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Land use, land management and environment in a subsistence mountain economy in Nepal

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Abstract

In view of the growing concern about the effects of human activities on the mountain environment of Nepal, this study examined the land use and management systems and their environmental effects with reference to a small watershed. It was shown that farmers had used cropping diversification, mixed cropping, cropping intensification and agroforestry to cope with the problem of food shortage arising from their marginal landholdings. They had terraced virtually all of their farm plots and applied compost/manure regularly, though in inadequate amounts, to control soil erosion and maintain land productivity. Nevertheless, farm lands on the ridges were undergoing unsustainable rates of soil erosion and soil nutrients depletion due to frequent hoeing and ploughing of lands, application of inadequate amounts of organic fertilisers, lack of mulching, and fallowing of lands for too short a period and without any vegetation cover. Soil erosion was not an acute problem in river valleys, as lands were flat and terraced, but lands were undergoing degradation owing to an unsustainable rate of removal of soil nutrients. Non-arable agriculture using biological soil fertilisation, including legume cultivation and compost application, could conserve soil in suitable locations and sustain the mountain environment.

Keywords: Land use; Land management; Mountain environment; Nepal

1. The issue

The mountains of Nepal, comprising nearly three-quarters of the national territory, have attracted the attention of many academic, policymakers and planners over the past 25 years, primarily to evaluate environmental conditions stemming from deforestation and land degradation (Ives and Messerli, 1989; Thapa and Weber, 1994). Most studies explored the extent and causes of deforestation and sustainable management of forest resources (Robbe, 1954; Wallace, 1981; Bajracharya, 1983; Fox, 1993; Metz, 1994). Little attention has been paid to the status and management of agricultural lands, which account for a substantial proportion of the total land area. Numerous studies have been undertaken on agricultural lands over the past two decades, but most of them have been confined to the analysis of crop production and cropping pattern. The few in-depth studies on land management focused on farmers' strategies of mitigating mountain hazards, namely landslide (Johnson et al., 1982). No studies have examined the environmental implications of the on-going land use and management practices. Besides land utilisation, it has been increasingly important to examine the local land management practices in the pursuit of formulating a sustainable mountain development strategy. Its relevance is explained by three major factors.

1. Being mostly steep slopes, agricultural lands are vulnerable to accelerating soil erosion, causing land productivity to fall. The annual average rate of soil formation is estimated to be 1 t ha^{-1} under favourable climatic and topographic conditions (Troeh and Thompson, 1993). Thus, if sustainable productivity is to be maintained, the pace of soil erosion should not exceed 1 t ha^{-1}.
2. Agricultural lands in the mountains are under heavy population pressure. There are 4.49 persons

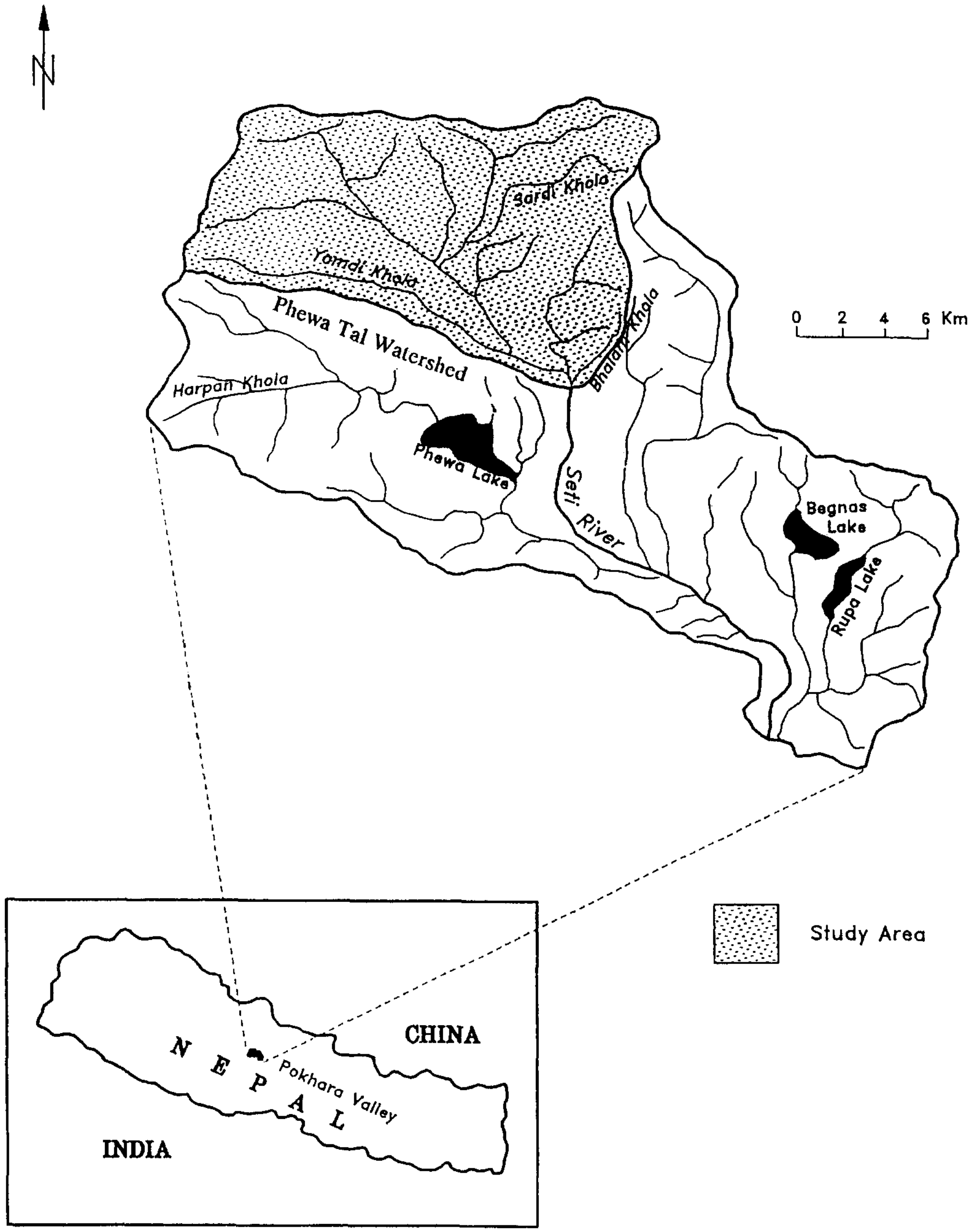

Fig. 1. Location of the study area in Pokhara Valley, Nepal.

per hectare of cultivated lands in the plains of Tarai, and 3.71 persons in the high Himalayan region. There are more than 5 persons per hectare in the mountains between Tarai and the Himalayas. Hence, lands in the mountains are intensively utilised compared with other ecological regions (Banskota et al., 1990).

