A Systems Analysis of Soil Fertility Issues in the Hills of Nepal: Implications for Future Research

A. Vaidya, C. Turton, K. D. Joshi and J. K. Tuladhar
Lumle Agricultural Research Centre, LARC, Pokhara, Nepal

1. PERSPECTIVE

Hill agriculture in Nepal is complex and precarious. Hill farming is characterized by a scarcity of arable land, diversified farming, few employment opportunities, market problems and weak institutional support to modernize agriculture. Variations in biological, physical and socio-economic influences have resulted in numerous micro-production localities. As a consequence, subsistence farming systems are highly interactive and dependent upon the forest, livestock and field crops to survive. Rapid population growth has changed the historical pattern of the use of these natural resources. A resultant decline in soil fertility has been noted by both farmers and researchers in Nepal.

Several efforts have been made to understand and address soil fertility problems in the hills (Sthapit, 1988, Subedi, 1989, Shah, 1991, Carson, 1992, Tamang, 1992, Joshi, 1994 and Joshi, 1995). Soil fertility research has been a priority issue at Lumle Agricultural Research Centre (LARC) since 1987, spearheaded by a multidisciplinary Soil Fertility Thrust. A decade of research by LARC has focussed on understanding indigenous soil fertility maintenance systems and utilizing or improving existing soil fertility practices in different agro-ecological zones. Although much work has been done, a thorough investigation of the factors influencing soil fertility was felt necessary in order to develop a future strategy.

This paper presents the findings of a collaborative study between the Soil Fertility Thrust of LARC and the Natural Resources Institute in the United Kingdom, which was conducted between May 1994 and March 1995 and covered nine hill districts of Western Development Region (WDR). The overall aim was to improve the perspectives for sustained agricultural productivity in the hills of Nepal. The specific objectives were to:

- identify, quantify and understand the factors affecting soil fertility in the hills of Nepal,
- identify among representative groupings of households the awareness and attitude to soil fertility related issues and
- formulate a long term strategy for soil fertility research for the mandate area of LARC.

The project was designed in three phases. First, an appropriate framework for soil research activities was established. Secondly, a multidisciplinary analysis was carried out, focussing on the environmental, institutional and socio-economic factors that influence soil fertility across LARC's Research Command Area (RCA) which includes Lamjung, Gorkha, Tanahun, Kaski, Parbat, Myagdi, Baglung and Syangja districts and the Palpa area. The farmers' perceptions and opinions of soil fertility were an integral part of the study and were obtained through surveys of representative houses. In the final phase, a long term strategy for soil fertility research at LARC is to be developed. The project is a relatively long exercise; therefore to limit the scope, this paper presents findings related to the second phase.

2. METHODOLOGY

The focus was on the representative farming systems in the LARC RCA, and covered systems that were locally adapted and representative of most environmental conditions in the area (Bennett, 1994). The land use systems and factors chosen in the analysis were: altitude, rainfall, fertility, management practices, accessibility, differences in proportion of khet and bari soils, population pressure, land fragmentation, *tar* areas, cropping intensity, livestock management systems, soil characteristics, forest resources, number of trees on private land, and outward sloping terraces. Seven study areas were proposed for research activities (Bennett, 1994).

Twenty eight villages within the seven study areas were visited and characterized in terms of all of the important factors in the farming systems. Thirteen sites were selected, and twenty biophysical, socio-economic and institutional factors were used to characterize all major variations in the hill farming systems of the area (Table 1). The study involved a review of soil fertility issues and the compilation of soil analysis results both from this study and previous crop cut surveys.

Table 1. Villages selected for household surveys.

Study area	Districts	Village/VDC	Altitude (masl) (Agro-ecological zone)	Accessibility (Walking distance from road head)	Market	Rainfall	Aspect
Arman	Myagdi	Kimchaur/Arman	1600-2000 (high hill)	poor (13 hrs)	poor	medium	NE
Baranja		Arman/Arman	1300-1400 (mid hill)	poor (12 hrs)	poor	low	NE
Marsyangdi River Basin	Tanahun Gorkha	Chambas/Bhanu	500-580 (low hill)	good (0 hrs)	good	medium	NE
		Bahrapirke/ Palung*tar*	500-635 (low hill)	medium (1 hr)	medium	medium	W
Tansen Area	Palpa	Nayatola/ Kusumkhola	1100-1450 (mid hill)	medium (0.75 hrs)	medium	low	N
		Deurali/Deurali	1150-1600 (mid hill)	medium (1 hr)	medium	low	W
Dhampus, Tanchok, Landruk	Kaski	Tanchok/Lumle	1800 (high hill)	poor (3 hrs)	medium	high	NW
		Landruk/Lumle	1775 (high hill)	poor (5 hrs)	medium	high	W
Khurkot, Pang, Durlung	Parbat	Kaphalchaur/ Durlung	1200-1350 (mid hill)	medium (3 hrs)	medium	high	NE
		Pang/ Pang	800 (low hill)	medium (1 hr)	medium	medium	S
Baidi Area	Tanahun	Tal bari/Baidi	740 (low hill)	poor (9 hrs)	poor	medium	NW
		Khalte/Baidi	240 (low hill)	poor (9 hrs)	poor	medium	S
Pokhara Seti River Valley	Kaski	Hyangja/Hyangja	950 (low hill)	good (0 hrs)	good	high	N

NE - North East; W - West; NW - North West; S - South; N - North

Various group discussions, field observation, RRA and PRA methods were used to collect the desired information. A detailed household questionnaire was administered to forty households within each village irrespective of village size. Within a village, households were stratified into three groups on the basis of food self-sufficiency, and random samples were drawn from each stratum in proportion to the size of the group. A total of 523 households from thirteen villages were involved in the survey. Field staff from District Agricultural Development Offices were trained and involved wherever possible.

The data was analyzed using SPSS PC+. Preliminary investigations were done using descriptive statistics (means, frequencies, graph and cross-tabulations). Further analyses were performed using correspondence analysis on multi-way tables, logistic regression on binary responses and principle component analysis on metric data (the results of the logistic regressions only are presented in this paper).

3. RESULTS AND DISCUSSION

3.1. Soil Fertility Status

The widely held view that soil fertility is declining in the hills of Nepal is based primarily on perceptions and observations with little reliance on quantitative studies. Soils analyzed during a crop-cut survey in 24 Village Development Committees (Extension Command Area, ECA of LARC) in 1991/92 and 1992/93 were examined to quantify current soil fertility status in farmer's fields. More than 300 soil samples were collected of which 70 samples are included in this analysis. It is not easy to generalize the findings in terms of statistical parameters as each specific location will demand distinct explanations due to highly diverse soil environments.

