Interventions to Minimise Nutrient Losses from Bari Land (Rainfed Upland) in the Middle Hills of the Western Development Region of Nepal[1]

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Abstract: *Bari* lands (rainfed upland bench or sloping terraces) in Nepal are increasingly becoming a focus of concern in terms of soil fertility decline and management. The understanding of the circumstances leading to high erosion and leaching losses, and the areas particularly affected by high losses, are essential prerequisites to attempting to improve soil conservation. Participatory research is being conducted with farmers in three contrasting agroecological regions; Nayatola (20—25° slopes, l,000—1,500mm annual rainfall); Landruk (terraces 0—5° slope, 3,000—3,500mm annual rainfall); and Bandipur (0—5° slope, 1,100—1,500mm annual rainfall). The research aims to develop soil and water management interventions that control erosion without resulting in high leaching and so are effective in minimizing total nutrient losses. Interventions being tested include the control of water movement through diversion of run-on, and planting fodder trees on terrace risers on bench terraces in high rainfall areas, and strip cropping in non-terraced sloping fields of low to medium rainfall areas. Results to date indicate that the interventions are effective in reduction of soil loss from the *bari* land in comparison with existing farmer practice, but no effect is observed on nutrient losses in solution form through runoff and leaching.
Keywords: soil fertility, soil and water conservation

1 Introduction

Bari lands are nonirrigated and nonbunded cultivated terraces on flat and sloping lands which occupy most of the cropped area in the middle hills of Nepal. The function of the terrac[1]es 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 angle and the western part has large outward sloping terraces. Maize (*Zea mays* L.) is the main *bari* land crop and occupies 667,000 hectares in the country and 192,940 hectares in the western development region alone (Joshi, 1998). However, soil fertility is declining in the *bari* land, primarily due to low applications of farmyard manure and soil erosion (Turton *et al*.,1995). Maize cultivation practices accelerate surface soil loss. Soil losses from rainfed terraces and sloping farmland vary from 5 to 20 t/(ha • year) with organic matter, nitrogen, phosphorus and potassium losses of 150—600, 7.5—30, 5—20 and 10—40 kg /（ha • year） respectively (Pratap and Watson, 1994). In the 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 least from sloping field cultivation in a low rainfall area (Nayatola, Palpa). They recorded soil losses in surface runoff of 2.5 to 5 t/ha/year and the losses of nitrate nitrogen and potassium through runoff were comparatively low but that losses through leaching were 45 and 180 kg/ha/year respectively.

The main objective of this study was to investigate cultivation practices for maintaining inherent soil fertility of *bari* land in the middle hills of the western development region.

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2 Methodology

2.1 Site selection

Field experiments were conducted in the *bari* land in the high rainfall area bench terracing system at Landruk and in the medium to low rainfall area sloping field cultivation system at Nayatola. The altitude of Landruk ranges from 1,200—2,000 m with narrow, bench terraces while at Nayatola, altitude ranges from 1,000—1,500 m with gentle to steep sloping and wide terraces. Farmers at Landruk have been cultivating maize, millet, wheat and naked barley in maize/millet-fallow, maize-wheat or naked barley cropping systems. Winter crops (wheat and naked barley) are cultivated as mixed crops with mustard or winter legumes. Maize-wheat or barley is the dominant cropping system and winter crops (wheat and barley) are mixed with mustard or winter legumes at Nayatola.

2.2 Experimental design

In Landruk, two interventions were investigated: run-on diversion (closed plots) in 2000 and 2001, and growing fodder grasses in the terrace risers (2001 only). The interventions were compared with farmers' practice. At Nayatola, strip crops of maize (*Zea mays* L.) and ginger (*Zingiber officinale* Roscoe) (2000 and 2001) and maize and soybean (*Glycine max* (L.) Merr.) (2000 only) were compared with farmers' practice. At both sites, plots were 20 m x 5 m (long axis downslope) and replicated in 5 blocks.

