Socioeconomic and Biophysical Interactions: Examples Relating to Soil Fertility

Sandra Brown
Institute for Resources and Environment, University of British Columbia,
Vancouver, Canada

Abstract

The constraints and opportunities faced by farmers are influenced by social, economic, cultural, and biophysical factors. Socioeconomic indicators such as population growth, land tenure, and ethnicity play an important role in the management of resources and resource degradation. In the middle mountains of Nepal, population growth has led to double and triple annual crop rotations and increased pressure on forest resources. The results of the study described here showed the following interactions. The use of compost and chemical fertiliser varied with farm size and economic constraints, holders of medium-sized farms applied the greatest inputs and their farms exhibited the best nutrient budgets. Agrochemical use and crop production were affected negatively by uncertain land tenure arrangements, share-cropped fields were less intensively managed. Reductions in the availability of animal fodder and in access to grazing areas have resulted in an increase in stall feeding during the monsoon. The intense pressure on forest resources is reflected in the soil fertility conditions, the poorest soil fertility conditions in the region were found on forest and rangelands. Ethnic affiliation influences access to resources and is reflected in nutrient inputs. High caste households apply the most chemical fertiliser; whereas low caste groups concentrate their manure inputs on irrigated fields. The socioeconomic factors influencing nutrient dynamics are interrelated, but within the study area population growth and access to land were the two key factors.

Introduction

Local knowledge and experience play an integral role in decision making within traditional communities; however, rapid population growth, increasing pressure on the resource base, and the increased availability of western technology have accelerated change. Communities near major markets such as Kathmandu are no longer isolated but are changing as they become more integrated into the cash economy. Population growth, land tenure, culture, and poverty are the underlying socioeconomic factors influencing farming system dynamics in the middle mountains. The current status of the farming system and recent changes have had an effect on land use and nutrient management and thus on natural resources. The implications for resource dynamics are both direct and indirect, and provide further insight into why resource degradation is occurring.

The following examples are drawn from the Bela sub-catchment in the Jhikhu Khola watershed, Nepal. Surveys of 85 households were used to compile data on socioeconomic indicators and farm management (Brown in this volume). At each location field data were collected on the crops grown, and additional data were compiled on nutrient inputs and yields. Socioeconomic and biophysical interactions were then assessed. While the relationships described are specific to one watershed, the framework linking social factors, nutrient management, and resource degradation are more broadly applicable.

The aim of this paper is to document the following relationships between socioeconomic and biophysical factors:

- relationships between population growth, land holdings, and nutrient dynamics;
- the impact of share cropping on the use of agrochemicals;
- livestock dynamics and its relationship with fodder availability and nutrient management; and
- ethnic factors and their impact on nutrient use.

Relationships between Population Growth, Farm Size and Nutrient Supplies

Population growth, and the resultant increase in demand for food, places additional pressure on the resource base and specifically on soil resources. The per capita availability of land in the study area decreased from 0.26 ha in 1972 to 0.17 ha per capita in 1995, which is a greater decrease than for Nepal as a whole. Double and triple crop rotations are applied where water is available, but nutrient inputs may not be sufficient to sustain these intensive levels of production (Brown and Schreier this volume). Expansion of agriculture to marginal lands (Shrestha 1999) in response to population pressure has brought steeply sloping and low soil fertility lands under cultivation to provide additional food supplies. Recent declines in forest cover (Schreier *et al.* this volume) and reported shortages of forest products are indicative of the continuing pressure on forest resources, as are the increased demand for wood in house construction and brick making. Population growth, both locally and regionally, is a dominant factor driving land use dynamics within the study region, and the associated increase in demand for food, animal feed, and fuelwood results in increased biomass removal.

Nutrient inputs may vary with farm size as a result of both limited availability and economic constraints. Figures 113a-b show increasing total inputs with land ownership on both irrigated and rainfed land for small and medium sized farms, but decreasing inputs on larger farms. The relationships between land ownership, crop nutrient budgets, and soil fertility are summarised in Table 106. Significant differences in nutrient budgets (Brown and Schreier 1999) were noted between small, medium, and large farms and reflect both lower fertiliser inputs on large farms and the distribution of land types with farm size. Both small and large farms were dominated by rainfed land and displayed lower nutrient budgets. Households owning moderate amounts of land (1-2 ha) typically owned a mix of rainfed and irrigated land, applied the most fertiliser and compost to their fields, and had the best nutrient budgets. Differences in soil variables were also noted with farm size. Larger farms displayed