Using the critical levels defined by Landon (1992), 85% of soil samples had low-to-medium nitrogen (N), indicating N as a major limiting nutrient. A large variation in phosphorus (P) levels was found but the majority of soils have medium-to-high phosphorous content and 60% of the K values lay in the range of 0.1 to 0.3 meq/100g soil, indicating low-to-medium exchangeable K status (Table 2).

Table 2. Properties of soil samples.

Soil Property	Mean (n=596)	Rating*	Range	Khet (n=247)	Bari (n=340)
pH (Soil:Water 1:2.5)	5.6±0.02	medium	4.1-7.6	5.54±0.03	5.6±0.03
Organic Carbon (%)	2.94±0.04	low	0.2-7.0	2.59±0.06	3.2±0.06
C/N Ratio	12.78±0.20	-	2.4-56.5	12.77±0.32	12.78±0.25
Total N (%)	0.26±0.004	medium	0.001-0.8	0.22±0.01	0.27±0.01
Available P (ppm)	153±8.0	high	1.3-1698	122.9±9.5	174±13.04
Exchangeable K (meq/100g)	0.37±0.01	medium	0.04-4.64	0.28±0.01	0.44±0.02

* Refers to values given in Landon (1992); samples include RCA and ECA.
Source: Soil analysis of crop-cut survey: 1991/92 and 1992/93.

Bari soils have significantly higher ($p \leq 0.05$) levels of organic carbon (OC), total N, available P and exchangeable K than khet soils. It is generally believed that farm yard manure (FYM) application on bari land is higher due to the nature of crops grown and proximity to homesteads where livestock are kept. This is also to balance nutrient loss from erosion by surface run off which may partially be gained by khet land accumulations of humus and sediments. However, cropping intensity and accessibility to market determine the amount of FYM and chemical fertilizer used.

The use of farmers' classification of soils is widely accepted. Throughout the visited area, *rato mato* (red soil) and *kalo mato* (black soil) are the common soil types. Farmers regard *kalo mato* as fertile soil because it contains higher organic matter and moisture regime compared to *rato mato.* This can be substantiated from the soil analysis report (Table 3) which shows that *kalo mato* has significantly higher OC, N and P ($p \leq 0.05$).

Table 3. Soil properties of *Kalo mato* and *Rato mato.*

Soil property	*Kalo mato* (n=159)	*Rato mato* (n=77)
pH	5.7±0.04	5.6±0.01
Organic Carbon(%)	3.1±0.08	2.9±0.11
Total N (%)	0.27±0.01	0.22±0.01
Available P (ppm)	138±18.59	102.0±19.3
Exchangeable K (meq/100 g soil)	0.39±0.03	0.46±0.05

Source: Soil analysis of crop-cut survey, 1991/92 and 1992/93.

3.2. Fertility Management Dynamics

Interdependence between crops, livestock, forests, fodder and compost are the key issues in hill farming systems in Nepal. The livestock, forests and crops contribute to the synthesis of compost or FYM which are the major sources of plant nutrients. Inevitably, the availability of compost forms the basis for most of the soil fertility regimes in traditional hill farming practices, and fertility dynamics are the result of interactions between existing components of the farming systems.

The traditional soil fertility management in the hills is a dynamic process which adjusts to changes in resource availability, socio-economic and institutional factors. No farmer in the study area reported using `improved' techniques of compost preparation. The PRA investigation shows that FYM is still the dominant source of plant nutrients, although the degree varies across agro-ecological zones (Figure 1). In the high hill and inaccessible areas, the role of FYM is predominant in supporting traditional farming systems, but the use of chemical fertilizers is important in low and middle hill areas where access to markets and inputs is better. Fertilizer use is higher on khet land than on bari land.

In the high hills where in-situ manuring is declining and in the low hill sites where cropping intensification is higher, a shift towards intensive management of khet land has been observed. This is the reverse of the situation 10-15 years ago. Changes in soil fertility management strategies with time are well illustrated by the case of Chambas, a low hill village. Ten years ago, management on bari land was more integrated, but now, the contribution of chemical fertilizer has increased and in-situ manuring is no longer used. It is apparent that management of khet land is becoming more integrated with increases in FYM use along with legume and trash burning. Fallowing, which was the most important strategy in the past, is no longer practised. There are few changes in high hills and inaccessible areas. Pang, a classic case of a low hills system with almost no access to forest resources, has undergone hardships during the protection stage. This has forced farmers to use chemical fertilizers even though they know that the soils are being eroded.

3.3. Farm Yard Manure

The pressure on the resources has also changed the pattern of uses. FYM is still the major nutrient source (Figure 1), and changes in strategies have not reduced its importance. In the high hills, reductions in livestock numbers have induced collection of leaf litters to maintain the quantity of FYM produced. Mid and low hill lands have experienced a decline in the proportion of plant residues due to forest restrictions and labour shortages, although crop residues and remaining twigs of fodder compensate to some extent. This is because byproducts such as straws and twigs are also used for fuel, thatching, fencing and matting purposes.

Traditionally, the majority of FYM went to the bari land. Some 63% of the farmers reported no change in the patterns of distribution between khet and bari. Nevertheless, there is a gap between demand and supply of FYM due to the range of factors discussed above (Figure 2).

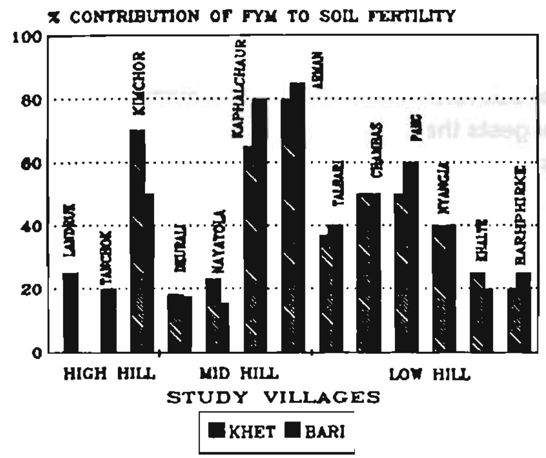


Figure 1. Contribution of FYM to soil fertility in study villages.

