Soil Fertility Status, Soil and Nutrient Loss, and Conservation Practices for Improving Rainfed Upland (Bari) Terraces in the Western Hills of Nepal

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Introduction

The type of land called 'bari' in Nepal includes all non-irrigated terraces, flat land, and sloping land used for cultivation, and covers most of the cropped area in the hills. Maize is the main crop. Soil fertility is declining in bari mainly as a result of low application of farmyard manure and erosion (Turton et al. 1995). The ploughing and soil disturbing operations involved in cultivating maize accelerate surface soil loss. Soil losses from rain fed terraces and sloping farmland vary from 5-20 t/ha/year, and include losses of 150-600 kg/ha organic matter, 7.5-30 kg/ha nitrogen, 5-20 kg/ha phosphorous, and 10-40 kg/ha potassium (Partap and Watson 1994).

A wide range of technologies are available to support conservation of soil and nutrients. The main objective of this study was to explore the less eroding crop cultivation practices that exist in local farming systems in the middle hills of western Nepal to maintain the inherent soil fertility of bari.

Methodology

Survey of soil fertility status

Farmers' group discussions using participatory rural appraisal (PRA) techniques were held to gain understanding of the farmers' perceptions of soil fertility and soil nutrient losses from bari. Two representative sites, Nayatola in Palpa district and Landruk in Kaski district, were selected for the survey and soil sample collection. PRA was organised to collect information on crop productivity and soil fertility. Soil samples were collected from five farmers' fields representing each major land type such as slope and terraces. Benchmark soil samples collected from intervention plots were analysed in the laboratory for total nitrogen, available phosphorous, exchangeable potassium, organic carbon, pH, and texture. The results were compared within land variables.

Field experiments

Field experiments were conducted in the high rainfall bari areas with bench terracing systems, and in medium to low rainfall areas with flat land and gentle to steep sloping crop cultivation systems, to discover the effect of rainwater on runoff and leaching, which encourages the loss of nutrients and topsoils.

For the high rainfall condition, an experiment was designed and conducted in five complete blocks in farmers' fields in Landruk. An intervention of run-on diversion (closed plot) was selected as a control for the existing open plot practice. Treatments were randomised in the block using a previous research plot as a control. The net experimental plot size was 100 m^2 extending from 3 to 10 terraces. Farmers grew crops following their own existing cropping patterns, either maize-millet or maize-wheat/naked barley. The plots were marked by fixing a metal sheet to insure runoff collection in the trough and drum.

Similarly, an experiment on strip cropping land in the low to medium rainfall area was designed and conducted in five complete blocks in farmers' fields in Nayatola. Strips of maize and ginger were used as an intervention control to compare with farmers' practices in five blocks that varied slightly in slopes and fertility.

Data collection regarding soil loss and runoff

Runoff was measured from a 100 m^2 plot designed to collect runoff in drums. Runoff samples of 0.5 l were taken from each drum during each measurement, while stirring, for sediment estimation; a sample of clean solution from the last drum containing runoff was also taken for nutrient analysis. All drums were drained after each measurement and sampling.

Results

Soil

In Landruk, most farmers reported medium soil fertility in their fields. Laboratory analysis of the soil samples from this area showed that available phosphorous was high, while total nitrogen, exchangeable potassium, and organic carbon were low. The soil is slightly acidic. The soils measured from the plough layer contained about 27% gravel and stones larger than 2 mm, the remaining soil contained more than 50% sand, about 40% silt, and less than 10% clay; the soil was classified as sandy loam. The results indicated that in this area small soil particles are lost through runoff and that much of the gravel and stones remained in the fields. Organic matter and total nitrogen were lost from the soil along with runoff during the rainy season, and production depends on the application of heavy amounts of farmyard manure (FYM) each year. The variation in terrace size did not significantly influence the total nitrogen, available phosphorous, exchangeable potassium, organic carbon, or soil pH. The variance of total nitrogen, available phosphorous, and organic carbon was larger in the large plots than in the small plots, and that of exchangeable potassium was larger in the small plots.

In Nayatola, the soil depth of cropped fields was more than 25 cm; the colour was mostly red followed by brown, this is called locally 'gagreto mato'. Almost no chemical fertilisers were applied, application of FYM was heavy to low. Farmers know that planting legume crops improves soil fertility. Each farmer grew ginger on at least one piece of land and applied mulch to the ginger. The analysis of soil samples indicated that total nitrogen and organic carbon contents were low, available phosphorous and exchangeable potassium were medium, and the pH was slightly acidic. The soil contained 20% gravel and stone in the plough layer, the remaining soil contained 38, 50, and 31% sand, silt, and clay, respectively, indicating a clay loam soil texture. Field slope did not significantly affect soil properties except for exchangeable potassium, which was significantly higher in the more sloping area, indicating more leaching in the flatter areas. Organic matter was higher in flatter than in steep slopes. Farmers apply large amounts of FYM to the fields, but there was still a deficiency even on flatter slopes. Organic carbon loss was high compared to soil particles.

