

Soil Fertility Status of *Bari* and *Khet* Land in a Small Watershed of Middle Hill Region of Nepal¹

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ABSTRACT

Soil fertility is a critical issue to the farmers, particularly where population pressure is high and agriculture is the main source of income. A study to identify soil-fertility status of land use systems ie *Bari* (upland) and *Khet* (irrigated lowland), which are the two district and dominant agricultural land use systems in the Hills of Nepal was carried out in Lohorne Watershed, Dailekh District of Nepal. Soil fertility status of nitrogen (N), phosphorous (P), potassium (K) and organic matter (OM) is better in *Bari* than in *Khet* land. The pH was found to be slightly low, more acidic in *Khet* than in *Bari* land. Root depth and bulk density of *Khet* land were higher than that of *Bari* land. Higher application rate of farmyard manure (FYM) in *Bari* land and less crop intensity resulted *Bari* land more fertile than *Khet* land.

Key words: Nutrient land use, nutrient management, plant nutrients, soil fertility

INTRODUCTION

A vast majority of the agricultural population has been residing in the hills where the average land holding is less than 0.5 hectares, compared to 1.7 hectares in the Terai (CBS 2000). The hills of Nepal are generally characterized by two distinct and dominant land-use systems, ie (i) *Bari* (rainfed uplands, with maize-based cropping systems) and (ii) *Khet* (irrigated lowlands, with rice-based cropping systems). Agriculture is largely subsistence type and people have to rely on limited land parcel. Soil fertility status of farmland depends directly on farming practices. Soil fertility management issues are becoming critical for the productivity of the land, particularly in the hills of Nepal, where population pressure is high.

The increasing population pressure in the hills of Nepal stresses the environment and threatens the agricultural productivity and consequently the food security. The sustainability of hill agriculture depends how farmers manage, protect and utilize their farm and forest resources (Basnyat 1995). Shifting cultivation, overgrazing, overuse of marginal land are contributing to the loss of soil-fertility (Regmi 1999). The topsoil being washed down the river systems into India and Bangladesh is now Nepal's most precious export, for which it receives no compensation (Eckholm 1976). The annual silt load from the Karnali catchment in the mid-western region of Nepal has been estimated at 75 million m³, equivalent to a denudation rate of 1.7 mm/year (Ives and Messerli 1989). Soil loss and nutrient depletion due to rainfall erosion are very high, particularly in the rainfed marginal land and the degraded grazing lands in hills. The losses of soil organic matter and nutrients are threatening the sustainability of agriculture (Thapa 1996).

Farmers' indigenous knowledge on soil fertility management strategy is crucial in managing their agricultural soils. How and what resources are being used by the local people to sustain soil

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fertility in different land use systems is the key question. Therefore, there is need to investigate on soil fertility status between *Khet* and *Bari* land. For a typical small watershed, this paper examines the fertility status and management practices in these two land-use systems. The main objective of this study was to find out soil fertility status between two distinct land use systems (ie *Khet* and *Bari*). Other specific objectives were to find out the levels of input use, to find out crop production and productivity and to prepare nutrient budget for two distinct land use systems.

METHODOLOGY

Lohorne Khola, a small watershed in western Nepal (Dailekh District, Narayan Municipality, Kharigaira VDC), which is typical for the Middle-Hill region of Nepal, was selected for the study (Figure 1). Household survey to characterize socioeconomic conditions of the local people and a soil survey were carried out covering both land-use systems (*Bari* and *Khet*). Thirty-two soil samples, 16 from each land use system were analyzed for plant nutrients. Topsoil samples (0 – 20 cm) were collected and analyzed. Soil samples were measured in the lab of Nepal Agricultural Research Council (NARC), Katmandu using standard methods (Table 1). Composite soil samples were taken out from the depth of 6-9 cm. Random sampling was done for selecting the households to be surveyed and participatory discussion was carried out in order to identify the sites for soil samples collection from two land use systems.

