14 INTERVENTIONS TO MINIMISE NUTRIENT LOSSES FROM BARI LAND (RAIN-FED UPLAND) IN THE MIDDLE HILLS OF THE WESTERN DEVELOPMENT REGION OF NEPAL

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Abstract

Bari land (rain-fed upland bench or sloping terraces) in Nepal is increasingly becoming a focus of concern in terms of soil fertility decline and management. Understanding the circumstances leading to high erosion and leaching losses, and the areas particularly affected by high losses, are essential prerequisites for attempting to improve soil conservation. Participatory research was conducted with farmers in three contrasting agroecological regions: Nayatola (20-25° slope, l000-1500 mm annual rainfall); Landruk (bench terraces 0-5° slope, 3000-3500 mm annual rainfall); and Bandipur (bench terraces 0-5° slope, 1100-1500 mm annual rainfall). The research aimed to develop soil and water management interventions that control erosion without resulting in high leaching and so are effective in minimising total nutrient losses. Interventions tested include the control of water movement through diversion of run on, planting fodder trees and grasses on terrace risers on bench terraces in high rainfall areas, and strip cropping in non-terraced sloping fields of low to medium rainfall areas. The interventions were effective in reducing soil loss from bari in comparison with existing farmer practices, but no effect was observed on nutrient losses in solution through runoff and leaching.

Introduction

Bari land comprises non-irrigated terraces on flat and sloping lands, and occupies most of the cropped area in the middle hills of Nepal. The function of the terraces is to maximise water availability within the physical constraints of the slope and the cropping pattern (Carson et al. 1986). The eastern part of the country has narrow bench terraces with low slope angles and the western part has large outward sloping terraces. Maize (*Zea mays* L.) is the main crop on bari and occupies 667,000 ha in the country, 192,940 ha in the western development region alone (Joshi 1998). However, soil fertility is declining in bari, thought primarily to be due to low applications of farmyard manure and soil erosion (Turton et al. 1995). Maize cultivation practices accelerate surface soil loss. Soil losses from rain-fed terraces and sloping farmland vary from 5 to 20 t/ha per year, with organic matter, nitrogen, phosphorous, and potassium losses of 150-600, 7.5 - 30, 5-20, and 10-40 kg/ha per year respectively (Partap and Watson 1994). In the

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study area, Gardner et al. (2000) reported that the greatest erosion was from bench terraces in a high rainfall area (Landruk, of Kaski District) and the least from sloping field cultivation in a low rainfall area (Nayatola, Palpa). They recorded soil losses in surface runoff of 2.5 t/ha per year, the losses of nitrate-nitrogen and potassium through runoff were comparatively low but losses through leaching were 45 and 180 kg/ha per year respectively.

A wide range of soil and nutrient conservation technologies are available that are appropriate to the Nepalese middle hills. Underseeding of white clover into maize fields considerably reduces surface runoff during May to June (when rainfall erosion is low) without decreasing maize yields (Goeck et al. 1989). Better soil cover in the crop fields improves water infiltration and increases crop yields by reducing erosion and stabilising soil minerals and organic matter (Barry et al. 1995). Grass strips are found to be useful for reducing soil loss in runoff (Lewis and Nyamulinda 1996). The adoption of technology depends upon the local farming environment. The intercropping of legume crops, mulching, and diversion of runon water from fields are practised in hill farming. Selecting technologies on the basis of local crop management could control soil erosion and lead to wide adoption. The main objective of this study was to investigate the effect of traditional cultivation practices on soil fertility and the effectiveness of locally appropriate technologies for maintaining inherent soil fertility of bari land in the middle hills of the western development region by controlling nutrient losses in solution form and in sediment movement.

Methodology

Site selection

Participatory research was conducted with farmers on bari land in three contrasting agroecological regions in the middle hills of the western development region of Nepal (Figure 14.1). On the basis of the survey results, Landruk was selected as a site representative for high rainfall areas with bench terracing cultivation systems. Nayatola was selected for low to medium rainfall with sloping land cultivation systems, and Bandipur was selected for low to medium rainfall with diversified cropping systems. The main features of these sites are given in Table 14.1.

Table 14.1: **Characteristics of the research sites**

Sites	Terrace slope angle	Rainfall (mm)	Common cropping systems
Landruk	0-5°	3000-3500	Maize/millet or maize + legume/wheat or barley + mustard
Nayatola	20-25°	1000-1500	Maize/wheat or barley + mustard + winter legume
Bandipur	0-5°	1100-1500	Maize-fallow-fallow or upland rice-blackgram and citrus orchard

Experimental design

Interventions were chosen by participatory rural appraisal and local knowledge acquisition. The interventions were designed to test basic principles of the relative influence of runoff and runon in causing nutrient loss and the relative merits of barrier and cover effects in the prevention of such losses in different conditions. A limited range of farmers were involved in the testing of interventions, because of the necessary costs

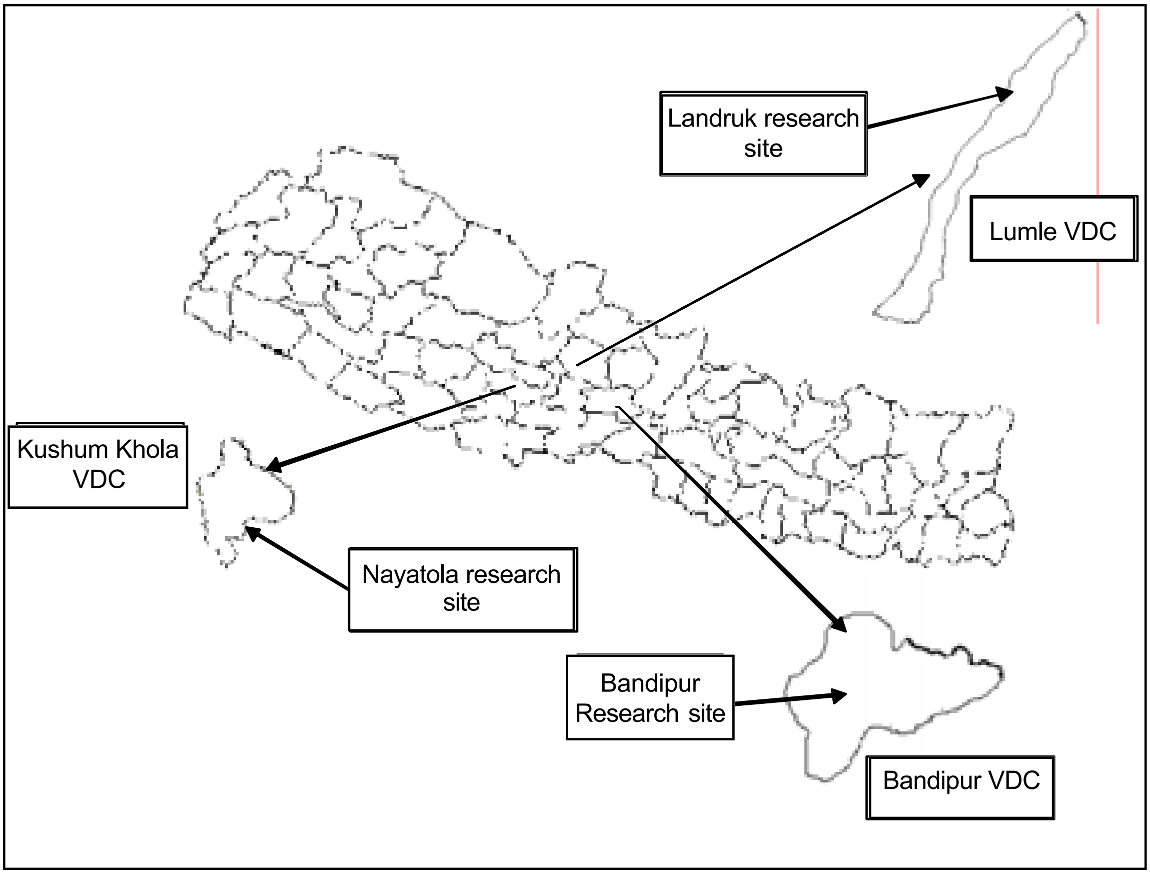

Figure 14.1: **Map of Nepal showing research sites**

and rigour of experimentation. However, a broader spectrum of interventions and farmers were involved in less rigorous farmer-managed trials (Shrestha et al. this volume). The interventions tested at different sites and crops are given in Table 14.2. Plots were 20m by 5m (long axis down slope) and replicated in 5 blocks at Landruk and Nayatola. *Setaria anceps* was planted in the terrace risers and *Flemingia congesta* was planted on the top of the riser in the second intervention at Landruk. *Flemingia congesta* did not perform well, because of its slow initial growth under Landruk's climatic conditions. Thus, in the next year only *Setaria* was planted across the whole riser. At Nayatola, strip crops were compared with the farmers' practice. Observations of soil and nutrient losses from different existing farming systems were continued in previous soil erosion research plots (Gardner et al. 2000) at Bandipur. The interventions were compared with the farmers' practices in which maize was grown without strips (Nayatola) and maize was grown without diversion of runon and with native grass (not planted) in terrace risers (Landruk).