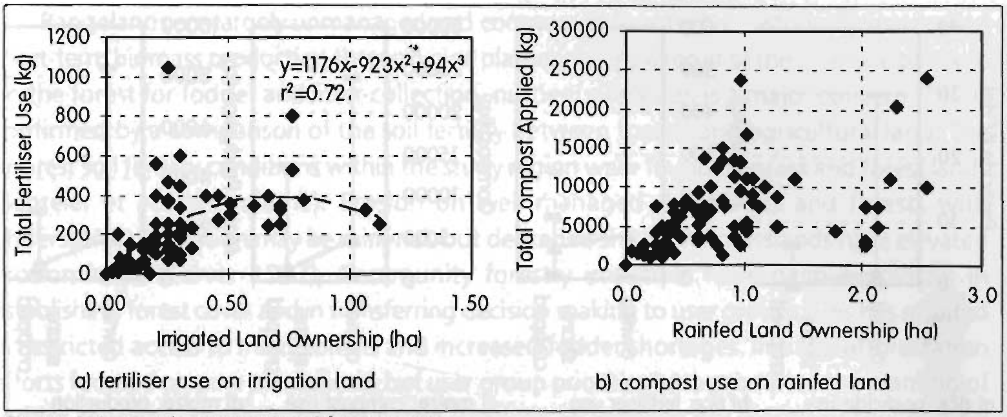

Figure 113: **Nutrient Inputs with Farm Size**

Table 106: **Relationships Between Farm Size, Crop Nutrient Budgets, and Soil Fertility (median values and Mann Whitney U test)**

Farm Size			P-M-W Nutrient Budget (kg ha^{-1} furrow slice)		
			N-budget	P_2O_5-budget	Ca-budget
small	<1.0 ha	(n=20)	-24	-29	-16
medium	1.0-1.9 ha	(n=8)	-18	35	9
large	2.0-3.4 ha	(n=6)	-32	-43	-15
small vs. medium farms			+	++	++
medium vs. large farms			++	+	+
			Exch. Ca (cmol kg^{-1})	CEC (cmol kg^{-1})	C (%)
small	<1.0 ha	(n=20)	3.4	11	0.9
medium	1.0-1.9 ha	(n=8)	4.4	12	1.0
large	2.0-3.4 ha	(n=6)	3.3	9	0.8
medium vs. large farms				+	++

++ Significant differences between groups α<0.05
\+ Significant differences between groups α<0.10

lower exchangeable Ca, CEC, and %C, suggesting that there is a limited availability of organic matter on larger farms.

The Impact of Share Cropping on the Use of Agrochemicals

Share cropping was thought likely to have a negative impact on land management as a result of the uncertainty of land tenure arrangements and an unwillingness on the part of tenant farmers to invest in share-cropped land. Figure 114 shows the differences in inputs and production on owned and share-cropped land for rice and maize, the dominant crops grown on share-cropped irrigated and rainfed fields. Significant differences were noted between owned and share-cropped land in the total pesticide expenditures on rice fields, the total compost applied to maize fields, the total fertiliser used on both rice and maize fields, and in maize production. The differences in inputs were not significant on a per ha basis, but median pesticide, fertiliser, and compost values were all lower on share-cropped land. No difference was noted in rice yield between owned and share cropped fields, but maize

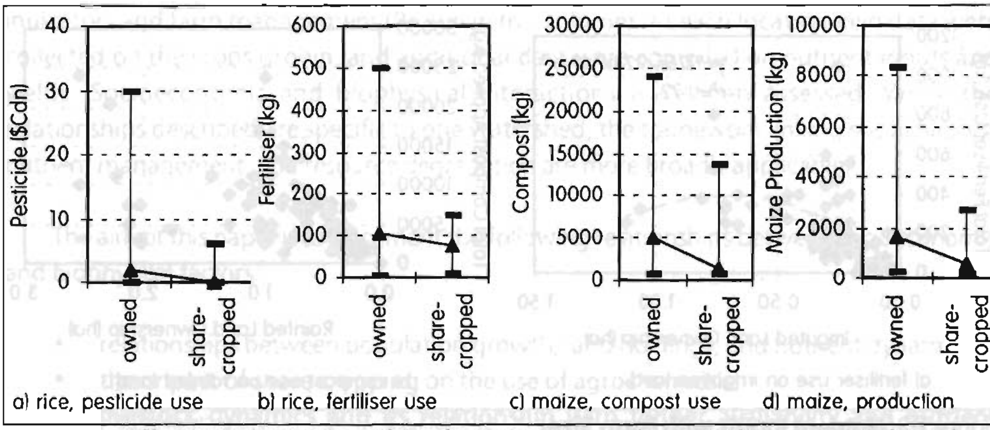

Figure 114: **Differences in Inputs and Production on Owned versus Share-cropped Land**