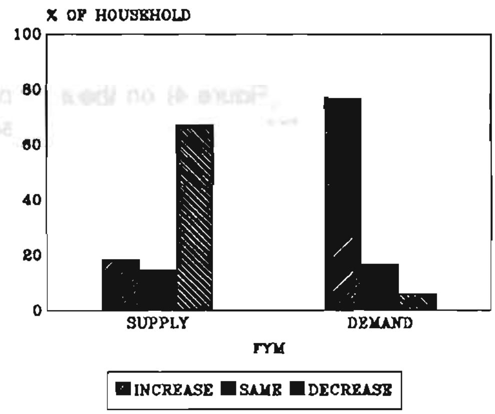
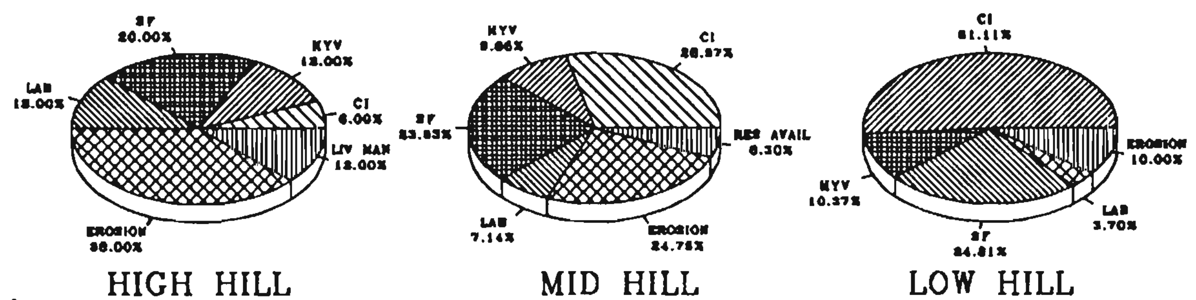


Figure 2. Demand and supply of FYM.

PRA investigation shows that, in low and mid altitudes, FYM is diverted to khet in order to meet the demand of crop intensification. However, Hyangja, Pang and Talbari (low hills) reported a decline in FYM contribution. Chambas and Arman are sites with low forest resources, and they reported increased use of FYM on both khet and bari. Erosion and decline in soil fertility are the major reasons cited by farmers for the increasing demand for FYM (Figure 3). The contribution of soil erosion increases with increasing altitude, while cropping intensity and use of high-yielding varieties (HYV) have contributed in increasing the demand in the low hills.



3.4.

Figure 3. Major reasons for increasing demand of FYM.

Key: CI=Cropping Intensity; SF=Soil Fertility; LAB=Labour; LIV MAN=Livestock Management; RES AVAIL=Resource Availability; HYV=High Yielding Variety

3.4. Chemical Fertilizers

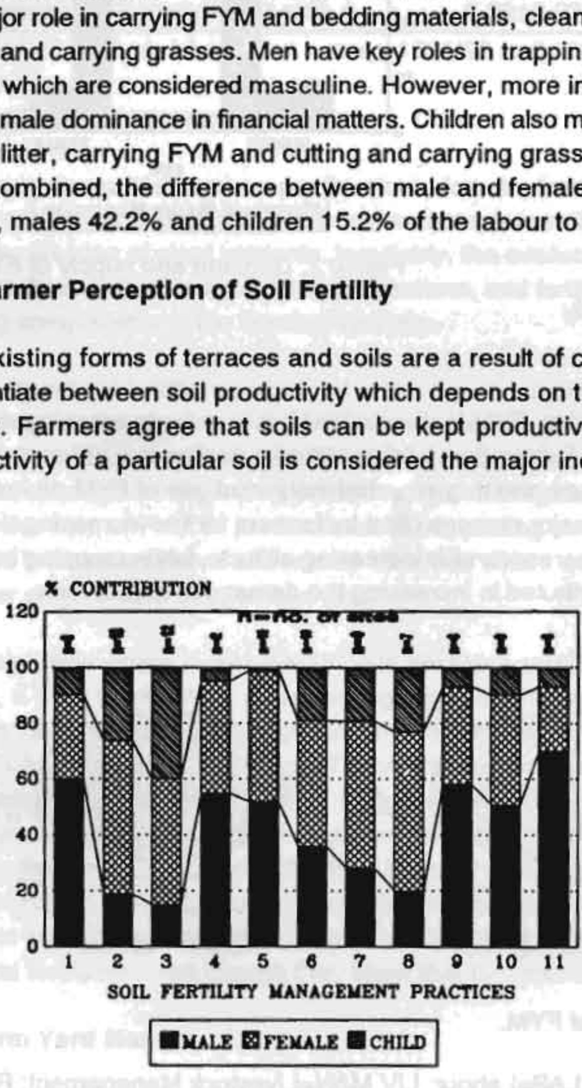
The use of chemical fertilizer is significantly correlated ($p \leq 0.001$) with altitude, accessibility and markets. Overall, 39% of the farmers are using fertilizer, 7% used it previously but stopped using it, 46% never used fertilizers and 8% are occasional users. Of those who use fertilizer, 87% come from the low hills, followed by 19% in the mid hills, and 85% of fertilizer users are located less than two hours' walking distance from the road. Farmers are aware of the negative effects of fertilizers on soil properties. Farmers from Bowa Pokhara in Palpa related declining performance of legumes to the use of chemical fertilizer.

3.5. Gender Roles in Soil Fertility Management

PRA investigations (Figure 4) on the division of labour for soil fertility management showed that there are variations in activities between study villages. Figure 4 suggests that all activities are shared between men, women and children, but the degree of involvement varies according to the nature of the work. Women play the major role in carrying FYM and bedding materials, cleaning animal sheds, spreading FYM on the field, and cutting and carrying grasses. Men have key roles in trapping flood water, turning FYM heaps and work related to *goth* which are considered masculine. However, more involvement of men in purchasing chemical fertilizer shows male dominance in financial matters. Children also make useful contributions, especially in the collection of leaf litter, carrying FYM and cutting and carrying grasses. When all reported activities in the thirteen sites were combined, the difference between male and female contributions was negligible. Females contributed 42.6%, males 42.2% and children 15.2% of the labour to soil fertility management practices.

3.6. Farmer Perception of Soil Fertility

The existing forms of terraces and soils are a result of continuous efforts over many generations. Farmers differentiate between soil productivity which depends on the human-managed status of soil and inherent soil fertility. Farmers agree that soils can be kept productive if sufficient manure and moisture are available. Productivity of a particular soil is considered the major indicator of soil fertility.



Key: (1) work in *Goth* and in-situ manuring; (2) carrying FYM; (3) collection, carrying of leaf litters and trash burning; (4) work in sheep *goth*; (5) application of chemical fertilizer; (6) cleaning animal sheds; (7) spreading FYM on the field; (8) cutting and carrying grasses; (9) turning compost heap; (10) carrying chemical fertilizer from sale depot; (11) trapping flood water.

Figure 4. Gender contribution in soil fertility management practices.

