Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Year 9, No. 9/ 2010, pp. 41-48

ASSESSMENT OF SOIL FERTILITY MANAGEMENT PRACTICES AND THEIR CONSTRAINTS IN DIFFERENT GEOGRAPHIC LOCATIONS OF NEPAL

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Abstract

A farmers' field survey was conducted in 2009 to evaluate soil fertility management practices and their constraints in certain hill and valley farming systems of Nepal. Thirty households from Okharpouwa village development committee (VDC), Nuwakot and thirty households from Fulbari VDC, Chitwan districts were surveyed using semi-structured questionnaires. In addition, key informants' interview, checklist survey, observation in the field and documentation of the individual cases were carried out during this research. The study revealed that farm yard manure (FYM) was the major source of nutrients, although the use of poultry manure, goat manure, green manure and chemical fertilizers was also common. We realized that the management of FYM and that of other types of organic manure in the manure pit and in the field was not efficient in conserving nutrients. Similarly, farmers preferred the continuous cultivation of cereal or commercial crops, without mixing the crops or rotating with legumes, the sliced terrace risers in hills, which constrained better production in hills and valleys of Nepal. The specific problems in hills included erosion and leaching of nutrients, soil acidification, while those of valley lands included the imbalanced use of fertilizers, intensive cropping, and crop failure due to improper management.

Keywords: *soil productivity, erosion, farm yard manure, crop management, soil degradation*

Rezumat

*Evaluarea practicilor de management al fertilităţii solului şi constrângerile acestora în diferite locaţii din Nepal***.** În anul 2009 a fost realizat un sondaj cu fermierii pentru a evalua practicile de management al fertilităţii solului şi constrângerile aferente în sistemele agricole din anumite zone de deal şi de vale din Nepal. La anchetă au participat treizeci de gospodării din comitetul rural de dezvoltare (CRD) Okharpouwa, districtul Nuwakot şi treizeci de gospodării din CRD Fulbari, districtul Chitwan, fiind folosite chestionare semi-structurate. În plus, pe parcursul cercetării au fost realizate interviuri cu furnizorii-cheie de informaţii, anchete prin liste de control, observaţii în teren şi documentări asupra cazurilor individuale. Studiul a evidenţiat faptul că îngrăşământul natural de fermă (ÎNF) a constituit principala sursă de nutrienţi, deşi folosirea gunoiului de la păsări, de la capre, a celui vegetal şi a fertilizatorilor chimici a fost, de asemenea, comună. A fost înţeles faptul că managementul ÎNF şi al altor tipuri de îngrăşământ natural în groapa de gunoi şi pe câmp nu este eficient pentru conservarea nutrienţilor. În mod similar, fermierii au preferat cultivarea permanentă a cerealelor sau realizarea culturilor comerciale, nefiind realizate culturi amestecate sau rotaţii cu legume, şi terasările în zona de deal, ceea ce a limitat producţiile agricole superioare din dealurile şi văile nepaleze. Problemele specifice din arealele deluroase au inclus eroziunea şi pierderea nutrienţilor, acidificarea solului, în vreme ce dificultăţile specifice zonelor de vale au inclus folosirea dezechilibrată a îngrăşămintelor, culturile intensive şi pierderile agricole determinate de managementul necorespunzător.

Cuvinte-cheie: *productivitatea solului, eroziune, îngrăşământ natural de fermă, managementul culturii, degradarea solului*

INTRODUCTION

Nepal is facing a serious problem of soil quality decline as a result of recent changes in agricultural practices and increasing resource constraints. Hartemink et al. (2008) documented several constrains in soil fertility management in Nepal because of deforestation and other land use changes. These changes include non-agricultural uses of fertile land, land fragmentation and cultivation in marginalized areas, cultivation on the slopes, overgrazing, burning of crop residues, imbalanced use of agrochemicals, and declining use of organic manure. In South and South-East Asia, the principal soil degradation processes associated with land use changes include

accelerated erosion by water and wind, salinization, flooding, water logging, and soil fertility depletion (Jacinthe et al., 2004). The pace of soil degradation issue is the highest in mountains because of the fragile environment and the steep slopes (Acharya and Kafle, 2009; Rasul, 2009). Moreover, due to rugged mountainous topography, active tectonics and concentrated monsoon precipitation, Nepal is naturally highly vulnerable to soil erosion on slopes and flooding in the low-lands.