production on share-cropped fields was significantly lower. The variability in agrochemical use and crop production was substantially greater on owned versus share-cropped land, with the greatest inputs applied to owned land. While this limited data set is not conclusive, share-cropped fields on both irrigated and rainfed lands appeared to be less intensively managed than fields with secure land tenure.

Livestock Dynamics, Fodder Availability and Nutrient Management

The free grazing of animals, and the resultant removal of vegetation and trampling of the soil surface, have an impact on soil infiltration rates and erosion, and heavy grazing is responsible for much of the environmental degradation on government lands (Carson 1992). The proportions of stall-fed versus grazed animals during the wet and dry seasons reported by female farmers surveyed in 1989 and 1996 are shown in Figure 115. No change was noted in the proportion, of stall fed animals in the dry season between 1989 and 1996, but stall-feeding during the wet season increased significantly from 63 per cent in 1989 to 85 per cent in 1996. Female farmers were asked: "compared to five years ago, has the availability of grazing areas for your animals changed?" For the 1991-1996 period, 79 per cent responded that there were significantly fewer grazing areas available in 1996. Traditionally, the forests supplied 40 to 60 per cent of the total fodder, but pressure on the forest ecosystem from increasing human and livestock populations and agricultural encroachment has led to reduced availability of fodder, and a recent decrease in livestock holdings. The lack of fodder is in part due to the degradation of forest resources, as well as the new trend of reducing open access to the forests.

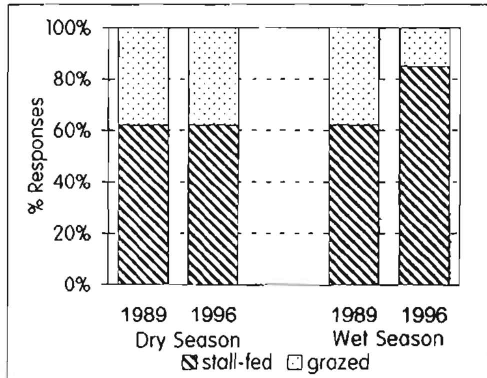

Figure 115: **Stall-feeding and Grazing Dynamics (n=27)**

Rangelands are largely unmanaged and community forestry has historically focused on short-term biomass production through pine plantations. As a result of the intensive pressure on the forest for fodder and litter collection, nutrient depletion is a major concern. This is confirmed by a comparison of the soil fertility between forests and agricultural land. The poorest soil fertility conditions within the study region were found on grass and forest lands (Schreier *et al.* this volume). Erosion on well managed rangelands and forests with understorey vegetation may be minimal, but degraded shrub and grasslands have elevated erosion rates (Carver 1997). Community forestry initiatives have been successful in establishing forest cover and in transferring decision making to user groups. This has resulted in restricted access to many forests and increased fodder shortages. Initially, afforestation efforts focused on pine plantations, but user group priorities have prompted the planting of fodder species such as *Dalbergia sissoo*. Options to improve dry season production on rangelands, such as the incorporation of legumes and deferred grazing, are constrained by the current land tenure system. The successful implementation of pasture management techniques will require the establishment of property rights either privately or communally, similar to the establishment of forest user groups. To date, the Department of Forestry has concentrated on planting trees and few resources have been focused on grasses.

Livestock type and holdings influence compost application to a household's farm land. Manure lost through grazing is decreasing as more households are stall feeding their livestock, and selling of manure is rare. The relative manure production potential of different types of livestock was represented by tropical livestock units (TLU). Livestock units are based on the N content of manure produced by a standard cow, which has a live weight in the tropics of between 200 and 350 kg. The factors for calculations relating cattle to other domesticated species are shown in Table 107. For example, one bullock is equivalent to five swine or 125 chickens (FAO 1975, Williamson and Payne 1978). The amount of compost applied to rainfed land showed a weak positive correlation with the number of TLUs owned, but only 10 per cent of households owned more than 10 TLU per ha. The lack of fodder has a significant impact on agriculture because manure is the main source of nutrients for many farmers.