Farmers from Pang also differentiate between soil productivity and soil properties stating that, although crop yields have increased (soil productivity), soil properties have deteriorated (*mato bigrio*), and soils are becoming less fertile (*rukho*). Here farmers increased fertilizer use to compensate for declining FYM output due to changes in the forest resource base and restrictions in forest use. Therefore, FYM or nutrient requirements can be a proxy indicator of soil fertility status.

Farmers use a range of parameters to characterize local soils, such as crop suitability, productivity, water holding capacity, ease of working with the soil, drainage, and assessment of amount of FYM or nutrient requirement as measures of yield. For example, farmers from the Marshyangdi river basin explain that *rato mato* (red soils) are rated poorly because they are difficult to manage due to their depth, and clay loam structure.

3.7. Soil Fertility Trends

Farmers widely support the view that declining soil fertility is a major problem in the hills irrespective of land type (Figure 5). Of the households surveyed, 67% reported a decline in fertility on bari lands and 61% on khet lands. No clear pattern can be seen across the sites, but more problems were observed in the low hills with higher cropping intensification and in higher inaccessible areas.

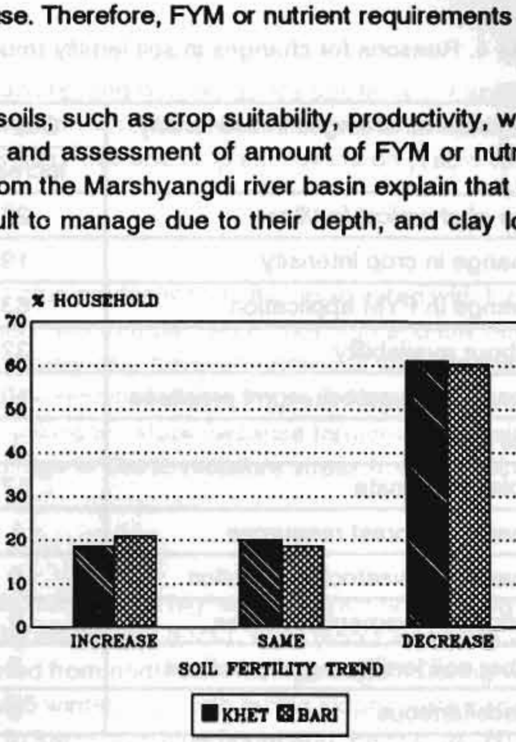


Figure 5. Soil fertility trends on khet and bari.

The farmers' perceptions of the reasons for declining soil fertility are given in Table 4. Perceptions vary across the agroecological zones and between khet and bari lands (Figures 6 and 7).

On bari lands, erosion is regarded as the major factor in decreased fertility in the high and mid hills (Figure 6). In the low hills, the decline is related to reductions in FYM output, and adverse effects such as cost and unreliable supplies of chemical fertilizers. Across the zones, other important factors are dwindling forest resources, livestock management, forest access and FYM demands and supplies.

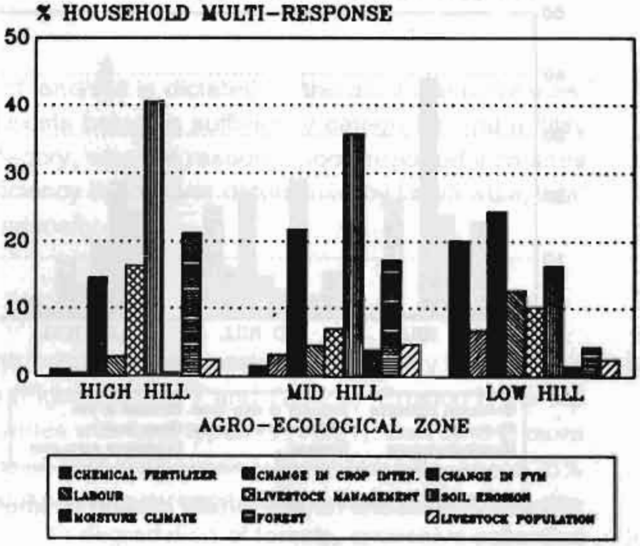


Figure 6. Reasons for soil fertility decline on bari lands.

Khet lands also present a similar picture to bari in the high and mid hills (Figure 7). In the low hills, the khet problem is related to higher fertilizer use due to crop intensification and shortage of FYM. The importance of labour increases with decreasing altitude.

Summer maize, paddy, upland rice (*ghaiya*) and spring maize were taken as reference crops to assess the effect of soil fertility trends in different land use systems. Declining crop productivity in summer maize (60%), paddy (53%), *ghaiya* (53%), and spring maize (49%) was reported.

Association of crop productivity trends with agroecological zone, accessibility, market, rainfall and aspect were tested. All of these factors have significant relationships ($p \leq 0.03$) with soil fertility trends in summer maize, paddy, and *ghaiya* except for agro-ecozone and rainfall on *ghaiya* and for rain on spring maize.

Table 4. Reasons for changes in soil fertility (multi-response frequencies).

Reasons for changes in soil fertility	Soil fertility trend on bari		Soil fertility trend on khet	
	increase	decrease	increase	decrease
Use of chemical fertilizer	26	71	33	77
Change in crop intensity	19	31	28	53
Change in FYM application	63	165	50	114
Labour availability	32	59	17	46
Change in livestock mgmt practices	10	85	2	46
Soil erosion	1	229	0	103
Moisture/climate	17	16	22	19
Change in forest resources	1	102	0	60
Change in livestock population	0	25	0	17
Land improvement practices	2	1	1	0
Other soil fertility mgmt practices	5	0	6	1
Miscellaneous	0	4	0	0

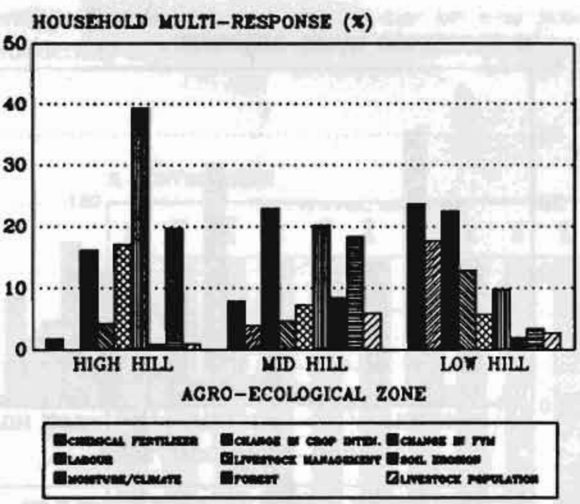


Figure 7. Reasons for soil fertility decline on khet.

