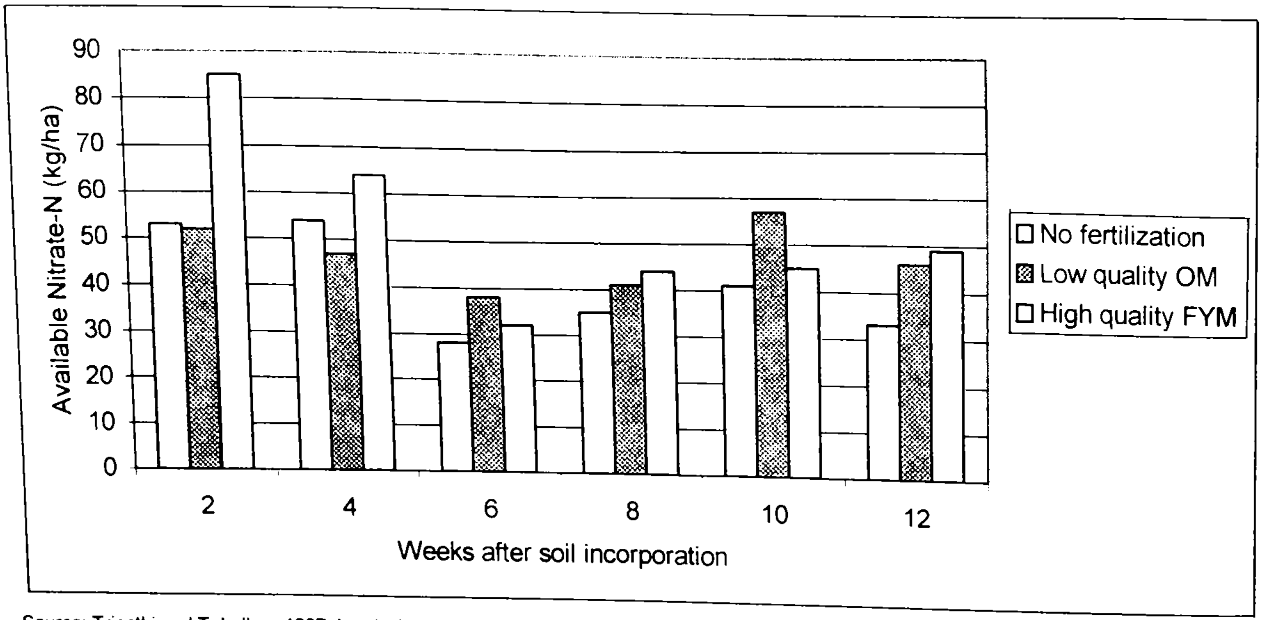
3 Scientific evidence and opportunities for IPNS

IPNS builds on scientific evidence from a range of disciplines. The analysis of all available information is therefore an essential step. The subsequent chapters present examples on how scientific evidence contributes to the development of IPNS.

3.1 Nutrient use efficiency

Nutrient use efficiency seems to be low in many mid-hill cropping systems. Tripathi et al. (1999) report in several sites in Western Nepal leaching losses above 50kg/ha of N. Most of these losses occur early in the season when the mineralization of N with the first rains causes an N-flush before the plant roots start major N-uptake (see Figure 4). The application of high quality farmyard manure increased in trials at a high-rainfall site, Lumle, the early availability of N by about 60%. Poor quality organic manure (high C:N-ratio) initially demobilized free soil-N while it increased Nitrate-N availability by about 40% later in the season starting at 8-10 weeks after application (Tripathi and Tuladhar, 1997). This indicates, that on fertile soils with high inherent N-release capacity and under high rainfall conditions, poor quality manure may support the most efficient use of N. On soils with a low-moderate N-release capacity and under moderate rainfall conditions, good quality manure with a slightly delayed N-release may best support production. This is one of the major challenges for IPNS: the synchronization of soil-inherent processes with plant uptake. Farmers catch the early N-flush by planting bari-land crops long before the recommended planting time derived from meteorológical data.

Figure 4. The pattern of Nitrate-N release in the soil at the beginning of the cropping season under maize. Low quality OM (straw and litter) and high quality farmyard manure were applied at about 40 kg/ha of N.



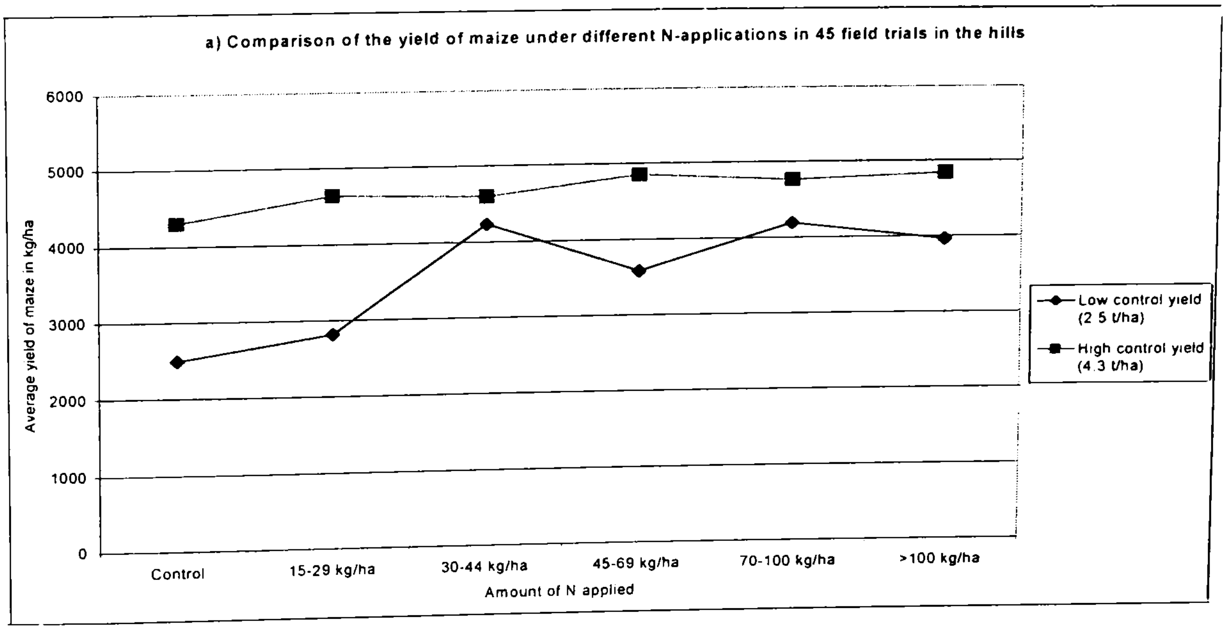
Source: Tripathi and Tuladhar, 1997; Lumle Agricultural Research Centre.

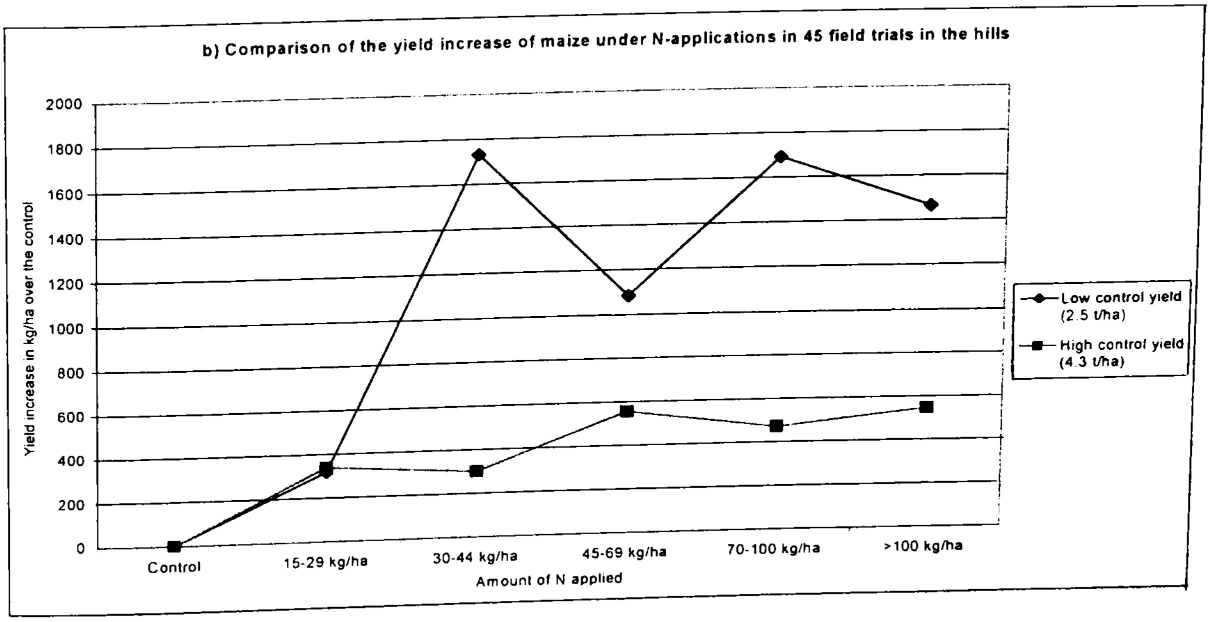
Nutrient-use efficiency tends to be particularly low in highly intensified cropping systems with mineral fertilizer use. A rapid survey in intensified khet and bari cropping systems in Kavre indicates, that only about 20-30% of the applied N is utilized for crop production. Nutrient losses in at least 60% of the farms were calculated to be equivalent to more than 1000 NRs/ropani (PARDYP, unpublished).

3.1.1 Crop response, synchronization and input cost on a short-term

Research in the mid-hills indicates that plant response tends to be different than anticipated by conventional agronomy. An analysis of 45 maize trials across the mid-hills reveals that the application of 15-30 kg/ha of N as mineral fertilizer ensures on average the best yield response in fields with a good control yield (Figure 5a and 5b). The application of 30-45 kg/ha of N can on average be recommended for fields with low control

Figure 5. Analsis of yield response of maize to nitrogen application in 45 trials in the mid-hills (a), the diminishing return in maize yield for every kg N applied (b, c), the approximate economic response expected by farmers (d), and the N-export through grain and stover harvest from the field (e).





c) Yield response kg maize per kg N:

Low control yield:	0	16	43	18	21	15
High control yield:	0	17	8	9	6	5

d) Minimum expected yield response based on market prices of urea and maize and a double return on investment; compare to Fig. 5c.

Minimum expected response kg maize per kg N (road-side farmer, Central Nepal):	3.5
Minimum expected response kg maize per kg N (1-day walking distance from road):	4.5
Minimum expected response kg maize per kg N (1-day walking distance, share cropping):	6.75

e) N-uptake by maize in kg/ha:

Low control yield:	58	65.7	98.6	83.5	97.7	92.4
High control yield:	100	108	107	113	111	113

yields. These values are below presently valid recommendations and they are below the amounts needed to replace the exported nutrients through crop harvest (Figure 5e). This indicates a high contribution of N from soil-inherent sources, the soil-N pool. The top-dressing of 30-45 kg/ha of N at the time of highest plant demand can give an excellent response of more than 30 kg of maize for every kg of N applied under low control yields. In fields of high control yields, the top-dressing of 15-30 kg/ha of N can provide a yield response of about 15 kg maize for every kg N applied (Figure 5 c).

The inherent capacity of many soils in the mid-hills to provide nutrients for crop development seems to be sufficient to approximately maintain maize yields of 2-4 tons/ha in the short-term. The resulting soil-mining, however, is not sustainable. Long-term trials indicate gradually declining yields under soil-mining land use. Results from long-term trials, however, vary widely and are site-specific. The overriding importance of the complementary utilization of organic manure in the form of farmyard manure or green manure, however, is common to all trials (see Shakya, Gharti and Upadhyay, 1998; Sherchan and Gurung, 1996; Tripathi, 1998; Tripathi, 1999; Tuladhar, Chaudhary and Chaudhary, 1998).

Thus, we are confronted with a dilemma. The conventional concepts of (a) calculating fertilizer-response curves or (b) calculating mineral fertilizer requirements based on exported nutrients from crop harvest, do not provide the correct answers for deriving fertilization recommendations for the mid-hills. IPNS has to be based on soil processes for sustainable soil management on a medium-term. Taking into account the overriding importance of soil-derived nutrients for determining crop yield, soil processes and in particular soil organic matter dynamics need to be in the centre of IPNS for the mid-hills.