Measurement of rainfall, runoff, erosion, and leaching

Surface runoff volumes and nutrient content were monitored on a weekly basis in standard runoff plots. The experimental plots were enclosed by metal sheets on all sides to prevent lateral water movement (except for the upper border in the open plots at Landruk). The edge of the metal sheet was raised about 0.3m above and extended 0.2m below the surface of the soil. A 5m long trough was located at the lower end of

Table 14.2: **Treatment combinations studied at different sites**				
Sites	**Treatment**	**Crops**		
		2000	**2001**	**2002**
Landruk	Runon diversion	Maize/millet (*Eleusine coracama*)	Maize/naked barley (*Hordeum vulgare Var. nudum*)	Maize/millet
	Runon and grass planting in terrace risers	Maize/millet	Maize/naked barley	Maize/millet
	Control (runon in farmers' practice)	Maize/millet	Maize/naked barley	Maize/millet
Nayatola	Maize + ginger (with mulch) Strip cropping	Maize and ginger (*Zingiber officinale* Roscoe)	Maize and ginger	Maize and ginger
	Maize + legume strip cropping	Maize and cowpea (*Vigna ungulata*)	Maize and soybean (*Glycine max* (L.))	Maize and field bean (*Phaseolus vulgaris*)
	Farmers' maize practice (control)	Maize	Maize	Maize
Bandipur	Wide terraced	Maize-fallow	Upland rice fallow	Maize-fallow
	Young citrus orchard	Maize and soybean intercropping	Maize and cowpea intercropping	fallow
	Narrow terraced, maize based	Maize-fallow	Maize-fallow	Maize-fallow
	Narrow terraced, maize based	-	Maize-fallow + grass planted in risers	Maize-fallow + grass planted in risers
	Old citrus orchard	Fallow	Fallow	Fallow

the plot and connected with polythene pipe to a drum, in which total runoff from the experimental plot was collected. Eroded sediment was estimated in runoff samples of 0.5 l collected from each drum after vigorous stirring. A sample of clean solution from the last drum containing runoff was also taken for nutrient analysis. Infiltrated water was collected in lysimeters constructed and inserted in such a way as to collect leachate from the top 40 cm layer of the soil. They were constructed from polythene pipes of 11 cm diameter and 25 cm length and filled with soil. A leachate collection cup was fitted in the end of the pipe and 2 small, soft tubes of 5 cm diameter passed out through the pipe, remaining above the soil surface and allowing leachate to be pumped out. These lysimeters were inserted in the runoff plots (3 per plot) 15 cm below the surface of the soil. Rainfall amounts and intensities were recorded over the monsoon period (May-October) using both automated and manual recorders.

Results

Leachate and nutrient losses

At Landruk, the total annual rainfall was 3193 mm in 2000, 3691 mm in 2001 and 3440 mm in 2002 (Figure 14.2). The total leachate was higher in closed plots than in open plots, though the differences were only significant in 2000 (Figure 14.3).

In closed plots, the losses of nitrate-nitrogen (N) and exchangeable potassium (K) due to leaching were higher in all the seasons of 2000 (early, mid, and late) than in the farmers' practice (Table 14.3) (although not at a significant level [P= 0.29]). This was due to the fact that there was no control of rainwater in the farmers' practice, whilst the

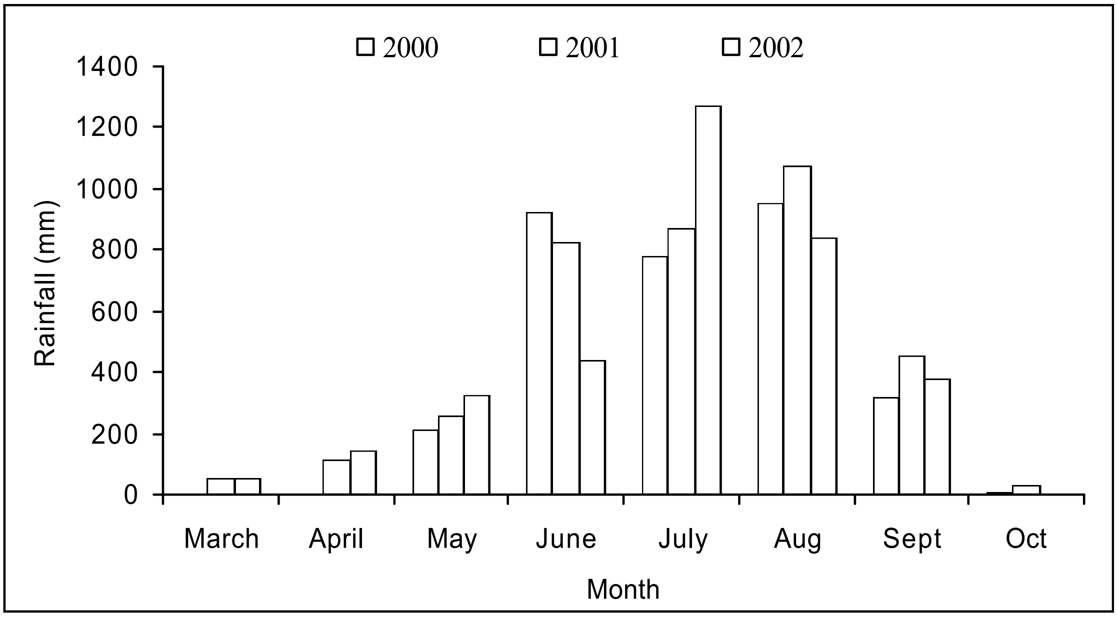

Figure 14.2: **Rainfall amount and pattern at Landruk during 2000-2002**

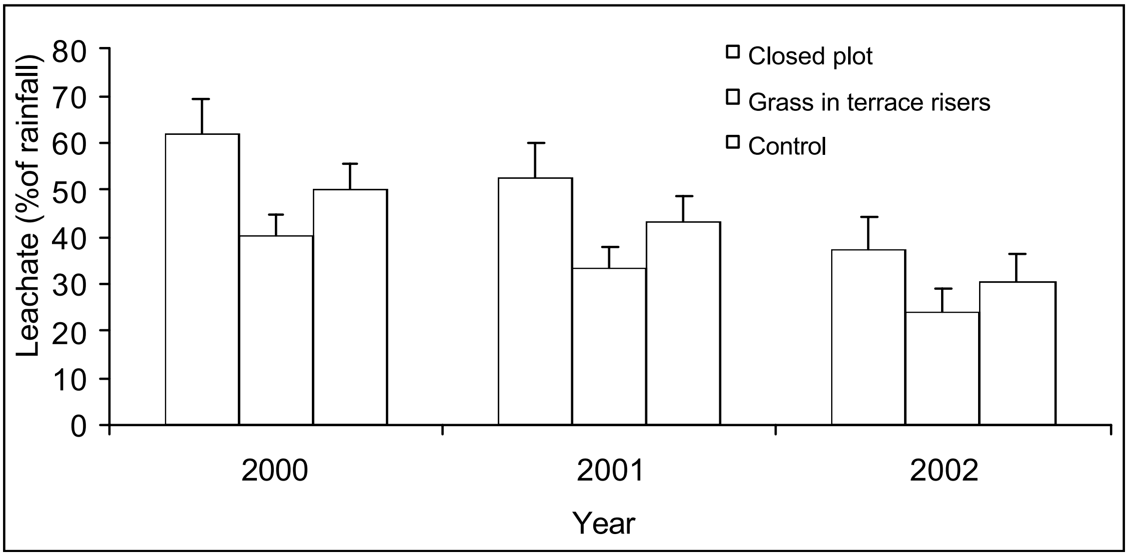

Figure 14.3: **Leachate (percentage of rainfall) at Landruk during 2000-2002**

rainfall water is controlled and infiltration of water takes place in closed plots, which results in more leaching of nutrients in the infiltrated water. The total losses of nitrate-N (97.9 kg/ha) and exchangeable K (99.2 kg/ha) were higher in the closed plots than in the farmers' practice, where nitrate-N and exchangeable K losses were 73.4 kg/ha and 75.7 kg/ha respectively.