Declining productivity of these crops has been mainly associated with change in soil fertility, use of high yielding varieties (HYV), increase in cropping intensity, uncertain climate and moisture stress, adverse effects of chemical fertilizer and its unreliable supply, and FYM supply. However, the emphasis changes as altitude changes. The effects of disease/pests, chemical fertilizer and labour increase in the lower hills. Labour is cited as an important constraint in *ghaiya*.

3.8. Soil Fertility Status Determinants

The issue of soil fertility in an interactive hill farming context is complex because several factors are involved. The fertility trends as discussed below refer to the human-managed level of fertility and not inherent soil fertility. Soil fertility in Nepal can be maintained by management practices, not by inherent properties of soils (Carson, 1992).

3.8.1. AGROECOLOGICAL ZONES

Agroecological zones are synonymous with altitude and sites were classified as high (>1500 m), middle (901-1500 m) and low (<900 m asl) hill sites. A significant relationship ($p \leq 0.001$) exists between fertility trends on khet and bari lands and agroecological zones. Across the agroecological zones and irrespective of land types, over 60% of households report declining soil fertility. However, both on bari and khet, the incidence of

increasing and decreasing soil fertility trends are higher in the low hills and more stagnant in the mid hills. Decreasing trends are highest in high hills (74% on khet and 78% on bari).

3.8.2. ACCESSIBILITY AND MARKETS

Accessibility and markets are related to the level of infrastructure, and both influence soil fertility. Fertility in areas with good markets has a higher probability of increasing than in remote areas. Increases in soil fertility along roads (Chambas/ Hyangja) are related to chemical fertilizer use and crop intensification (Table 5).

3.8.3. RAINFALL

Rainfall has a significant effect ($p \leq 0.001$) on soil fertility and crop productivity as it is associated with topsoil erosion. Increases in soil fertility are reported from medium rainfall sites and decrease from high and low rainfall sites in maize, rice and *ghaiya*. Problems of moisture and timely rain have an immense value in rainfed agriculture. An irregular pattern or low amount of rainfall is widely reported especially from Palpa and Myagdi. This has served to mask the importance of soil fertility issues during the study because farmers relate rainfall and fertility to crop productivity. In Palpa, low winter crop coverage is due to moisture stress from low rainfall.

3.8.4. ASPECT

A significant relationship was found between aspect and fertility trends. The highest incidence of declining soil fertility is reported from south facing villages (77%), followed by north-west (69%), west (65%) and north-east (49%). Higher incidence of increasing fertility was also reported from north-east facing villages. During visits in western Palpa, which received almost no rain during 1994/95 winter, the north facing slopes were capable of raising winter crops. North slopes conserve moisture due to lower sunshine hours and Joshi *et al.*, (1994) reported mandarin orchards facing North perform better.

3.8.5. FOOD SUFFICIENCY

A general hypothesis is that the quality of management of land/soil is dictated by the available resources. However the results show that a significant relationship exists between sufficiency categories and fertility trends on bari land ($p=0.03$). Some 54% of the <6 month category, who are resource poor, reported increases in soil fertility while 38% reported constant fertility. Food deficiency is however determined by family size, total cultivable land per capita, area of khet land and cropping intensity.

3.8.6. EROSION

Soil erosion is perceived by the farmers as the largest contributor leading to a decline in fertility both on bari and khet, becoming more important as altitude increases (Figures 6 and 7 and Table 4). Erosion is the top problem for 99% of the high hill farmers, but the problem varies with land types ($p \leq 0.001$). Bari land is more prone to erosion forces (53%). Farmer also reported problems on khet (12%) mainly in the low hills. About 35% of the farmers reported problems both on khet and bari. High hill sites have reported more loss of khet land due to landslides. Women in Kimchor associated increased run-off with degradation of forests, excessive collection of leaf litter and reduced natural regeneration of forests.

Palpa presents an interesting case for soil erosion. Land is on outward sloping terraces with high clay content and low rainfall (<1500 mm per annum). Coarse and stony structure on the surface indicates severe erosion. Fifteen to thirty centimetres of soil is lost every year from the top edge of the terrace leaving behind a barren sub-soil. The barren top edge is normally covered by ground grasses and fodder material. Farmers often plant *Khar* grass (thatching grass) as a last resort. Significant areas of land have been abandoned 50-70 years after the start of cultivation.

The erosion has resulted in a steady decline of crop productivity. Ploughing also causes soil movement on sloping terraces. Traditionally large terraces are symbols of social prestige and associated with ease in ploughing. High clay content in the soil in the region can cause waterlogging and slumping of terraces (Carson, 1992) if bench terraces are made. The explanation partly lies with return to investment where terrace improvement will hardly make any difference without irrigation and other inputs. Even *tars* were turned into khet terraces soon after irrigation was available.

Table 5. Summary of categorical factors affecting soil fertility on khet and bari.

Factors	Categories	khet (n=513)			bari (n=397)		
		Increase	Same	Decrease	Increase	Same	Decrease
Agro-ecozones	high hill %	6.1	19.7	74.2	12.1	10.3	77.6
	mid hill* %	3.7	31.5	64.8	11.1	44.8	32.2
	low hill* %	30.7	14.1	55.1	24.4	15.1	60.5
	Chisq p		<0.001			<0.001	
Accessibility	> 2 hrs %	17.8	11.8	70.4	39.5	24.1	52.8
	0 hr %	51.6	16.1	32.3	41.3	23.8	35.0
	< 2 hrs %	7.3	29.1	63.6	8.1	23.7	68.2
	Chisq p		<0.001			<0.001	
Market	good %	41.3	23.8	35.0	51.6	16.1	32.3
	medium* %	7.3	20.1	72.6	6.1	25.9	67.9
	poor* %	17.6	8.2	74.2	24.8	10.5	64.8
	Chisq p		<.001			<.001	
Rainfall	high %	18.4	24.0	57.6	16.8	23.9	59.4
	medium %	24.5	17.9	57.6	19.7	14.7	65.5
	poor %	4.3	18.6	77.1	18.9	20.4	80.7
	Chisq p		<0.002			<0.001	
Aspect	NE %	23.9	27.0	49.1	20.9	24.3	54.8
	NW %	24.1	7.4	68.5	14.5	9.2	76.3
	S %	14.9	8.1	77.0	7.7	5.1	87.2
	W %	9.8	25.0	65.2	11.7	15.0	73.3
	Chisq p		<0.001			<0.001	
Food Sufficiency	> 12 months	15.2	15.2	69.5	10.5	14.0	75.4
	6-12 months*	17.9	22.2	59.9	12.8	19.5	67.7
	< 6 months*	23.2	21.4	55.4	21.6	16.2	62.3
	Chisq p		0.239			<0.030	

Note: % = row percentage, n = no of respondents, NE = North-East NW = North-West, S = South, W = West, * = level is significantly different (<0.05) for both khet and bari from reference category in logistic regression

3.8.7. LIVESTOCK SYSTEMS

Total livestock units were calculated using the formula published by Rajbhandary and Pradan (1989) for each household across the agroecological zones. The study involved cattle, buffalo, goat and sheep. Unit numbers do not vary significantly (p=0.08) across the agroecological zones, but the actual livestock numbers do (p=0.007). For example, higher numbers of cattle per household were found in the low hills whereas buffalo numbers were higher in the high hills.