Crop response becomes more apparent, as the growth cycle of crops is shortened. Short-cycled varieties and many vegetable crops have a high and concentrated nutrient demand over a short time period. This demand per day of crop growth goes beyond the inherent capacity of soils to release nutrients. In these cases, it becomes more appropriate to calculate crop response. The focus needs to shift in these cases towards the synchronization of complementary nutrient supply with crop demand.

The more external inputs are utilized, the more pressing is the problem of calculating the economic return to inputs. Figure 5b and Figure 5c show the declining rate of return to applied N. Assuming that farmers want to have a double return on investment (recovering the NRs for buying the urea and gaining 1 additional NRs for each 1 NRs invested), an application of 15-30 kg/ha and 30-45 kg/ha is the best choice for the farmer in fields of moderate and low fertility, respectively. In the case of share-cropping, however, the tenant may have to pay the full cost for the fertilizer while sharing 50% of the additional yield with the land-owner. This reduces the economic return on fertilizer for the farmer by half. An estimate of the approximate economic return on the application of small amounts of N indicates, that it is likely to be highly profitable for most farmers (Figure 5d in comparison to Figure 5c).

3.1.2 Nutrient balances on a medium-term

The concept of balancing nutrient input/output relationships is the basis for long-term sustainable soil management. However, most farmers and local extension staff do not have information about nutrient demand by crops, nutrient supply from soil and different inputs and how to calculate nutrient balance sheets.

The nutrient demand can be estimated from available data. For every Muri (70 kg) of maize, about 1.6 kg N and 0.6 kg P_2O_5 are taken up by the crop (see Figure 6). The nutrient supply is more difficult to assess. Figure 7 indicates estimates of nutrient supply from different inputs and fertility management practices in the mid-hills. Nutrient contributions from farmyard manure and green manure can only approximately be assessed as they vary between farms. Most outstanding is the difference between poor and high quality farmyard manure. A major difference lies in the release pattern of N over time. Therefore, as estimate of the N available to the first crop may be more important than the total N-content for planning IPNS.

The need for visual tools to discuss nutrient demand and supply with local extension staff and farmers remains an important challenge. Graphical designs and local measures as shown in Figure 6 and 7 may be used to facilitate communication with farmers.

Figure 6. Estimated nutrient removal from the soil through crop harvest

Crop	Yield level per ropani	Nutrient uptake in grain and stover: N kg/ropani	P2O5 kg/ropani
Maize	1 Muri of 70 kg	1.6 kg	0.6 kg
Rice	1 Muri of 48 kg	1.0 kg	0.3 kg
Wheat	1 Muri of 70 kg	1.6 kg	0.5 kg
Mustard	1 Muri of 62 kg	2.5 kg	1.2 kg
Soybean (3.2 kg N from N-fixation)	1 Muri of 65 kg	1.7 kg	1.1 kg
Potato	10 Doko of 22 kg	1.2 kg	0.32 kg
Tomato	10 Doko of 20 kg	0.6 kg	0.3 kg

Figure 7. Estimated nutrient contribution through different fertilization practices and from organic matter mineralization in the soil

Practice	Amount used per ropani	N-content in application kg/ropani	N available to first crop kg/ropani	P-content in application kg/ropani (P2O5)
Urea	1 Pathi or 3.9 kg	1.8 kg	1.3 kg	0 kg
DAP	1 Pathi of 5 kg	1.0 kg	0.7 kg	2 kg
poor FYM	10 Doko of 25 kg	1.1 kg	(early) - 0.8 kg (later) 0.6 kg	0.3 kg
good FYM	10 Doko of 25 kg	4.4 kg	1.5 kg	0.4 kg
Dhaincha on khet (green manure)	16 Doko biomass or 150 kg dry matter	5.3 kg	1,8 kg	1.35 kg
Hiunde simi relayed into maize on bari (green manure)	16 Doko biomass or 150 kg dry matter	5.3 kg	2.0 kg	0.68 kg

Soil contribution for soil of moderate P-content and pH above 5.0:

Practice	Amount used per ropani	N-content in application kg/ropani	N available to first crop kg/ropani	P-content in application kg/ropani (P2O5)
Soil (OM-mineralization)	Low OM-content Mod. mineralization	3.3 kg	1.4 kg	0.53 kg
Soil (OM-mineralization)	Mod. OM-content Mod. mineralization	7.3 kg	3.0 kg	1.52 kg

The need to supply additional nutrients from external sources depends finally on both, the input/output ratios and the available soil reserves. As most soils in the mid-hills have a high P and K reserve, deficits in P- and K-balances can be accepted in many mid-hill soils until cash cropping and market access are improved.

3.1.3 The concept of modern agriculture

Farmers see "modern" agriculture as high external input agriculture, not as a nutrient-use efficient agriculture. The same concept of "modern" agriculture is partly reflected in the APP. Science has in the meantime identified organic matter management and nutrient use efficiency as guiding principles of "modern and sustainable" agriculture. Thus, a change of concept of "modern" agriculture has to be part of the promotion of IPNS at the policy as well as at the farm-level.

3.1.4 Inputs used for other purposes than nutrient supply

Farmers may use nutrient-rich inputs for other purposes than nutrient supply. Potato farmers in Kavre, for example, were found to use high amounts of FYM on potatoes to create a less compacted soil structure suitable for potato production. This contributes to a low efficiency in nutrient use although it improves crop performance. The reasons for farmers' practices need to be carefully assessed before recommendations can be made.

3.1.5 Over-utilization of mineral fertilizers

Farmers in areas of good market access with intensive cropping of vegetable crops tend to apply much higher amounts of fertilizers than needed for crop growth and yield. For example, vegetable farmers in Panauti and Khopasi of Kavre district apply up to 1 bag of urea per ropani (more than 400 kg/ha of N) on vegetable crops. This is partly due to the relatively low price of urea fertilizers in comparison to the value of high-value crops such as vegetable in these areas. The lack of knowledge about the required amounts of nutrients needed and the correct timing of application contribute, too.

3.1.6 Conclusions on nutrient use efficiency

(1) There is a need to identify simple methods to calculate nutrient balance sheets and to identify the reasons for nutrient losses. The calculations need to include OM-balance estimates. These can be used by local extension staff and farmers in designing locally appropriate IPNS.

(2) A different concept of modern agriculture needs to be promoted as well at the policy level as at the farmers' level. Emphasis needs to be shifted towards organic matter management, synchronization and nutrient-use efficiency.

(3) Crop response analysis can guide only short-term nutrient management for the mid-hills. It may indicate, for example, the application of small quantities of complementary fertilizer. It may also be relevant for intensively managed systems with short-cycled crops and vegetable. Medium-term recommendations for IPNS need to be based on soil OM-balances and overall organic/inorganic input versus nutrient export relationships.

3.2 Organic matter dynamics

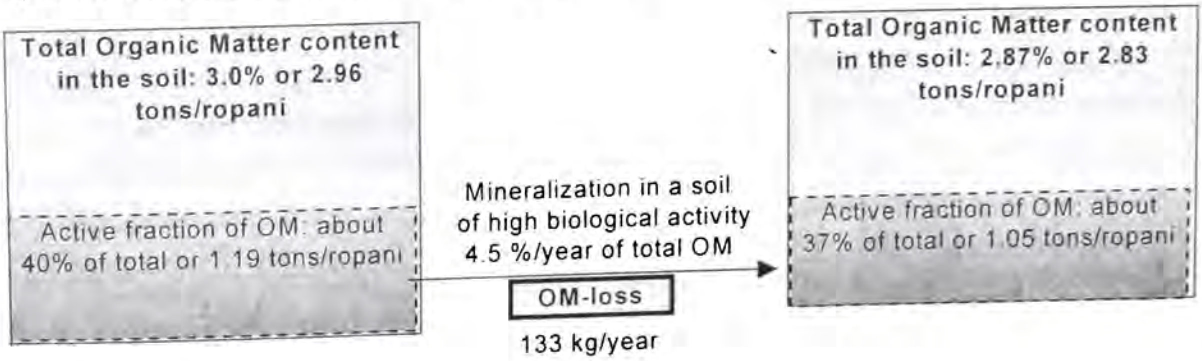
There is general consensus that organic matter management is an essential component of SSM in the hills. Long-term trials show the contribution of compost and biomass applications to maintaining soil productivity. In spite of this general consensus, agreed-upon recommendations on organic matter management for IPNS have not emerged. Data on organic matter pools and decomposition rates are scarce for the mid-hills. Thus, until better data are collected, we have to work in extension with the best available information from Nepal and similar ecologies.

Based on available information, we can estimate in bari land systems in the mid-hills losses of humified OM of about 40-60 kg/ropani and year for soils of low OM-content and about 130-180 kg/ropani and year for soils of moderate OM-content (Figure 8). This loss of humified OM needs to be replaced for

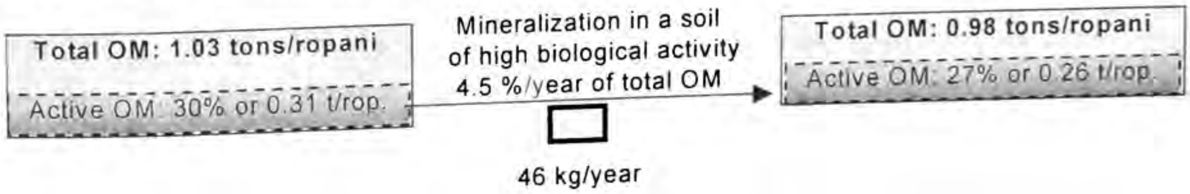
maintaining soil OM under an SSM-concept. Soil of low OM may need additional applications of OM over several years if the inherent fertility of these soils is to be regained.

Figure 8. Estimated change in organic matter content in soils of moderate and low OM-content. Bari land, mid-hills, change over 1 year under normal cropping without OM input.

a) Soil of a moderate organic matter content of 3%

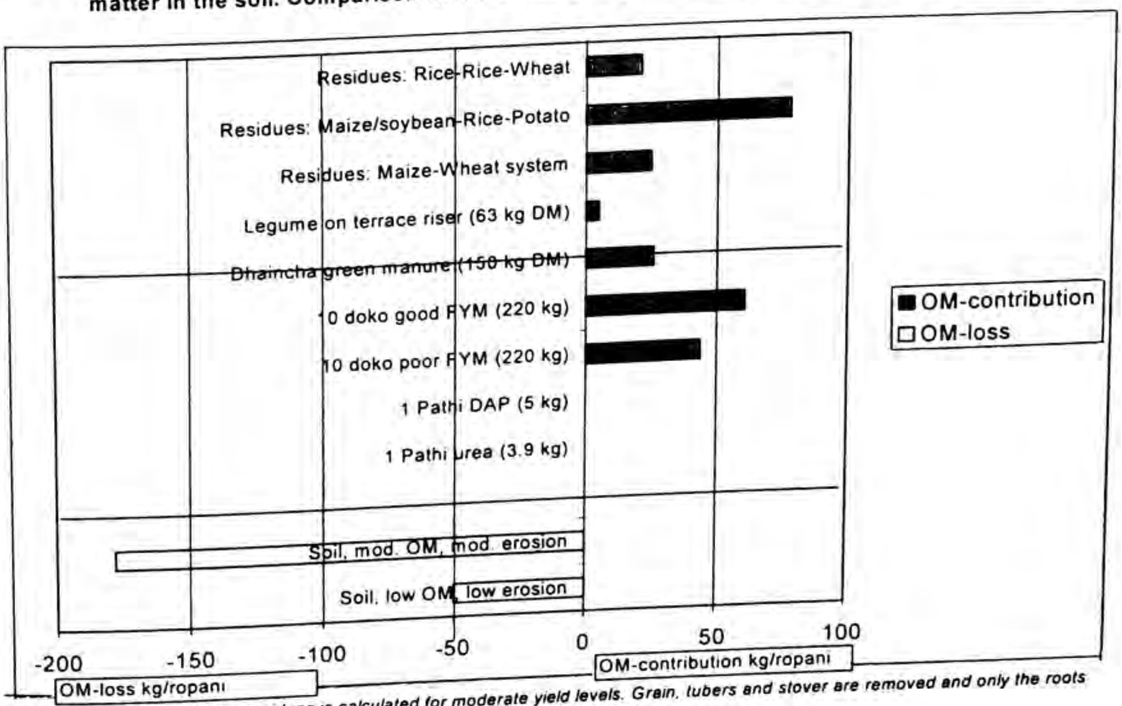


b) Soil of a low organic matter content of 1%



The addition of humified OM through biomass input can also be estimated from available information. The highest addition of OM can be achieved by terrace riser slicing. The addition of humified OM through FYM depends on the degree of decomposition of the FYM. Approximately 40-60 kg/ropani of humified OM are applied for every 10 dokos of FYM. Crop residues are often removed from the field and only small amounts of humified OM are left in the field from root biomass (Figure 9).