Table 107: **Tropical Livestock Unit Equivalents**

Animal Type	TLU
Cattle – Bullock	1
Cattle – Cow	0.8
Cattle – Calf	0.4
Buffalo – Bull	1.2
Buffalo – Cow	1
Buffalo – Calf	0.5
Goat	0.1
Pig	0.2
Chicken	0.008
Duck	0.008

Caste and Ethnic Factors and Their Impact on Nutrient Use

A household's access to capital and other resources is influenced by caste and ethnic affiliation, thus compost, fertiliser, and pesticide use may vary between groups. The differences in the inputs used by high, medium, and low caste groups are presented in Table 108. On irrigated lands, high caste households applied more fertiliser while low caste households applied more compost suggesting affordability may limit the use of chemical fertilisers by low caste households. On rainfed fields, high caste households applied more

Table 108: Relationships between Caste/Ethnic Affiliation, Land Management, and Soil Fertility (median values and significant differences based on Mann Whitney U test).

		Caste			Significant Differences	
		High	Medium	Low	High vs. Med.	High vs. Low
Irrigated land (*khet*)						
Compost	(kg)	1313	0	1124	+	
	(kg ha^{-1})	2725	0	4786		
Fertiliser	(kg)	195	15	50	++	++
	(kg ha^{-1})	522	128	284	+	+
Pesticide	($ Cdn)	2	0	0		++
Rainfed land (*bari*)						
Compost	(kg)	7500	5160	2500		++
	(kg ha^{-1})	8346	7097	7259		
Fertiliser	(kg)	274	220	155	+	++
	(kg ha^{-1})	320	236	359		
Livestock						
	TLU	3.7	3.8	4.1		
	TLU ha^{-1}	3.6	3.9	5.7		++
Soil fertility						
base saturation	(%)	60	57	45		++
exch. Ca		3.9	3.0	3.2		++
PH		4.9	4.8	4.6		++

high caste = Brahmins (n=46); medium caste = Chhetri, Newar, Jogi and Magar (n=20);
low caste = Tamang, Danuwar, Kami and Sarki (n=19)
++ Significant differences between groups $_{\alpha}<0.05$
+ Significant differences between groups $_{\alpha}<0.10$

total fertiliser and compost, but no significant differences were found on a kg per ha basis. Lower caste households owned significantly more livestock on a TLU per ha basis than did high caste households and they distributed the compost differently. The low caste households concentrated their manure inputs on irrigated fields, whereas the high caste households applied more compost to rainfed fields. Differences in soil fertility were also noted between fields owned by high and low caste groups, with high caste households owning fields with better soil fertility conditions, but the differences might have reflected the sampling design. The fields in the sample were selected on the basis of soil fertility conditions, and more irrigated fields owned by high caste households were sampled. Recognizing the complexity of the Nepali class structure, caste and ethnic affiliation appear to influence nutrient management and thus, potentially, soil fertility conditions.

Conclusions

The socioeconomic factors driving nutrient dynamics and thus affecting soil fertility are not isolated but interrelated, and these factors may be influenced by resource degradation (Figure 116). Population growth, access to land, and cultural practices are closely tied to poverty. Poor families own smaller land holdings, typically own poorer quality land, and will be affected most by soil degradation. Population growth is driving land use change and thus altering nutrient flows within and between land uses. To meet the demands of a growing