Continuous cultivation without addition of substantial amount of soil organic matter (SOM) in rugged hilly terraces causes the sharp decrease in SOC and nitrogen (Shrestha et al., 2006). It is reported that Nepal needs to increase the production of major crops to provide food for rapidly growing population (Gami et al., 2001). However, deterioration of soil by erosion, nutrient mining and fragmentation caused a decreasing trend in soil fertility (Tripathi et al., 1999). Farmers realized that continuous application of chemical fertilizers, without addition of FYM, resulted into soil degradation and ultimately, productivity decline (Mathema, 1999). The low technical knowledge of farmers regarding these problems and resource-constraints to adopt rational management practices aggravated the problems of land degradation and soil fertility deterioration in Nepal.

Crop and livestock integrated farming is common in Nepal. However, recent changes in technologies and knowledge of farmers, increasing resource constraints and decreasing availability of manpower brought significant transformations in soil fertility management practices. More profit-oriented production, with limiting resources, diverted the farming practice toward mono-cropping and reduced the number of livestock per farmer, which served as a continuous source of FYM needed for farm-crops (Shrestha et al., 2000). This further deepened the problems of soil fertility degradation and productivity decline, requiring a big leap on soil management technologies to feed mushrooming population and to meet their changing demands. Thus, we designed a study to assess the existing soil and crop management practices in the hill and valley (plain) agriculture of Nepal and the problems associated with them; this assessment provides a basis for the understanding of the possible management options for better soil fertility and increased land productivity.

DATA AND METHODS

The study was conducted in Fulbari village development committee (VDC) of Chitwan and Okharpauwa VDC of Nuwakot district, Nepal (Fig. 1). Chitwan represents the valley land system of Nepal, which has tropical to sub-tropical climate with a total annual rainfall of 2666.3 mm. The annual mean minimum and maximum temperatures are 7.5ºC and 36.4 ºC, respectively. Three-fourths of the district area are on a valley, well-known as Rapti-Dun valley, with high agricultural potential. The district is the producer of cereals (paddy, wheat, and maize), vegetables (seasonal, as well as off-season), oilseeds, legumes, fruits, and flowers. In contrast to Chitwan, Okharpauwa VDC of Nuwakot represents the mountain land system. The district has temperate to sub-alpine climate, with the average annual rainfall of 1431 mm, the maximum temperature of 26.6ºC and the minimum temperature of 6.3 ºC. Due to the climatic diversity that goes from sub-tropical to alpine, the different parts of the district are famous for evergreen to temperate fruits, vegetables (both on season and off-season), being especially recognized for the strawberry and ginger production. The major staple food crops grown in the district include rice, maize, wheat, millet, and potato (CBS, 2010).

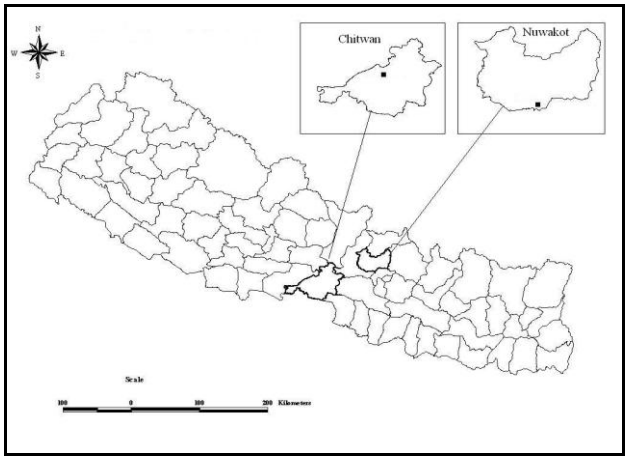

Figure 1. Study locations in the Chitwan and the Nuwakot Districts, Nepal

Literature survey was used to select the study locations that comprised diverse land uses, notably influencing the crop productivity and the ecosystem sustainability. Information regarding soil fertility and crop management practices was recorded from the questionnaire survey of 30 households in both districts (sixty households in total). We developed several questions about the source of manure and

fertilizers, manure storage and application methods, crops they grow and crop management practices associated with soil fertility. Specific questions related to slope management were developed for Nuwakot, as it was not a common problem on the valley soils of Chitwan. Similarly, checklist survey, key informants interview, focal group discussion, documentation of successful cases and direct observation in the field were used to evaluate the soil fertility management system of the study areas. We used semi-structured questionnaires for the checklist survey. The objective of the documentation of individual cases, key informants interview, and assessment in the field was to know the specific crop and soil management practices in the study location. The collected data pertaining to soil, crop and fertilizer management was coded and tabulated for computer entry and analyzed by descriptive as well as inferential statistical tools, using statgraphics plus 5.1 (Statpoint Technologies Inc.) and SPSS-16 (http://spss.en.softonic.com/) statistical packages.

