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# Bioterracing & Soil Conservation

## Experience with Contour Hedgerow Planting in Parts of the Hindu Kush-Himalayan Region

**In the Hindu Kush-Himalayan region, agriculture is the main occupation of about 80% of the population. Due to limited arable land and increasing population growth, farming encroachment on ecologically fragile and marginal mountain lands will continue. Unless sustainable farming alternatives that conserve soil are sought, developed, and implemented, land degradation and the impoverished living conditions of resource-poor upland farmers are bound to worsen with time. Hence, it is urgent to seek new options for farming sloping lands that can enhance crop yields and conserve soils to an acceptable level and which can further improve soil conservation on and the soil fertility of bench terraces. Work carried out by ICIMOD in parts of the Hindu Kush-Himalayan region shows that Contour Hedgerow Technology might be one answer to these problems.**

Ever-increasing pressure is being exerted on limited land resources and the available agricultural land is decreasing rapidly due to land degradation. The combination of population growth and loss of farmland has resulted in a reduction in per capita availibility of agricultural land. According to Sharma (1993), per capita cultivated land decreased by 23.1-60.7% in selected areas of the Hindu Kush-Himalayan (HKH) region from 1991 to 1981 (Box 1). Decrease in the yields of main food crops has also been observed. For example, in Nepal, from 1970 to 1990, the average national yields of maize dropped from 1,869 to 1,599 kg/ha/yr (HMG/N 1990, cited by Carson 1992). Increasing population and decrease in crop yields make it more difficult to meet basic needs. Farmers in the mountains have to cultivate lands intensively and/or clear more land on steep slopes, resulting in further depletion and degradation of land resources. Soil erosion is an important contributing factor to land degradation and poverty in the region. The challenge therefore is to produce food for the ever-growing population while conserving agricultural soils.

### Effect of Soil Erosion on Farmland

Although detailed data regarding soil erosion overall in the HKH region are lacking, limited measurements of sediment show that values for the HKH region exceed the world average by almost twice the magnitude (Alford 1992). The direct and primary effect of soil erosion is soil loss and nutrient leaching, resulting in reduction of land productivity. In a study carried out by ICIMOD in Ningnan County, China, the nitrogen and organic matter in eroded soils were 2.7 and 4.2 times higher respectively than of the topsoil of cultivated land. A study in middle Nepal indicates a soil loss of 20 tonnes/ha/yr from rainfed marginal land, indicating a nutrient loss of 300 kg of organic matter, 15 kg of nitrogen, 20 kg of phosphorus, and 40 kg of potassium (Carson 1992). Soil loss from sloping farmlands under farmers' practices in the eastern Himalayas of India, the uplands of north-eastern Myanmar, and the uplands of south China is even higher at 54 to 57 tonnes/ha/year (Partap & Watson 1994). A study of sedimentation in the Yangtze River, China, indicates that one tonne of eroded soil contains 2.55 kg of nitrogen, 1.53 kg of phosphorus, and 5.42 kg of potassium (Huang et al. 1989).From these data it becomes clear that soil erosion is a key cause of decline in soil fertility. These soil changes resulting from soil erosion will, in time, reduce crop yields

**Box 1: Per Capita Cultivated Land in Selected Areas of the HKH**

| Country/region | Year | Per capita cultivated land(ha) | Decrease in percentage |
|---|---|---|---|
| Bangladesh | | | |
| Chittagong Hill Tracts | 1951 | 0. 247 | |
| | 1974 | 0.150 | 60.7 |
| | 1981 | 0.097 | (as of 1951) |
| India | | | |
| Himachal Pradesh | 1961 | 0.220 | |
| | 1971 | 0.190 | 39.1 |
| | 1981 | 0.134 | (as of 1961) |
| U. P. (8 districts) | 1971 | 0.30 | |
| | 1981 | 0.16 | 46.7 |
| Nepal | 1971 | 0.173 | |
| | 1981 | 0.133 | 23.1 |
| China | | | |
| Xizang (Tibet) | 1960 | 0.150 | |
| | 1982 | 0.105 | 30 |

Source: Sharma 1993.

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***Although soil erosion is common in various land use practices, it is estimated that 70% of the annual erosion occurs on land used for agricultural purposes.***

and thereby farm income and household nutrition. Uncontrolled and continuous soil erosion will greatly reduce the soil depth and soil nutrient content, leading to abandonment of farming lands.

The off-site effects of soil loss often have broader economic and environmental implications. Soil loss increases sediment and nutrient loads in streams.Eroded soils clog reservoirs and rivers and often cause flooding in the lowlands. Deforestation and serious soil erosion in the Chinese Himalayan region were identified as the main causes for the disastrous floods in the Yangtze River this year. Eroded soils also silt dams and irrigation channels in the basin area of the catchment. Such examples of siltation of dams are not unusual in the HKH region. The lifespan of the Kulekhani Reservoir in central Nepal has been reduced to half of the targetted design and one quarter of the expected lifespan due to serious soil erosion. The unusual rainfall in 1993 alone resulted in sedimentation of 5.12 million cubic metres, which is 6% of the designed storage capacity of the reservoir and is about 60 times higher than the expected annual sedimentation (Sthapit 1995; Galay et al. 1995). A similar example was found in the upper reaches of the Yangtze River of China. Sedimentation in one reservoir during a period of four years from 1980 to 1984 amounted to the amount of sedimentation expected over 40 years (Li 1989). The above facts clearly indicate that conservation of water and soil is important for the harmonious development of population, resources, and environments.