2.3 Measurement of rainfall, runoff, erosion and leaching

Runoff plots were installed by fixing metal sheets around the plots (except for the upper border in the open plots at Landruk). Runoff was collected in a series of drums with overflows and the height of the runoff was measured and actual volume calculated. 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 its nutrient analysis. All drums were drained after each measurement and sampling. Three lysimeters were installed in each plot. Leachate volume was measured after each rainfall event, and samples collected for nutrient analysis. Rainfall was measured for whole season by automatic rain gauges.

3 Results

3.1 Leachate and nutrient losses

At Landruk, the total rainfall was about 3,193 mm during 2000 (Table 1) and more than 3,691 mm during 2001 (Table 2) indicating a large variation in rainfall between years.

The total leachate was higher in closed plots than in open plots , though the differences were only significant during 2000. The losses of nitrate–N and exchangeable K due to leaching were higher in all the seasons (early, mid and late) of 2000 in closed plots compared to farmers' practice (Fig. 1) because there is no control of rain water in the farmers' practice but the rainfall water is controlled and infiltration of water takes place in closed plots. This 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 as compared to the farmers' practice, where nitrate- N and exchangeable K losses were 73.4 kg/ha and 75.7 kg/ha respectively. However, these losses were not significantly different. During 2001, the leaching of both nitrate-N and exchangeable K was higher particularly in mid and late seasons than that of early season (Table 2). No significant difference in leaching was recorded among the treatments in early, mid and late seasons. The total loss of exchangeable K was the highest (59.4 kg/ha) in closed plots followed by 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 more or less similar (61.3 kg/ha—61.6 kg/ha) in the grasses and farmers' practice treatments. However, these differences were not significantly different. The grasses in the risers were established in 2001 only. It is expected that grasses of the risers will become more effective in the second year (2002) because the roots of grasses will be well established so that more biomass will be produced.

Table 1 Leaching losses of exchangeable k and nitrate-n (kg・ha^{-1}) at Landruk, 2000

	Early season Exch. k	Early season Nitrate-n	Mid - season Exch. k	Mid - season Nitrate-n	Late season Exch. k	Late season Nitrate-n
Closed plot	3.1	18.2	63.0	61.0	33.1	18.7
Farmers' practice	1.7	8.0	45.0	48.0	28.9	17.4
Rainfall (mm)	215		1,700		1,278	

Table 2 Leaching losses of exchangeable k and nitrate-n (kg・ha^{-1}) at Landruk, 2001

kg • ha^{-1}	Early season Exch. k	Early season Nitrate-n	Mid – season Exch. k	Mid -season Nitrate-n	Late season Exch. k	Late season Nitrate-n
Closed plot	4.6	9.1	26.8	61.8	29.0	30.6
Grasses in riser	1.4	8.0	21.7	33.4	12.4	23.4
Farmers' practice	2.9	20.2	26.9	24.2	18.7	21.0
Rainfall (mm)	432		1,700		1,560	

At Nayatola, the total rainfall was 1,386 and 1,123 mm in 2000 and 2001(Tables 3 and 4) respectively.

The total leachate in strip cropping was low in 2000 and high in 2001 compared to farmer's practice but the differences were not significant in either year. The amount of leachate was correlated with maximum rainfall irrespective of treatments. Both nitrate-n and exchangeable k leaching losses were slightly higher in maize and ginger strip than that of 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 their roots as well as they covered the ground in 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 maize and ginger strip than that of farmers practice (60.3 kg/ha) (Table 3). 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 loss of both the nutrients were not significantly different between the interventions.