DISCUSSIONS

Farm yard manure and poultry manure as source of nutrients

Soil fertility management involves soil and nutrient management operations that have direct relation with the nutrient supplying capacity of soils. Farm yard manure (FYM) is the primary source of nutrients and serves as the major means for soil fertility management in Nepal (Suresh et. al., 1999). Traditional subsistence farming in Nepal includes integration of crops and livestock in a single management structure (Neupane and Thapa, 2001) that provides FYM needed for the crops and forage needed for livestock. Thus, all farmers in Chitwan and Nuwakot used FYM to their crops, irrespective of the location or the agricultural land use types. However, there are many other sources of SOM common in the Nepalese farming (Table 1), which are based on the availability of source material and the technical know-how of the farmers.

Table 1. Number of farmers using different sources of organic manure (data presented as frequency of total survey population; survey, 2009)

Sources of Organic manures	Frequency used by farmers (percent)	
	Nuwakot (n=30)	Chitwan (n=30)
Farm Yard Manure	100	100
Poultry manure	73	83
Biogas slurry	0	75
Green manure	20	58
Compost	6	25
Fish pond manure	6	-
Goat manure	80	33
Commercial organic fertilizer	0	8

Use of poultry manure was also common in Chitwan (83 percent) and Nuwakot (73 percent) farming. This is developing as an alternative of FYM in Nepalese agriculture, as poultry industry is growing all over the country and, thus, availability of poultry manure is also increasing. The third source of manure includes goat manure. Raising few goats and local poultry breeds (hens + ducks) was the heritage in Nuwakot. Hence, 80 percent of them used the goat manure in their farms, though in small quantity. Chitwan farmers, on the other hand, used biogas slurry as a useful manure source in their agriculture, but goat farming was not common like in Nuwakot.

Green manure and other sources of nutrients

Green manure was the important source of organic manure in our study districts. Farmers grow green manure crops during spring and turned them into soil in situ to supply manure for crops in the rainy season. Farmers also practice the use of green leaves collected from forest and of alleyways as green leaf manure. The popularly grown green types of manure we documented in Chitwan were Dhaincha (*Sesbania aculeate*), Sunhemp (*Crotalaria juncea*), Til (*Sesamum indicum*), and less popularly Lentil (*Lens esculenta*) and Cowpea (*Vigna catjang*). Certain common green types of manure used in Nuwakot were Sunhem (*Crotalaria juncea*), Titepati (*Artemisia vulgaris*), Asuro *(Adhatoda vasica*), Siris (*Albizia lebbek*), Cowpea (*Vigna catjang*), Banmara (*Eupatorium adenophorum*), Velvet bean (*Mucuna sp*.), and Bhatmase (*Flemengia congesta*).

We also documented individual farmers using urine, wood ass, vermicompost, oilseed cakes, kitchen wastes and swine manure as a source of soil organic matter in their farms. Some farmers in Nuwakot turned the runoff channels from forest toward their farm, so that it carried down the nutrient rich forest litter, which supported the maintenance of soil fertility in the area. Use of

compost tea, vermicompost and fish-pond compost as sources of organic manure was also recorded in the study area.

The evaluation of the sources of the organic manure used in the survey area allowed us to further investigate the crops getting priority on receiving these types of manure. The amount of manure used in crops varied on the survey sites and on the crops grown on these sites (Table 2); however, Chitwan farmers applied larger quantities of manure than Nuwakot farmers. They applied the highest quantity of FYM (19.0 $Mg.ha^{-1}$) and poultry manure (5.72 $Mg.ha^{-1}$) in vegetables, followed by rice and other cereals, whereas Nuwakot farmers applied the maximum quantity of FYM (2.86 $Mg.ha^{-1}$) in strawberry, followed by cereals and vegetables. The application of poultry manure was low for strawberry and no for other crops in Nuwakot. This difference by locations and by priority of farmers to different crops was due to the inequality in the economic value of that particular crop in the nearby market, the availability of manure, and the dissimilarity in socio-economic condition of farmers to afford the production cost.