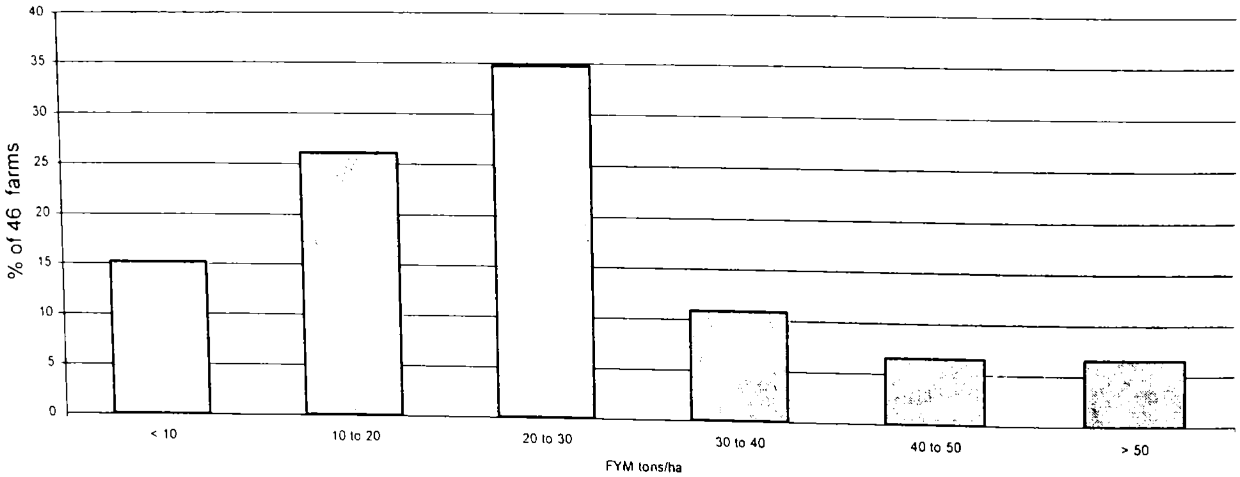
Figure 9. Estimate of the contribution of crop residues and different soil management practices to organic matter in the soil. Comparison with the loss of organic matter in the soil through mineralization.



Note: The contribution of crop residues is calculated for moderate yield levels. Grain, tubers and stover are removed and only the roots and the fallen leaves are added as biomass to the soil.

Based on these data, we can estimate the design of OM-management in IPNS. Data from farm surveys in Western Nepal indicate, that farmers apply every year between 10 and 50 t/ha of farmyard manure (Figure 10). Data from surveys in Eastern Nepal confirm a similar wide range of applications (Gurung and Neupane, 1991).

Figure 10. Approximate amount of farmyard manure applied in 46 farms in the mid-hills of Western Nepal (Rasali et al., 1995)



The average application in Western Nepal is calculated at approximately 600-900 kg/ropani of FYM every year (Figure 11a). This corresponds to an addition of about 120-160 kg/ropani of humified OM in case of poorly decomposed FYM (the normal situation). This is about equal to the OM-losses through mineralization and erosion in soils of low OM-content. But it is 12-33% below the annual loss of humified OM from soils of moderate OM-content (Figure 11b). Thus, only those farmers applying close to the maximum of 900 kg/ropani of FYM will be able to maintain soil OM-levels. The other farmers are likely to observe a gradual decline of soil OM-levels unless other practices for OM-additions (such as terrace riser slicing) are utilized. If well decomposed FYM can be prepared, the application of humified OM increases to about 170-230 kg/ropani. Thus, these farmers can maintain the OM-levels in the soil (Figure 11b).

The situation is different in highly intensified systems in Kavre district. Soils have been overexploited in the past and have low OM-content. Normal maize-wheat or rice-rice-wheat systems can just maintain the low OM-content in the soil. The change towards intensified systems with potato and vegetable are managed with high FYM-inputs and produce larger amounts of crop residues. These new systems are likely to gradually increase OM-levels in the soil. This is confirmed by farmers in Kavre district, who report an improvement in soil fertility and physical properties since the start of intensive cropping of potato and vegetable in the area (PARDYP 1998, unpublished).

3.2.1 Conclusions on OM-management

Continued efforts by research on OM-management are needed. The rate of organic matter turn-over in the soil, the different organic matter fractions and the N- and P-supply/exchange capacity of the organic matter fractions needs to be better understood. In the meantime, extension needs to work with the best available information to quantify OM-management.

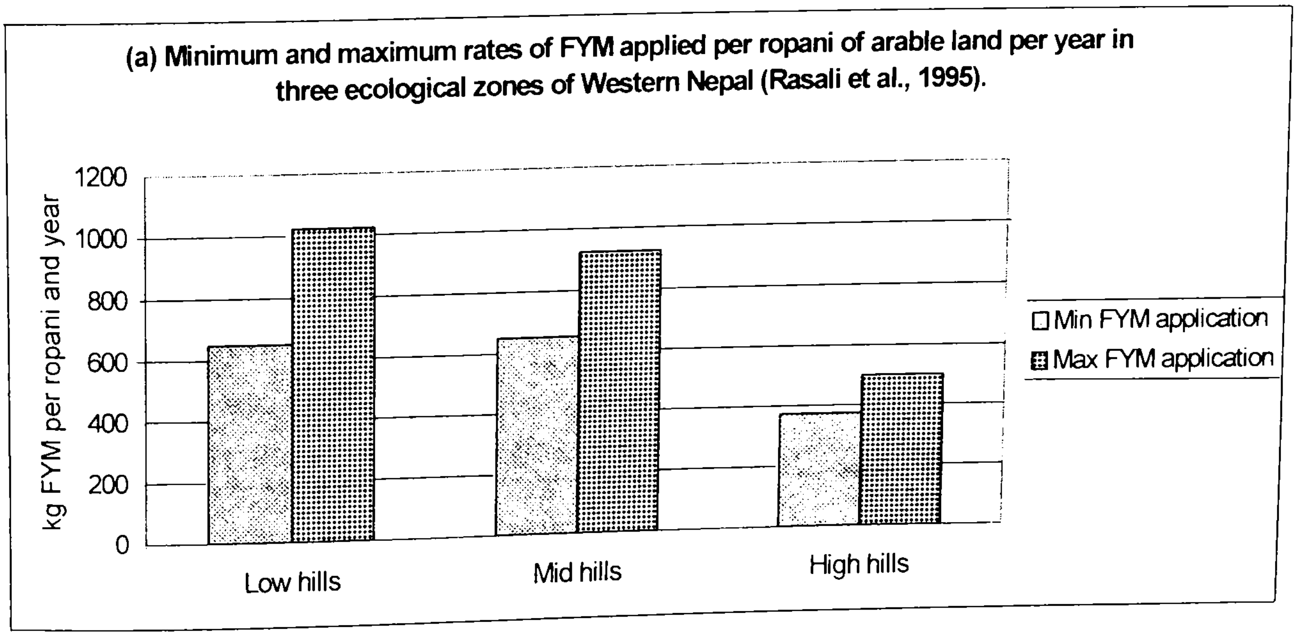
(1) There is no need to convince farmers about the value of organic matter in the soil, they invest substantial efforts in organic matter management. The focus in extension needs to be on helping farmers to understand OM-dynamics and to decide on the quantitative OM-balances in their fields.

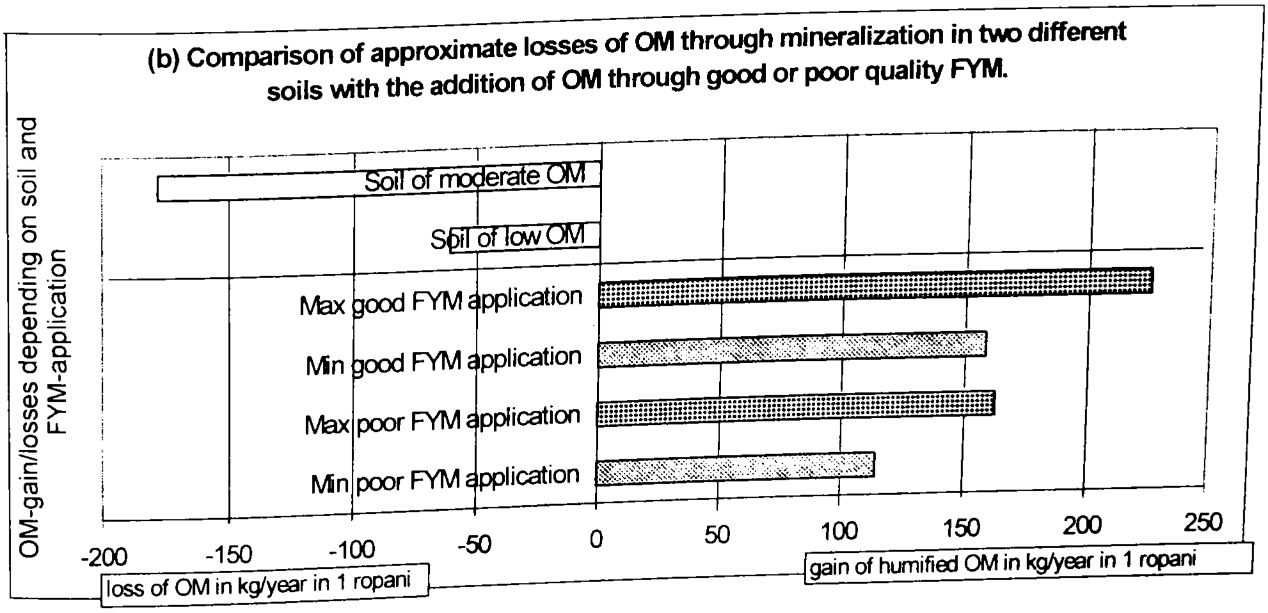
(2) The lack of sufficient biomass is one of the major constraints to OM-management. Additional biomass production in farm niches and in-situ composting as an alternative to FYM-management need wider emphasis.

(3) Tillage has a substantial effect on OM-decomposition. The intensification of land use is accompanied by more intensive and more frequent tillage leading to enhanced OM-decomposition. The identification of opportunities for reduced tillage for OM-maintenance need to be explored.

(4) The better management of farmyard manure can lead to a better decomposition of the bedding material and other biomass in the manure. The improved decomposition contributes to a higher proportion of humified organic matter in the manure.

Figure 11. Maximum and minimum rates of farmyard manure applied by farmers in Western Nepal (a) compared to an estimate of the approximate amount needed for organic matter maintenance in soils of low and moderate OM-content (b)



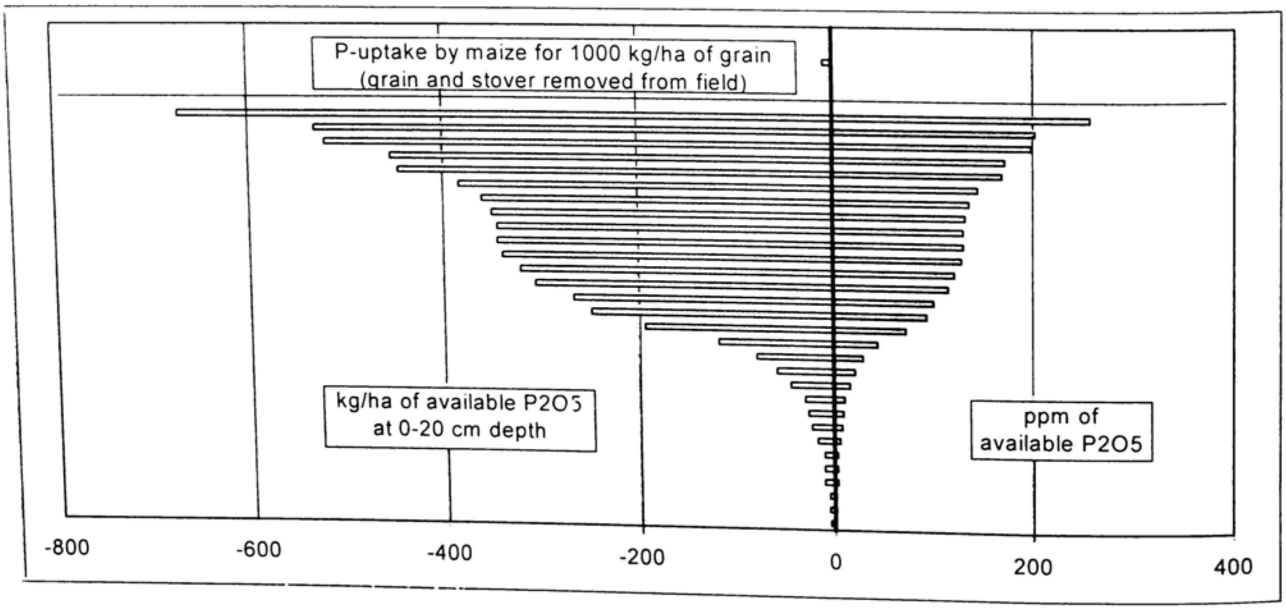


3.3 Management of Phosphorous

Phosphorous is often mentioned as the second most limiting nutrient after N for the mid-hills. A critical analysis of evidence indicates a complex situation. If we want to manage P as part of IPNS, a differentiated view is needed.