Rainfall

The weekly total rainfall was recorded from the second week of May to the last week of September in Landruk and from the last week of May to the second week of September in Nayatola (i.e. during the main monsoon period).

In Landruk, the highest weekly rainfall was recorded during the last week of July, followed by the third week of June. The maximum recorded intensity of rain was during the last week of August (96 mm/minute[1]) followed by 84 mm/minute[1] in different events. The maximum erosive rain occurred during the third week of June, when the Hudson Kinetic Energy (KE) was 2766 joule followed by 2250 joule in the last week of August.

In Nayatola, the highest weekly rainfall was recorded in the second week of June. The weekly total rain decreased after the third week of July. The rainfall was distinct before and after the second week of July, and the rain was most erosive during the second week of June, when the maximum intensity of rain was 84 mm/minute, producing 2002 joule of Hudson KE.

Runoff

In Landruk, the total runoff in the closed plot was low compared to the open plot. The highest runoff was recorded as 78 mm in the open plot and 34 mm in the closed plot during the last week of August. Lower runoff was found from the closed plot in weekly runoff measurements throughout the season except for the second week of July, when runoff was greater from the closed plot, with a difference of 11 mm.

In Nayatola, the runoff recorded from the strip cropping site was less than from that under farmers' practice. The difference was at a lower confidence level, even so strip cropping showed a trend of less runoff during most of the weeks for which runoff was recorded.

Leachate

In Landruk, the total seasonal leachate was significantly higher from the closed plot than the open plot throughout the season, except for the first time recording in the second week of May. The highest leaching of water was 250 mm in the third week of July in the closed plot and 153 mm in the third week of June in the open plot.

In Nayatola, the total leachate in the strip cropping control was lower than for farmers' practice, but the difference was at a low level of confidence and during the early rain, strip cropping had more leachate than farmers' practices. The maximum leachate was observed for both treatments in the second week of June when rainfall was at a maximum.

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[1] The editors think that rainfall intensity of 96 and 84 mm/minute is impossible; the authors assure us these figures are correct.

Nutrient Loss through Runoff and Leachate

In both Landruk and Nayatola, the loss of soluble nutrients with runoff was very low, and the difference between plots was insignificant. The loss of NO_3-N and exchangeable K was higher, but the effect of treatment was insignificant.

Loss of Sediment

In Landruk, sediment loss with runoff was more from the open plot than the closed plot, although the difference was insignificant. The sediments contained high concentrations of organic matter, phosphorous, and potassium. Organic matter loss in a single season was calculated as 79 kg ha^{-1} from the closed plot and 243 kg ha^{-1} from the open plot.

In Nayatola, the loss of sediment from strip cropping was less than for farmers' practice, but the difference was barely significant. Again the sediments had higher concentrations of organic matter, phosphorous, and potassium.

Discussion

Gravel and low organic matter in the soils tended to increase with increase in field slope, indicating loss of small soil particles and organic matter with runoff. In addition, the higher concentration of organic carbon in the runoff sediment and N and K in the leachate show that soil fertility losses occur continuously from bari during the rainy season.

The diversion of run-on (closed plot) reduced soil erosion in areas susceptible to high rainfall erosion (Landruk) without having a significant effect on the loss of nutrients. Landruk appears to be particularly susceptible to runoff and erosion, which relates to the high rainfall, run-on, and red/brown type of soils (Tripathi et al. 1999). The strips of maize and ginger reduced both runoff and leachate volume under low rainfall and sloping field conditions, but did not affect the losses of soluble nutrients in runoff or leachate; only sediment yield was low in the maize and ginger strip plot as compared to farmers' practice. Ginger strips were followed by mulching with plant materials. This mulching worked as a filter and stopped the movement of soil particles with runoff water so that soil loss was low in the maize and ginger strip-planting plot. Inclusion of grain legumes in the rotation, and mulching or recycling of forest litter or crop residues, are recommended practices for maintaining soil fertility in the lower hills (Subedi and Gurung 1991).

The existing cultivation practices for maize are the main reason for soil and plant nutrient losses from bari. However, ploughing and other operations can help prevent nutrients from leaching. The supply of nutrients to the crops is limited by the scarcity of resources. The way to improve soil fertility under such circumstances would be through utilising available technology in cultivation practices and a crop combination that protect soil and nutrients against losses and improve soil fertility. Mulching is being used on a small scale for a few crops like calocassia and ginger. It can be extended to other crops, provided that mulching material is available, or it can be extended in traditionally mulched crops through marketing. Intercropping of legumes with maize is the traditional practice, but this accelerates soil movement. Ginger is usually mulched in this area; cropping of maize and ginger with mulching reduce the soil loss through runoff significantly and improve the fertility status of the eroded bari for sustainable crop yields. Similarly a corn-soybean rotation reduces NO_3-N leaching loss as compared to continuous corn planting practices (Owens et al. 1995).

The percentage of rainwater and nutrient content in runoff is small compared to leaching, but the sediment movement carried much more organic matter and available phosphorous. Therefore, technical efforts should be based on decreasing leaching and increasing runoff containing less sediment.

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