The change in livestock population across agroecological regions in last 15 years is shown in Figure 8. The livestock population has decreased by 46.6%, but the number of households keeping livestock grew by 3.0%. About 4.5% of the households do not have livestock. The high hills had the highest potential to keep larger herds, but: (1) a sharp decline in transhumance, (2) in-situ manuring in the high hills, (3) an emphasis on strengthening private land resource, (4) a scarcity of labour, (5) an increase in number of school children, and (6) a change in livestock management can explain the change.

Surprisingly livestock units and livestock numbers do not influence soil fertility. Instead, caste and markets influence livestock numbers (p=<0.001).

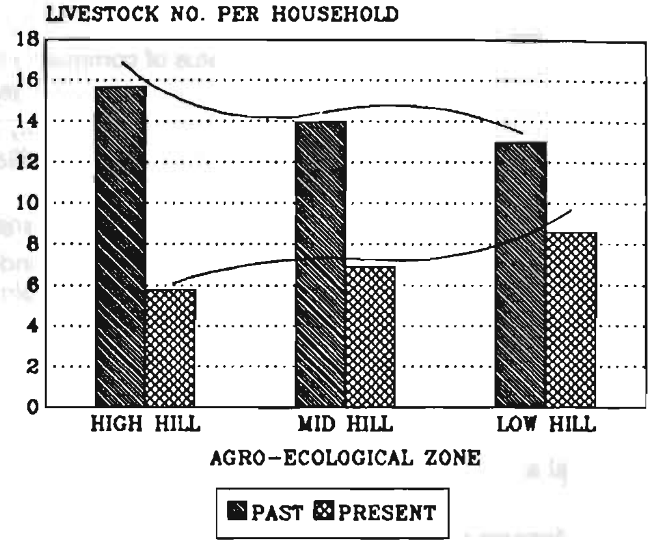


Figure 8. Trend of livestock no. per household in past and present across agro-ecological zones.

There has been a marked shift in livestock management in the hills to respond to changes in the resource base. Six major types of management systems have been reported: stall-fed, semi-extensive, *goth*, *goth* + stall-fed, stall-fed in monsoon, semi-extensive during winter and kharka (Figure 9). On average there is a 31% increase in stall-feeding, 36% decrease in semi-extensive feeding, a slight increase in *goth* and an almost disappearance of the transhumance (*Kharka)* system. Stall feeding is more popular in mid hills, but around 50% of the livestock in the high and low hills is managed under the semi-extensive system. It is not the number of animals kept which is important from a soil fertility point of view but the management of manure. The increase in stall feeding has apparently increased manure collection and consequently the amount of FYM available despite decreases in livestock.

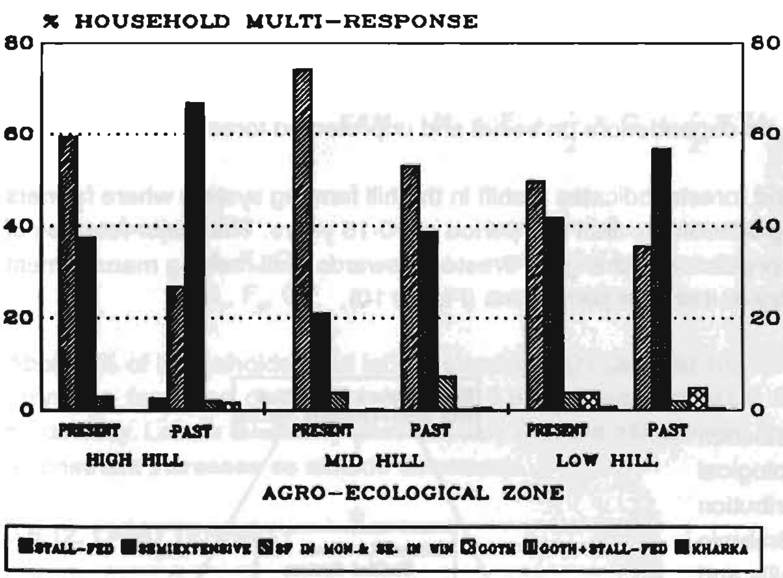


Figure 9. Livestock management practices in past and present across agro-ecological zones.

Note: SF in mon.= stall-fed in monsoon; SE in win= semi-extensive in winter.

3.8.8. FOREST RESOURCES

Promotion of community forestry has brought positive changes across the region as it shifts authority to the local user. In many cases, although the status of community forest has not yet been attained, local people and traditional institutions prevailing in the Nepalese hill society enforce regulations to maximize social welfare, protect natural resources and maintain their cultural integrity (Vaidya, 1991). However, in Chambas (low hills), this has not been possible due to demographic and politico-social problems. Bowa Pokhara Thok in Palpa reported protection in 1967/68 and has experienced an increase in livestock population as an effect. Landruk and Tanchok in the Annapurna Conservation area are experiencing strong conflicts with wildlife causing considerable damage to crops. Pang in the low hills is undergoing hardship due to restricted access.

Deforestation has an indirect effect on soil fertility. Forests have contributed to declining crop productivity from 4% to 40% on bari and 3%-20% on khet lands. Dependence on forest resources increases as altitude increases which suggests the interdependence between forest, livestock and crops becomes less as elevation decreases. This is possible because land can be managed with reduced FYM at lower elevations due to biophysical and institutional advantages such as fertiliser and green manures.

Only 25% farmers across all domains reported an increase in availability of forest resources, 38% reported a decline and 20% were unchanged. There is a significant difference on the state of social and community forestry across the agroecological zones ($p \leq 0.001$). Highest increases after the declining phase (51%) were reported from the mid hills. The increases reflect the positive effect of social/community forestry and indicate that the system is recuperating even though the declining trends in the mid and low hills show sustained pressure on forest resources. No change in the availability of resources was reported by 48% of high hill respondents, and 37% reported increasing availability after a decreasing phase. It is interesting to note that 98% of cases reporting no access to forests came from the low hills signifying greater pressure on forest resources. In response, more trees are being planted in the low hills (49%) followed by the mid hills (30%), though it is not statistically significant. Farmers in the lower hills depend on private farms for fodder and bedding materials whereas high hill farmers depend more on social and unprotected forests.