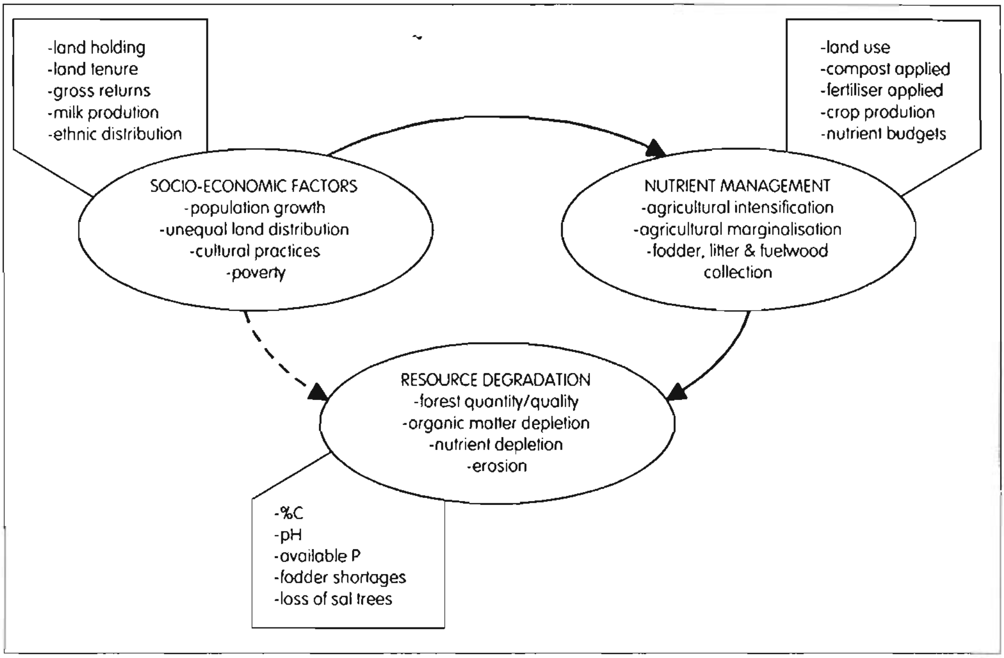

Figure 116: **Framework Linking Social Factors, Nutrient Management, and Resource Degradation.**

population, agriculture has been intensified and extended to marginal lands, and evidence of renewed deforestation is beginning to appear.

Access to land is a key factor driving nutrient management and influencing economic well-being. Land is the main agricultural asset of households in the study area, and irrigated land is more productive and provides greater opportunities for cash crop production than rainfed land. The poorest soil fertility conditions were found on common property lands (grassland, shrub, and forest). Share-cropped land was less intensively managed, and received lower inputs of chemical fertiliser, organic matter, and pesticides. Irrigated land received the most nutrient inputs per ha, showed the best nutrient budgets, and had the best overall soil fertility conditions.

While caste/ethnic distribution is not equivalent to class structure, differences were noted between Brahmins and other groups in the study area. Brahmins tended to use more agrochemicals, own more land, and own land with better soil fertility.

The economic well-being of households in the study area was strongly tied to the quantity and quality of land owned, and reflects a traditional versus a market-oriented agriculture (vegetable and milk production). Households with lower production returns, lower agricultural assets, and lower cash income tended to apply less nutrients to their fields. Equally, households growing vegetable crops (which have higher gross margins) may still have a negative impact on soil fertility as a result of the high nutrient demands of these crops. Farm management and nutrient dynamics are influenced by a combination of socioeconomic factors, but within this study area population growth and access to land were the two key components that affected resource conditions.

References

Brown, S. and Schreier, H. (this volume). 'Nutrient Budgets: A Sustainability Index'. In Allen, R.; Shreier, H.; Brown, S. and Shah, P. B. (eds) *The People and Resource Dynamics Project: The First Three Years (1996-1999)*. Kathmandu: ICIMOD.

Brown, S. (this volume). 'The Use of Socioeconomic Indicators in Resource Management'. In Allen, R.; Shreier, H.; Brown, S. and Shah, P. B. (eds) *The People and Resource Dynamics Project: The First Three Years (1996-1999)*. Kathmandu: ICIMOD.

Carson, B. (1992). *The Land, the Farmer and the Future: A Soil Fertility Management Strategy for Nepal*, ICIMOD Occasional Paper No. 21. Kathmandu: ICIMOD.

Carver, M. (1997). 'Diagnosis of Headwater Sediment Dynamics in Nepal's Middle Mountains: Implications for Land Management'. Ph.D. Thesis. Vancouver: University of British Columbia.

FAO. (1975). *FAO production yearbook,* Vol. 29. Rome: Food and Agriculture Organisation of the United Nations.

Schreier H., Saha, P.B. and Allen, R. (this volume). 'Soil Fertility Status and Dynamics in the Jhikhu and Yarsha Khola Watersheds'. In Allen, R.; Shreier, H.; Brown, S. and Shah, P. B. (eds) *The People and Resource Dynamics Project: The First Three Years (1996-1999)*. Kathmandu: ICIMOD.

Shrestha, B. (this volume). 'Population Dynamics and Land use in the Yarsha Khola Watershed'. In Allen, R.; Shreier, H.; Brown, S. and Shah, P. B. (eds) *The People and Resource Dynamics Project: The First Three Years (1996-1999)*. Kathmandu: ICIMOD.

Williamson, G. and Payne, W. (1978). *An Introduction to Animal Husbandry in the Tropics*. New York: Longman.