During 2001, the leaching of both nitrate-N and exchangeable K was higher in the mid and late seasons than in the early season (Table 14.3). No significant difference in leaching was recorded between treatments with grasses in the risers and the farmers' practice in early, mid, or late seasons. The total loss of exchangeable K was the highest (59.4 kg/ha) in closed plots followed by the farmers' practice and grasses in the risers. Similarly, the total nitrate-N loss was the highest (99.7 kg/ha) in the closed plot and

Table 14.3: **Effect on nutrient loss (kg/ha) in leachate at Landruk during 2000-2002**								
Treatment	**Early season**		**Mid season**		**Late season**		**Total**	
	N	**K**	**N**	**K**	**N**	**K**	**N**	**K**
2000								
Closed plot	21.2	3.0	61.1	63.0	18.7	33.1	97.9	99.2
Grass in terrace riser	5.7	3.8	73.6	38.4	15.0	20.8	95.4	61.1
Farmers' practice	7.2	3.6	48.0	45.0	17.4	28.9	73.4	75.7
p	0.36	0.87	0.29	0.86	0.84	0.88	0.46	0.87
2001								
Closed plot	4.0	4.0	62.0	27.0	31.0	29.0	99.7	59.0
Grass in terrace riser	3.0	2.0	33.0	22.0	23.0	12.0	61.6	35.0
Farmers' practice	21.0	4.0	24.0	27.0	21.0	19.0	61.3	48.0
p	0.80	0.69	0.45	0.89	0.50	0.74	0.59	0.78
2002								
Closed plot	3.5	3.5	19.9	24.0	6.6	8.8	28.0	35.3
Grass in terrace riser	3.0	2.1	10.8	18.4	6.1	6.6	18.3	26.7
Farmers' practices	4.2	2.6	11.8	20.7	3.5	7.9	17.3	30.7
p	0.89	0.61	0.09	0.89	0.57	0.93	0.45	0.91
N = nitrate-nitrogen; K = exchangeable potassium; *p* = level of significance								

more or less similar (61.3-61.6 kg/ha) in the grasses and the farmers' practice treatments. However, these differences were not significant as the grasses in the risers were poorly planted in 2001 and were still becoming established by the end of the monitoring period.

In 2002, intervention plots lost more N (18.3-28.6 kg/ha) than the farmers' practice (17.3 kg/ha) (Table 14.3). More nitrate-N was lost from the closed than the grass planting in terrace riser plots. The loss of nitrate-N was more in the mid season and less in the early season for all treatments except the farmers' practice, which lost slightly more in the early season than the late season. The closed plots lost more K (35.3 kg/ha) than the farmers' practice (30.7 kg/ha) and the plot of grass planting in terrace riser lost least K (26.7 kg/ha). However, the differences among the treatments for the loss of K in leachate were not significant in any period of the season. K loss in leachate was most in the mid season, followed by the late season, and least in the early season for all treatments.

At Nayatola, the total rainfall was 1386, 1123, and 867 mm in 2000, 2001, and 2002 respectively (Figure 14.4). The total leachate in the strip cropped plots was lower in 2000 and higher in 2001 and 2002 than in the farmers' practice but the differences were not significant in any year (Figure 14.5).

Both nitrate-N and exchangeable K leaching losses were slightly higher in the maize and ginger strip than in the farmers' practice in the early season 2000. Losses were reduced in the maize and ginger strip in the mid season because the maize and ginger plants established well and they covered the ground by the mid season. However, it was not so in the farmers' practice. As there was no rainfall in the late season of 2000, no samples of leachate were collected from the lysimeters. The total loss of nitrate-N was less (52.6 kg/ha) in the maize and ginger strip than in the farmers' practice (60.3 kg/ha) (Table 14.4). The total exchangeable K losses in both the interventions (maize and ginger strip as well as farmers' practice) were similar (22.5-23.0 kg/ha). However, leaching losses of both the nutrients were not significantly different between the interventions.

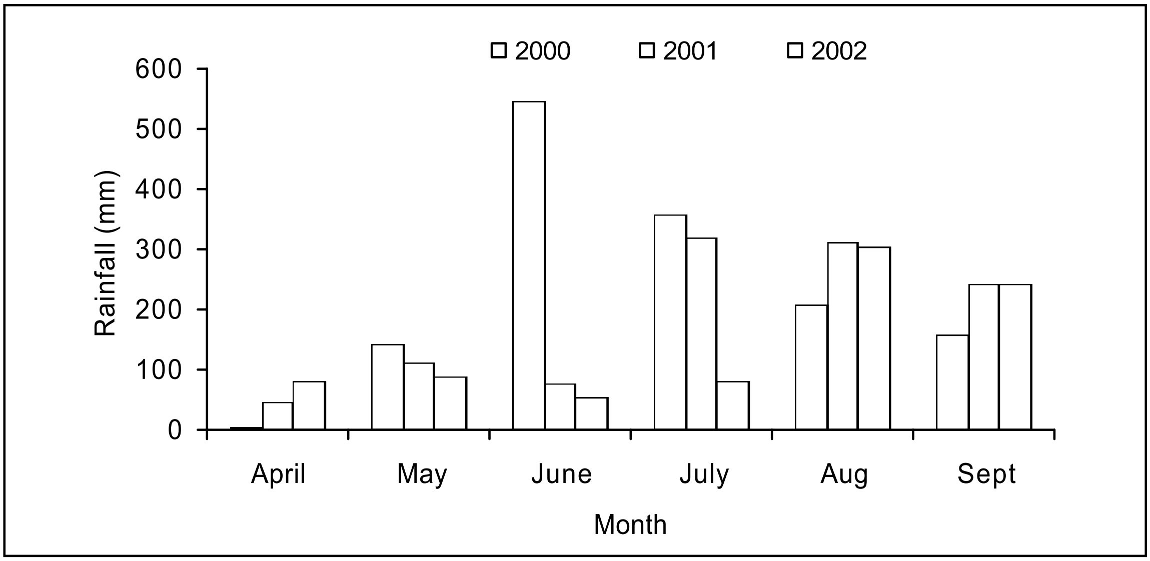

Figure 14.4: **Rainfall amount and pattern at Nayatola during 2000-2002**

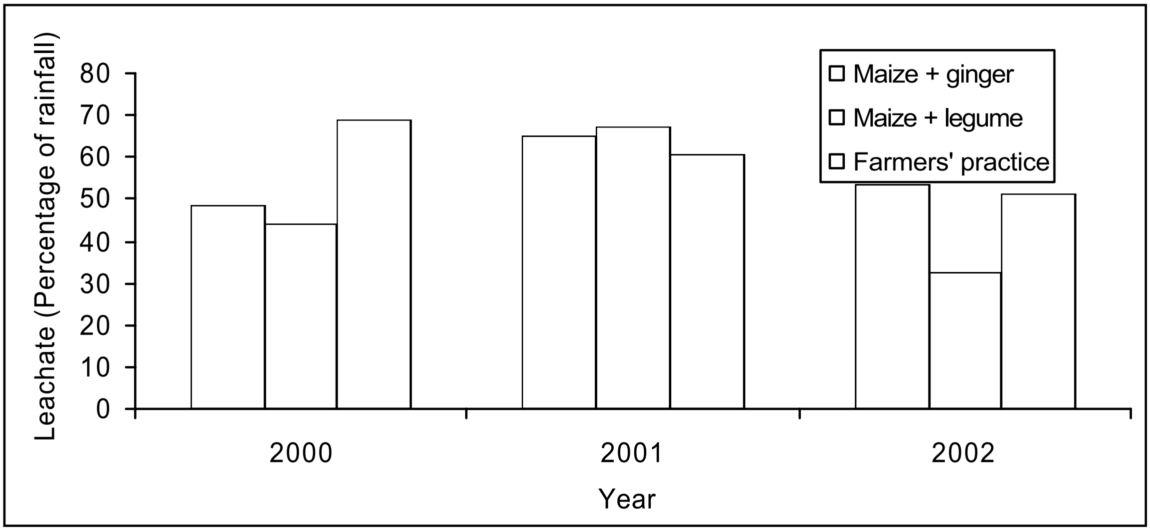

Figure 14.5: **Leachate (percentage of rainfall) at Nayatola during 2000-2002**

Table 14.4: **Effect on nutrient loss (kg/ha) in leachate at Nayatola during 2000-2002**

