Chapter 1

Erosion and Degradation of Sloping Agricultural Land and Technologies for Mitigation

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INTRODUCTION

Pressure on land in mountain areas has increased considerably in recent years as a result of a variety of factors including the increasing human population, the continuing loss of cropland to other uses, and erosion and degradation of existing crop land. It is both the cause and the result of a general degradation of the environment. In the Hindu Kush-Himalayan (HKH) region this pressure has led to forest clearance and the intensified use of sloping land for agriculture. This has led to a further deterioration of the resource base with a general decline in soil fertility, an increase in soil erosion, and an increase in the number of landslides and landslips.

Soil erosion and degradation are widely regarded as a major threat to sustainable growth in agricultural production in both developed and developing countries. Soil erosion is one of the most important factors contributing to land degradation and the decline in soil fertility of sloping croplands. Farmers in the mountains are facing problems of land degradation and low productivity as a result of topsoil loss and nutrient leaching. Each year, large amounts of soil are lost from sloping land in the Hindu Kush-Himalayan (HKH) region, mainly as a result of water erosion. Especially the nutrient rich topsoil is eroded from this marginal agricultural land, damaging the productive capacity of the land and impacting on stream water quality. In India, for example, water erosion leads to an annual loss of some 6,000 million tonnes of soil containing nutrients equivalent to five and a half million tonnes of NPK, much of this from the northern mountainous areas (Bosu and Sivanappan 1989). In China, the annual soil loss from erosion is 5,000 million tonnes, containing nutrients equivalent to 40 million tonnes of NPK (Niu Chonghuan; Wang Lixian 1992). The eroded soil that is left behind contains coarser particles that are relatively low in nutrients and less capable of absorbing water. Water flows faster across such fields, causing more damage. Surface erosion is a natural process, but soil erosion has increased drastically as a result of inappropriate land use and management, and the current amount exceeds the natural rates many times.

One of the most effective ways that farmers have found to increase the stability and workability of sloping cropland has been to build terraces. Bench terraces can greatly reduce erosion, increase water infiltration, and make the land easier to manage. Many traditional agricultural systems have developed extremely effective terraces that ensure the long-term stability of the land, and terracing is a common practice in many areas of the HKH. Terraces have occasionally been promoted as the panacea to all erosion problems on sloping agricultural land. However, although they can be effective, there are also clear limitations. Terracing alone cannot be used to stabilise sandy and coarse-textured soils or very steep slopes. When marginal areas are cleared of vegetation and terraced, there is a danger that they will have to be abandoned after several years cultivation as a result of severe degradation and reduced soil fertility if proper and effective measures are not taken. Nutrients will be leached out, and without stabilising permanent vegetation the terraces may simply slip down the hillside.

SLOPING AGRICULTURAL LAND TECHNOLOGY

Sloping agricultural land technology (SALT), also known as contour hedgerow intercropping (agroforestry) technology (CHIAT), was developed some twenty years ago as a new approach that combines the strengths of terracing with the strengths of natural vegetation to stabilise sloping land and make it available for farming. In this system, the terraces are developed by planting dense hedgerows of fast growing perennial woody tree or shrub species along contour lines (Partap and Watson 1994). The hedgerows create a living barrier that traps sediments and gradually transforms the sloping land to terraced land forming a 'bioterrace'. The final terrace has almost all the functions of a hand-cut terrace but is lined on both sides by the hedgerows. In general, the hedgerows are established using fast growing nitrogen-fixing species. These have the added potential to improve soil fertility, both directly through nitrogen fixation at the roots, and indirectly through incorporation of the hedgerow trimmings into the soil in the alleys between the hedgerow plants. The hedgerows must be pruned regularly to prevent shading of the crops and to make the biomass available, this can also offer additional benefits through the production of fuel and/or fodder.

SALT or CHIAT was originally developed for use in tropical countries, where it has shown considerable potential for controlling soil erosion and improving the fertility of sloping agricultural land. There are numerous research papers on the potential or actual effect of hedgerows in the tropics (e.g., Laquihon and Watson 1986; Lal 1988; Paningbatan 1990; Kiepe and Young 1992; Kang et al. 1993; Tacio 1993; Kiepe 1995), but there are far fewer reports of the technology being used in other areas, although the method has proven effective in reducing soil erosion, improving soil fertility, and enhancing crop yield in subtropical China (Sun Hui et al. 1999a, 1999b, 2001; Tang Ya et al. 2001).