3. Agriculture is the economic mainstay of the majority of households and will remain so for the foreseeable future since there is very limited scope for the development of non-farming employment opportunities.

In a mountain environment lands are susceptible to accelerating soil erosion and landslide (Froehlich and Starkel, 1993). Therefore, the land use and management systems need to be evaluated. Accordingly, this paper examines the role of land use and land management practices in soil conservation with reference to a small mountain watershed (see Fig. 1). The specific focus is on cropping systems, crop diversification, cropping intensity, agroforestry, crop management practices, and structural as well as biological measures of soil management. Besides contributing to studies on the mountains, this study will contribute towards the formulation of an environmentally and economically sound land management strategy.

2. Research design

Information on local land use and management practices was collected through a questionnaire survey of 298 households in the Upper Pokhara Valley. The study area was divided into four watersheds: Yamdi, Mardi, Seti and Kali (see Fig. 2). Subsamples were drawn for each watershed. Two villages, one representing the ridge and one representing the

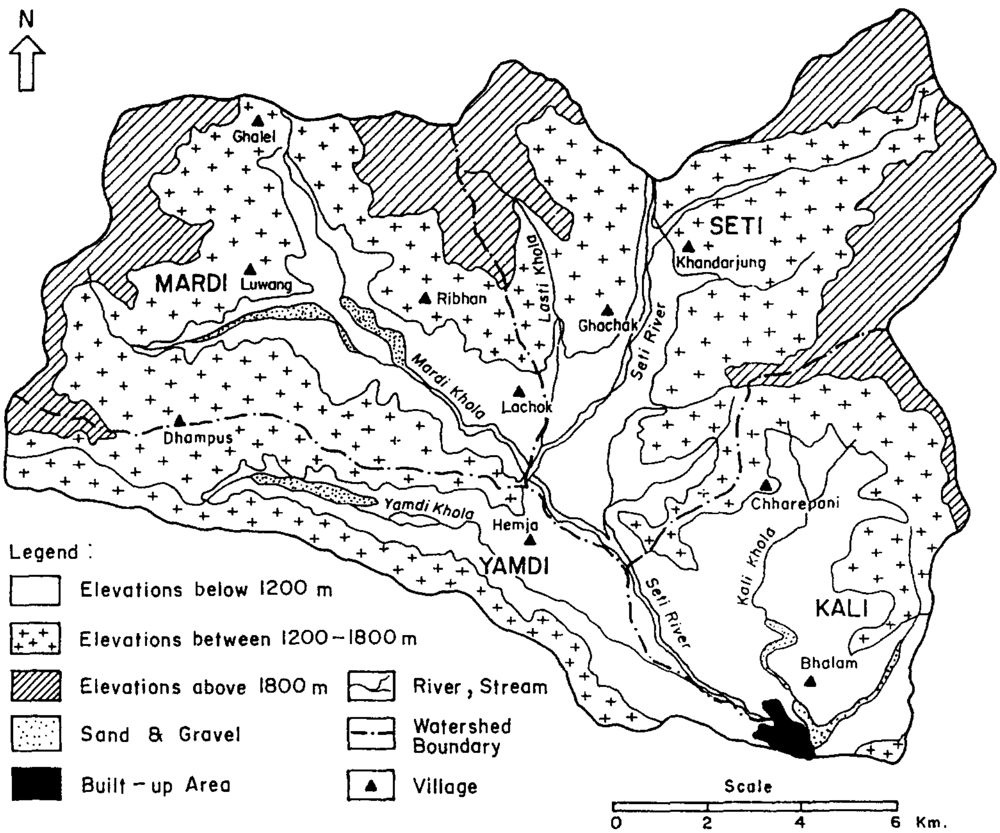

Fig. 2. Topographical features of the Upper Pokhara Valley.

Table 1
Household survey results by watershed and village location

Watershed	No. of households	Subsample (n)	Valley village	No. of households surveyed	Ridge village	No. of households surveyed
Yamdi	1604	75	Hemja	40	Dhampus	35
Mardi	1623	75	Lachok	35	Rivan	40
Seti	1338	64	Ghachok	35	Khandarjung	29
Kali	2400	84	Bhalam	39	Chharepani	45
Total	6965	298		149		149

valley, were selected from each watershed to examine the influence of location on land use and land management (see Table 1).

The lack of lists identifying individual households prevented the adoption of simple random sampling to determine which households were to be surveyed. Accordingly, the random walk method was adopted. Field assistants were instructed to walk into a particular part of a selected village and start surveying households at a certain fixed interval. The survey was conducted from the fourth week of May until the third week of July, 1989. This survey included information on cropping systems, crop productivity, labour input in crop cultivation, agroforestry and land management. Field observations were also carried out and informal interviews held with farmers to evaluate the resource management systems.

Supplementary information was collected through a follow-up field study conducted at Maramche Village of the Yamdi Watershed in April 1992. A questionnaire survey and personal discussions were employed to collect the data. The questionnaire covered information on land use, field crop production and agricultural inputs. It was sent to 29 randomly identified households out of the total of 35 farm households. Informal interviews were held with 19 of the 29 respondents. All information was analysed using SPSS.