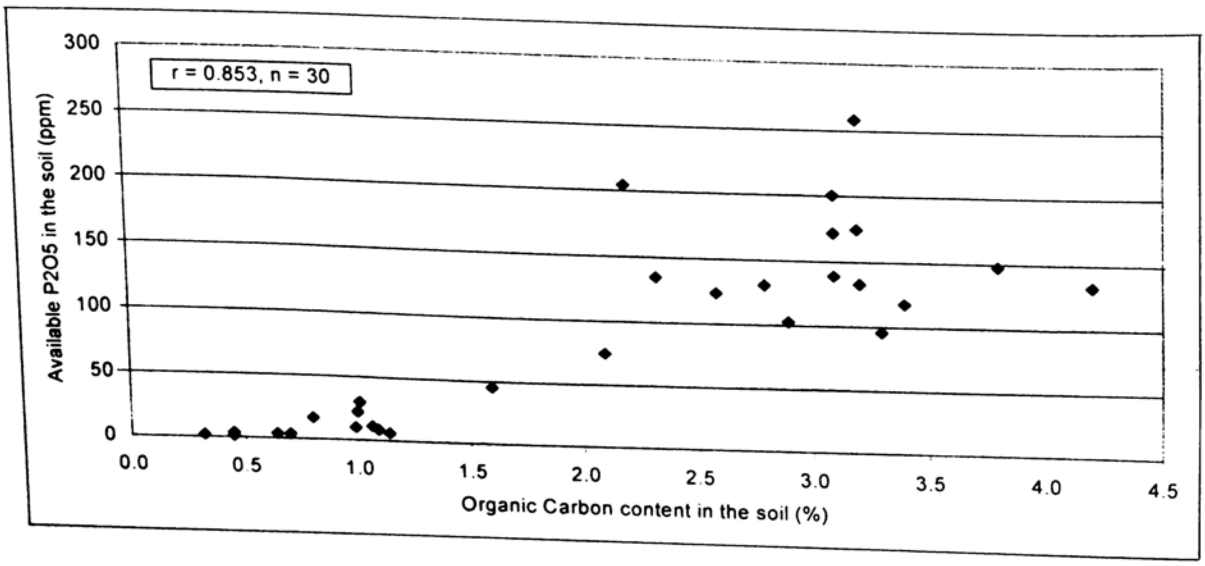
An analysis of 30 aggregated soil samples from more than 500 fields from the mid-hills indicates, that about 50% of the soils are rather rich in P and that 70-80% have sufficient P to fulfil crop demand on the short-medium term (Figure 12). Thus, in most mid-hill soils it seems to be unlikely to observe significant crop responses to P-application. Data from STSS support these findings.

Figure 12. Concentration and amount of available P in 30 aggregated soil samples (based on more than 500 field samples) from mid-hill soils in comparison to P-uptake by maize



The development of a longer-term strategy of P-management in IPNS requires an understanding of the processes of P-availability and demobilization in the soil. One overriding factor for the mid-hills is the strong dependence of available P on the soil OM-content (Figure 13). As the OM-content in the soil declines, P is increasingly immobilized and P-deficiency becomes more likely.

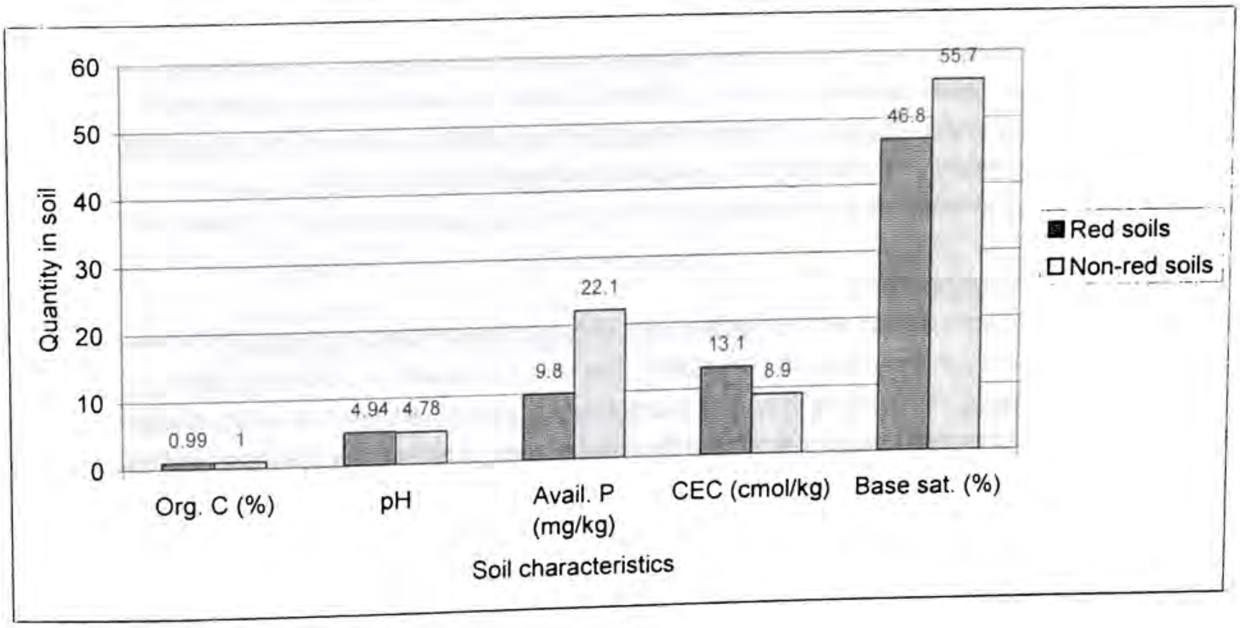
Figure 13. Relationship between available phosphorous and organic matter content of soils in the mid-hills of Nepal based on more than 500 field samples aggregated into 30 samples.



Another major factor determining P-availability is soil pH. This is well known. As soil pH declines, P is immobilized. This effect is more pronounced in soils of low OM-content and low P-content and among these it is more in red soils than non-red soils (Figure 14).

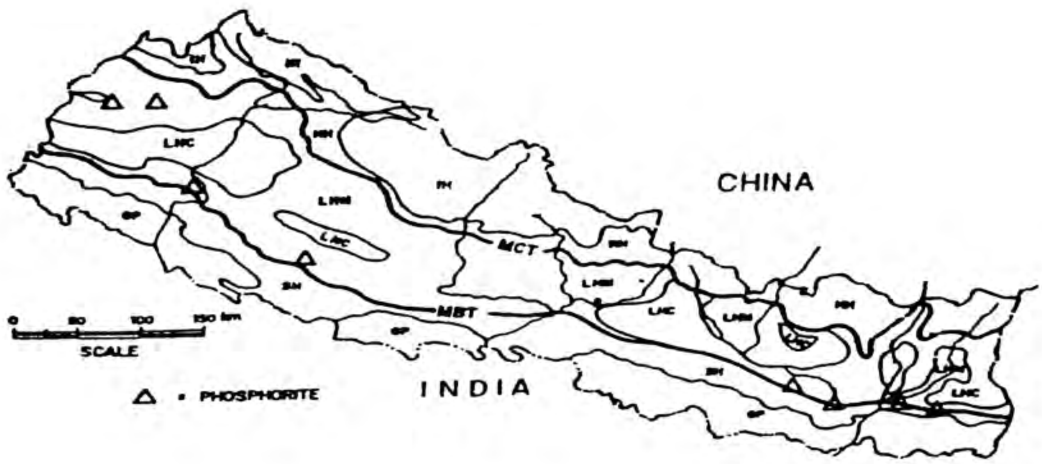
The utilization of local sources of P may offer an opportunity in a few areas. Only a few rock-P sources have so far been identified and none of these has been exploited (Figure 15).

Figure 14. Comparison of soil characteristics in 90 red soils and 110 non-red soils from the Jhikhu-Khola watershed in Kavre district.



Source: Schreier, Shah and Lavkulich, 1995

Figure 15. Sources of rock-phosphate reported in Nepal (after DMG, Nepal)



3.3.1 Conclusions on P

(1) An estimated 70-80% of soils in the mid-hills have moderate to high P-content, 20-30% of the soils have low inherent P-content. In these soils, P-additions through organic, mineral or rock-P are needed. Thus, mineral P-fertilizers and P-transfer through biomass are the only solutions for these farmers. Soil analysis and P-deficiency symptoms on maize are the best indicators.

(2) The application of P to soils of low OM-content or low pH will not be lasting and efficient unless additional practices are utilized to avoid P-immobilization.

(3) The management of available P in soils is the major challenge for the mid-hills. This implies a management of organic P-fractions and OM-processes as discussed in the previous chapters. Additionally, P-mobilization can be achieved in perennial crops such as Litchi through mycorrhiza. In annual crops, certain weed species (Lantana, Tithonia...) have the potential to mobilize soil P. This results in a relatively high content of P in the biomass of these plants. However, the amount of biomass of these plants needed for P-enrichment in soils is often beyond local availability.

(4) Another important challenge for P-management is the prevention of soil acidification (see next chapter).

3.4 Soil acidity management

The proportion of acidic soils across all ecological zones of Nepal is estimated at about 57%, based on an analysis of more than 9000 soil samples (STSS, 2000). The result is based on classifying all soils with a pH below 6.0 as acidic. Taking into account that most crops tolerate a moderate level of acidity and that liming is not accessible for most farmers in Nepal, a more differentiated view of soil acidity management may be needed.

Two causes of soil acidity need to be differentiated: inherent and induced acidity.

3.4.1 Inherent acidity

Inherent acidity is largely determined by the origin of the soil from the underlying parent material. The natural vegetation on such soil is adapted to low soil pH. The most appropriate ecological way to utilize these soils is through the planting of acidity-tolerant crop species and varieties. A summary of crop tolerance to acidic soils is given in Table 1. However, variety specific differences do exist and a characterization of crop varieties for acidity tolerance (as initiated by a LAC/PAC project) is an important step to provide extension staff and farmers with management options for acidic soils.

Table 1. Example of crop tolerance to acidic soils.

Crop species	**Minimum pH for tolerance to soil acidity**
Examples for food crops	
Maize	pH 4.8 (minor variety differences known)
Upland rice	pH 4.6 (large variety differences)
Wheat	pH 5.2
Cowpea	pH 4.3
Beans (simi)	pH 5.2 (minor variety differences known)
Groundnut	pH 4.5
Soybean	pH 5.0 (minor variety differences known)
Examples for fodder crops	
Stylo	pH 4.0
Clover	pH 5.5 (some species more tolerant)
Fodder peanut	pH 4.2
Pea+oats	ph 5.5

Note: Optimum conditions for crop growth (often defined as crop requirements) are concentrated around pH 6-7 for most crops. Crop tolerance indicates the ability of the crop to grow and produce a moderate yields under stress conditions.