Treatment	Early season		Mid season		Late season		Total	
	N	K	N	K	N	K	N	K
2000								
Maize + ginger	39.1	7.5	13.5	15.6	-	-	52.6	23.0
Maize + legume	41.5	7.9	23.1	17.3	-	-	64.5	25.1
Farmers' practices	37.3	4.3	23.0	18.2	-	-	60.3	22.5
p	0.94	0.25	0.12	0.94			0.54	0.96
2001								
Maize+ ginger	27.9	5.9	18.9	12.4	17.5	8.3	64.2	26.6
Maize + legume	29.3	6.0	33.9	15.7	20.4	7.8	83.6	29.5
Farmers' practices	32.6	5.0	14.0	9.3	15.5	7.4	62.1	21.7
p	0.84	0.75	0.21	0.36	0.64	0.74	0.35	0.38
2002								
Maize+ ginger	10.9	6.1	10.2	5.7	33.8	4.9	52.9	15.2
Maize + legume	0.4	2.3	3.5	4.0	16.1	4.5	21.7	10.7
Farmers' practices	8.2	2.6	4.4	3.6	23.2	4.2	34.8	10.2
p	0.30	0.20	0.13	0.27	0.63	0.84	0.40	0.35

N = nitrate-nitrogen; K = exchangeable potassium; *p* = level of significance

During 2001, nitrate-N losses in the early, mid, and late seasons were lower in the maize and ginger strip plots than in the farmers' practice and maize and soybean strip. Nitrate-N leaching loss was greatest in maize and soybean most probably due to fewer soybean plants germinating in this treatment. Exchangeable K leaching loss was higher (15.7 kg/ha) in the maize and soybean strip in the mid season than in the maize and ginger and farmers' practice (9.3-12.4 kg/ha) but remained more or less the same in the early and late seasons. The total nitrate-N loss was higher (83.2 kg/ha) in the maize and soybean strip than in the maize and ginger (64.2 kg/ha) and farmers' practice (62.1 kg/ha) (Table 14.4). The same was true in the loss of exchangeable K, where the maize and soybean plot had 29.5 kg/ha and the maize and ginger and farmers' practice had 26.4 and 21.7 kg/ha respectively. However the results were not significantly different.

In 2002, nutrient losses were not significantly affected by the treatments. The loss of total nitrate-N through leachate was the highest (53 kg/ha) in the maize and ginger strip cropping, followed by 35 kg/ha in the control. The lowest loss was 22.0 kg/ha in the plot of maize and legume strip cropping. The seasonal distribution of N loss through leaching was the highest in the late monsoon period. Likewise, the total K loss through leachate was the highest (15 kg/ha) in the plot of maize and ginger strip cropping and its loss was 10.7 kg/ha from the maize and legume strip cropping and 10.2 kg/ha from the control plot (Table 14.4). The seasonal distribution of K loss through leaching was slightly higher in the early period followed by the mid and late periods.

At Bandipur, annual rainfall was 1250, 2043, and 1681 mm in 2000, 2001, and 2002 respectively (Figure 14.6). Leaching of nutrients was the highest in the old citrus orchard (36.4 kg of N and 32.0 kg of K per ha) and the lowest in the young citrus orchard (8.2 kg of N and 11.7 kg of K per ha) in 2000 (Table 14.5). The old citrus orchard lost more nutrients throughout all the years. The lowest loss of nutrients was 25.9 kg N per ha in

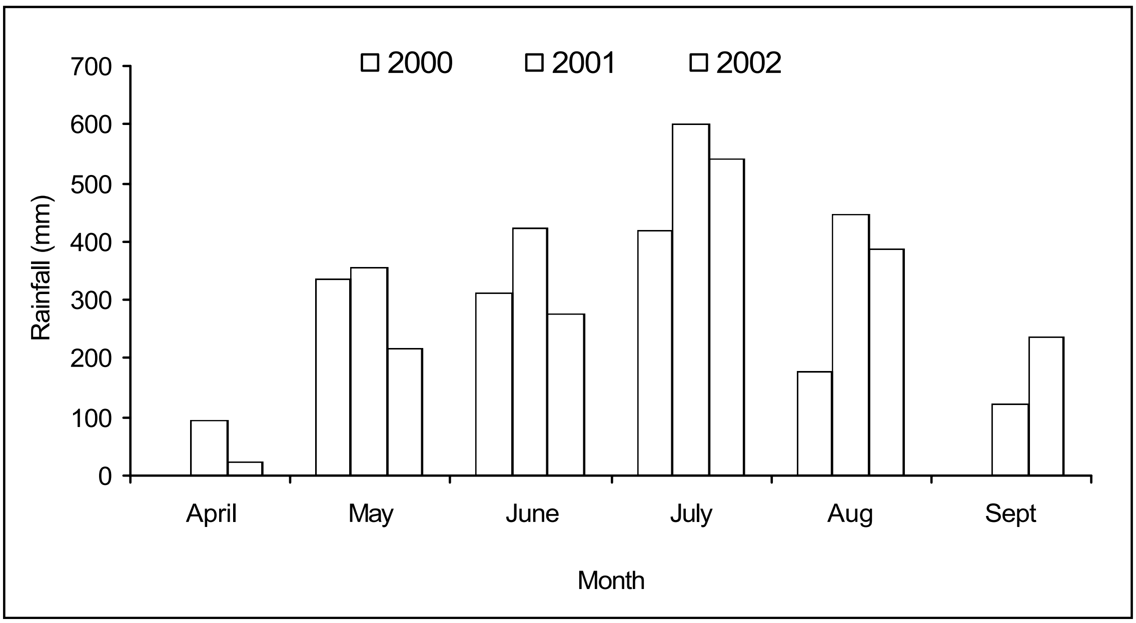

Figure 14.6: **Rainfall amount and pattern at Bandipur during 2000-2002**

Table 14.5: **Effect on nutrient loss (kg/ha) in leachate at Bandipur during 2000-2002**								
Cropping system	**Early season**		**Mid season**		**Late season**		**Total**	
	N	**K**	**N**	**K**	**N**	**K**	**N**	**K**
2000								
Wide terrace and M-F-F	0.9	9.8	8.4	4.8	6.5	6.1	15.8	20.7
Young citrus orchard and intercropping	0.2	1.1	5.6	7.2	2.4	3.3	8.2	11.7
Narrow terrace and M-F-F	2.8	1.8	3.2	4.2	8.1	5.6	14.2	11.5
Old citrus orchard	9.0	3.6	14.5	13.1	12.9	15.2	36.4	32.0
2001								
Wide terrace and M-F-F	2.5	0.8	12.1	6.7	11.4	4.4	25.9	11.9
Young citrus orchard and intercropping	15.9	3.4	17.5	5.7	17.1	3.6	50.4	12.7
Narrow terrace and M-F-F	10.5	3.7	9.6	8.7	25.5	6.0	45.6	18.4
Narrow terrace and M-F-F + grass planting in terrace riser	10.0	3.4	2.5	3.0	14.1	4.2	26.6	10.5
Old citrus orchard	24.2	102	16.5	202	24.8	95	65.5	399
2002								
Wide terrace and M-F-F	15.9	4.9	12.5	11.5	4.2	7.2	32.6	23.6
Young citrus orchard and intercropping	19.1	26.6	23.0	5.8	6.8	1.7	48.9	34.1
Narrow terrace and M-F-F	12.9	3.7	8.9	9.5	7.6	4.3	29.4	17.5
Narrow terrace and M-F-F + grass planting in terrace riser	19.5	3.6	8.4	8.1	11.9	6.5	39.8	18.3
Old citrus orchard	38.7	8.5	12.8	6.9	3.3	1.3	54.9	167
N = nitrate-nitrogen; K = exchangeable potassium M-F-F = maize - fallow - follow								

the leachate of the wide terrace maize-fallow-fallow system and 10.5 kg K per ha in the leachate of the narrow terrace maize-fallow-fallow system with grass planting in terrace riser in 2001 (Table 14.5). In 2002, the lowest losses of both N and K were in the leachate of the narrow terrace maize-fallow-fallow (Table 14.5). The loss of total phosphorous (P) in the leachate was less than 1 kg/ha. This indicates that the loss of soluble P is negligible in leachate.

Runoff and eroded sediments

Sediment loss at the high rainfall site of Landruk in 2000, 2001, and 2002 and average runoff from the different types of plot over the same period are shown in Figures 14.7 to 14.10. The total runoff from closed plots was significantly lower than from open plots during 2000 but it was similar during 2001 and 2002. However, the amount of runoff was very low in all years as compared to rainfall.