3. Agricultural lands in the Upper Pokhara Valley

The study area is predominantly mountainous, with interspersed river valleys. The agricultural lands, which account for nearly 47% of the total area, can be broadly divided into valleys and terraced lands (Thapa and Weber, 1990, p. 59). The valleys are located along the four major rivers: Yamdi, Mardi, Seti and Kali. The 1200 m contour line roughly separates them from the terraced lands. Valley lands, particularly in the middle parts of the Yamdi and Mardi Watersheds are alluvial plains and alluvial fans, characterised by nearly level lands and slope gradients of less than 1° (see Fig. 3). Entisols are the predominant type of soils which are deep and fertile with loamy/bouldery texture. The valley lands in the Seti Watershed and in the lower parts of the Kali and Mardi Watersheds are river terraces or tar. Gentle slope gradients ranging from 0 to 5° and deep, well drained inceptisols with loamy/skeletal texture are their typical features. In some parts of Seti, Kali and Mardi Watersheds, soils are of the calcareous, coarse, gravely type. These lands are suitable for both arable and non-arable agriculture (see Fig. 4). The regular hoeing and ploughing involved in arable agriculture results in frequent disturbance of the soil structure. Non-arable agriculture, however, does not cause such frequent disturbance in soil structure, as lands are not regularly tilled. Despite requiring regular hoeing and ploughing, arable agricultural does not aggravate soil erosion, since lands are nearly levelled.

All agricultural lands on ridges and slopes between 1200 and 2200 m are here referred to as terraced lands. Most lands are on slopes between 5 and 30° (see Fig. 3). Soils are inceptisols, 50–100 cm deep and well drained, with loamy/skeletal texture (see Fig. 4). As a consequence of their soil characteristics and because these steep slopes are vulnerable to accelerating soil erosion, they are most suitable for agricultural systems which do not require regular hoeing and ploughing, i.e. forestry, horticulture and livestock raising (see Fig. 4).

The average annual amount of rainfall on the ridges is about 4700 mm, compared with 4000 mm on the plains. Most rainfall occurs between May and September. In the months of July and August, the average monthly rainfall is as high as about 1300 mm on the ridges and about 1000 mm in valleys. From November to March, the mean monthly rainfall amounts to less than 75 mm in both locations. Steep slope gradients combined with a relatively heavy rainfall have made these lands vulnerable to accelerating soil erosion. It is thus sensible to examine the on-going agricultural and land management systems with regard to their role in soil conservation and management.

3.1. Landholdings

Agricultural lands in the study area fall into two main categories, dry crop lands or bari and paddy lands or khet. Owing to the lack of irrigation facilities, most bari were predominantly under maize, millet and wheat crops. Rice was the single crop cultivated in most khet. More than half of the total farm lands in all but Bhalam Village of the Kali Watershed were khet (see Table 2). In the three ridge villages of Rivan, Khandarjung and Chharepani, farmers' khet are along the Mardi, Seti or Kali Rivers, whereas their bari are in hill slopes.

The limited amount of land suitable for agriculture, combined with the concentration of the major proportion of the national population in the moun-

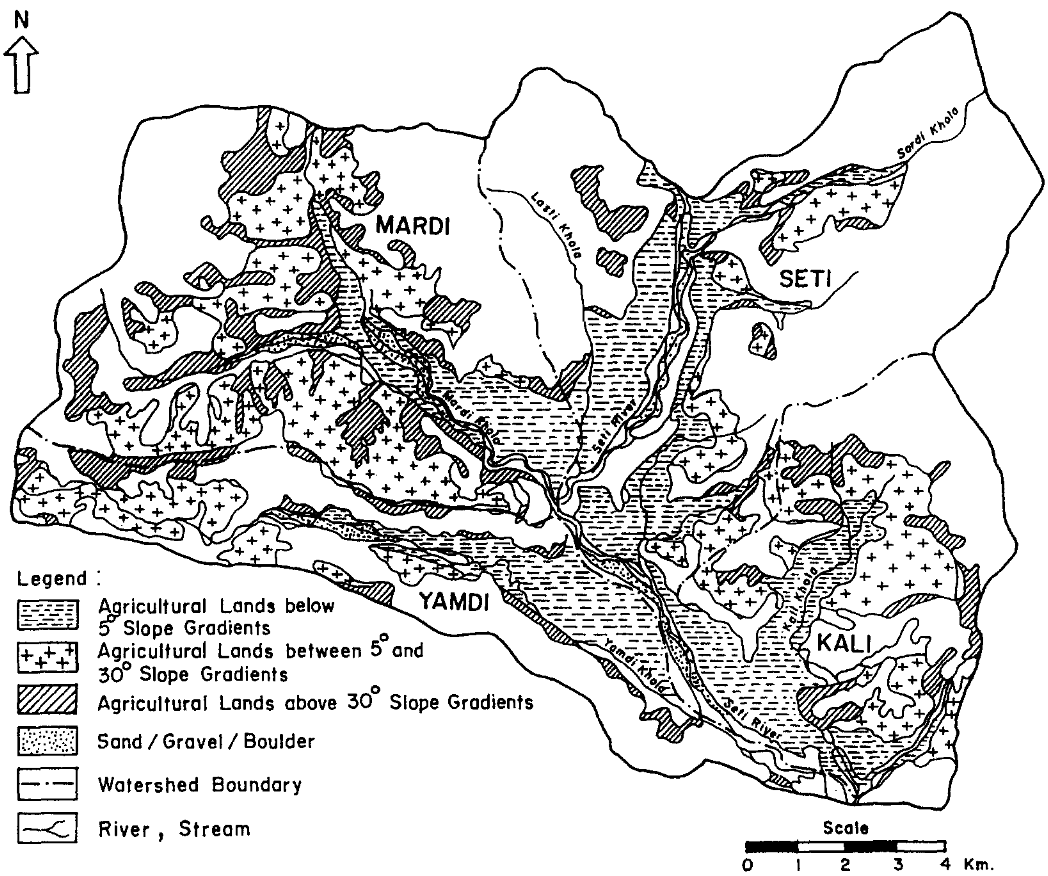

Fig. 3. Agricultural lands by slope category in the Upper Pokhara Valley.