The application of lime is economically not viable in most areas. Trials on acid soils in Dolakha, for example, indicate an increase of soil pH after the application of 5 tons/ha of lime from 5.0 to 5.6. No significant effect on maize yield was observed, while wheat yield increased by 0.5-0.8 tons/ha (Tripathi and Sah, 1984). A rough estimate indicates, that a yield increase of at least 660 kg/ropani of maize after liming is needed to justify the application of lime on fields at the road side. A yield increase of at least 2000 kg/ropani is needed to justify lime application on fields at a 1-day walking distance from the road side. The minimum yield increase to pay the cost of lime after removal of subsidies increases to 1200 kg/ha and 2500 kg/ha, respectively (Table 2).

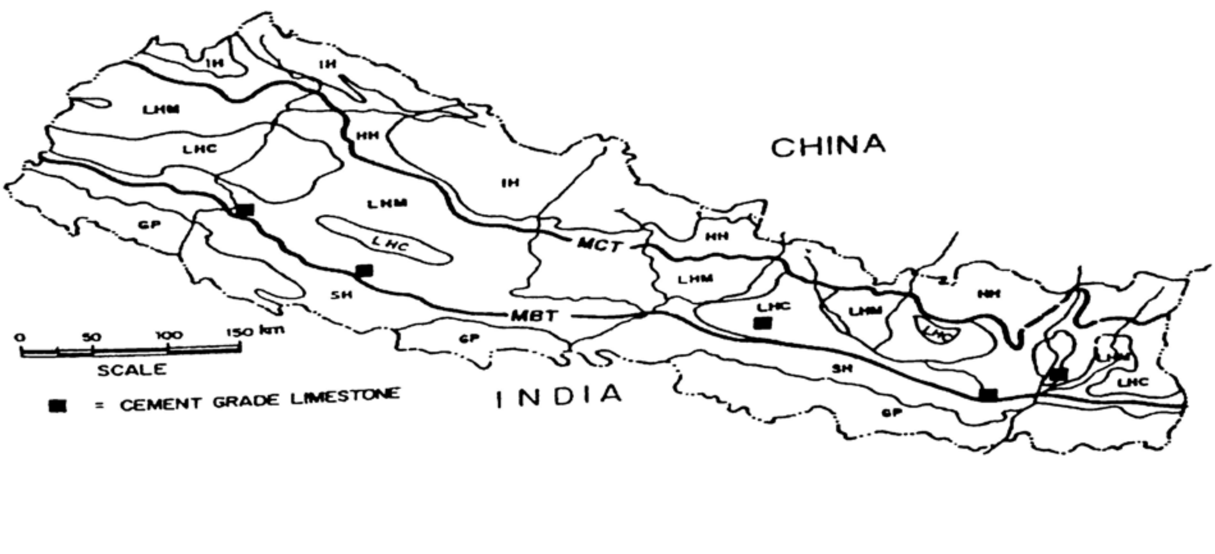
Transport costs make lime non-accessible for most farmers in the mid-hills. The exploitation of local limestone sources may be an option in some areas (Figure 16).

Table 2. The cost of liming and the minimum yield increase of maize to pay for the investment for fields at the roadside and at a 1-day walking distance from the roadside.

Location	**Lime application**	**Cost estimate**	**Increase in maize yield to pay cost of liming**
Roadside	4000 kg/ha	8000 NRs/ha *14400 NRs without subsidy*	660 kg/ha *1200 kg/ha*
1 day walking distance	4000 kg/ha + 80 porter days	8000 NRs/ha + 16000 NRs/ha = 24000 *30400* without subsidy	2000 kg/ha *2533 kg/ha*

Calculations based on the following assumptions: Cost of subsidized lime is 2 NRs/kg with free transport to the roadside. Cost of non-subsidized lime is about 3.6 NRs/kg including transport to Central mid-hills. Porter charge of 200 NRs/day for 50 kg transport. Maize prize of 12 NRs/kg.

Figure 16. Sources of rock-phosphate reported in Nepal (after DMG, Nepal)



3.4.2 Induced acidity

Induced acidity is mainly caused by human intervention through (a) a reduction in soil organic matter content, (b) a leaching of cations through rainfall and irrigation, (c) the application of acidifying fertilizers and (d) the

utilization of acidifying biomass. Soil acidification occurs mainly on soils with an inherently low buffering capacity.

The conversion of coarse textured soils into agricultural land, in particular to khet land, increases cation leaching. Thus, the irrigation of these soils cannot be recommended. The establishment of permanent crops reduces the risk of cation leaching into layers below the rooting zone. A similar effect can be achieved with the inter-cropping of deep-rooted trees and shrubs into annual crops. They contribute to a recovery and recycling of leached nutrients.

A gradual acidification through the application of N-fertilizers is one of the most pressing problems of modern, external input-based agriculture. Long-term trials on different soils are needed to analyze the importance of this soil degradation in different areas. Trials in the hills of Eastern Nepal indicate, that the application of N:P:K mineral fertilizer without additional organic matter utilization results in a reduced pH, an increase in the amount of exchangeable acidity, a reduced organic matter content, a reduced level of exchangeable cations, a reduction in available P and a lower cation exchange capacity after 6 cycles of maize/millet cropping (Table 3). As long as the application of lime is out of reach for most farmers, we need to minimize the application of acidifying fertilizers on bari land. This is particularly important in soils with a low buffer capacity and an inherent risk for acidification. The analysis of the risk and prevention of acidification needs to be an essential component of IPNS in the intensification pockets under the APP.

Table 3. The effect of different soil fertilization practices on soil properties after 6 years of maize/millet cropping.

Treatment	pH	Exch.Acidity	O.M.	Avail. P	Exchangeable cations (cmol/kg)		
		(cmol/kg)	(%)	(mg/kg)	CEC	Ca	Mg
Compost 15 t/ha	5.9	0.63	1.57	20.1	12.0	8.1	1.4
Compost 15 t/ha + 30 N kg/ha topdressing	6.0	0.62	1.74	23.5	13.0	8.0	1.5
N:P:K, 120:60:30 kg/ha	5.4	1.97	1.44	12.2	11.5	6.1	1.0
Compost 15 t/ha + 30 N kg/ha topdressing + 2 t/ha lime	6.2	0.30	1.58	24.8	13.1	11.1	1.2

Source: Tripathi, B.P. 1999 after Sherchan and Gurung, 1996

The risk of acidifying biomass is well known in the case of pine needles. A rapid decline in exchangeable Ca and Mg was, for example, observed over 1 year after the application of pine litter. This decline was more pronounced on red soils than on non-red soils (Schreier, Shah and Lavkulich, 1995). However, in view of the lack of other biomass sources, it is difficult to convince farmers to avoid such biomass. A forward looking strategy needs to identify and promote the planting of new sources of biomass such as broad-leaf fodder-trees in these areas. The medium-term contribution of legume-cropping to soil acidification is less known and is still being disputed. However, there is evidence of soil acidification through N-fixation. This process seems to be more pronounced if the legume-biomass is removed from the field. Further research on this topic is needed.

3.4.3 Conclusions on soil acidity management

(1) The application of lime will not be economically feasible in most mid-hill areas in the near future. Thus, two main strategies need to be pursued: the ecological management of inherently acidic soils and the avoidance of induced acidification in soil of low buffer capacity.

(2) Crops with tolerance to low pH need to be promoted in areas of inherently low pH. Varieties need to be characterized for acidity tolerance and amendments such as Rhizobia need to be assessed for acidity tolerance.

(3) Soils with low buffer capacity and at risk of acidification need to be identified. The IPNS for these soils needs to focus around practices, which reduce the risk of acidification. These include a minimum use of N-mineral fertilizer inputs, the maintenance of or increase of the OM-pool in the soil, the reduction of cation leaching through early cropping and inter cropping with deep-rooted crops.

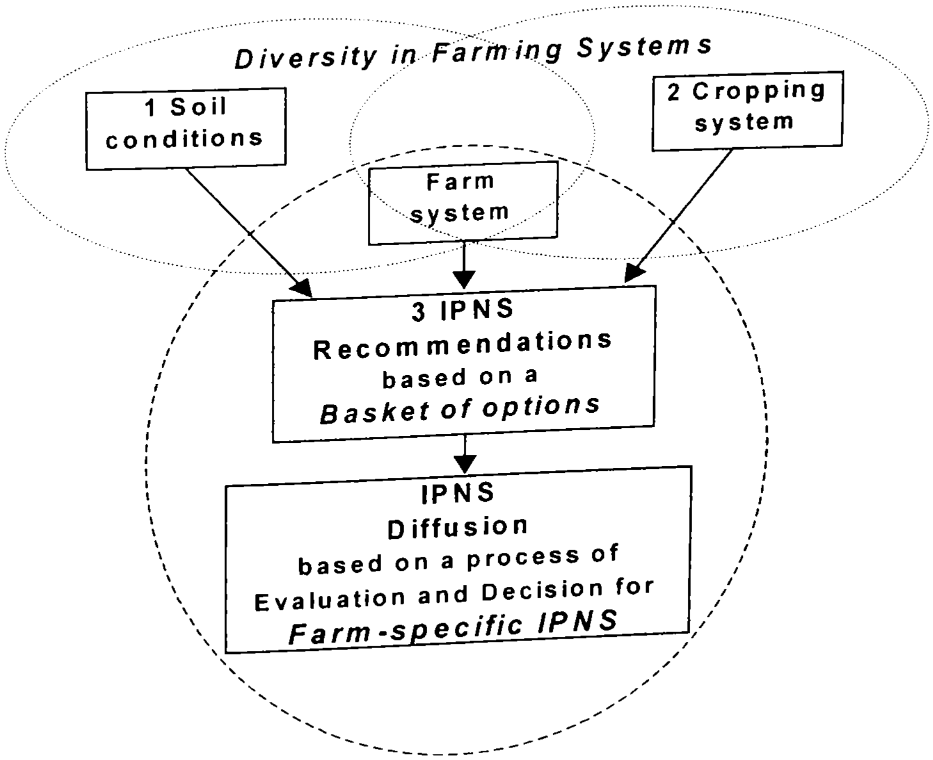
(4) Visual tools such as pH-paper for identifying and showing the risk of acidification need to be promoted. They are essential component of creating wider awareness among farmers and extension staff about the problem.

(5) The exploration of local limestone may be tested in some areas.

4 Example for an IPNS in the mid-hills

The previous chapters indicate, that IPNS needs to be system-specific. A genuine IPNS provides a range of opportunities (a basket of options) for system-specific design. Figure 17 indicates a step-wise procedure for IPNS-development.

Figure 17. Diversity in farming systems requires a basket of soil and soil management practices to develop IPNS-recommendations. Local conditions determine farmers' decisions on farm-specific IPNS.



Step 1: Evaluation of the soil system: It defines the constraints and opportunities of the physical, chemical and biological characteristics of the soil and its management. Recommendations for IPNS-practices are derived for the different soil systems. They form part of the basket of options for IPNS.

Step 2: Evaluation of the cropping system: It defines the constraints and opportunities of different cropping systems in terms of crop nutrient requirements and the crops' contribution to soil conditions. Recommendations for IPNS-practices are derived for the different cropping systems. They form part of the basket of options for IPNS.

Step 3: Decision for IPNS in the farm system: The farm system is the utilization of a specific cropping system on a specific soil system in a certain farming system. The farming system is additionally characterized by the access of the farm to external inputs or markets. The access to inputs may be

determined by the location of the farm in an accessible or remote area or by the purchasing power of the individual farm household.

4.1 Prototype of IPNS for Maize-wheat systems on bari land in the mid-hills

The development of IPNS needs to be driven by opportunities to overcome constraints to productivity, to increase the efficiency of external or local inputs for productivity and to explore new options for production increase. This needs to be done gradually for all major soil-crop systems for the mid-hills and other ecological zones. The decision for the specific design of IPNS is taken at the farm level. The subsequent chapter gives an example for a prototype of IPNS for a maize-wheat system on bari land in the mid-hills.

4.1.1 Evaluation of the soil system

Scientific evidence and farmers' experiences indicate that organic matter management needs to be in the centre of the soil system for bari land in the mid-hills. The most important other determinants for this soil system are: soil texture, pH, N-content, P-content, K-content, micro-nutrient content, erosion and soil compaction. Each of these determinants of the soil system is assessed so as to derive specific recommendations on IPNS.

Figure 18 and Table 4 provide an outline for the details on this procedure. The Figure can be used by extension staff as a checklist in discussion with farmers. The Table provides concrete recommendations for those determinants identified with farmers as important for IPNS in the farm. As mentioned earlier, local adaptations of these decision tools are desirable.