The preceding discussion on livestock and forests indicates a shift in the hill farming system where farmers have modified the system to arrest the degradation process in a period of 10-15 years. The major features of the shift are a drastic reduction in livestock population, a change of livestock towards stall-feeding management and more emphasis on community forestry and private plantations (Figure 10).

3.8.9. ETHNIC GROUP

There is a significant variation in the distribution of ethnic groups across the agro-ecological zones ($p \leq 0.001$). A clear pattern of distribution can be observed in the study area, with Brahmin and Chetries concentrated in the lower hills and valleys with better farming prospects and Gurung and Magar in higher mountains. Middle hills are often inhabited by mixed communities. Occupational castes are an integral part of any society.

Ethnic group also influences the fertility status of both khet and bari ($p \leq 0.01$). Decreasing soil fertility on bari is associated more with Brahmin/Chetries (31%) and Gurung/Magar

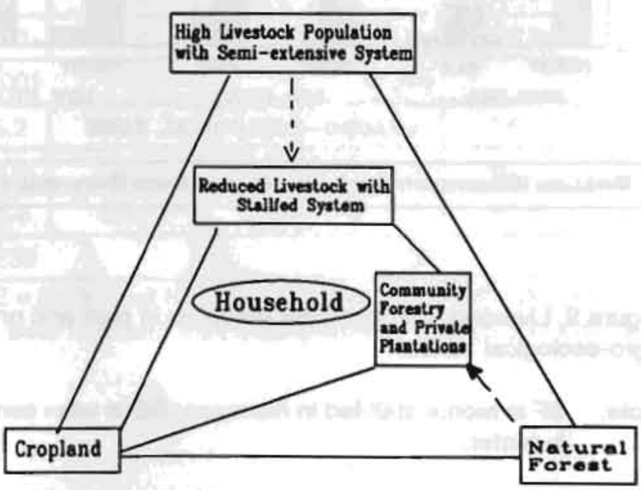


Figure 10. Shifting triangle of hill farming system (adapted from Joshi, 1994).

(39%). Only 14% of households from occupational castes reported declining soil fertility. A similar trend was evident on khet.

3.8.10. LAND HOLDINGS

No association between land fragmentation, distance to fields from homestead and size of holding with soil fertility was evident. Given that hill farming is essentially subsistence in nature with low opportunity cost of farming activities and very low land holding size in the hills (0.68 hectare per household in the study area), it can be argued that management will not be influenced by these factors. Similar explanations also work in Tanchok and Landruk where households have pension and tourism incomes.

The size of land holding is certainly related to ethnicity and agroecological zones ($p \leq 0.001$). Brahmin/Chetri and Gurung/Magar have larger holdings compared to occupational castes. About 61% of occupational castes own less than two ropani (0.1 hectare) of total cultivable land. The size is inversely related to altitude; however, the mid hills are densely populated which reduces the land per household. No association with soil fertility could be found.

3.8.11. LABOUR

Hill farming is traditional and labour-intensive. Therefore, total able manpower within the household, labour supply in the market during peak season, migration and opportunity cost of labour (market wage) affect farming activities as a whole. The increasing number of school children, positive impact of family planning, and tourism opportunities are reported to have affected the labour available for hill farming in the study area.

Total available manpower affects number of livestock reared ($p=<0.001$) but does not influence productivity on khet or bari. The total available manpower is defined as follows:

$$TAM \quad M_f + F_f + \frac{1}{2} \times C_f + \frac{1}{2} \times (M_p + F_p + C_p)$$

where:			
	TAM	=	total available manpower
	M_f, F_f, C_f	=	number of full-time males, females and children respectively
	M_p, F_p, C_p	=	number of part-time males, females and children respectively

About 8% of households cited labour shortages (household and hired) as a reason for declining soil fertility. From the foregone discussion (section 3.8.7), it was apparent that livestock numbers do not influence productivity. Labour availability does not vary with the altitude and food sufficiency levels. However, labour as a constraint increases as altitude decreases.

3.8.12. LAND TENANCY

Land tenancy is expected to influence soil fertility management practices (Regmi, 1976; Tamang, 1993). Zaman and Regmi (1976) discussed lower output per unit area from tenant-cultivated land compared to owner-cultivated land. In the study villages, 26% of farmers are involved in land tenancy arrangements. Almost 90% of farmers who rent-in land are from the <6 months category (46%) and 6-12 months category (43%), while the majority of farmers from the >12 months category do not hire-in land ($p=<0.001$). Similarly 49% of those who rented-out came from the >12 months category ($p=<0.001$).

The majority of tenancy land is under a share cropping arrangement (57%), others being contract (14.5%) and various combinations depending on land types. There is 51% tenancy under unassured tenancy, 21.5% mortgaged land kept until a loan is repaid and 21% ranging from one season to five years. Tenancy applies to all crops in 73% of cases and 19% reported that it applies to rice only. Tenancy is found equally both on khet and bari. Over 80% of farmers do not discriminate between owner-cultivated land and tenant land. Manure application is primarily the responsibility of the tenant (80%), in 11% of cases both tenants and owners apply manure and in 5.5% of cases only the landowner reported responsibility for manure application.

It is believed that tenants try to maximize output, and it could be argued that fertility management is compromised. Hill farmers are cautious about long term management of soils and are particularly concerned about degradation in soil properties related to chemical fertilizers. In Chambas, landlords make an agreement with the tenant that chemical fertilizer will not be applied in return for which the landlord agrees to contribute FYM. In Mustang, where tenancy arrangements are skewed in the tenants favour, farmers reported relaxation of fertility management towards the end of the contract (Joshi, 1994). However, the study failed to detect any relationship between land tenancy and trends in soil fertility on bari and khet.

A shortage of labour was reported by 74.5% of households as the main reason behind renting out land, while 20% mortgaged their lands because of indebtedness. Other reasons were a shortage of manure, excess land, physical inability and distant land parcels.