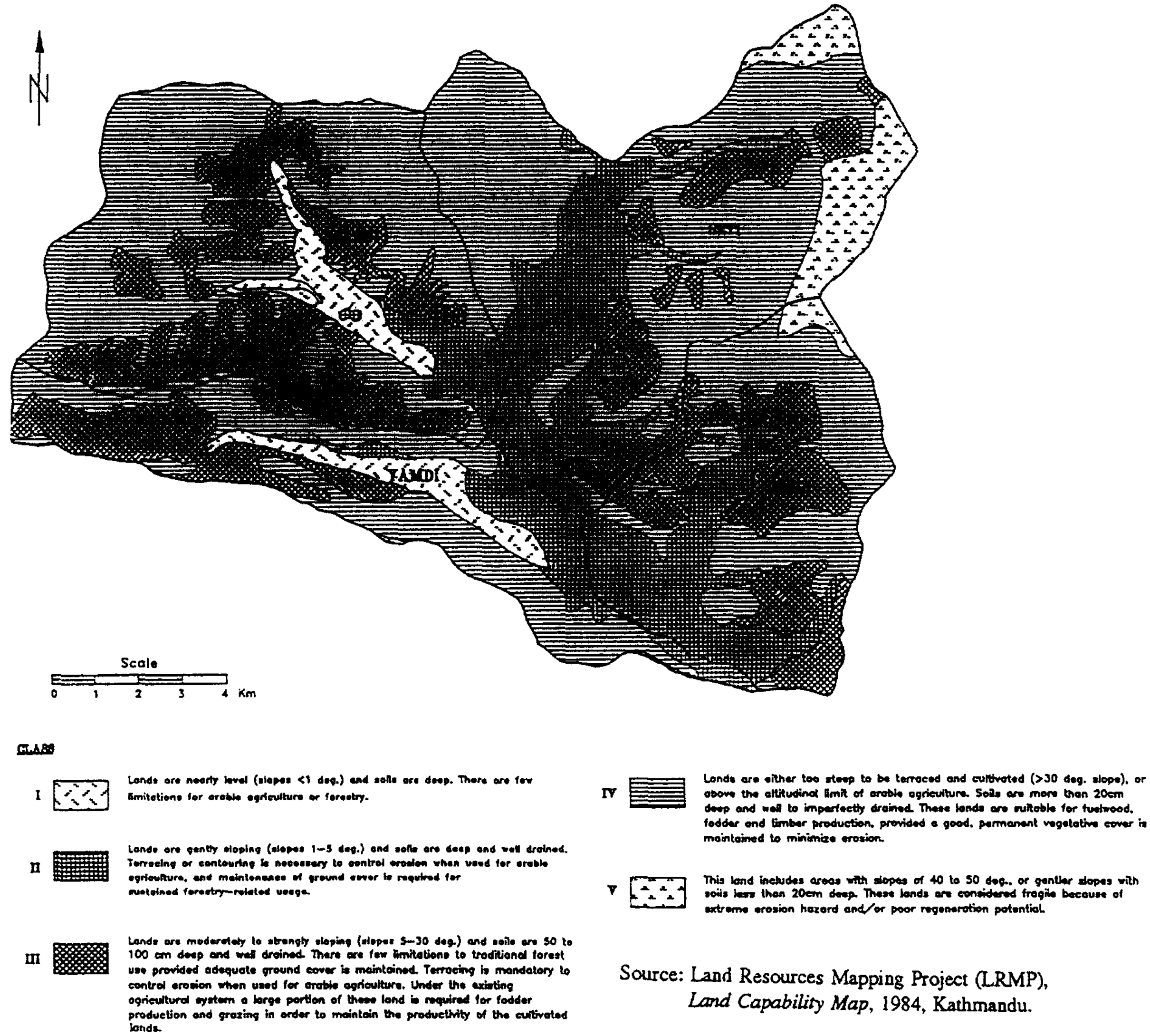

Fig. 4. Land capabilities in the Upper Pokhara Valley. Source: LRMP (1984).

Table 2
Type of lands by location of villages surveyed

Watershed	Total land (ha)	Valley village	Bari (%)	Khet (%)	Ridge village	Bari (%)	Khet (%)
Yamdi	31.7 (0.75)	Hemja	35.7	64.3	Dhampus	43.5	56.5
Mardi	26.2 (0.75)	Lachok	37.5	62.5	Rivan	42.5	57.5
Seti	24.9 (0.70)	Ghachok	41.0	59.0	Khandarjung	31.7	68.3
Kali	26.5 (0.75)	Bhalam	55.8	44.2	Chharepani	45.1	54.9
All	109.3 (0.75)	All(0.75)	42.5	57.5	All(0.75)	42.2	57.8

Figures in parentheses are the average landholding size per household.

Table 3
Proportion of cropped area by staple field crop

Watershed	Village	Total cropped area (ha)	Rice	Maize	Millet		Wheat	
			Khet (%)	Bari (%)	Bari (%)	Khet (%)	Bari (%)	Khet (%)
Valley		150.1	43.1	20.3	4.5	18.9	3.4	6.9
Yamdi	Hemja	39.5	53.0	16.2	9.6	12.3	5.0	9.0
Mardi	Lachok	40.7	44.5	18.5	6.5	15.0	6.2	6.2
Seti	Ghachok	31.7	45.2	19.8	9.1	20.4	0.9	7.2
Kali	Bhalam	38.2	29.2	27.1	4.1	28.7	0.7	5.2
Ridge		153.7	44.3	21.9	2.6	21.9	3.7	4.1
Yamdi	Dhampus	31.1	47.3	22.0	2.5	21.7	4.4	2.0
Mardi	Rivan	42.0	44.2	21.7	12.0	22.6	4.8	4.2
Seti	Khandarjung	20.2	43.5	22.1	3.3	21.2	1.2	0.0
Kali	Chharepani	60.4	43.3	22.0	21.8	3.4	6.2	

tains has given rise to an agricultural economy characterised by small landholdings (Regmi, 1977). Thus, historically as well as at present, mountain farmers have been working on small landholdings, which are getting steadily smaller in size due to population growth. The study area is not an exception. In 1962, for example, an average farm household at Kahun Village, located adjacent to the Upper Pokhara Valley, possessed 69 ropani or about 3.5 ha of land (Gurung, 1965). Assuming this to be typical of the study area, an average farm household was found holding 15.1 ropani or 0.76 ha of land in 1989 (see Table 2). None of the farmers had landholdings exceeding 4.5 ha or 90 ropani. Notably, nearly

Table 4
Indices of crop diversification (ICD) [a] and mixed cropping (IMC) [b] by location of villages surveyed

Watershed	Valley village	ICD	IMC	Ridge village	ICD	IMC
Yamdi	Hemja	31.50NS	0.04 *	Dhampus	30.50NS	0.13 *
Mardi	Lachok	28.84NS	0.20 *	Rivan	34.46NS	0.14 *
Seti	Ghachok	32.21NS	0.23 *	Khandarjung	37.64NS	0.46 *
Kali	Bhalam	30.25NS	0.02 *	Chharepani	29.89NS	0.82 *
Average		30.68NS	0.11 *		32.67NS	0.41 *

[a] This index was constructed using the formula developed by Bhatia (1965). Six major field crops, namely, rice, upland rice, maize, millet, wheat and mustard were taken into consideration in preparing this index.