4.1.2 Evaluation of the cropping system

The constraints and opportunities of the maize-based cropping system in relation to the seasonal climate is in the centre of the cropping system analysis. The most important determinants for this cropping system are: market access of the area, specific field conditions, land preparation, variety selection, basic fertilization, planting and inter cropping, top-dressing, harvest and residue management.

Each of these determinants of the cropping system is assessed with farmers so as to derive specific recommendations on IPNS. Figure 19 present an outline for the details on the procedure. It also contains specific opportunities for action. As before, local adaptations need to be developed.

4.1.3 Decision and recommendations on system-specific IPNS

The recommendations derived for the soil system and for the cropping system form part of the IPNS to be used in the farm. Additionally, specific nutrient management recommendations need to be provided. This is derived from a comparison of the nutrient requirements of the cropping system (depending on yield expectations) and the nutrient supply through the soil system (including inputs).

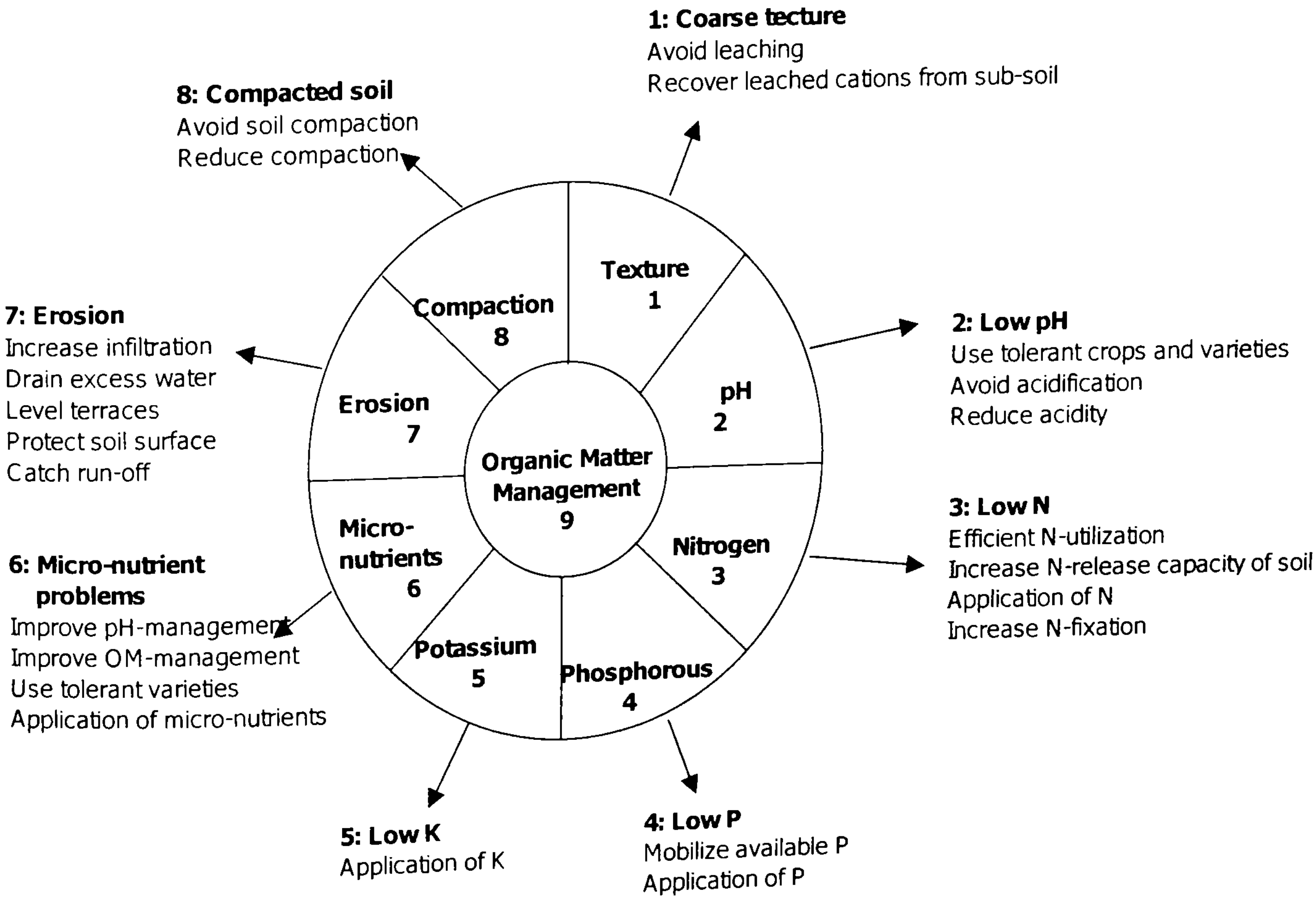
Table 5 presents an example for the opportunities of nutrient management for the maize-wheat system on bari land in the mid-hills. The specific nutrient management in a farm depends on the following:

- yield expectations,
- organic matter content in the soil,
- availability of farmyard manure,
- access to external inputs,
- farm-specific opportunities for green-manure inter cropping (labour, rainfall, inter crops...),
- specific soil limitations such as P-deficiency or soil acidity.

The example in Table 5 shows, that an effective management of IPNS can support maize yields of about 4 t/ha with the application of 15 doko of normal farmyard manure and the top-dressing of about 30-45 kg/ha of N in soils of low fertility. The same yield can be achieved in areas of poor market access without external inputs through dhaincha of sunhemp inter cropping. Once an effective IPNS is established, the major yield limiting factors are likely to be other constraints than nutrient supply (rainfall, crop density, pests and diseases...).

Figure 18. Evaluation of soil conditions and soil management: Step 1 in the process of identifying farm specific recommendations for IPNS in maize-based systems on bari land in the mid-hills.

Note: Check each point 1-9 for farm-specific constraints. Identify possible solutions to the most important constrating in Table 4.



9: Organic matter management	***9.1 Soil of low OM (about 1% OM)***	***9.2 Soil of moderate OM (about 3%)***
9.1 Normal FYM required to maintain soil OM (minimum for OM-maintenance; higher amounts are needed under intensive cropping)	**minimum of 15 doko/ropani** Higher amounts should be applied if available to increase soil OM	**45 doko/ropani**

9.2 Alternatives to normal FYM:

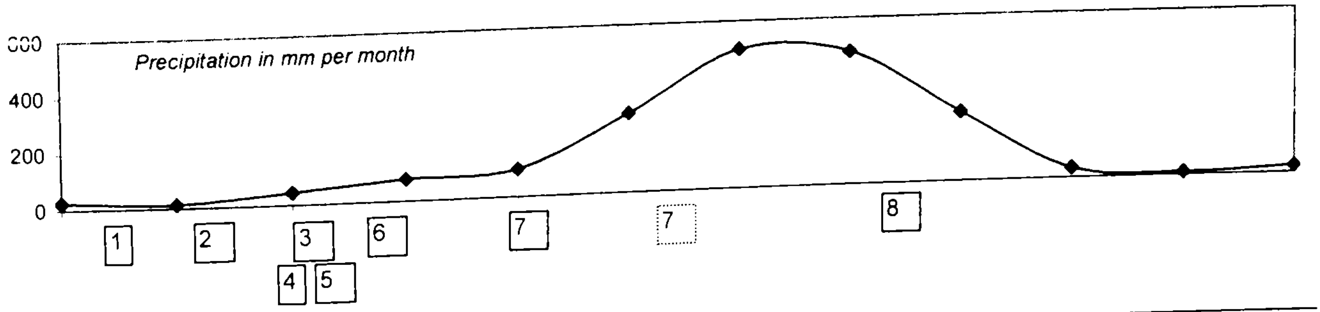
	Equivalent to normal FYM
Good, well decomposed FYM: Application of 10 doko	15 doko
Terrace riser slicing in fields with about 25% of area as terrace riser every 2-4 years:	17 doko
Application of dry biomass of weeds from terrace riser (Asuro...): 250 kg DM/year	11 doko

Table 4. Summary of recommended practices for soil management based on farm-specific constraints identified following Figure 18.

Topic	Actions needed	Recommended practice
1: Coarse texture	1.1 Avoid leaching	- Early planting with first rains for uptake of early N-flush - Drought-tolerant winter catch crops to reduce free cations
	1.2 Recover cations from sub-soil	- Intercrop with deep-rooted crops (e.g. pigeon-pea) - Tree intercropping
2: Low pH	2.1 Use tolerant crops and varieties	- Maize, soybean up to pH 4.8-5.0 - Cowpea, upland rice up to pH 4.3-4.5 - Varieties need to be identified; check for local varieties
	2.2 Avoid acidification (in soils of low bugger capacity)	- Reduce cation leaching (see 1.1) - Minimize mineral fertilizer use - Increase OM-content through additional FYM (see point 9)
	2.3 Reduce acidity (mainly for induced acidity)	- Consider lime use in areas close to road side (minimum yield response of maize to lime at least 600 kg/ha) - Consider local lime stone utilization
3: Low N	3.1 Efficient N-use	- Avoid N-leaching (see 1.1) - Avoid water-logging to reduce denitrification losses of N - Apply organic N at planting, top-dress 15-45 kg N at 4-8 weeks - Incorporate FYM and mineral fertilizer directly after application
	3.2 Increase N-release capacity of soil (for soils of low OM)	- Apply double the recommended amount of FYM (see 9) - Improve the FYM-quality (well decomposed; urine collection) - Terrace riser slicing (see 9) - Apply weed and other biomass - Activate soils of low mineralization capacity
	3.3 Application of N	- Apply good quality FYM as basal (see 9) - Use DAP as basal in soils of low P-content - Top-dressing of urea or urine at 4-8 weeks
	3.4 Increase N-fixation	- Green manure intercropping, slash and incorporate at first weeding - Food or fodder legume intercrop to increase residual N for next crop - Use Rhizobia for increased N-fixation (soils of low Rhizobia content) - Increase N-fixation from free-living organisms (e.g. Azotobacter application in deficient soils)
4: Low P	4.1 Mobilize available P (70-80% of mid-hill soils have sufficient P)	- Increase the OM-content of soils (see 9) - Avoid acidification (see 2.2) - Intercropping/rotation with P-mobilizing crops (e.g. pigeon pea, Tithonia...) - Use mycorrhiza in perennial intercrops (e.g. Litchi)
	4.2 Application of P (20-30% of mid-hill soils have a low P-content)	- Apply mineral P before planting (DAP, Complexol) - Apply biomass rich in P (Asuro, Tithonia...) - Consider use of local rock-P in soil or compost
5: Low K	5.1 Application of K (rarely necessary in mid-hills)	- Collect urine and apply urine-rich FYM - Apply mineral K before planting if necessary (K-deficient soils)
6: Micro-nutrient problems	6.1 Improve pH-management	- see point 2
	6.2 Improve OM-management	- see point 9
	6.3 Use tolerant varieties (rarely a problem for maize)	- Use varieties tolerant to Micro-nutrient deficiency (e.g. B on wheat) - Use varieties more tolerant to deficiencies
	6.4 Application of micro-nutrients	- Rarely necessary for maize; Zn may be deficient in soils of high pH - B may need to be applied against sterility in wheat
7. Erosion	7.1 Use of erosion control practices	- Check if erosion is indeed a serious problem (often overestimated) - Check for general erosion control practices (e.g. mulching, cover crops, early crop establishment, grasses on terrace bunds...)
8. Compaction	8.1 Avoid soil compaction	- Minimize the use of mineral fertilizers - Increase the OM-content of the soil - Protect and increase soil life (e.g. earthworms)
	8.2 Reduce soil compaction	- Intercrop with deep rooted plants (e.g. pigeon pea)

Step 2: Evaluation of the crop system

Figure 19. Evaluation of the crop system: Step 2 in the process of identifying farm-specific recommendations for IPNS in maize-based systems on bari land in the mid-hills.



Maize-based system Bari-land Mid-hills

1: Area
Market access:
- Combine local and external nutrients sources
- Avoid negative side effects (acidification, compaction...)