The cropping pattern and practices may vary from place to place depending on the location and variation in soil, climate, farm-size, family labour supply, transportation, market demand and availability of inputs. However, it may not vary within a homogenous agro-ecological zone. The

farmers' practices for the soil fertility management are assumed to be homogenous. Farmers having upland fields have also the lowland fields in the same watershed. Another facet of the land holding is that it is not concentrated in a single place but rather scattered in different parcels of small sizes. Therefore, soil management in individual parcels as well as upland and low land may vary. But under the umbrella of broader farming system perspectives, the households' practices are found to be more or less homogenous within the watershed. Considering this fact 55 households (equal to 20% of the total households in the watershed) were selected for the study purpose.

The primary data were collected through reconnaissance survey, group discussion, key informant interviews and households' surveys. Secondary data were collected from different government offices, ie, Kharigaira Village Development Committee (VDC), District Agricultural Development Office (DADO), District Soil and Water Conservation Office (DSWCO), District Forestry Office (DFO) and District Development Committee (DDC) and Narayan Municipality. Land use and land capability maps were collected from His Majesty's Government (HMG) of Nepal, Department of Survey (DoS).

Table 1. Soil characteristics and method of measurement

Characteristics	Methods of measurement/analysis
Slope and altitude of the sample sites	Topographic map
Soil color	Munsell color chart
Bulk density	Replacement method
Nitrogen	Kjeldahal titration method
Phosphorous	Bray I and Bray II method
Potassium	Ammonium acetate extraction method
Organic matter	Wakley-Black method
pH	Electronic pH meter
Texture	Hydrometer
Rooting depth	Measuring tape

RESULTS AND DISCUSSION

Farmers in the hills of Nepal have been facing a serious problem in managing the soil fertility because of the steep slopes, the dependency on rainfall and unavailability of required inputs such as fertilizers. The gradual decline in soil fertility, the increase in soil erosion, a reduction of the productive forest area and misuse of agro-chemicals are the major agricultural and environmental problems in Nepal. The agricultural environment, particularly in the hills of Nepal, is degrading at a high rate (Regmi, 1999). Apart from these problems, the most severe constraint recognized by the farmers as well as agricultural scientists is the declining crop productivity.

Main crop yields

Major crops grown in the area were maize, wheat and rice. However, millet and buckwheat were also grown in some areas as minor crops. Vegetables were grown only for home consumption but a few farmers started growing vegetable for selling. Table 2 reflects the situation of crop productivity in the area as compared to the national figure.

Table 2. Yield levels of main staple crops

Crop	Average yield of grain, t ha ⁻¹	
	Study area	National
Maize	1.11	1.68
Wheat	1.59	1.59
Rice	0.89	2.40
Potato	7.92	9.87

Source: Field survey 2001, CBS 2000.

Manure and fertilizer uses

Poor soil fertility status of the farmland in the Middle Hills of Nepal is a major constraint faced by the farmers (Pandey 1995). Soil productivity is being reported as declining because of increasing agricultural activities such as crop intensification and the expansion of agriculture into marginal lands with insufficient plant nutrient replenishment.

The number of livestock per household determines the extent of farmyard manure (FYM) use in the farmlands. A positive relation was found between livestock number and farmyard

manure application. A negative relation was found between livestock number and the use of chemical fertilizers (Regmi 2001). The farmers used less chemical fertilizers when they had more livestock that produced manure. The major share of manure was produced by cattle and buffaloes (Table 3). However, sheep and goats were also important sources of manure. Pigs and poultry contributed insignificant quantities.

The study also revealed that the dose of FYM was different for *Khet* and *Bari* lands (Table 4). Farmers believed that maize – grown on *Bari* land – removes more plant nutrients from the soil than other crops. Therefore, they needed to apply more nutrients. Also *Bari* land is located nearby household. Therefore, *Bari* land received more FYM than that of *Khet* land.

Chemical and physical soil fertility parameters

Some selected chemical and physical soil properties have been used as indicators for the soil-fertility status of *Bari* and *Khet* lands in the study area.

Nitrogen

Nitrogen (N) is the key macro-nutrient for the crops. The soil analyses have shown that N level in the soil was low. The range of total nitrogen in the sampled soils was between 0.083% to 0.223%. *Bari* land had a slightly higher nitrogen content than *Khet* land (Table 5). The reason for this is the higher FYM and compost use, which contributed to the increase in N. *Khet* lands are irrigated, with high N losses through leaching and runoff. In the rainfed *Bari* land the level of leaching is much lower.