$\text{ICD} = P_a + P_b + P_c \ldots P_n/N_c$

where ICD is the index of crop diversification, P_a is the proportion of sown area under crop a, P_b is proportion of sown area under crop b, P_c is the proportion of sown area under crop c, P_n is the proportion of sown area under crop n and N_c is the number of crops. The lower the index value, the higher the crop diversification.

[b] This index was developed as follows:

$\text{IMC} = M_{c1}^2 + M_{c2}^2 \ldots + M_{cn}^2/L^2$

where IMC is the index of mixed cropping, M_{c1} is area under mixed cropping combination 1, M_{c2} is area under mixed cropping combination 2, M_{cn} is area under mixed cropping combination n and L is the total landholding, excluding lands under *Typha angustata*. The higher the index, the higher the degree of mixed cropping.

NS, F-test not significant at 0.05 confidence level.

* F-test significant at 0.05 confidence level.

three-quarters of the households surveyed had landholdings smaller than 20 ropani or 1 ha, accounting for 44% of the total landholdings.

3.2. Cropping pattern, crop diversification and mixed cropping

As noted earlier, the land use potential differs throughout the study area owing to variations in soil type, climatic condition, elevation and slope gradient. Despite this, there was no significant variation in cropping pattern. Owing to the small size of landholdings and scarce non-farming employment opportunities, virtually all farm households in all settlements had utilised their lands for cereal crop production to safeguard their food supply (see Table 3). With one exception, rice occupied the major proportion of the total cropped area in all settlements, followed by maize, millet and wheat. This explains why there was no significant locational variation in the index of cropping diversification (ICD) (see Table 4). As ICD lies between 28 and 38, this indicates that approximately three crops were grown per village. The proportion of farm households cultivating non-cereal crops, i.e. mustard, potato and vegetables, cultivated mainly in valley settlements, was negligible.

Confronted with the problems of increasing food demand and marginal landholdings, both valley and ridge farmers have adopted a practice of mixed cropping or growing two field crops simultaneously in one plot, though not necessarily sown, as a strategy of securing more produce by tapping limited resources. While maize and millet was the predominant type of mixed crop combination in all settlements, the degree of mixed cropping was significantly higher in ridge settlements than in valley settlements (see Table 4). This was explained by the fact that a significantly high proportion of ridge land had been utilised for the mixed cropping of maize and millet, since waterlogging was not a problem for the millet cultivation there. The other mixed crop combinations were mustard/wheat and wheat/peas which accounted for a negligible proportion of the total cropped area.

Crop diversification and mixed cropping are both environmentally and economically sound practices. When two or more crops are grown in sequence in the same field, each crop uses the fertility of the soil in its own particular way. Different plants grow to different depths and require different nutrients (Dupriez and De Leener, 1988). When many plants are associated in the same field, more waste and organic matter are available. The economic benefits of multiple cropping or mixed cropping could be three to four times higher than that of monocropping on a per hectare basis (Wen et al., 1992).

To make the best use of limited land resources, farmers plant beans, soyabean and pulses on bunds and terrace risers. Owing to the ever-increasing demand for food, farmers cannot cultivate legume crops in farm plots. Although there is the possibility of cultivating these crops in khet following the harvesting of rice, farmers have not taken any initiative towards it, owing to (i) the tradition of releasing livestock into the fields, especially after the harvesting of monsoon crops and (ii) farmers' ignorance of the importance of legumes as soil fertilisers.

3.3. Cropping intensity

Following assessment of the cropping pattern, it is sensible to examine the intensity of land utilisation.

Table 5
Index of cropping intensity [a] by location of villages surveyed and land type

Watershed	Valley village	Bari	Khet	Ridge village	Bari	Khet
Yamdi	Hemja	1.81NS	1.35NS	Dhampus	2.45NS	1.81NS
Mardi	Lachok	2.37NS	1.58NS	Rivan	2.04NS	1.31NS
Seti	Ghachok	2.08NS	1.27NS	Khandarjung	2.15NS	1.35NS
Kali	Bhalam	2.04NS	1.49NS	Chharepani	2.14NS	1.49NS
Average		2.06NS	1.43NS		2.19NS	1.49NS

[a] This index was created by dividing the total cropped area by the total landholding size, excluding the area under khar or *Typha angustata*.
NS, F-test not significant at 0.05 confidence level.

Accordingly, the index of cropping intensity, which indicates the average number of times that a given plot of land is cultivated per agricultural year, was formulated in order to analyse variation in cropping intensity by type of land and settlement.

Overall, bari were more intensively cultivated than khet. Although bari on ridges were relatively more intensively utilised than bari in valleys, this variation was statistically insignificant (see Table 5). This can be explained by the fact that the millet crop accounted for a marginally higher proportion of bari on the ridges than in valleys (see Table 5). Most bari had been utilised for two to three crops per year (average cropping intensity 2.31), depending on moisture and nutrient supplies, size of the household labour force and location of farm plots. Maize was sown in March and harvested in the second week of July. Millet was inter-cropped with maize, normally 3–4 weeks before the harvest of the latter crop. Following the harvest of millet in the second week of November, fields were immediately ploughed and cultivated with either mustard or wheat, to be harvested 2–3 weeks before the cultivation of another maize crop in the following agricultural year. Maize and millet were typical crops cultivated in bari. Plots with adequate moisture supply were also utilised for wheat and mustard.