Table 3 Leaching losses of exchangeable k and nitrate-n (kg・ha^{-1}) at Nayatola, 2000

kg • ha^{-1}	Early season Exch. k	Early season Nitrate-n	Mid – season xch. k	Mid –season Nitrate-n
Maize-ginger	7.5	39.1	15.6	13.5
Farmers' practice	4.3	37.3	18.2	23.0
Rainfall (mm)	473		912	

Table 4 Leaching losses of exchangeable k and nitrate-n (kg・ha^{-1}) at Nayatola, 2001

kg ha^{-1}	Early season Exch. k	Early season Nitrate-n	Mid – season Exch. k	Mid – season Nitrate-n	Late season Exch. k	Late season Nitrate-n
Maize-ginger	5.9	27.9	12.4	18.9	8.3	17.5
Maize-soybean	6.0	29.3	15.7	33.9	7.7	20.4
Farmers' practice	5.0	32.6	9.3	14.0	7.4	15.5
Rainfall (mm)	190		430		503	

During 2001, nitrate-n losses in early, mid and late seasons were comparatively low in the maize and ginger strip compared to the other two interventions (maize and soybean strip, and farmers practice). Between maize and ginger, and farmers' practice, nitrate-N leaching loss was comparatively more in maize and soybean strip than farmers' practice most probably due to fewer soybean plants germinated in this treatment. Exchangeable k leaching loss was higher (15.7 kg/ha) in maize and soybean strip in mid season as compared to maize and ginger and farmers' practice (9.3 kg/ha—12.4 kg/ha) but remained more or less the same in early and late seasons. The total nitrate-n loss was higher (83.2 kg/ha) in maize and soybean strip than that of maize and ginger (64.2 kg/ha) and farmers' practice (62.1 kg/ha) (Fig. 4). The same was true in the loss of exchangeable k, where maize and soybean plot had 29.5 kg/ha and maize and ginger and farmers' practice had 26.4 and 21.7 kg/ha respectively. However the results were not significantly different.

The loss of total P in the leachate was less than 1 kg/ha (unpublished data). This indicates that the loss of soluble P is negligible in leachate.

3.2 Run-off and eroded sediments

In the high rainfall site of Landruk, the total runoff from closed plots was significantly lower than from open plots during 2000 but it was similar during 2001. However, the amount of runoff was very low in both the year as compared to rainfall.

Sediment loss (Fig. 1) was higher in farmers' practice (2,229 kg/ha) than closed plots (994 kg/ha)during 2000 Similarly, during 2001, the total loss of the sediment was the highest in the grasses grown in the riser (1,293 kg/ha) followed by the farmers' practice (886 kg/ha) and closed plots (478 kg/ha). In both the years, low sediment loss in the closed plots is due to the limited area of run-off, where water could not flow freely from the above terraces. The higher loss of the sediment from grasses grown in the riser than farmers' practice during 2001 was most probably due to first year planting of grasses in the riser, where roots were not well established to conserve soil.

The total sediment loss (Fig. 2) was higher in farmers' practice (144 kg/ha) than maize and ginger strip (58 kg/ha) in 2000. In 2001, the total loss of the sediment was the highest in the farmers' practice (867 kg/ha) followed by maize and soybean strip (472 kg/ha) and maize and ginger strip (231 kg/ha). Maize and ginger strip is better than maize and soybean as well as farmers' practice for minimizing sediment loss by run-off because in maize and ginger strip, ginger was mulched with locally available materials at planting, which acted as a cover to the soil as well as minimizing the soil run-off.

The total loss of soluble nutrients in runoff was not significantly affected by interventions at both sites.

However, eroded sediments contain high concentrations of organic matter and phosphorus (Acharya *et al.*, 2001).