Sediment loss (Figures 14.7 - 14.9) was higher in farmers' practice (2229 kg/ha) than in closed plots (994 kg/ha) during 2000. Similarly, during 2001, the total loss of the sediment was the highest in the plots with grasses grown in the riser (1293 kg/ha) followed by the farmers' practice (886 kg/ha) and closed plots (478 kg/ha). In both years, low sediment loss in the closed plots was due to the limited area in which runoff water could not flow freely from the terraces above, and because runoff velocities were reduced, hence reducing erosion. The higher loss of the sediment from grasses grown in the riser than in the farmers' practice during 2001 was most probably due to first-year planting of grasses in the riser, where roots were not sufficiently well established

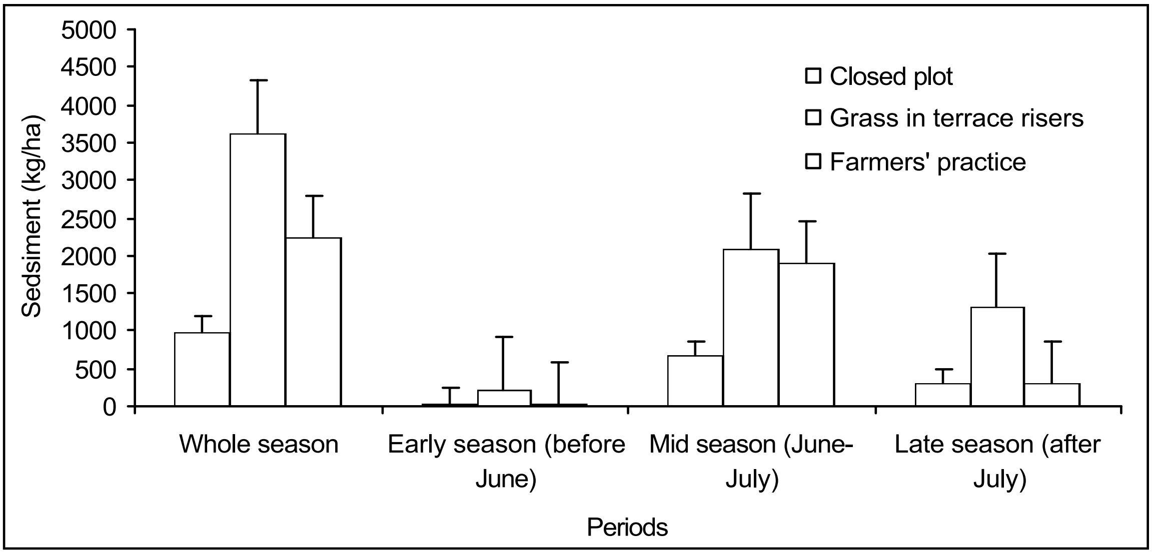

Figure 14.7: **Soil losses at Landruk during 2000**

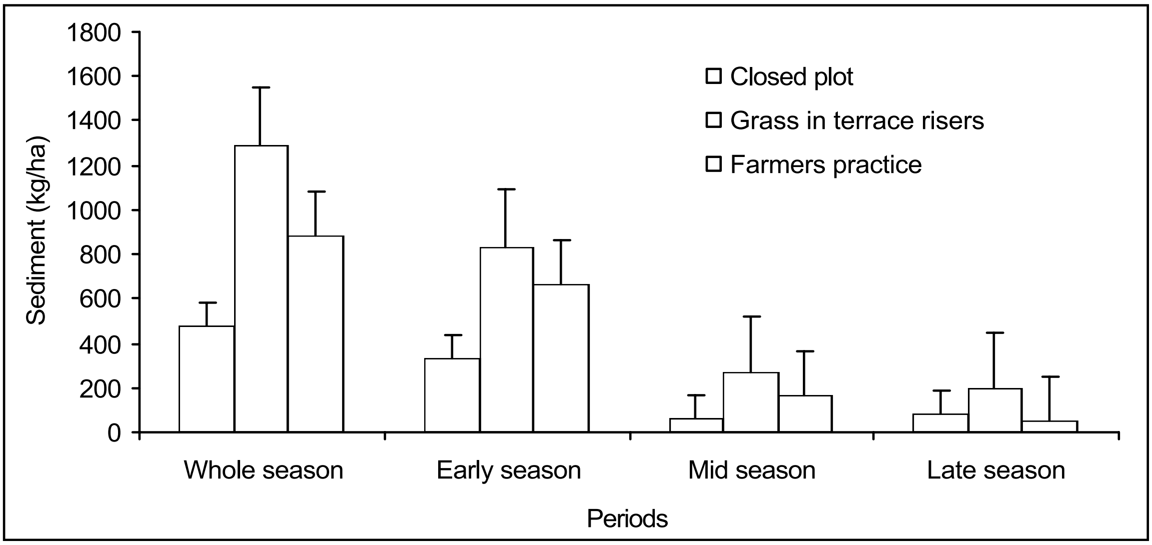

Figure 14.8: **Soil losses at Landruk during 2001**

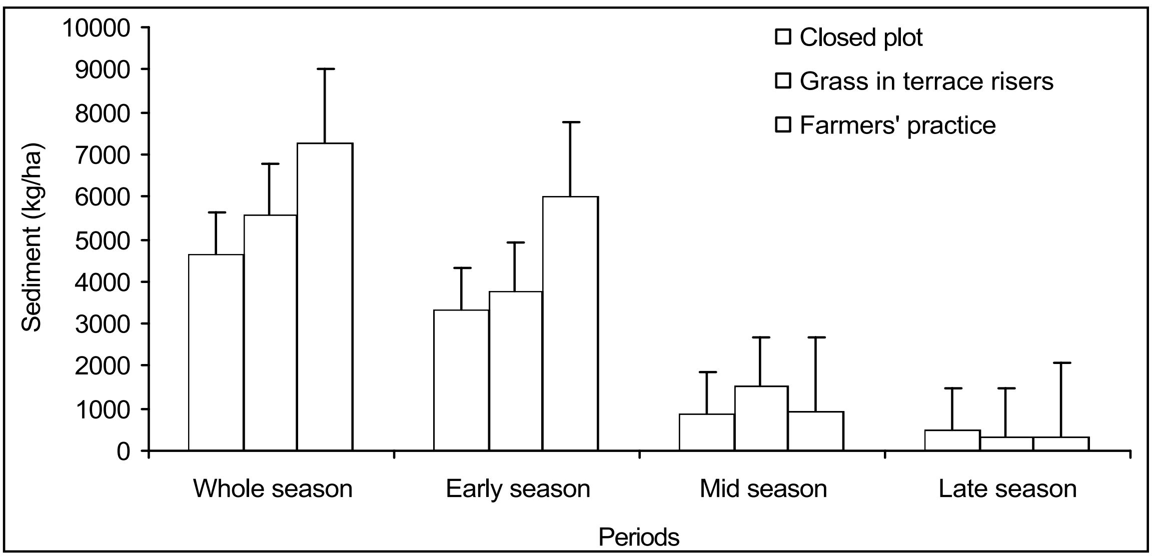

Figure 14.9: **Soil losses at Landruk during 2002**

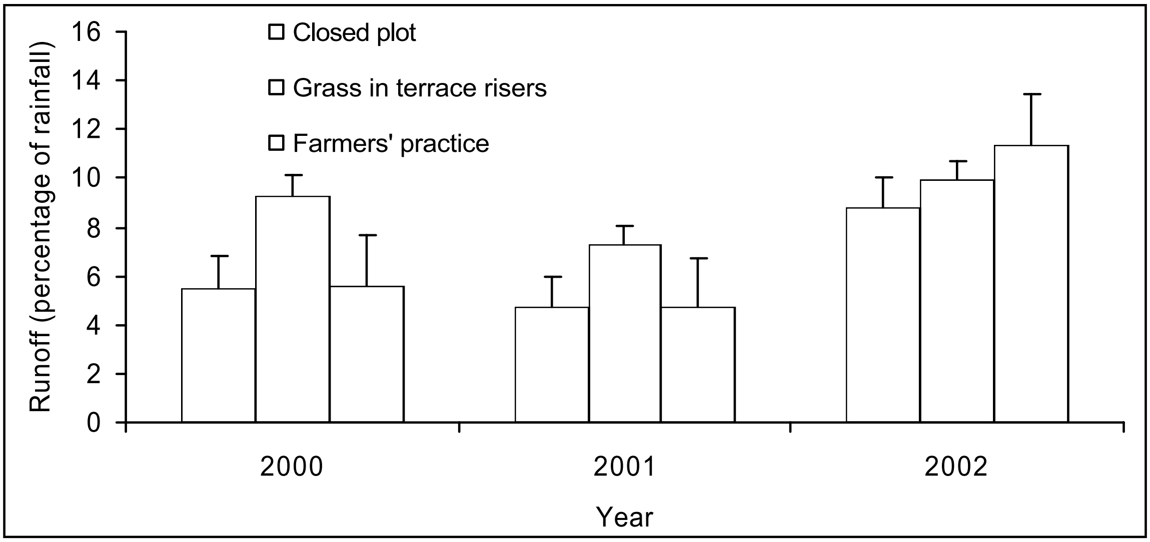

Figure 14.10: **Runoff (percentage of rainfall) at Landruk during 2000-2002**

to conserve soil. In 2002, the soil loss from the closed plots was the lowest (4653 kg/ha) and it was the highest (7256 kg/ha) in the farmers' practice. The soil loss from the plot with grass planting in terrace risers was also less than the loss from the farmers' practice.