On average, a typical khet plot was utilised 1.79 times per year (see Table 5). Rice was the staple crop cultivated in khet. While traditional winter crops, including legumes, were not cultivated in khet because of their relatively distant location and the practice of releasing cattle into the fields after harvest of the monsoon crops (Regmi, 1978), these lands were being gradually utilised for both summer and winter crops in order to cope with the problem of food supply. Thus, plots with adequate moisture and relatively close to the farmhouse had been utilised for wheat and maize cultivation. The reason for cultivating plots relatively close to farmhouses was that farmers could protect crop from cattle. Maize was sown in the first week of February and harvested in the first week of June, allowing rice planting in the second week of June simultaneously with all other khet lying fallow until then. Following the rice harvest from the last week of October until the first week of November, most khet were left fallow until the following June.

3.4. Agroforestry

Planting trees in association with field crops is a long established tradition in the hills. Accordingly, farmers in the study area had grown assorted varieties of fruit and fodder/fuelwood trees and bamboo clumps. The most common varieties of local fruits were tangerine, guava, lemon, orange, mango, lime, pear, peach, plum, papaya and banana. Tangerine, orange, mango, lime and pear were the typical varieties of fruits in valley settlements. In ridge settlements, peach, plum, papaya and pear were common. Despite suitable soil, temperature and moisture, both the proportion of households engaged in fruit cultivation and the average number of trees per household

Table 6
Farm households growing trees by location of villages surveyed

Watershed	Village	Fruit (%)	Fodder/fuelwood (%)	Bamboo (%)
Valley		78.5 (14)	72.8 (35)	72.4 (3)
Yamdi	Hemja	85.0 (22)	65.0 (31)	67.5 (4)
Mardi	Lachok	62.9 (6)	73.5 (15)	73.5 (4)
Seti	Ghachok	80.0 (10)	60.0 (27)	66.7 (2)
Kali	Bhalam	84.6 (17)	92.1 (63)	81.6 (3)
Ridge		36.9 (3)	57.0 (21)	51.0 (2)
Yamdi	Dhampus	8.6 (1)	31.4 (9)	34.3 (2)
Mardi	Rivan	32.5 (2)	60.0 (14)	57.5 (2)
Seti	Khandarjung	34.5 (1)	48.3 (4)	41.4 (1)
Kali	Chharepani	64.4 (7)	80.0 (47)	64.4 (4)

Values in parentheses are the average number of trees/'bamboo clumps' per household.

were considerably lower in ridge settlements than in valley settlements (see Table 6) mainly as a result of fragmentation of landholdings, very small size of homeplot, lack of transportation facilities, out-migration of labour force, poor extension service and hailstorms (Thapa and Weber, 1990).

Regarding the fodder/fuelwood trees, *Schima wallichi* (chilaune), chestnut (katus), *Ficus rumphi* (pakhuri), (chuletro), *Artocarpus lakoocha* (badahar), *Ficus lacor* (kavro), *Litesa* sp. (kutmiro), *Madhuca latifolia* (mahuwa), *Ficus roxburhii* (nimaro), and *Ficus nemoralis* (dudhilo) were the predominant species grown in farm lands. Confronted with the problem of shrinking forest resources, these trees have been highly useful in fulfilling both fodder and fuelwood requirements of farmers. As in the case of fruits, both the proportion of households growing fuelwood/fodder trees and average number of trees per household were found to be substantially higher in valley settlements than in ridge settlements, owing to relatively distant location and strict community control of forest, and large size of homeplot.

Despite the traditional belief that trees adversely affect field crop productivity, farmers in valley villages had grown fruit and fodder trees mixed with maize and wheat crops primarily on their bari plots. While trees were seldom grown on khet to avoid the adverse effect of shade on rice yield, most trees were grown on bari located relatively close to farmhouses. Specifically, fruits were found confined mainly to homeplots as these were well fenced to prevent cattle and human trespassing. As their landholdings were highly fragmented (an average farm household held seven farm plots), it was futile for farmers to plant fruit trees on scattered farm plots which could not be either fenced or watched regularly to prevent the theft of fruits. A substantial proportion of fuelwood/fodder trees were growing on kharbari, plots of land, together with bari, utilised for growing *Typha angustata*.

4. Crop management

Farmers have adopted assorted practices of hoeing/ploughing, manuring, transplantation, weeding and irrigation to secure good crop yield, and there is very little spatial variation in labour allocation in these activities.

Table 7
Average labour inputs (man-days) in staple field crop cultivation

Activity	Rice	Maize	Millet	Wheat	Total
Ploughing	30	7	5	3	45
Manuring	14	8	0	3	25
Nursery preparation	5	0	2	0	7
Sowing/transplanting	26	3	12	1	42
Weeding	22	14	11	0	47
Irrigation	13	0	0	0	13
Harvesting	15	4	6	3	28
Threshing and transporting	12	1	4	2	19
Total	137	37	40	12	226

Being staple crops, rice, maize, millet and wheat accounted for nearly 98% of the total labour input in field crop production (see Table 7). Rice, maize and millet accounted for 92% of the total labour input. As field crops are the major source of livelihood of most farm households, farmers adopted the most labour intensive techniques of cultivation to minimise the risk of severe food shortage. Fertilisation accounted for 11% of the total labour input (see Table 7). Particularly in ridge settlements, farmers had to transport manure and compost to their khet. Rice, maize and wheat were regularly fertilised, but millet was not fertilised, as farmers believed that the manure applied for the maize crop was sufficient for this crop too. Although this is an appropriate strategy for efficient use of scarce manure resources, it might have accelerated the rate of soil nutrition depletion, a topic which requires further research.

Following manuring, farm plots are ploughed or weeded thoroughly two to three times to break the soil, to level farm plots and to mix the manure and compost well into the soil. Also, farmers clear field bunds of weeds using an iron-blade hoe. Particularly in rice cultivation, farmers plaster bunds with mud to control weeds and to protect the crop from pest attack. Ploughing is one of the most labour intensive tasks, requiring nearly one-fifth of the total labour input (see Table 7).

Transplanting rice and millet is another labour consuming task, accounting for 30% of the total labour input in millet and nearly one-fifth of the total labour input in rice production. Farmers could broadcast rice and millet to save labour and reduce physical hardship, but they did not do so, owing to the imminent threat of dwindling crop production.