Poor access:
- Concentrate on local resources
- Identify opportunities for additional biomass production

2: Field conditions
Sloping land: Consider no-tillage of maize
Water-logging: Make drainage ditches

3: Land preparation
Early land preparation for early planting and reduced leaching of N and cations
Spread FYM and incorporate directly to reduce N-losses

4: Variety selection
Use short-cycled, input-responsive varieties in areas/fields of high N-availability
Use longer-cycled, local varieties in areas/fields of low N-availability
Use acidity tolerant varieties in acidic soils
Use shorter and not-leafy varieties for intercropping

5: Basic fertilization (see Table 5)
Incorporation of FYM (see point 3)
P-application in P-deficient soils

6: Planting and intercropping
Early planting to catch N-flush at start of rains
Green manure intercrop, slash and incorporate at 1st weeding (e.g. Dhaincha)
Food legume intercrop in maize to increase N to subsequent crop (soybean, cowpea, ...)
Fodder legume intercrop in maize to increase N to subsequent crop

7: Top-dressing (see Table 5)
Areas of urea availability:
Apply on maize 15-45 kg N/ha at 4-8 weeks
Incorporate urea to reduce N-losses
Areas of no urea availability:
Apply urine as top-dressing
Incorporate green manure (see point 6)

8: Harvest and residue management
Crop/Livestock systems:
Recycle biomass through FYM
Areas of surplus biomass:
Mulching in areas of surplus biomass (no burning)

9: Crop uptake in maize-based systems

Grain yield	N-uptake by crop	P-uptake by crop	K-uptake by crop
Maize: 1 Muri/ropani (70kg)	1.6 kg	0.6 kg	1.6
Wheat: 1 Muri/ropani (70 kg)	1.6 kg	0.5 kg	1.3
Millet: 1 Muri/ropani (70 kg)	2.5 kg		
Mustard: 1 Muri/ropani (62 kg)	2.5 kg	1.2 kg	

Table 5. Decision for recommendations on IPNS: Step 3 in the process of facilitating farm-specific decisions for IPNS in maize-based on bari land in the mid hills.

	3.1 Soils of low OM-content (about 1%)		**3.2 Soils of moderate OM-content (about 3%)**	
1. Recommened practice for Maize	**Expected yield of maize per ropani** *3 Muri/ropani (210 kg/ropani)*	*5 Muri/ropani (350 kg/ropani)*	**Expected yield of maize per ropani** *3 Muri/ropani (210 kg/ropani)*	*6 Muri/ropani (420 kg/ropani)*
Normal FYM, decomposed, incorporated before planting	15 doko	25 doko	20 doko	35 doko
DAP in pathi/ropani before planting	0.5 pathi	1 pathi	0	1 pathi
Urea in pathi/ropani as top-dressing at 4-8 weeks	1 pathi	1.5 pathi	0	1.5 pathi
1.1 Alternative to urea and DAP (if not accessible): Green manure of Dhaincha or Sunhemp, incorporated as green manure at 4 weeks	No DAP and urea necessary	Reduce DAP and urea by 50%	Increase of yield likely	Reduce DAP and urea by 50%
2. Recommended practice for wheat following maize	**Expected yield of wheat per ropani** *1 Muri/ropani (70 kg/ropani)*	*2 Muri/ropani (140 kg/ropani)*	**Expected yield of wheat per ropani** *2 Muri/ropani (140 kg/ropani)*	*3 Muri/ropani (210 kg/ropani)*
Normal FYM, decomposed, incorporated before planting	5 doko	10 doko	10 doko	10 doko
Urea in pathi/ropani	0.3 pathi	0.5 pathi	0.5 pathi	0.5 pathi
2.1 Alternative to urea and DAP: Fodder legume relay cropped into maize 75% of legume biomass removed for fodder	Increase of yield likely	No DAP and urea needed	No DAP and urea needed	No DAP and urea needed

Comments:

1) The yield depends significantly on rainfall, pest and disease attack. The indicated nutrient recommendations permit a maintenance of soil fertility.
2) The organic matter supply under system 3 (soil of moderate OM, 3 Muri of maize and 2 Muri of wheat) does not fully maintain the OM-content of the soil. The application of an additional 15 doko of FYM or other practices would be desirable. An alternative is a terrace riser slicing every 2 years.
3) The yield of wheat depends significantly on the rainfall pattern.

Note: 1 doko FYM of 25 kg, 1 pathi DAP of 5 kg, 1 pathi urea of 3.84 kg

4.2 *Field-level action*

The previous example shows that the farm-specific design of IPNS is built on an evaluation and decision process. This requires tools for field-level assessment and the capacity for facilitating decision processes with farmers. Extension staff and leader farmers need to be enabled to develop their knowledge and skills accordingly. Knowledge enhancement through training and decision support tools are therefore essential elements for the development of IPNS.

5 Conclusions

There is a wealth of information on soils, soil processes, plant nutrient requirements and related information. IPNS tries to integrate this information into a coherent concept. This is a challenge for research and extension.

Research and extension are continuous processes. Thus, extension needs to provide answers to farmers on questions that research has yet to answer. Thus, we need the courage to develop a practical IPNS now based on available information. Research will continue to improve IPNS over time.

There is a risk to shy away from this effort and to be overwhelmed by the complexity of the task. IPNS is site-specific and is to a large degree an interactive process of learning and approximation with and finally by local actors, in particular farmers.

The following recommendations can be given:

(1) **Continuity in research:** There is a need to continue research on IPNS. The recommendations for IPNS need to be gradually refined so as to develop IPNS for major soil and cropping systems in Nepal.

(2) **Practical guidance for extension:** There is a need to develop now practical recommendations for the extension of IPNS. The wealth of available information needs to be analyzed and translated into well targeted IPNS for specific soil and cropping systems.

(3) **Implementation beyond the APP:** The implementation of IPNS supports the goals of the APP. It contributes to an increase in productivity for well targeted systems based on a systems' perspective. Additionally, IPNS goes beyond the strategies and goals set in the APP. It contributes to an increase in land productivity at much lower amounts of external inputs than foreseen in the APP. It reduces therefore the impact of the removal of subsidies on fertilizers. Additionally, the focus on the efficient use of local resources and the focus on organic matter management increase the likely impact beyond the APP-defined pocket areas and can reach a larger proportion of farm households under subsistence agriculture.

(4) **Coordinated effort:** IPNS is not just a technical message of amounts of nutrient to be applied based on soil analysis. It is a concept of understanding soil processes, plant growth, and soil-plant interactions. It is based on resource availability in a local farming system. Thus, IPNS is about enabling women and men farmers and extension staff to decide on soil management and to design locally appropriate IPNS-systems. This requires a close link of soil specialists with local farming communities and those organizations from the governmental or non-governmental side, which support community and agricultural development.

(5) **Knowledge enhancement and decision taking:** IPNS contains a basket of technologies and practices. Farmers may use any combination of the practices in an integrated way and as locally appropriate. This implies to enable women and men extension staff and leader farmers through training on how to design with farmers locally appropriate IPNS. Simple tools for evaluating soils and cropping systems need to be developed for this purpose. The difusion of IPNS needs to be seen as a major challenge to communication and interactive learning by women and men farmers.

(6) **Sustainable systems:** IPNS in the context of SSM is about preventing problems rather than correcting deficiencies. This implies a focus on OM-management and avoidance of acidification. In the context of the APP, it requires an understanding of the emerging risk for soil productivity in the intensifying pocket areas. Recommendations for IPNS in these intensifying pocket areas need to put the pathway towards increasing production and productivity on a sustainable footing.

(7) **Integrated Soil Fertility Management:** IPNS in the context of sustainable soil management goes beyond nutrient management. Thus, the term "Integrated Soil Fertility Management" as used by some other organizations may be more appropriate.

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\IPNS02

Soil Management Programme: present situation, challenges and future strategies

Group Report by Workshop Participants, compiled by S.N Jaishy and T.B. Subedi, STSS. DoA

1. Introduction:

Crop production and population growth have almost increased at parallel rates over the past 25 years. The increase in crop production is mainly due to an increase in area of production rather than in productivity per unit area. Almost all marginal land has been brought under cultivation and there is little chance to further expand in the future. The only way to increase the production in the future is by increasing productivity. However, it is realized that soil fertility is deteriorating over time putting agricultural productivity at risk.

At present farmers use 2.5-3 ton/ha of organic manure for fertility management. Mid-hill soils are receiving more organic manure compared to Terai soils, whereas cropping intensity is higher in Terai. The national average use of chemical fertilizer is about 30 kg per hectare. At this rate of manure and fertilizer application, it is not possible to meet the nutrient demand of crops. The use of microbial fertilizer is also minimal in farmers' soil fertility management practices. Therefore, there is a large gap between nutrient uptake from the soil by crop plants and nutrient supply into the soil through soil fertility management practices resulting into a decline in soil fertility year after year.

2. National priority: The Agricultural Prospective Plan (APP) and Pocket Package Strategy (PPS)

From the onset of the 9th five-year plan a twenty-year agriculture perspective plan (APP) has been put into practice with the following objectives:

- Accelerating agricultural growth rate through increased factor productivity
- Transforming the subsistence agriculture into a commercial one through diversification of production based on comparative advantages
- Expanding opportunities for overall economic transformation by fulfilling the precondition of agricultural development
- Alleviating poverty through accelerated growth of agriculture and generating employment opportunities
- Identifying immediate short-term and long-term strategies for preparing periodic plans and programs

3. Overview of issues in soil fertility in different farming systems

3.1. Prevalent Agriculture system

Over time the agriculture system has been changing from low input agriculture system (LIAS) to high input agriculture system (HIAS). The intensification of agriculture has been brought by two reasons: (1) Increase in population has forced people to grow two or more crops in a year from the same field. (2) With the improvement in irrigation facility, access to market and advancement in agriculture technology, new opportunities have emerged for growing many crops in a year from the same field. This intensification of agricultural systems has put extra pressure on soil resources. It has resulted in a decline in soil fertility. Therefore, if no appropriate measure is taken, it will be impossible to sustain productivity and feed the growing population.

3.1.1. Characteristics of different systems

3.1.1.1. Subsistence Farming

- Mostly Rainfed
- Poor quality seed
- Very low /no use of chemical fertilizers
- Erosion hazards in mid-hill and high-hill

The result of these conditions and practices are:

- Declining soil fertility
- Low production

3.1.1.2 Intensive cropping

a. Market/technology driven

- Good irrigation
- High yielding variety
- High dose of chemical fertilizer
- Unbalanced use of chemical fertilizer
- Intensive (3 crops/year)
- Good technical support
- Farmer's understanding about nutrient management is comparatively better

The result of these conditions and practices are:

- Better yield compared to traditional/subsistence farming
- Micro/macro nutrient deficiency
- Poor organic matter maintenance
- Decrease in soil fertility
- Long term unsustainability of production/productivity
- Possibility of environmental pollution

b. Population driven:

- Poor or no irrigation
- Intensive cropping
- High yielding variety
- High dose of chemical fertilizer
- Unbalanced dose of chemical fertilizer
- Comparatively poor technical support
- Farmer's understanding about nutrient management is poor

The result of these conditions and practices are:

- Unscientific cropping pattern.
- Better yield compared to traditional/subsistence farming
- Micro/macro nutrient deficiency
- Poor organic matter recycling
- Greater erosion hazards
- Quick decline in soil fertility
- Quick decline in agriculture production aggravating poverty in society

Both in subsistence as well as in intensive cropping system soil fertility is declining. The main reasons of soil fertility decline can be summarized as follows.

- Organic matter depletion both in hill and Terai
- Acidification of soil: Mostly middle mountain and Eastern Nepal's soils are acidic due to parent material (sand stone, silt stone quartzite) and use of acidic fertilizer also
- Soil erosion /vulnerability: Mostly high hill, hill, upland and marginal land have high rate of soil erosion
- Micro nutrient deficiency: Visible hunger signs in paddy (Zinc) and root crops (boron). Hidden hunger is also affecting the production of cereals, vegetables and fruits crops

- Siltation problem: Seti river irrigated area and Narayani irrigation sector command area is more prone to siltation
- Degradation of forest land marginal land
- Crop intensification (multi cropping in one year)
- Mono-cropping for long period (paddy-wheat-maize)
- Low quality fertilizer: Serious problem is faced by farmers due to introduction of low quality fertilizer in the country.