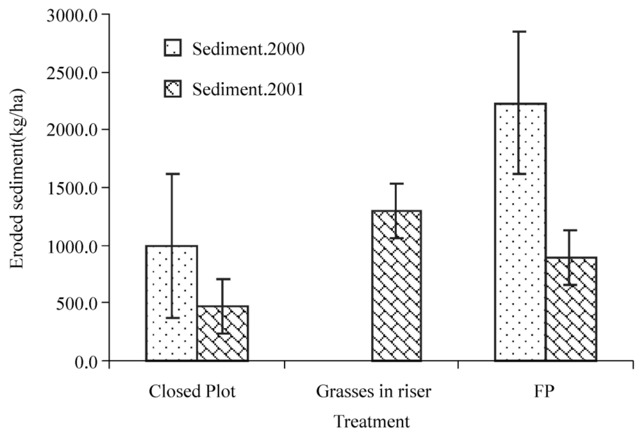

Fig.1 Sediment loss (kg • ha^{-1}) in runoff at Landruk during 2000 and 2001

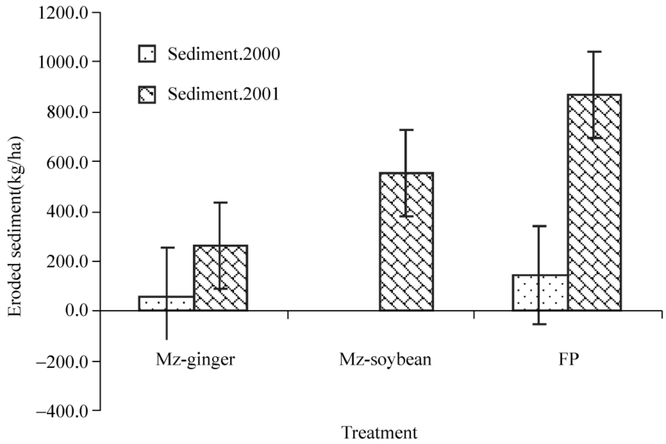

Fig.2 Sediment loss (kg • ha^{-1}) in runoff at Nayatola, during 2000 and 2001

4 Discussion

The diversion of run-on reduced soil erosion in the high rainfall area (Landruk, Kaski) without a significant effect on the losses of nutrients. Landruk appears to be highly susceptible to runoff and erosion, which relates to high rainfall, run-on and red/brown type of soils (Tripathi *et al*., 1999). 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 % sediment runoff loss in early June (Gardner *et al*., 2000) when the soil is bare. They further reported that the timing of heavy rain vis-à-vis the land management activities of ploughing, weeding, mounding and weed cutting that affect the percentage of ground cover (weeds predominantly) during May/June/early July period is an important, abeit 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 t/(ha • year)—5.0 t/(ha • year)) in all the terraces studied, even where rainfall totals and erosivity were high. However, uncontrolled surface (run-on) 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 farmer's practice. However, it did not affect the losses of soluble nutrients in runoff or leachate, only sediment . The ginger strips were mulched with plant materials. This mulching works as a filter and prevents the movement of soil particles with runoff water so that 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 mulchig of straw to the soil surface at 50 % slope in a semiarid region (Snobikowski *et al.*,1998). Mulching is being used on a small scale for a limited number of crops such as on dasheen (*Colocasia esculenta* (L.) Schott) and ginger. It can be extended to other crops provided the mulching material is available or the area under farmers' traditionally mulching 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 the *bari* land. 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. Inter cropping of legumes with maize is the traditional practice but intercultural operation of the maize accelerates soil movement. A slight change in the traditional practice such as inclusion of bushy types of legume crops with maize as strips reduces intercultural operation and controls soil nutrient loss from the cropped fields particularly through runoff. The use of mulch in ginger production is the usual practice of the farmers of this area and if it is modified slightly into strip cropping of maize and ginger, it could reduce significant amounts of soil loss through runoff and improve the fertility status of the eroded *bari* and for sustainable crop yields. A corn-soybean rotation reduces NO_3-N leaching loss as compared to continuous corn planting practices (Owens et al., 1995). Cover crops could be grown to protect the soil from erosion and to improve soil fertility through reducing the potential of nutrient leaching (Changkija and Yonghua, 1997).

The amount and nutrient content in runoff is very low compared to leaching but the associated sediment movements carry significant amounts of organic matter and available phosphorus. Therefore, the technical effort should be based on decreasing leaching and controlling sediment losses in runoff.

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