Sediment loss at Nayatola in 2000, 2001, and 2002 and average runoff from the different types of plot over the same period are shown in Figures 14.11 to 14.14. The total runoff from the strip cropped plots was less than for the farmers' practice (Figure 14.14); however differences were only significant in 2001. The total sediment loss (Figures 14.11 - 14.13) was higher in the farmers' practice (144 kg/ha) than the maize and ginger strip (58 kg/ha) in 2000. In 2001, the total loss of sediment was highest in the farmers' practice (867 kg/ha) followed by the maize and soybean strip (472 kg/ha) and maize and ginger strip (231 kg/ha). The maize and ginger strip was more effective than the maize and soybean as well as the farmers' practice for minimising sediment loss by runoff because in the maize and ginger strip the ginger was mulched with locally available materials at planting time, which acted as a cover to the soil as well as minimising the soil runoff. In 2002, 280.7 kg/ha of sediments were lost from the maize and ginger strip crop plots compared to 865 kg/ha from the maize and legume strip cropped plots and 1756 kg/ha from the control plots. Sediment losses were greatest in the early season irrespective of treatment. The losses of soil in the early season were 269.5, 843.0, and 1730.6 kg/ha from the maize and ginger strip plots, maize and bean strip plots, and control plots respectively. Insignificant amounts of soil were lost in the mid and late seasons, however the trend among the treatments was the same as for soil loss in the early season.

The total loss of soluble nutrients in runoff was not significantly affected by interventions at any of the sites. However, eroded sediments contain a high content of organic matter and P (Acharya et al. 2001). The results showed that a large amount of organic carbon was lost with sediment rather than other nutrients (Tables 14.12 and 14.13) in both Landruk and Nayatola. Organic matter is one of the most important