Table 4. Average application of farmyard manure (FYM) and chemical fertilizers on *Khet* and *Bari* land, kg ha⁻¹ yr⁻¹

Village	<i>Bari</i> Land		<i>Khet</i> Land	
	FYM	Chemical fertilizers	FYM	Chemical fertilizers
Bhirmoura	12456	5.32	3345	24.84
Wallo Kalimati	8678	4.75	3487	34.25
Pallo Kalimati	9184	7.89	2914	35.40
Golsin	10238	4.25	4035	19.73
Luchhekanda	9136	7.87	3274	34.83
Dewalkanda	7069	2.36	2832	25.72
Overall	9523	5.41	3370	28.91

Table 5. Some physical and chemical parameters of soil of *Khet* and *Bari* land

Soil parameter	Khet	Bari
Nitrogen, %	0.13	0.14
Phosphorous, kg ha ⁻¹	14.38	54.53
Potash, kg ha ⁻¹	305.86	648.90
Organic Matter, %	2.09	2.70
pH	5.20	5.57
Bulk Density, g cm ⁻³	1.36	1.28
Rooting depth, cm	59.69	55.19

Phosphorous

Phosphorous (P) has great importance for crop production. Phosphorous is essential for the maturity of crops and for root growth. Especially small seedlings benefit from a good phosphorous supply. The available phosphorous in the soil was very limited, although the total phosphorous levels were high. The soil conditions that made phosphorous available to plants varied greatly in the area. Soil pH plays very crucial role in P availability. The soil tests showed that available phosphorous in *Bari* land was higher than on *Khet* land. However, most of the soil samples were in the lower range. Only a few soil samples had a high P levels. The reason for the higher P content on *Bari* land could be due to the higher levels of pH (Table 5) and the high soil organic matter content that improved the general soil condition and provided some P to the soils.

Potassium

Most potassium (K) in plants is found in the above-ground portion, mainly in the straw. Therefore, if crop residues are returned to the soil, a good proportion of the potassium is conserved. In soils, potassium is found as part of the mineral structure of many clay minerals particularly micas. In this form, however, K is locked up from plant roots. The soil tests have shown that the K-content of the soil was generally high. This is typical for the soils of Nepal. The soil tests have also revealed that K-levels were significantly higher in *Bari* land than in *Khet* land. This is due to the returning of crop residues into the soil and the higher rate of organic fertilizer use (eg farmyard manure) on *Bari* land.

Soil pH

The range of soil pH was between 4.7 to 7.7 in the sampled soil. The lowest pH was found on *Khet* land and the highest on *Bari* land. On an average, pH-levels in *Bari* land were higher than in *Khet* land (Table 5). The reasons for the lower pH-levels in *Khet* land are most likely to be the higher chemical fertilizer use and the effect of leaching induced by the irrigation of *Khet* land, contributing to the more acid conditions. This was not the case with the rainfed *Bari* land (Table 4).

Organic matter

The organic matter content of the topsoil on *Bari* land was significantly higher than on *Khet* land (Table 5). Generally, however, most of the soil samples were in the lower range of acceptable organic matter level, only a few samples could be classified as medium. The field survey showed that the use of farmyard manure, compost and the level of *in situ* manuring were higher on *Bari* land than on *Khet* land. This explains the more favorable organic matter conditions on *Bari* land.

Bulk density

Bulk density is a measure of the compactness of the soil. It relates to the pore size distribution, thus indicating the range of water-holding capacity and soil aeration. Bulk density can be modified by soil-organic matter management and tillage practices. Bulk density on *Khet* land was generally higher than on *Bari* land (Table 5). This is because of higher soil organic matter content on *Bari* land, which is favorable for a good soil structure and the tillage practices on the *Khet* land, with common soil puddling that compacts the soil, resulting in a high bulk density. However, for rice, which is the dominant crop on *Khet* land, puddling is required to prevent percolation of water losses.