In the early nineteen nineties, the International Centre for Integrated Mountain Development (ICIMOD), in collaboration with a number of national institutions introduced contour hedgerow technology to subtropical and warm temperate areas of the HKH region. SALT was introduced, tested and demonstrated on farmers' lands in six countries in the Hindu Kush-Himalayas – Bangladesh, China, India, Myanmar, Nepal and Pakistan – to assess its feasibility in the region, mostly under the project on Appropriate Technologies for Soil Conserving Farming Systems funded by the Asian Development Bank. This publication focuses on the results of the tests at the main test site in Nepal.

Despite its great appeal and potential, SALT is often viewed with suspicion by farmers. During the course of testing, demonstration, and extension, a number of concerns appeared. A particular concern voiced by farmers is that of possible competition between the hedgerows and crops for nutrients. Competition between hedgerows and crops in alleys has been observed in tropical regions, where it was regarded as one of the main causes for poor adoption. However, the real extent of such competition, and the question of whether the benefit of the hedgerows outweighs any possible negative impact, can only be determined through proper long-term trials.

SALT Trials at the Godavari Trial and Demonstration Site

A series of trials have been carried out since 1993 at ICIMOD's Godavari Trial and Demonstration Site to develop, test, and demonstrate various aspects of SALT. The establishment of hedgerows and selection and performance of hedgerow species is described in another book in this series (Tang Ya 2004a). Once hedgerows had been established, it was necessary to assess their effectiveness in soil conservation and soil fertility improvement, as well as to investigate the extent of nutrient and moisture competition between hedgerows and crops. Two experiments were carried out at the ICIMOD site. The first, from 1995 to 2001, investigated the impact of hedgerows on soil erosion and soil fertility; the second, from 1998-2001, looked at the potential competition between hedgerows and crops for soil nutrients and soil moisture. The results of these experiments are described in this book.

The study site

The study was conducted at ICIMOD's Godavari Trial and Demonstration Site, which lies some 15 km from Kathmandu in the south-east corner of the Kathmandu Valley at the foot of the Phulchoki Mountain, the highest mountain bounding the Kathmandu Valley. The area lies in the Himalayan mid-hills of Nepal. The site is described in more detail in the first book in this series (Tang Ya 2004b).

The climate is subtropical monsoon with an annual average rainfall of around 2000 mm and distinct rainy and dry seasons; 80% of the precipitation falls during the monsoon (June-September). The mean annual temperature during the trials was 15.9ºC, with the coldest month in January and the hottest month in June (Figure 1.1).

The experiment was carried out on newly-cleared land in an area that had been degraded forest reduced to shrub land with a few trees. The site lies at 1540-1800m and is sloping with gradients of 26-31º (45.5-60%) with a north-northeast aspect. The soil is sandy loam with a high content of organic matter and nitrogen, moderate available potassium and phosphorous, and very acidic. The major biophysical characteristics are summarised in Table 1.1. The land had not been cultivated prior to establishing the hedgerows.

Hedgerows

The background and basic methodology of SALT is described elsewhere (Partap and Watson 1994; Tang Ya 1999) and the results obtained with different hedgerow species in another book in this series (Tang Ya 2004a).