## Need for Conserving Farm Technologies

Mountain farmers in the region have long been aware of the effects of soil erosion and decline in soil fertility. They have created and adopted various practices to control soil erosion and to maintain soil fertility, of which terracing is the most common response. Terracing has various advantages and has contributed considerably to soil conservation on sloping agricultural lands. The advantages of terracing include easier tillage and substantial reduction in soil erosion. Terraces have been constructed in almost all suitable locations and are a characteristic landscape feature in the HKH region.

However, there are also some limitations disturbance of the soil strata and considerable decline in soil fertility in the first several years, considerable soil loss during construction and in the first two years, and need of tremendous labour and investment for construction and maintenance. Further, they are not always stable in many cases and not suitable for sandy and coarse soils and on very steep land. Soil loss and nutrient leaching from bench terraces affect about 25% of the marginal land. According to Carson (1992), soil loss from rainfed bench terraces is 5 tonnes/ha/yr, and nutrient leaching contains 75 kg/ha/yr of organic matter, 3.8 kg/ha/yr of nitrogen, 5 kg/ha/yr of phosphorus, and 10 kg/ha/yr of potassium. Of the limitations mentioned above, high investment and instability are the main limitations. Preliminary survey carried out by ICIMOD showed that it costs about US$3,200 to 4,800 to establish one hectare of terrace land in the Northern Areas of Pakistan and US$ 600 to 5,500 in southwestern China.

## Contour Hedgerow Technology: Concept and Application

Contour Hedgerow Technology has different names in different regions and publications. For example, hedgerow intercropping (ICRAF), avenue cropping (Sri Lanka), contour hedgerow farming, Slopping Agricultural Land Technology (SALT) (the Philippines, HKH), alley farming (Africa, the Philippines), hedgerow barrier technology, etc. It is basically an agroforestry system in which hedgerows of nitrogen-fixing trees or shrubs are planted very closely together and food or cash crops grown in the alleys. The hedgerows are spaced usually 3-6 metres apart, depending on the slopes, and are periodically pruned to provide green manure or mulch and to prevent shading of the crops in the alleys. Young leaves of some hedgerow plants provide good fodder for livestock. Hedgerows can also be managed to provide fuelwood if necessary and, in such cases, hedgerows are pruned less frequently. The hedgerows and their trimmings provide mechanical and biological barriers that help minimise soil erosion by reducing surface runoff velocities, leading to higher deposition of soil sediments, improving runoff infiltration rate, and prolonging infiltration rates. Besides controlling soil erosion, the hedgerows also serve as an effective, living source of nutrient cycling.

**Contour Hedgerow Technology provides some or all of the following benefits:**

- considerable reduction in soil loss,
- green manure and mulch for companion crops,
- biologically fixed nitrogen for companion crops,
- improvement in runoff water infiltration,
- favourable conditions for beneficial soil organisms,
- high-protein fodder for livestock, and
- staking materials and/or fuelwood.

This technology has been tested and applied successfully in the tropics of South East Asia and Africa. But its application in areas outside of the tropics has been limited. Testing and demonstration of the technology by ICIMOD in Nepal (Godawari and Tistung), China (Ningnan), Myanmar (Lashio), and Pakistan (Islamabad) indicate that this technology is also applicable in the subtropics. But the key factor for the success is to select appropriate nitrogen-fixing plants that adapt to lower temperature and uneven distribution of annual rainfall in the region. Meteorologically, most of the HKH region is influenced by the monsoon climate and 70-92% of the annual rainfall is received during the monsoon. The duration of monsoon varies from three to six months and the drought season is from six to nine months, during which precipitation accounts for only 8 to 30% of the annual total. This condition implies that monsoon is the most important period for soil conservation, because most of the annual rainfall is received during this period and the rainfall intensity is also very high. Drought season and lower temperatures are the determining factors for species' selection. Freezing in many parts of the region is another factor to be considered in the selection of species.

The application of this technology in the HKH region started in 1991 when ICIMOD established its first field-testing and demonstration site in cooperation with the Chengdu Institute of Biology, Chinese Academy of Sciences, in Ningnan County, Sichuan Province of China. Promising results led to the establishment of testing and demonstration sites in Bangladesh in 1993 and in Nepal, India, Myanmar, and Pakistan in 1994/1995. Some primary but promising achievements have been made, and it has also become apparent that this technology is applicable outside tropical areas. Special priority is given to species' selection and around 60 species have been tested for all ten project sites. Of the 60 tested species, about 5 species are found to be most suitable as hedgerow species in the various project areas. The primary results show that Contour Hedgerow Technology is effective in reducing soil loss and runoff, improving runoff water infiltration, improving soil fertility, and enhancing crop yields.