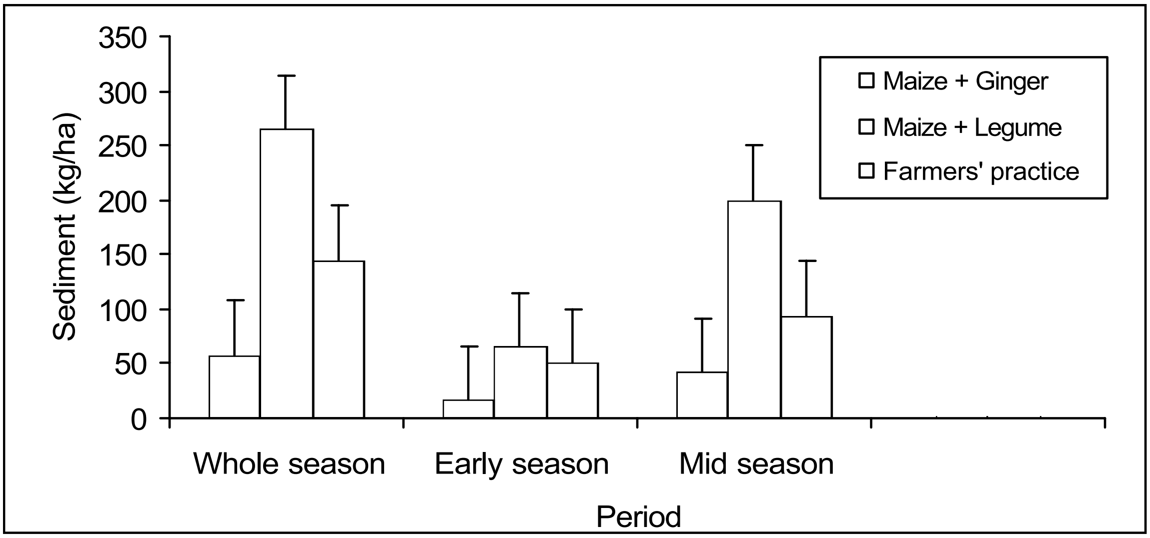

Figure 14.11: **Soil loss at Nayatola during 2000**

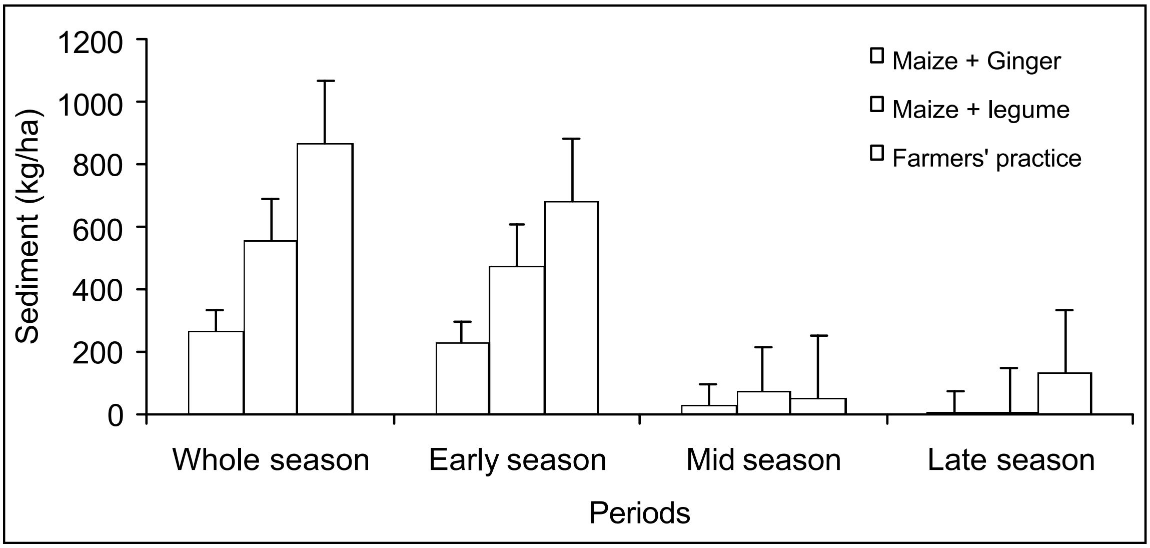

Figure 14.12: **Soil loss at Nayatola during 2001**

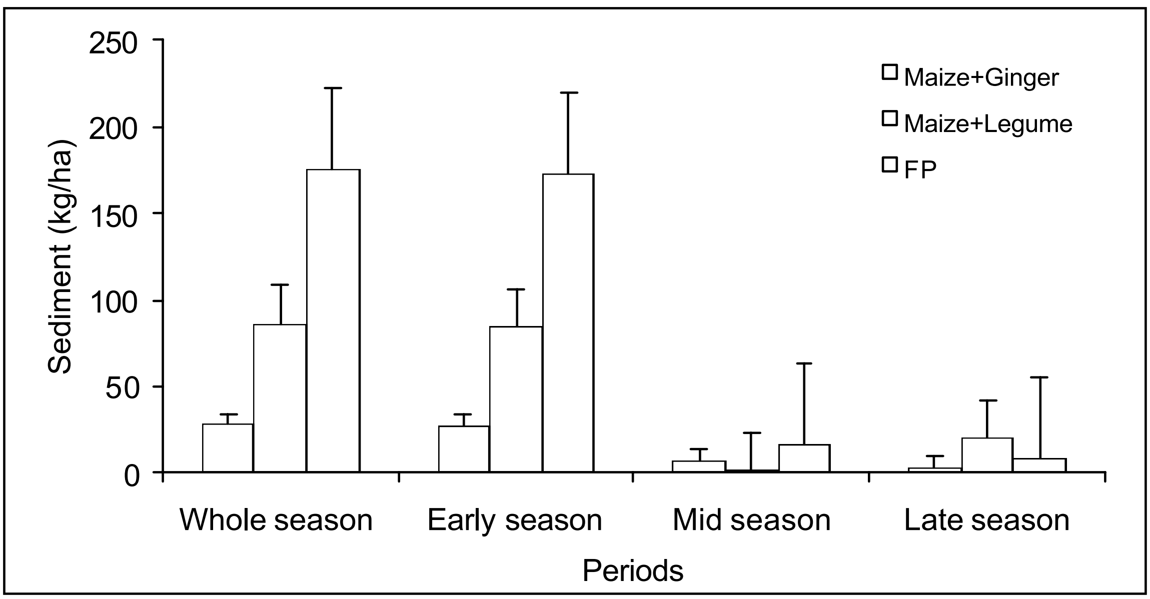

Figure 14.13: **Soil loss at Nayatola during 2002**

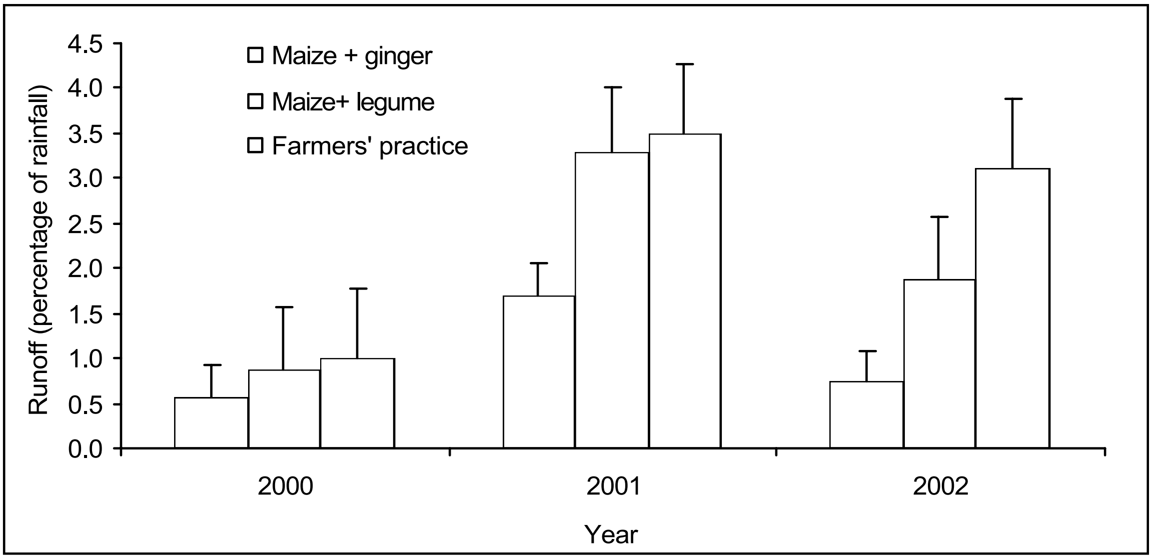

Figure 14.14: **Runoff (percentage of rainfall) at Nayatola during 2000-2002**

Table 14.12: **Nutrient loss in eroded sediment at Landruk (3 years' average)**

Treatment	Organic C (kg/ha)	Total N (kg/ha)	Available P (kg/ha)	Exchangeable K (kg/ha)
Closed plot	55.1	4.7	0.14	0.30
Grass in terrace riser	108.3	8.0	0.26	0.44
Farmers' practice	114.2	8.4	0.20	0.47

Table 14.13: **Nutrient loss in eroded sediment at Nayatola (3 years' average)**

Treatment	Organic C	Total N (kg/ha)	Available P (kg/ha)	Exchangeable K (kg/ha)
Maize+ginger strip cropping	6.7	0.2	0.01	0.05
Maize+legume strip cropping	17.2	0.4	0.02	0.10
Farmers' practice	22.4	0.5	0.04	0.15

sources of nitrogen and plays a major role in the improvement of the physical properties of soil.

Sediment loss at Bandipur in 2000, 2001, and 2002 is shown in Figures 14.15 to 14.17. At Bandipur, the highest sediment loss in 2000 was 1316.3 kg/ha from old citrus orchard and the lowest was 201.8 kg/ha from young citrus orchard, in 2001 the loss was the highest from the narrow terrace maize-fallow-fallow cropping system. Grass planting in the terrace riser had reduced soil loss from the narrow terrace maize-fallow-fallow cropping system indicating the riser planting could help to minimise soil movement along with runoff. In 2002, again the narrow terrace maize-fallow-fallow system yielded more sediment loss and the riser planting with grass did not show any reduction in soil loss.