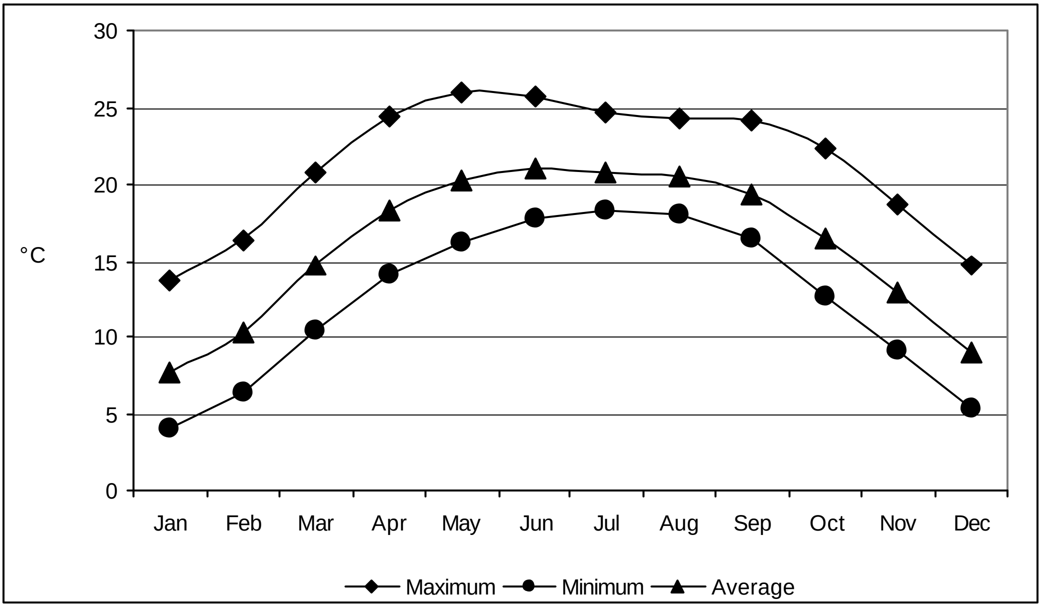

Figure 1.1: Mean monthly maximum, minimum, and average temperatures, 1996-2000

Table 1.1: Biophysical characteristics of the Godavari site

Latitude	27°35'19'' to 27°35'41''N
Longitude	85°23'16'' to 85°23'44'' E
Altitude	1540-1800 masl
Slope gradient	26-31° (45.5-60%)
Temperature (1996-2000)	
• Average annual maximum	21.3°C
• Average annual minimum	12.4°C
• Average annual mean	15.9°C
• Mean hottest month (June)	21.0°C
• Mean coldest month (January)	7.6°C
• Absolute minimum (18 January 1998)	-0.5°C
• Absolute maximum (10 June 1998)	33.8°C
Mean annual rainfall (1996-2001)	2062 mm, 80% between June and September
Soil	
• Texture	clay loam to sandy and silty clay loam
• Depth	25-100 cm
• pH	4.2-5.5
• Organic matter content (0-30 cm)	8.3%
• Total nitrogen content (0-30 cm)	0.29%
• Available K	238.6 ppm
• Available P	7.1 ppm
Natural vegetation	mixed deciduous and evergreen broadleaved forest

Hedgerows were established by transplanting seedlings in a double row along the contour lines of a slope at a density of about 20 plants per metre (10 per metre single row). The double rows occupied a strip of about 0.5m and were separated by an alley with a width determined by the slope and experiment. Any plants that died were replaced with fresh seedlings at the start of the next monsoon season. With time, the topsoil washed down from the alleys above built up behind the hedgerows below to form natural terraces.

The hedgerows were pruned once in the first year after planting and one to three times a year thereafter depending on growth. The fresh trimmings were spread as mulch in the alleys. The twigs were placed within the double hedgerows.

The alleys were used for growing annual crops and/or fruit trees.

Experiments

Soil erosion and soil fertility

The first experiment was designed to assess the effect of hedgerows on soil erosion and soil fertility. Four different hedgerow treatments were tested with variations in the hedgerow species (*Alnus nepalensis* or *Indigofera dosua*), the use or omission of organic fertiliser, and the type of crop grown (annual crops or fruit trees with vegetables). Control plots were farmed without hedgerows according to local practice.

The hedgerows were planted in 1995; measurements were taken from 1996 to 2000.

Soil erosion was assessed from measurements of runoff and soil loss. Data were collected on a daily basis during the monsoon season and on an event basis during the dry season.

Soil fertility was assessed by chemical analysis of soil samples collected annually before planting of crops. The annual fresh biomass produced by the hedgerows and crop yield were also recorded.

Hedgerow-crop competition for nutrients and moisture

The second experiment was designed to assess the extent of competition between hedgerows and crops for nutrients and soil moisture.

The experiment was carried out on an established hedgerow intercropping alley. The hedgerows of *Alnus nepalensis* were established in 1993 by transplanting seedlings. By the time the experiment commenced in 1998, the alley between the hedgerows had become an almost level terrace.

There were two treatments each with three replicates: one with cultivation of crops and one without. The experimental plots for each treatment were 5m long and 3m wide and there was a 1m gap between treatments as a buffer area.

Nutrient competition was assessed by analysing the nutrient status of soil samples collected at three different distances from the hedgerows. Crop yield and fresh biomass production of the hedgerows were also measured. Data was collected for three consecutive years.

Soil moisture was assessed from measurements of soil tension at four different depths at each of three different distances from the hedgerows. Data were collected from May 1999 to January 2001. The potential competition for water between hedgerow and maize was investigated by modelling, using estimates of the water consumption of the plants.

Meteorological Data

A meteorological station was set up about 50m from the experimental plots. Air temperature, precipitation, evaporation, solar radiation, and sunshine duration were recorded manually on a daily basis, and on an hourly basis from an automatic weather station.

Results and Conclusions

The results of the soil erosion investigations are presented in Chapter 2, of the soil fertility experiments in Chapter 3, of the nutrient competition investigation in Chapter 4, and of the soil moisture competition experiments in Chapter 5.