Soil depth

The field survey revealed that the average soil depth (ie rootable soil depth) on *Khet* land was generally higher than on *Bari* land, although the ranges in both *Khet* land (38-77 cm) and *Bari* land (35-71 cm) were similar (Table 5). The differences might be due to the higher soil erosion rates on the sloping *Bari* land. Because the *Khet* land is flat and usually located further

downstream, it acted as sedimentation area for the eroded soils of the *Bari* land. However, most of the eroded soil entered directly into the streams and the absolute quantity of sedimentation on *Khet* land was not significant.

Nutrient balance in the farmers' fields

Assessment of the nutrient balance in farmland is dependent on the methods used and the information available. For the study area, the assessment focused on the balance between nutrient application and nutrient uptake by the crops. Fertilizer and organic matter applications varied significantly between farms, depending on factors such as the economic condition of the farmers, the number of farm animals, access to forest resources and access to the market.

The nutrient (ie N, P and K) contents and the average application rates of different types of fertilizers (ie farmyard manure, compost, green manure and chemical fertilizers) that are applied by the farmers were determined to establish an estimate of the total quantity of nutrients applied to the soil (Table 4). Based on reported yields, the quantities of nutrients extracted by the different crops were estimated (Table 6). The nutrient status was then determined by subtracting plant uptake from input.

Table 7. Cropped area under different crops (ha)

Crop	Cropped area	Percentage of total area
Rice	19.21	28.4
Wheat	18.51	22.4
Maize	20.63	32.2
Millet	6.23	8.7
Barley	1.21	3.8
Vegetables	0.51	0.01
Mustard	2.11	3.5
Total	59.93	100

Table 8 shows the nutrient balance on the farmlands of studied area. The table shows that there was a significant difference between the two land use systems. Though fertilizer applications on *Khet* land were much higher than on *Bari* land (Table 4). There was a general negative nutrient balance in *Khet* land. This might be explained by the higher crop yields on *Khet* land, which extracted significantly more

nutrients. However, there are also other factors that need to be considered in the nutrient balance. *Bari* was a more complex system than *Khet*, with an important agroforestry component that contributed large quantities of organic matter and nutrients to the soil.

Table 8. Nutrient balance in *Bari* and *Khet* lands[†]

Land use type	Input and uptake	Nutrient balance, kg ha ⁻¹		
		N	P	K
<i>Bari</i>	Input	59.62	12.38	57.14
	Uptake	56.35	9.00	37.34
	Balance	3.27	3.38	19.8
<i>Khet</i>	Input	33.52	4.38	20.22
	Output	34.02	5.2	34.07
	Balance	-0.5	-0.82	-13.85

[†] This analysis was based on Tables 2, 4, 6 and 7.

A similar study by Poudel (2001) in the Middle Hills of Nepal found that there were significant differences in nitrogen, phosphorous and potassium contents between *Khet* and *Bari* land, with *Khet* land also showing a negative nutrient balance.

Generally, the current soil fertility status in the study area was low, but not alarming. Although all indications pointed to a negative nutrient balance in the *Khet* lands, the general nutrient level and other soil conditions were not in an acutely marginal state. The farmers understood very clearly the importance of nutrient and organic matter management and they were keen to recycle as much organic matter as possible. The need to produce higher yields from the limited farmland would jeopardize the fragile agricultural production system.

However, there are scopes to improve overall soil fertility management in view of both ecological suitability and the growing needs of the farm families. There is a need to develop land-management guidelines that focus on the farmer specific needs rather than on the conventional general blueprint recommendations. This is a challenge to the extension service, which is traditionally accountable to its employer (usually government) rather than to its clients, the small farmers who need to survive under increasingly adverse conditions. It obviously showed that the fertility status in the farmland was low. Nutrient

balances further depicted that the sustainability of the soil fertility status were under threat. However, it is not a comprehensive calculation for exact amount of plants nutrients in and out, it is based on plant removal and prevailing soil fertility management practices, where balances seemed negative and marginal. There is a need to manage plant nutrients in an integrated way so as to achieve sustainable crop production through management of soil fertility.

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