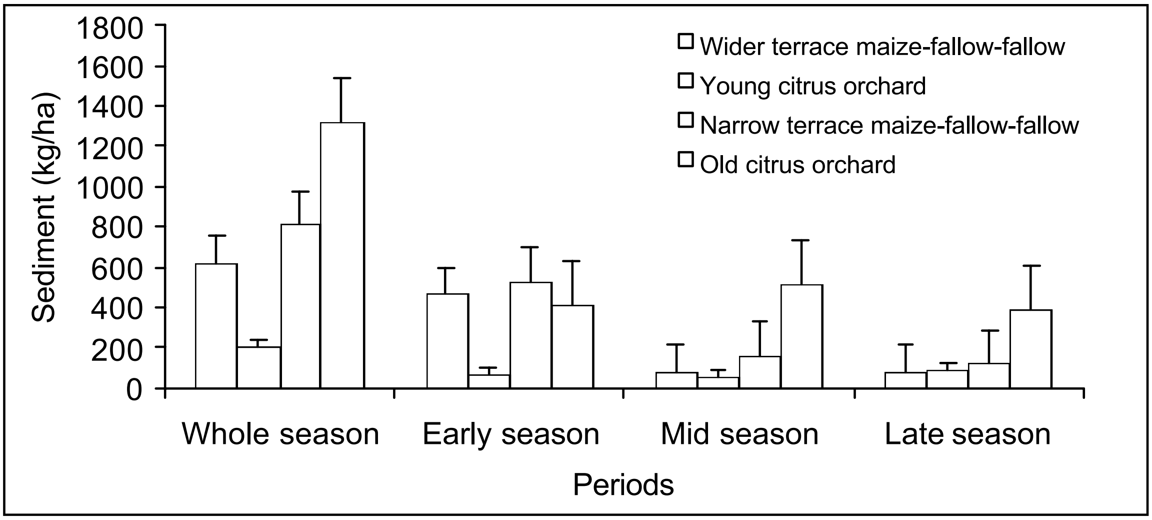

Figure 14.15: **Soil loss at Bandipur during 2000**

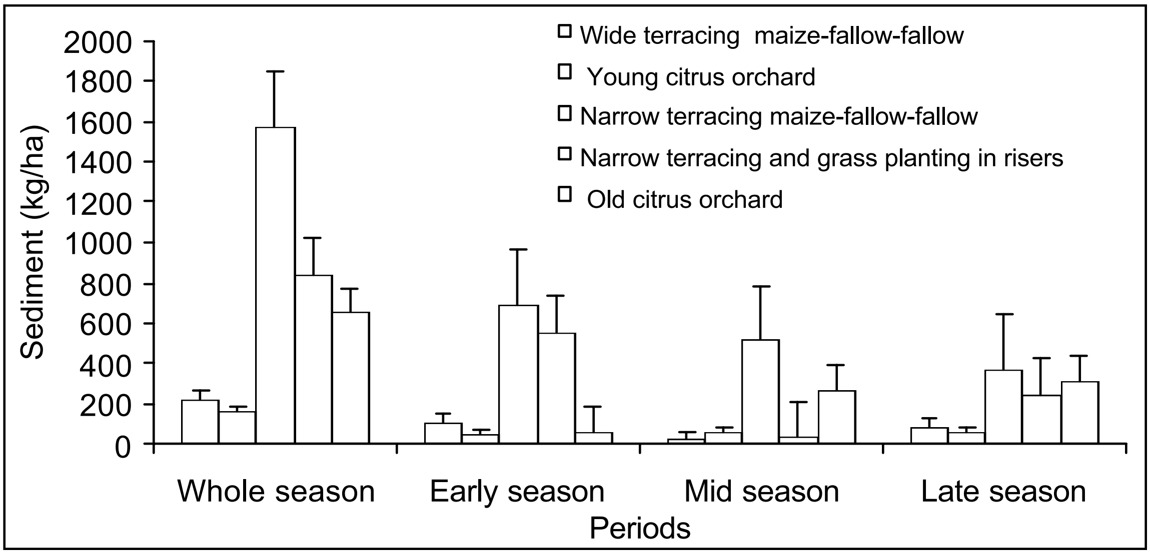

Figure 14.16: **Soil loss at Bandipur during 2001**

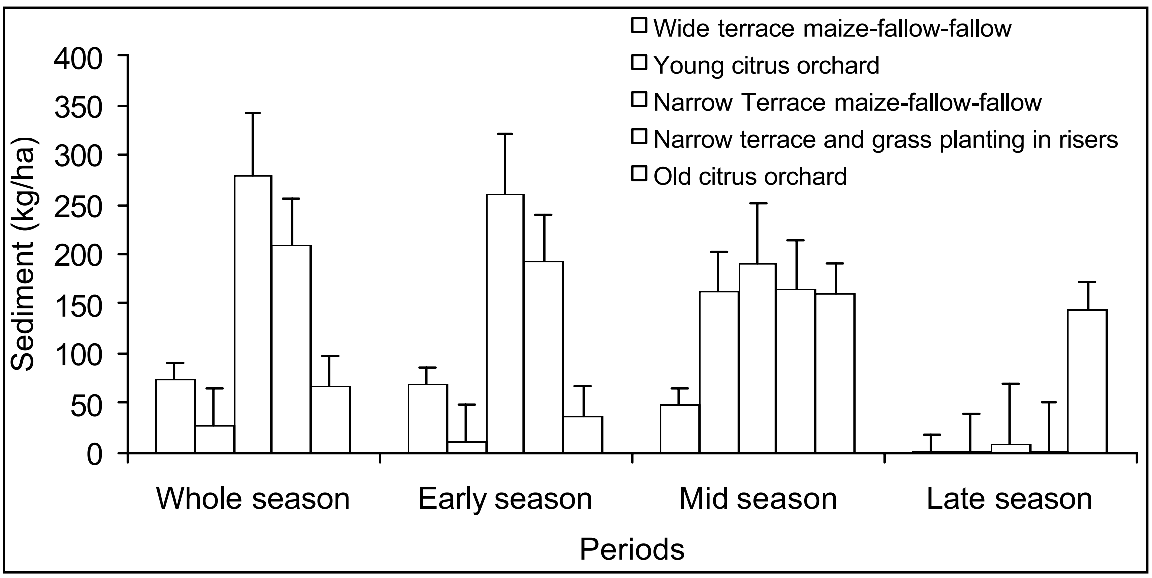

Figure 14.17: **Soil loss at Bandipur during 2002**

Yield and economy

Total productivity of the interventions was compared with the farmers' practice. The interventions did not reduce crop productivity at Landruk (Table 14.14); maize and ginger strip cropping gave a higher income than farmers' practice at Nayatola (Table 14.15), mainly because of the high value of the ginger crop.

Table 14.14: **Effect on crop grain yields (kg/ha) at Landruk**

Treatment	2000	2001	2002
Closed plot	3929	3381	4778
Plot of grass planting in terrace risers	3715	3866	5248
Control (farmers' practice)	3160	3650	4516
P	0.18	0.76	0.76

Table 14.15: **Income (NRs*/ha) from strip cropping at Nayatola**

Treatment	2000	2001	2002
Maize+ginger strip	18,110	31,868	33,647
Maize+legume strip	9,236	18,820	6,420
Control (farmers' practice)	15,332	21,089	9,398
P	0.02	0.04	<0.01
US $1 = NRs 69, 76, 78 in 2000, 2001, and 2002, respectively			

Discussion

The diversion of runon reduced soil erosion in the high rainfall area (Landruk, Kaski) without a significant effect on the loss of nutrients. However, diversion of runon enhanced water infiltration in which a great loss of nitrogen and potassium occurs. Grass planting in terrace risers showed a trend of reducing potassium loss in leachate. Landruk appears to be highly susceptible to runoff and erosion, which relates to its high rainfall and runon and red/brown type of soil (Tripathi et al. 1999; Gardner et al. 2000). The intensity of rain just after field ploughing (for crop planting and fertiliser incorporation) as well as intercultural operations accelerate the soil runoff causing about 50% of the total sediment loss in early June (Mawdesley et al. 1998) when the soil is bare. Gardner et al. (2000) further reported that the timing of heavy rain vis-a-vis the land management activities of ploughing, weeding, and mounding, all of which affect the percentage of ground cover (predominantly weeds) during the May/June/early July period, is an important, albeit random, determinant of the extent of soil loss in a particular year. Soil losses by surface erosion, where run-on is controlled, were low (2.5-5.0 t/ha per year) in all the terraces studied, even where rainfall totals and erosivity were high. However, uncontrolled surface (runon) or sub-surface (piping) water input may result in higher volumes of soil movement on the hillsides and potentially to severe net losses (Gardner et al. 2000).

At Nayatola, the strips of maize and ginger reduced both runoff and leachate volumes under low rainfall and sloping field conditions as compared to the farmers' practice. However, the losses of soluble nutrients in runoff or leachate were not affected, only those adhered to eroded sediments. The ginger strips were mulched with plant materials, which effectively functions as a filter, slows runoff, and prevents the movement of soil particles with runoff water so that the loss of the soil was observed to be low in the maize and ginger strip-planting plot. Montoro et al. (2000) observed a marked reduction of runoff and sediment yields with light mulching of straw to the soil surface at 50% slope in a semiarid region (Smoliowski et al. 1998). Mulching is being used in the area on a small scale for a limited number of crops such as dasheen (*Colocasia esculenta* [L.]) and ginger. It can be extended to other crops provided the mulching material is available or the area under the farmers' traditionally mulched crops can be extended if markets are assured. The existing cultivation practice for the maize crop is the main reason for soil and plant nutrient losses from bari. The sloping nature of the terrace also contributes to increased runoff and soil loss (Vaidya et al. 1995). McDonald et al. (2002) reported that contour-tree-hedgerows are effective for soil and water conservation through the sieve-barrier effect and increased water infiltration and have the potential to enhance the sustainability of the land-use system at a plot scale. The improvement of the terraces is the best technology to reduce runoff from the fields, but it could result in increased leaching unless an appropriate combination of crops is used. Intercropping of legumes with maize is the traditional practice, but tending the maize accelerates soil movement. The modifications to traditional practice as tested in this study, such as inclusion of bushy types of legume crops (for example, cowpea) with maize as strips, reduce operation and control soil nutrient loss from the cropped fields particularly through runoff. Similarly, the use of mulch in ginger production is the usual practice of farmers in this area and the introduced modification of strip cropping of maize and ginger was shown to significantly reduce rates of soil loss through runoff and improve the fertility status of the eroded bari for sustainable crop yields. A maize-soybean rotation may reduce nitrate-N leaching loss as compared to continuous corn planting practices (Owens et al. 1995). Other potential interventions could be extended to include cover crops to protect the soil from erosion and to improve soil fertility through reducing the potential of nutrient leaching (Changkija and Yonghua 1997).

In the citrus-growing area of Bandipur, old citrus orchard showed higher nutrient losses in leachate than young citrus orchard. Intercropping in young citrus orchard reduced nutrient losses. Potassium leaching losses were much higher from old citrus orchard. This result differs from the findings of Ongprasert (2002) who observed that compaction of topsoils in mature litchi orchards results in lower infiltration of water and enhanced runoff.

Soil loss is high during early monsoon. The rainy season was divided into three parts to understand the factors that increase or decrease the erosion rate. In the early rainy season soil remains mostly susceptible to erosion (before June). In the mid rainy season the soil remains resistant to erosion (late June to early August). After that erosion depends on the time of the monsoon and soil cultivation for the next crop cycle.

The amount and nutrient content of runoff were very low compared to leachate but the associated sediment movements carry significant amounts of organic matter and available P. Therefore, further developments should maintain the focus of decreasing leaching and controlling sediment losses in runoff.

Besides N and K leaching, strip cropping at Nayatola and runon diversion and grass planting in terrace risers at Landruk increased productivity by reducing the losses of organic matter in the sediment.

Conclusions

From these findings the following can be concluded.

- The amount of nutrient loss through runoff is very low, but significant amounts of N and P were lost through leaching. Significant amounts of organic matter and available P were washed out along with sediment movements.
- Strips of ginger and maize minimised soil loss and maximised net income from the sloping bari land. This practice can be recommended to the farmers of other areas to minimise soil erosion.
- Young citrus orchard followed by leguminous crop intercropping is beneficial in reducing soil loss as well as nutrient loss in predominantly citrus-growing areas.
- Wide terraces are better for management of soil fertility as they have less runoff and nutrient leaching.

Therefore, technical efforts should focus on trapping nutrients that are lost in solution through leaching and the use of barriers to reduce soil movement and nutrient losses in eroded sediments.

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