4. PREDICTION OF SOIL FERTILITY DECLINE

Soil fertility is the effect of several factors within and outside the farming system including state policies. Deforestation and demographic pressures leading to environmental degradation have brought a series of changes in patterns of resource usage which eventually impact soil fertility. Assuming an influence on the parameters under study, a logistic regression model was prepared taking households as the unit and using several key factors acting in hill farming systems which are expected to influence soil fertility trend on bari and khet. The independent variables used to predict soil fertility trends were food sufficiency category, ethnic group, sex of respondent, livestock management, total FYM output, total FYM going to bari and khet, forest index (indexed from fodder sufficiency, availability of resources in community forest, fodder from private land and trend in natural forest), fodder ratio (public: private source), total livestock units, livestock and management index (livestock unit and management combined), khet:bari ratio, market, rain, aspect, accessibility, agroecological zones, area and parcel of cultivable land and tenancy arrangements.

This model includes both categorical and continuous variables. A forward step method was used. For categorical variables, the reference category set for food sufficiency was the >12 months group, for ethnic groups, Brahmin and Chetri, for market, good, for respondent sex, male, for rain, high, for livestock management, stall-fed, for agro-ecozone, high hill, and for land tenancy arrangement, share cropping. The dependent variable has two values, 1 which means increasing or the same and 2, decreasing. For analysis purposes, increasing is considered as zero.

4.1. Model for Declining Soil Fertility on Bari

The model takes only six variables to predict soil fertility trends on bari (Table 6). These are food sufficiency, amount of FYM per unit bari land, forest index, market, rain and agroecological zone. Regression coefficients suggest that the <6 month category has more chance of increasing soil fertility than the 6-12 month group. Forest index has a larger effect than FYM. Locations with poor markets will have a chance of severe fertility problems. Medium rainfall is likely to favour increasing fertility than low rainfall. The chance of increasing soil fertility is greater in the mid hills than the low hills.

This model classifies 76% of responses correctly. Partial correlation shows a greater influence of market and agroecological zone on soil fertility trends. Using regression coefficients, the probability of decreasing soil fertility can be calculated for any particular household using the following equation:

$$\textit{Prob (decreasing soil fertility)} = \frac{1}{1+e^{z}}$$

where: z = 3.489+[0 or (-0.875 x category 2) or (-1.09 x category 3)]
+ (-0.015 x bari FYM) + (-0.35 x forest index)
+ [0 or (2.146 x medium market) or (2.617 x poor market)]
+ [0 or (-1.025 x medium rain) or (1.39 x poor rain)]
+ [0 or (-2.5 x mid hill) or (-0.824 x low hill)]

Table 6. Parameter estimates for logistic regression model on bari.

Variable	Regression coefficient (B)	Sig	Partial Correlation (R)
Food sufficiency category		.035	.089
Category 2 (6-12 month)	-.878	.028	-.091
Category 3 (<6 month)	-1.086	.015	-.107
FYM per ropani on bari	-.015	.013	-.110
Forest index	-.350	.010	-.120
Market		.000	.184
Market (medium)	2.146	.001	.160
Market (poor)	2.617	.000	.197
Rainfall		.007	.130
Rainfall (medium)	-1.025	.097	-.047
Rainfall (low)	1.390	.012	.113
Agro-ecozone		.001	.179
Agro-ecozone (mid hill)	-2.505	.000	-.194
Agro-ecozone (low hill)	-.824	.205	.000
Constant	3.489	.005	

4.2. Model for Declining Soil Fertility on Khet

The model takes only six variables to predict soil fertility trend on khet and classifies 70% of responses correctly (Table 7). This model explains a similar probability trend of selected variables as on bari. Logically, the forest index is lower on khet than on bari but more important than total compost.

5. CONCLUSIONS

1. The study was based on farmers perceptions, intensive visits to the study area and discussions with farmers. Although these findings may not provide the accuracy that direct measurement would have, given the resource and time constraints, information generated should be an adequate basis for the final phase of the project which is to produce a long term strategy for LARC soil fertility research.

2. Although farmers have often been blamed for resource degradation the results suggest that they have contributed towards reversing the process by adjusting various components of farming systems to the new resource base.

3. Soil fertility decline both on bari and khet has been widely reported. Major reasons cited for the decline in soil fertility are due to a decline in FYM supply, erosion, change in forest resources and problems associated with chemical fertilizers.

4. Logistic regression shows the effects of market and agroecological zones on soil fertility which are associated with accessibility. Lower hills with access to inputs have a greater chance of increasing soil fertility. This creates two distinct soil fertility domains, one with a greater potential of increasing productivity using external inputs such as chemical fertilizer and pesticides, and the second, inaccessible areas away from markets where traditional methods will continue as fertilizer use may not be feasible or practical.

Table 7. Parameter estimates for logistic regression model on khet.

Variable	Regression coefficient (B)	Sig	Partial Correlation (R)
Food sufficiency category		.048	.076
Category 2 (6-12 month)	-.603	.086	-.051
Category 3 (<6 month)	-.993	.015	-.105
FYM per ropani on bari	-.291	.020	-.097
Forest index	-.022	.022	-.095
Market		.001	.162
Market (medium)	1.986	.003	.140
Market (poor)	2.641	.001	.178
Rainfall		.001	.189
Rainfall (medium)	2.356	.001	-.174
Rainfall (low)	.803	.126	.031
Agro-ecozone		.006	.133
Agro-ecozone (mid hill)	1.955	.001	-.152
Agro-ecozone (low hill)	-.196	.722	.000
Constant	2.710	.017	

6. RECOMMENDATIONS

1. As a result of the study, thirteen villages have been identified in seven study areas. The framework for research using existing farming systems and identified study villages can be used for future research activities.

2. Upgrading the necessary data bases and developing recommendation domains around study villages should be a priority.

3. FYM is the output of a farm where all components of the farming system contribute as well as socio-economic and institutional factors. Nevertheless, understanding why farmers do not accept improved methods of compost preparation is as important as improving quality, minimizing the loss of nutrients and increasing efficiency. FYM has crucial role in high and inaccessible areas. Therefore understanding nitrogen and carbon dynamics for this domain is important.

4. Problems of erosion in the high hills and on outward sloping terrace call for immediate research and extension attention. The extent of erosion problems on khet land reported by farmers requires further investigation.

5. A high response related to negative effects of fertilizers shows a lack of research and extension about the correct use and combination of fertiliser. In the light of the envisaged encouragement of fertilizer use in the Agricultural Perspective Plan, the issue deserves more attention. A knowledge of long term fertility dynamics in different land use systems will contribute improved productivity using external inputs without injuring soil health. Integrated management of fertility has relevance in this context.

6. **The null effect of either livestock management, livestock units or their combination on soil fertility changes has come as a surprise from the study and requires further investigation.**

7. **Wider changes in the system are also a result of policy and socio-cultural practices beyond the scope of soil fertility research. However, the study underlines the influence of farmer category, land tenancy, deforestation, and community participation in forest management which needs to be considered to guide future research.**

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