Table 2. Types of organic manure and their amount used in the major crops of Nuwakot and Chitwan, Nepal (Field survey, 2009)‡

Location	Nuwakot				Chitwan			
Sources of organic types of manure*	Major crops				Major crops			
	Paddy	Wheat	Maize	Fruits	Paddy	Wheat	Maize	Vegetables
FYM ($Mg.ha^{-1}$)	1.71 ±0.34	0.59 ±0.08	1.48 ±0.11	2.86 ±0.06	3.97 ±0.42	2.04 ±0.18	3.15 ±0.24	19.06 ±6.26
Poultry ($Mg.ha^{-1}$)	0	0	0	0.86 ±0.12	1.23 ±0.17	4.53 ±0.42	4.43 ±0.22	5.72 ±1.85

*Values after ± indicate standard error

‡We included data of FYM and poultry manure, as they were the two major types of organic manure; other types of manure were used in negligible quantity, although they were common.

Farm yard manure preservation and application in the field

The time of organic manure application and the method of its preservation in manure pits plays an important role in its nutrient availability. The common practice in Nepal is that farmers bring organic types of manure, mainly FYM, during late winter to early spring for showing seeds after the first monsoon shower, which is not desired, from nutrient management perspective. Leaving the manure for long time in small heaps facilitates the loss of nutrients either by volatilization or leaching. More than 55 percent of the Nuwakot farmers followed that practice, which allowed maximum loss of nutrients from manure heaps either by sun or leaching by heavy down power in early monsoon (Fig. 2). Chitwan farmers were more aware of these negative consequences of early manure application in the field and only 21.5 percent of them followed that practice, not knowing the negative effects. Knowledgeable farmers followed the application of manure at the time of planting and incorporated it in soil, which was common in Chitwan (78.5 percent). Leaving manure exposed in the direct sunlight causes volatilization and oxidation of nutrients and leaching of dissolved ions (Schilke-Gartley and Sims, 1993) during summer rains. Carrying manure to the field at the time of planting and mixing it immediately with soil, on the other hand, reduces the loss of nutrients.

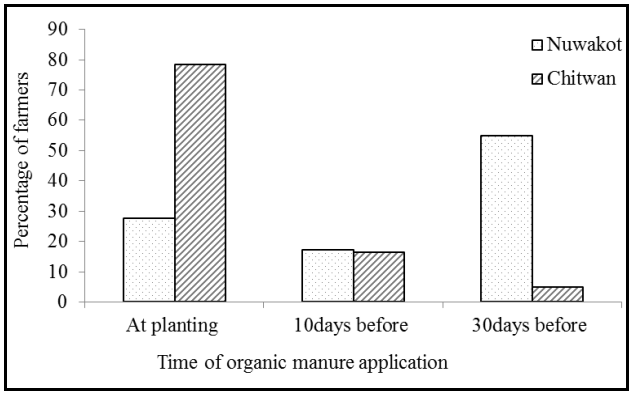

Figure 2. Percentage of farmers bringing organic manures in the field in Nuwakot (N = 30) and in Chitwan (N = 30) (Field survey, 2009)

The loss of nutrients from the manure heap is also a common problem in Nepal. Farmers leave manure in the open heap for a long time, allowing nutrients to be lost either by sun or by rain. More than 93 percent of the farmers in Nuwakot followed the traditional method of manure piling in open piles (Fig. 3). Chitwan farmers were better in realizing the importance of manure preservation

than Nuwakot farmers. One third of the survey farmers preserved manure heaps from sun light and/or rain either by making shade or by using plastic cover. The improved heap or pit method of FYM preparation, along with improved cattle sheds made by farmers helped reducing the nutrient loss from manure pits, which better supported the growth of the corps. Well decomposed FYM supplies 0.5 percent N, 0.2 percent P_2O_5, and 0.5 percent K_2O (Gaur et al., 1995), whereas FYM prepared by the improved method in heaps or pits can supply 2-3 times more nutrients than the ordinary manure and supports better yield of crops.