4. Research and extension services for soil fertility management

Realizing the importance and need for soil fertility management, soil management programmes were launched buy the Department of Agriculture (DoA) in its regular programme from the very beginning. The major programmes launched by the department are promotion of organic manure and compost, green manuring, balanced use of chemical fertilizer, soil and plant analysis service to the farmers, training to farmers and technicians, demonstration etc. Adaptive and basic research in soil fertility management and fertilizer recommendation for different crops has been carried out in government farms and stations. After emergence of Nepal Agricultural Research Council (NARC), the department is giving technical service to farmers and research on soil fertility management is carried out by NARC.

4.1 Soil fertility management activities in extension and research

The extension efforts by the Department of Agriculture cover the following major efforts:

- Soil analysis and fertilizer recommendation
- Soil survey and fertility mapping
- Soil management training
- Technical support
- Soil campaign
- Monitoring and evaluation of soil management activities

Research activities on soil fertility management focus on the following aspects:

- Recommendation of balanced dose of manure and fertilizer
- Timing and method for application of manure and fertilizers
- Isolation and distribution of effective strain of bacterial fertilize
- Cropping system research for better soil fertility management

Although several practices and technologies have been recommended for soil fertility management, no integrated package of soil fertility management has yet been developed. Therefore, much work is needed to solve the problem of soil fertility management in an integrated manner.

5. Concept of integrated plant nutrient system (IPNS):

As already discussed, soil fertility is declining in alarming rate. The main reasons of soil fertility decline are soil erosion, unbalanced and insufficient nutrient supply and organic matter depletion from soil. The use of chemical fertilizer may supply the nutrient requirements of crops, but the organic matter, which is the soul of soil, can be added only through organic manure.

It is reported that total farmyard manure (FYM) production is declining. There are many other sources of organic manure like composting, green manure, stubble farming etc. Therefore, for a resource poor country like Nepal, utilizing all available local resources along with the judicious use of chemical fertilizer is the only way for soil fertility management and increasing the agricultural production. The nutrient requirements of a rice crop yielding three ton per hectare and the effect of FYM and green manure on nitrogen and organic matter balance is presented in figure 1.

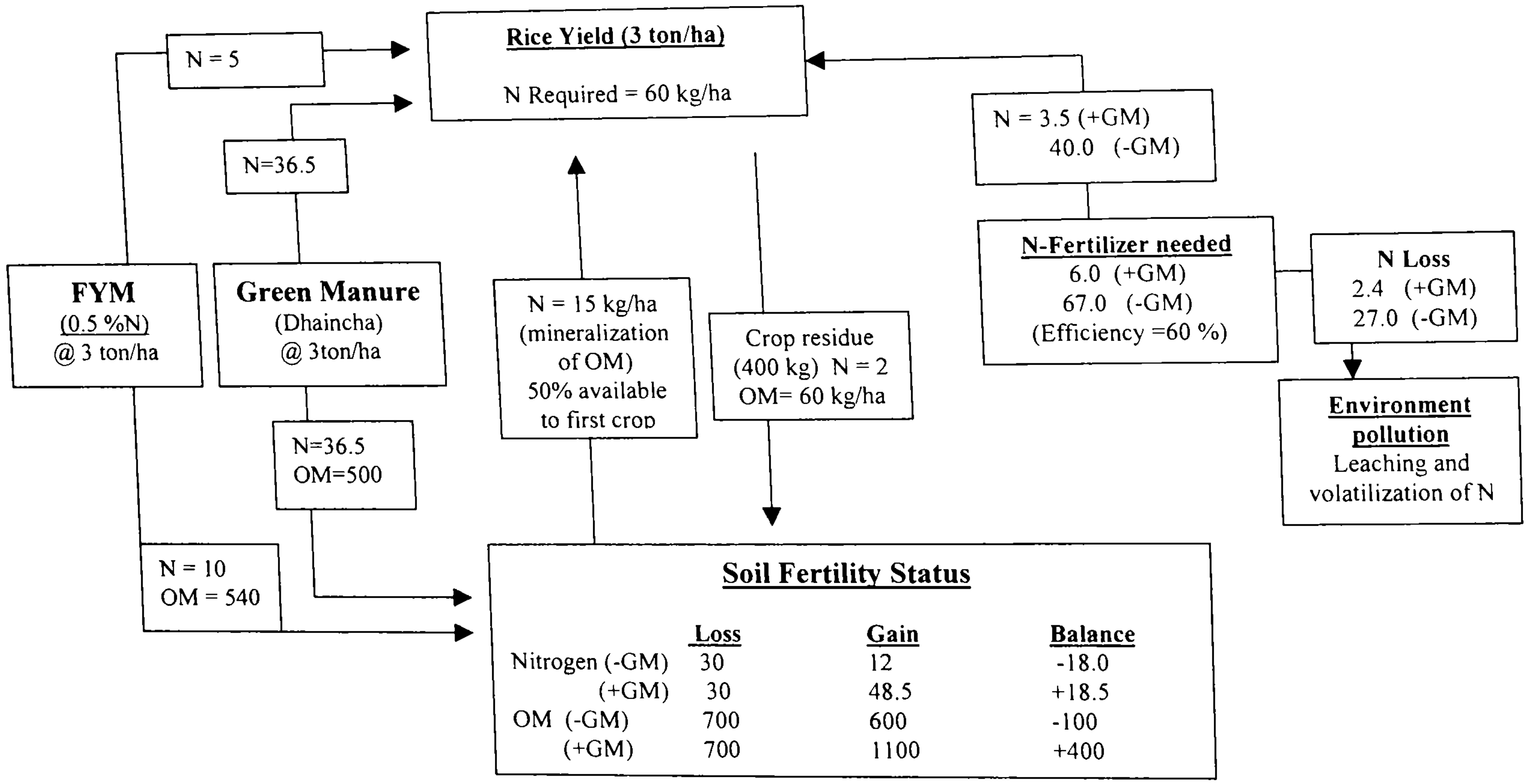

Figure 1. The effect of FYM and Green Manure on Nitrogen and OM balances in a soil with low OM content.
(The numbers/units are in kg wherever not mentioned)

From figure it is clear that at the present rate of FYM application 40 kg of nitrogen need to be added to meet the crop demand. Considering 60% efficiency of added fertilizer, 67 kg of nitrogen should be added as fertilizer. More over the organic matter content of soil is also depleted. But if we grow Dhaincha as green manure, it can supply almost all nitrogen requirements for the rice crop yielding three tons per hectare and also add organic matter and enrich the soil.

Intensive land use and unbalanced application of chemical fertilizer along with poor organic matter recycling has resulted in the decline of the inherent soil fertility status and a reduction in agricultural production. If no measures are taken in time for sustainable soil fertility management, we may not be able to feed the growing population in the future. Therefore, to cope with the problem the following activities are proposed for strengthening of the soil management programme.

(1) Strengthening of soil, plant and fertilizer analysis programme
- Strengthen the government sector for quality control and decision making.
- Promote private sector for analytical services.

(2) Soil fertility mapping
- At present only few districts are covered, but all districts should be mapped
- Essential to prepare fertility map of all potential pockets in the districts

(3) Develop IPNS model for sustainable fertility management (crop specific and location specific).
- Various component of soil fertility management have been studied and recommended for farmer's use but an integrated package of IPNS model is still lacking

(4) Demonstration of sustainable soil fertility management programme in farmer's field.

(5) Popularize soil test campaign and educate farmers about need for sustainable soil fertility management.
- Mobilization of manpower at DADO
- Training for extension workers about soil testing kit handling and interpretation of results.
- Training for farmers about sustainable soil fertility management.

(6) Utilizing farmer's indigenous knowledge about soil fertility management.

6. Limitation/constraints:

To strengthen the existing activities towards a sustainable soil fertility management programme (SSFMP) the limitations are as follow:

- Human resource
  - Lack of manpower (number)
  - Lack of trained manpower (quality)
- Physical facility
  - Lack of laboratory equipment
  - Lack of mobility (vehicles)
- Linkage and coordination

Although the soil management programme is one of the key components for agriculture development, it alone can do nothing for the overall development of agriculture. To make a soil management programme a success a good linkage among various institutions is very essential.

7. Conclusions

It is realized both by farmers and the agriculturists that soil fertility is declining. If no appropriate measures are taken in time, the country may face a great problem in the future. Therefore, all the concerned organizations and the farmers should work together to cope with the problem of soil fertility management and feeding the growing population in the future. The following points are suggested for better soil fertility management in future:

(1) Educate the farmers for need of sustainable soil fertility management

(2) Training of junior technicians and field level workers
(3) Improving the quality and quantity of compost/FYM
(4) Promote green manure crops
(5) Incorporating legumes in crop rotation
(6) Growing grasses and fodder crops for more biomass production
(7) Promote biogas and discourage burning of cow dung and rice straw
(8) Strengthening soil fertility management extension services in the district level
(9) Good linkage and coordination between all concerned organizations for effective implementation of soil management programmes.

Curriculum Outline for a Training Module on IPNS

Integrated Plant Nutrient Management (IPNS) is a new concept for most persons involved in extension. It is therefore necessary to develop a capacity on this topic, which enables extension staff to demonstrate IPNS to farmers. A preliminary outline for such a Training Module on IPNS is listed below.

Major points to be considered for Integrated Plant Nutrient Management

1. Soil Fertility Status (Nutrient availability)
2. Crop requirements
3. Factors and reasons of soil fertility decline
4. Sources of nutrients for IPNS, practices to reduce losses and opportunities for nutrient use efficiency

Elements of IPNS

1. Soil management (organic matter, tillage, erosion control...)
2. Crop management (cropping system, variety selection,...)
3. Biofertilizer (symbiotic, non-symbiotic...)
4. Organic manure (FYM, compost, mulch...)
5. Inorganic manure (fertilizers, rock sources, lime...)

Activities on IPNS at Farmers' level

Objectives:

1. Awareness creation
2. Concept of IPNS
3. Elements of IPNS
4. Sustainable Soil Management

Tentative content for capacity building:

Soil/Crop Mgmt	Org. Man.	Inorg. Man.	Biofertilizer
• Types of soil & their fertility status • Crop types & nutrient requirement • Cropping system • Water management • Soil erosion / conservation • First spring flood • Soil pH, nutrient availability & use of lime	• FYM (its quality, utilization, quantity) • Slurry management • Green manure • Suitable crops • In situ / GLF / Azolla • Organic recycling • Composting of crop residues & city waste • Stubble farming & cover crops • Slicing terrace riser	• Judicious use (Balanced use, proper time & method of application) • Function of major & micro nutrient • Recommended dose & level of management. • Diagnostic criteria of deficiency & toxicity	• Rhizobium / Azotobacter (Symb./Non-symb.) • Mycorrhiza • BGA • P-solubilizing bacteria

Note: The Course needs to be designed & materials to be used according to the level & knowledge of participants.

Abbreviations

ADB	Agricultural Development Bank, Nepal
ADO	Agricultural Development Office
AEZ	Agro-Ecological Zone
AIC	Agricultural Input Corporation
APP	Agricultural Perspective Plan
ASC	Agricultural Service Centre
CBS	Central Bureau of Statistics
DADO	District Agricultural Development Office
DIO	District Irrigation Office
DoI	Department of Irrigation
DRIS	Diagnosis and Recommendation Integrated System
DSCO	District Soil Conservation Office
DWMSC	Department of Watershed Management and Soil Conservation
FU	Fertilizer Unit
FY	Fiscal Year (mid-July)
FYM	Farm Yard Manure
GIS	Geographic Information System
HEIAS	High External Input Agricultural Systems
HIAS	High Input Agricultural Systems
HMGN	His Majesty's Government of Nepal
ICIMOD	International Centre for Integrated Mountain Development
ISFM	Integrated Soil Fertility Management
IPNM	Integrated Plant Nutrient Management
IPNS	Integrated Plant Nutrient Systems
JT	Junior Technician
JTA	Junior Technical Assistant
K_2O	Potassium
LAC	Agricultural Research Station Lumle
LEIAS	Low External Input Agricultural Systems
LER	Land Equivalent Ratio
LIAS	Low Input Agricultural Systems
LRMP	Land Resources Mapping Project
LUT	Land Use Type
N	Nitrogen
NARC	Nepal Agricultural Research Council
NPC	National Planning Commission
OM	Soil organic matter
P_2O_5	Phosphorous
PAC	Agricultural Research Station Pakhribas
PDDP	Participatory District Development Programme
pH	Soil reaction, pH
RS	Remote Sensing
SMS	Subject Matter Specialist
STSS	Soil Testing and Service Section
VAM	Versicular Arbuscular Mycorrhiza

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