Cognisant of the problems associated with weeds, all farmers cleared their rice, maize and millet crops of unwanted weed growth. Rice weeding accounted for 16% of the total amount of labour input. Maize and millet accounted for 38% and 28% of the total labour input, respectively (see Table 7). Maize and millet weeding required thorough hoeing of fields using an iron-blade hoe, given the normally dry and compact soils. This is why maize and millet weeding was more labour intensive than rice weeding. Thorough hoeing of maize and millet crops helped plant development by clearing fields of weeds and by loosening the soil. Farmers were aware of the necessity of proper plant care especially during the early growth stage, and field crops were weeded within 3–4 weeks of transplanting or sowing.

5. Structural and biological measures of land management

Farmers in the study area have adopted various types of management practices to control soil erosion and nutrition depletion. Terracing, manuring/composting and mulching were the most common practices.

5.1. Terracing

The necessity of creating terraced fields arises when there is accelerated erosion of soils due to slope gradient and water. Like shifting cultivation, regular ploughing or hoeing of soils without proper terracing causes severe soil erosion, particularly on steep lands. Thus, the extent of terracing of bari plots on ridges was examined. Since the narrow spaced bench-terraces, required to regulate water, was a typical feature of khet plots, it was not necessary to analyse terracing in this plot type.

Most bari plots in all ridge settlements were terraced (Table 8). The number of terraced plots was only slightly lower than the number of total plots. This was explained by the fact that even plots under

Table 8
Average number of terraced bari plots per farm household in the ridge villages

Village	Total plots [a]	Terraced plots	Terraced for more than 10 years
Dhampus	3.8	3.6	3.5
Rivan	6.2	5.8	5.4
Khandarjung	3.0	2.2	2.0
Chharepani	4.4	4.0	3.8

[a] Including plots under *Typha angustata*, which are not terraced.

Typha angustata, which were not terraced, were included in the total.

Most plots in all settlements have been terraced for more than 10 years, while only a very few were terraced recently. Reportedly, most plots were terraced many centuries ago. This is consistent with statements of the majority of respondents in all settlements that they did not know how these terraces were constructed. Household labour had been responsible for the recently constructed terraces. A very small proportion of households in all settlements had hired labourers for terrace construction.

Farmers in all ridge settlements repaired both khet and bari terraces regularly at the outset of each crop cultivation season. Throughout the monsoon season, khet terrace risers were lowered by rain. At the outset of the following agricultural year around May/June, farmers raised the paddy terrace risers by heaping soil onto them. Sometimes terraces collapsed as a result of torrential rainfall and were repaired using stone, logs/planks and clay. Nevertheless, it was beyond the affordability of farmers to rebuild terraces were they swept away by landslides.

5.2. Manuring / composting

All farmers applied compost/manure to their field crops, yet the question arises if the supply was adequate from their subjective perspective. Regarding the adequacy of manure/compost for the three staple cereal crops maize, paddy and wheat, the majority of farm households in all but one valley village reported that they had adequate manure/compost supply for maize (see Table 9). However, the majority of farmers in all but one

Table 9
Percentages of households reporting adequacy of compost for selected crops by location of villages surveyed

Watershed	Village	Rice	Maize	Wheat
Valley		40.3	59.3	34.2
Yamdi	Hemja	47.5	66.7	57.5
Mardi	Lachok	51.4	63.6	45.7
Seti	Ghachok	17.1	35.3	14.3
Kali	Bhalam	43.6	69.2	17.9
Ridge		38.3	58.6	25.5
Yamdi	Dhampus	48.6	73.5	34.3
Mardi	Rivan	40.0	51.4	35.0
Seti	Khandarjung	37.9	55.2	3.4
Kali	Chharepani	28.9	55.6	24.4

valley village had an inadequate supply of manure/compost for wheat, while at Lachok only slightly more than half the respondents reported adequacy in paddy cultivation. This is consistent with the above finding that the major proportion of farmers were using manure/compost for fertilising bari.

Overall, the reported adequacy of compost/manure in the three major cropping enterprises reflects a situation of clear priority for maize production irrespective of settlement location. Inversely, the implied inadequacy of compost/manure at farm household disposal indicates that rice has second priority and wheat third priority.

5.3. Mulching

Mulching or leaving crop stalks in the field is another important biological measure to protect soils from being directly exposed to agents of erosion and to improve soil structure and restore fertility. Most respondents in all settlements, regardless of their socio-economic status, reported that they did not leave crop residues in their fields, as they were needed for feeding livestock.

6. Environmental implications

Despite being comprised of valleys and ridges, with remarkably different types of biophysical conditions, there was not significant variation in land use and management practices in the study area. The impact of these practices on soil erosion and plant nutrients depletion are now considered.

As noted above, valley lands are almost flat, with slope gradients less than 5°. This, combined with the subhumid temperate climate, means these lands are not vulnerable to accelerating soil erosion. Arable agriculture is thus environmentally compatible. Regular hoeing and ploughing have disturbed the soil structure, but there is little risk of soil being removed from farm plots, since lands were almost flat and terraced.

Whatever the perceptions of farmers with regard to the adequacy of compost/manure, the amounts of nutrients removed by maize, rice and wheat crops were substantially higher than the amount replenished both in ridge and valley lands (Table 10). This assessment is based on an in-depth study conducted in the Yamdi Watershed (Maskey, 1994) where biophysical and socio-economic conditions are similar to those operating in the Upper Pokhara Valley; thus the results can be considered to reflect accurately the position in our study area. The actual nutrient depletion is even more than the values presented in Table

Table 10
Removal and replenishment of nutrients for rice, maize and wheat crops

Removal/replenishment	Nitrogen ($kg\ ha^{-1}$)	Phosphorus ($kg\ ha^{-1}$)	Potassium ($kg\ ha^{-1}$)
Average amount removed in the hills [a]	137.5	52.5	118.3
Average amount replenished in Yamdi Watershed [b]			
Irrigated valley land	86.5	22.6	44.5
Non-irrigated valley land	77.8	23.3	46.4
Ridge land	49.7	15.4	7.1

[a] Source: Sthapit (1987).
[b] Source: Maskey (1994).

10 if the amounts of nutrients removed by millet are taken into consideration. Despite their non-vulnerability to accelerating soil erosion, valley lands were undergoing degradation, due primarily to depletion of soil nutrients. Although crop diversification, mixed cropping, alley cropping and agroforestry had contributed to maintain soil fertility to some extent, farmers could not control land degradation.