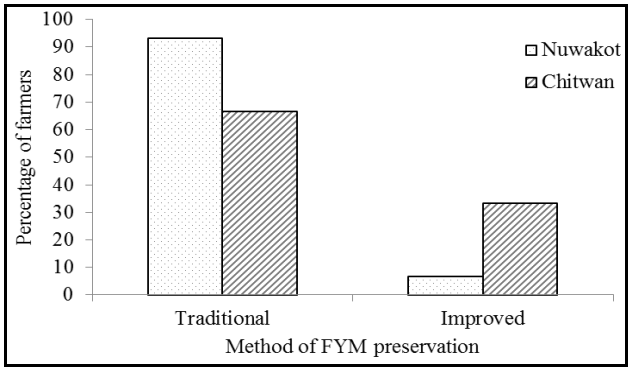

Figure 3. Percentage of farmers adopting different methods of FYM preservation in Nuwakot (N = 30) and in Chitwan (N = 30), Nepal (Field survey, 2009)

Crop management and rotations

Most of the agricultural land in Nepal is rain-fed or furrow irrigated during the rainy season and crop water management is beyond the control of farmers. More than 66 percent of the farm area in Nuwakot was rain-fed (bari) and 33 percent was irrigated only during the rainy season (khet land). The bari land was less in Chitwan (20 percent), as compared to Nuwakot. Thus, exhaustive dry land crops dominated Nuwakot farming. The major crops grown in the study area, in Nuwakot were maize, wheat, rice, millet, potato, and strawberries. However, farmers were more focused on strawberry production because of the emerging market opportunities in Kathmandu, in last 10-15 years. Chitwan, on the other hand, had more irrigated area and rice was the primary crop. Winter maize and wheat, vegetables and legumes like pea, beans and lentil were also common crops in Chitwan.

An appreciable aspect of the traditional farming system in Nepal is that they include legumes as a part of the cropping system. However, with the increasing need of cereals as staple food, the amount of legume use has been reduced in recent years. Many farmers (47.8 percent) in Nuwakot did not include legume in their rotations; however, including legumes in the farming system was relatively higher (66.7 percent) in Chitwan. Slicing terrace rises, growing non-legume non-bushy crops and outward facing slopes in Nuwakot resulted into removal of fertile top soil during the swift monsoon rain (Table 3). Besides, more than 87 percent of the Nuwakot farmers were attracted toward commercial strawberry cultivation. Hence, they prepared the vertical outward-sloping terraces to facilitate the harvest of strawberries, a higher number of plants per unit area, the maximum efficiency in the use of sunlight, the easy weed control and easy drainage of water. However, the terraces vertically built on the slopes are prone to erosion by water, resulting into particulate, as well as dissolved nutrient losses. MOEST (2006) estimated that, out of the total agricultural land in Nepal, 2.969 million ha (10 percent) are under degradation due to poorly managed terraces. Our study revealed a similar kind of problem in the Nuwakot hills.

Table 3. Crop and soil management practices in Nuwakot and Chitwan, Nepal

Practices	Nuwakot (n=30)	Chitwan(n=30)
Routine soil analysis	26.7 percent	46.7 percent
Burning crop residue	80 percent	53.3 percent
Canal irrigation	33.3 percent	80 percent
Use of legume in crop rotation	46.7 percent	66.7 percent
Slicing of the terrace riser	86.7 percent	-

Routine soil analysis and chemical fertilization

Understanding the fertility status of soil helps farmers to design the rational fertilizer management plan. However, traditional farming relied on the soils' inherent capacity and limited availability of farm manure and fertilizers. The farmers in the study districts did not analyze their soil for the nutrient status, the crop need and they did not care about the soil nutrient balance of the system. Our survey regarding the evaluation of crop and soil management practice (Table 3) to maintain soil fertility revealed that less than 50 percent of the farmers analyzed their soils for the nutrient status. The Nuwakot farmers sliced the terrace risers and burnt or removed farm

residues to make seed bed free of insect pest and diseases. However, burning or removing crop residue from field seriously depletes SOM (Lal, 2005) and, thereby, the nutrient supplying capacity of soils. This leads to the low soil fertility and crop productivity. Tiwari et al. (2010) reported that up to 90 percent of the nutrient loss occurred from the crop harvest could be recovered through incorporation of 30 percent or more crop residues back into soil.