Essentially, the results suggest that contour hedgerows are very effective in reducing soil erosion to a very low level and have the potential to facilitate continuous cultivation of sloping cropland. The hedgerows did not improve soil fertility in the experiments with freshly planted hedgerows, partly because the soils started with a high level of most soil nutrients, partly because of the low production of fresh biomass by the hedgerows. The hedgerows did help reduce loss of available potassium and would probably help maintain soil fertility in the long run.

There were higher levels of most soil macro-nutrients close to the hedgerows in the established terrace and there was no competition between hedgerows and crops for nutrients; but there was competition between the hedgerows and crops for soil moisture in the dry season. Interestingly, although yield of radish (the dry season crop) was higher closer to the hedgerows, yield of maize (the monsoon crop) was not, indicating that factors other than nutrient status affect crop yield, and that the effects on different crops are not uniform.

Contour hedgerow intercropping technology has a good potential for facilitating sustainable management of sloping cropland and can contribute to sustainable mountain agricultural development and environmental conservation by reducing soil erosion and increasing productivity, opening up the possibility of continuous cultivation of sloping croplands. In order for the technology to achieve its potential, other, possibly more appropriate, hedgerow species need to be tested, and more investigations of different crops and their yield need to be carried out to identify optimum combinations for applications in temperate and subtropical areas of the HKH.

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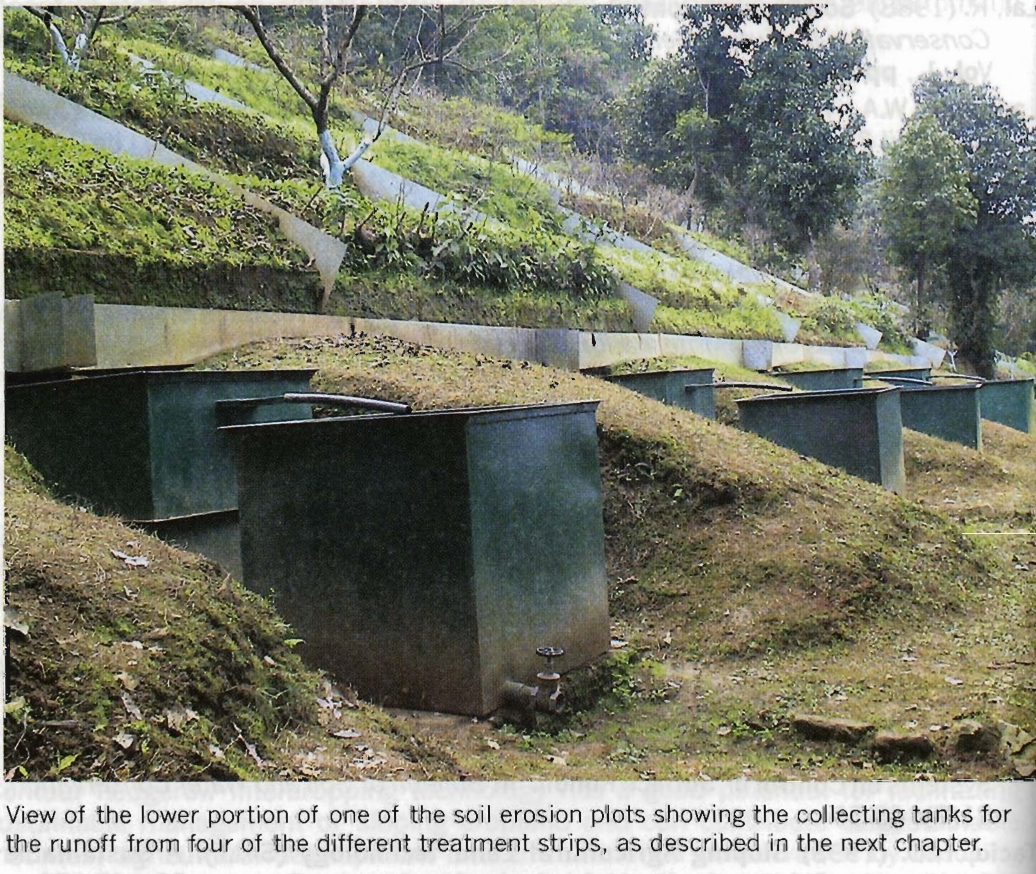

View of the lower portion of one of the soil erosion plots showing the collecting tanks for the runoff from four of the different treatment strips, as described in the next chapter.