Lands on the ridges are characterised by steep slope gradients and relatively shallow loamy/skeletal soils. These factors, in combination with a fairly high amount of annual rainfall (4700 mm), concentrated in 5 months of the year, have made soils prone to accelerating erosion. This is why lands with more than 5° slope gradients are considered to be most suitable for non-arable agriculture and forestry (Fig. 4).

Despite their capabilities, ridge lands were utilised for arable agriculture. The frequent breaking and loosening of soil through regular hoeing and ploughing of steep lands had aggravated soil erosion. Although nearly all farm plots were terraced, bari plots were more vulnerable to accelerating erosion than khet plots for two reasons. First, as noted by Ives (1985), they slope outward to avoid waterlogging of crops, and to prevent accumulation and penetration of water which would cause landslide. Secondly, terraces are relatively widely spaced to enable ploughing (Shaxson et al., 1989, p. 49) and their construction does not require as much time and labour as inward sloping and closely spaced khet terraces. The disadvantage of widely spaced outward sloping bari plots is that they are steeper than the narrow spaced terraces, accelerating the rate of soil removal.

In a field experiment carried out in the Phewa Tal watershed located adjacent to the study area (Fig. 1), the annual average rate of soil erosion was found to be 10 t ha^{-1} of terraced land (Fleming, 1983, p. 236). As both the biophysical environment and agricultural practices in this watershed were similar to the study area, it was plausible to assume that the agricultural lands in the study area were also undergoing soil erosion at the same rate. Under normal conditions, as noted earlier, it takes about 500 years to form 1 inch of soil (1 t ha^{-1} $year^{-1}$) (Troeh and Thompson, 1993). The actual rate of soil formation in the study area might be even less than this, owing to steep slope gradients, relatively heavy rainfall and regular ploughing and hoeing. Hence, on the ridges, the rate of soil erosion was substantially higher than the rate of its formation.

Terracing certainly helps to control soil erosion to some extent, but it cannot effectively control the sliding of loose soils under the influence of rain. Lack of a deep and dense root system causes the spreading of mudflows and debris flows on saturated grounds during continuous rains (Froehlich and Starkel, 1993, p. 287). In the Darjeeling Himalayas of India, the frequency of mass movements was found to be at least 10–20 times higher in terraced areas than in the forests (Starkel, 1972).

In ridge lands, the total quantities of nitrogen, phosphorus and potassium extracted by paddy, maize and wheat were found to be considerably higher than the quantities replenished (Table 10). The actual amount of depletion is substantially higher than that estimated if the loss of nutrients through the cultivation of millet and soil erosion is taken into consideration. Regular hoeing and ploughing has also accelerated the rate of nutrient removal, as amounts of organic matter and nitrogen in the soil invariably decrease with increasing frequency and depth of tillage (Lebbink et al., 1994). Lands on the ridges were thus undergoing degradation due to soil erosion and depletion of soil nutrients.

A popular contention is that the loss of topsoil and its nutrients can be offset by chemical fertilisers (Burt, 1981). However, the problem is that only a small proportion of farmers use fertilisers and they apply negligible amounts in their fields owing to poverty, inadequate availability of fertilisers and fear of land degradation (Thapa and Weber, 1990; Maskey, 1994). Even if adequate amounts are applied, chemical fertilisers cannot replace topsoil because of lost organic matter and moisture-holding capacity, increased runoff, reduced infiltration, and poorer seedbed qualities (Walker, 1982).

7. Sustainable land use and land management strategies

Based on the above assessment of environmental implications of land use practices, it can be concluded that the valley lands were confronted with the problem of depletion of soil nutrients, while ridge lands were undergoing both soil erosion and depletion of nutrients. In order to ensure the sustainable fertility of valley lands, farmers should attempt to increase the supply of soil nutrients through legume cultivation, compost application and mulching of crop residues. There is ample scope for legume cultivation, particularly in khet plots. As khet plots are utilised primarily for the paddy crop, their fertility could be restored considerably by legume cultivation which would not require much time and labour. Currently, legume cultivation has not been a common practice, owing partly to farmers' lack of awareness of its importance in soil fertility restoration, and partly to the traditional practice of free livestock grazing following the harvesting of paddy. Extension agents should play an active role in disseminating information on the usefulness of this practice, motivating farmers to cultivate legumes which would pave the way for controlling free livestock grazing. Even villagers should be persuaded to impose a mutually agreed ban on letting cattle loose in fields in the winter season. In many instances, villagers had taken such decision in order to manage community resources effectively (Thapa and Weber, 1990; Thapa and Weber, 1993).

Farmers applied organic fertilisers, including manure, to their field crops, although most were not composted. As a result, the nutritional value of the organic fertilisers was quite low. Cognisant of this, extension agents should be mobilised to persuade farmers to make compost using manure, crop residues and other organic wastes. Likewise, soil quality can be enhanced to some extent by motivating them to mulch farm plots with crop residues and legumes.

There is a need to control soil erosion caused by the regular hoeing and ploughing of steep lands on the ridges. Non-arable agriculture or crops which do not disturb soil structure should be promoted in suitable areas. By virtue of their biophysical conditions, ridges have potential for forestry and horticulture which could help control soil erosion and strengthen the rural economy. Therefore, the concerned agencies should explore the potential of specific locations by making a detailed study on land suitability and then create an environment conducive to tap such potentials. Following the example of the Lumle Agriculture Centre (Pound et al., 1992), agricultural extension agents should play an active role in all these related endeavours.

Swift changes to the present cropping system are not feasible, owing to low risk taking capabilities of farmers stemming from small landholdings and scarce non-farming employment opportunities. As the regional town of Pokhara is relatively close to the study area, there are prospects that the arable system may be changed gradually to a non-arable agricultural system. A feasibility study of the private commercial fuelwood plantation on the ridges of the Yamdi Watershed found that farmers had a positive attitude towards its gradual adoption, provided their cereal crop production was not impaired significantly (Thapa and Weber, 1993, p. 39). While it will take a long time to change the present land use system completely, it is necessary to make it environmentally and economically sustainable by minimising tillage, and promoting legume cultivation and mulching. Likewise, the conversion of all manure into compost and its application to field crops could be useful in replenishing soil nutrients.

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