Commercial chemical fertilizers like Urea, Diammonium Phosphate (DAP) and Muriate of Potash (MOP) were also common in the hill and valley farming system in Nepal. The most commonly applied chemical fertilizer is urea, followed by DAP. The use of micronutrient sources for crops is not very common in Nepal, except in some commercial crops. The farmers intuitively know that secondary and micronutrients released from soil are sufficient to meet the crop need whatever the crop is. The amount of different fertilizers applied in various crops in the study area is presented in table 4.

Table 4. Chemical fertilizers used in different crops in Nuwakot and Chitwan

Location	Nuwakot				Chitwan			
Inorganic manures*	Major Crops				Major Crops			
	Paddy	Wheat	Maize	Fruits	Paddy	Wheat	Maize	Vegetables
Urea (Kg/ha)	18.31 ±1.36	13.73 ±2.71	12.91 ±2.70	51.25 ±1.94	46.20 ±3.16	57.95 ±2.55	52.60 ±4.32	16.00 ±3.91
DAP (Kg/ha)	12.90 ±0.92	11.89 ±0.80	10.69 ±2.48	27.52 ±1.83	35.70 ±2.90	73.85 ±3.72	66.85 ±2.88	30.90 ±7.39
MOP (Kg/ha)	0	0	0	16.01 ±0.77	27.70 ±2.31	23.85 ±2.25	25.35 ±2.25	33.35 ±8.19

***Values after ± indicate standard error**

Chitwan farmers applied a larger amount of chemical fertilizers than Nuwakot farmers, but the average rate was below the National recommendation in both locations. Wheat in Chitwan and strawberries in Nuwakot received the higher amount of urea, as compared to other crops. Besides the major nutrients, few commercial vegetable growers of Chitwan applied borax 20-60 $kg.ha^{-1}$ and wood-ash to their crops. Synchrony of nutrient supply with crop demand is essential to ensure optimum crop yield and to avoid negative environmental impacts (Grant et al., 2002). However, farmers did not realize the fact and they applied the fertilizers recklessly, which gradually deteriorated the soil and added other associated problems.

Major soil fertility management constraints

Given the fact that Nepal is diverse from the agro-ecological viewpoint, the management strategies for soil fertility also vary in order to deal with niche specific problems. The farmers' response on the soil fertility management problems from Nuwakot hills and Chitwan valley (Table 5) indicated that soil loss and crop damage by erosion and landslide were the major problems in Nuwakot and imbalanced/excessive use of chemical fertilizer was the most grieving issue in Chitwan.

Table 5. Ranking constraints of soil fertility management in Chitwan and Nuwakot

S.N.	Constraints	Famers' response (percent)	
		Nuwakot (n=30)	Chitwan (n=30)
1	Top soil removal and crop damage by erosion	50	-
2	Increasing soil acidity by chemical fertilizer	20	44
3	Intensive cultivation	-	26
4	No sufficient supply of fertilizers	12	-
4	Lack of government support	10	17
5	Others	8	13

The high soil erosion and the acidity problem in Nuwakot might be due to the increasing attraction of the farmers towards the high value crop 'strawberry' in outward sloping terraces. These allowed soil to be washed from the surface by monsoon rains and the nutrients to leach from the terraces during belowground water movement. The strawberry plants flourish well in acidic environment below pH 6.5 and support in further acidification of the soils. However, if they are grown in high pH soils, some of the micronutrients become unavailable with increasing soil pH above 7 (Kassel, 2003). Thus, the acidifying nature of the strawberry plant, the poor cultural practices and

the higher doses of chemical fertilizers might have caused the increasing acidity on these soils. The growing use of chemical fertilizers, especially of urea, caused soil acidity in Chitwan. Other problems we documented include exhaustion of soil by intensive cultivation, lack of technical support from government and low knowledge-base of farmers.

CONCLUSION

The study conducted in the Chitwan plain and in the Nuwakot hills revealed that the soil fertility management system involved traditional methods of soil and crop management and relied maximally on the available local resources. FYM was the main source of SOM and nutrients for the major crops, although there were many other sources and considerable differences in the amount of fertilizers applied in the fields. The Chitwan farmers had better idea of the soil and crop management than the Nuwakot ones and they were found to apply more manure and fertilizers in their crops than the Nuwakot farmers. However, there are several constraints like erosion, soil acidity and faulty management practices, which are caused by the low technical knowledge and resource compulsions and which hindered better soil fertility management in hills and valleys of Nepal.

ACKNOWLEDGEMENTS

We would like to acknowledge all survey farmers for their time and valuable information for this study, which was impossible without their support.

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