**Most suitable species for Contour Hedgerow Technology**

*Tephrosia candida*
*Leucaena leucocephala*
*Albizia lebbeck*
*Alnus nepalensis*
*Desmodium rensonii*
*Flemingia macrophylla*
*Indigofera pulcherima*
*Acacia mearnsii*
*Acacia dealbata*
*Dalbergia sissoo*
*Bauhina purpurea*
Albizia chinensis

## Contour Hedgerow Technology Application in the HKH: A Summary of ICIMOD's Findings

### *Effect on soil conservation*

Preliminary results show that contour hedgerows of nitrogen-fixing plants can function effectively as soil erosion barriers from the second year of planting, and their efficiency in controlling soil loss improves considerably with time. The data collected from Godawari, Nepal, indicate that, in the second year, soil loss and runoff from areas on which various hedgerow species are planted are only 14.9 to 54.6% and 75.3 to 94.4% respectively of the soil loss from plots without hedgerows. In the third year, soil loss and runoff in the areas with hedgerows are 4.7 to 22.5% and 72.9 to 85.9% respectively of those without hedgerows. Similar results were obtained from several sites in China and Nepal. Data from the site in China indicate that as much as 37 to 47% of the runoff water is reduced by hedgerow systems owing to a prolonged infiltration period, thickly planted hedgerows, and improved infiltration rates of soils.

### *Effect on soil fertility changes*

Soil fertility is an important component that determines land productivity. Soil erosion can reduce soil fertility considerably through nutrient leaching. It was found in Ningnan that the contents of total nitrogen and organic matter in eroded soils are 2.7 and 4.2 times respectively of those in the topsoils of farming lands. Reducing soil loss is therefore an important measure for maintaining soil fertility. In addition, the hedgerows of nitrogen-fixing plants are pruned several times a year and provide large amounts of fresh green manure and mulch material.This nitrogen and protein rich foliage can improve soil fertility effectively. On-farm research data indicate that, on a very degraded soil, compared to the control, the content of the total nitrogen of the soil with hedgerows increased by 14.3-58.2% and 69.3-133.9% in the second and third years respectively after hedgerow planting. Similarly, the organic matter content increased by 4.8-32.3% and 19.8-55.5% in the second and third years respectively.

### *Effect on crop yields*

The final goal of this technology is to maintain crop yields or land productivity. Although the hedgerows occupy about 15-25% of the land space, crop yields from areas with hedgerow plantations are higher than in control areas. On two sites, it was observed that the crop yields of maize increased by 17-51% in the second year and 30-60% in the third year .

## Further Considerations for Wider Application in the HKH Region

Adaption of any technology by farmers will take place only if the technology can meet local needs. Although conservation measures can reduce soil loss remarkably, not all improved measures are acceptable to farmers. Socioeconomic factors can be a critical influence in determining whether or not farmers will adopt a technology. Terracing has numerous limitations that have limited its further application by farmers. Contour hedgerows of nitrogen-fixing trees/shrubs can reduce soil loss and improve soil fertility, but usually they do not directly generate cash income for farmers. Hillside ditches are too costly for poor farmers to establish and are not attractive to farmers. Modification of management options, inclusion of certain cash plants, and modification of the technology to fit to local biophysical conditions should also be considered. Inclusion of mulberry trees between two rows of hedgerows has proved successful and many local farmers have started using this model in their own farming activities in the project areas of Ningnan. Demonstration of the Contour Hedgerow Technology with terrace farming and the conventional slope farming has also proved to be useful in educating the local people. The obvious advantages of Contour Hedgerow Technology over traditional slope farming, have been observed, e.g., great reduction in soil loss, improvement in soil fertility, and vigorous growth of crops.

Farmers' acceptance of this technology has long been debated. The limitations of this technology include the intense labour needed to manage hedgerows, lack of direct cash returns, and the space occupied by hedgerows. Interaction with farmers in the region revealed that the farmers care most about two points: competition between hedgerows and crops and the land space occupied by hedgerows, especially in comparison to terrace farming. In order to address their concerns,

**Contour Hedgerow Technology has numerous advantages over terrace farming: low cost, stability, effective soil conservation, soil fertility improvement, and availability of fodder and/or fuelwood.**

farmers were encouraged to measure the land occupied by the hedgerows and by the terrace risers. It was found that hedgerows occupy about 15-20% of farming land, which is almost the same as that occupied by terrace risers. Data indicated that the nutrient status near the hedgerows is better than that in the middle of the alley. Very vigorous growth of mulberry trees within the hedgerows also demonstrated that the competition is not as great as farmers thought it was.

It is true that hedgerows cannot generate direct cash income. But it is also true that this technology can reduce inputs by reducing the use of chemical fertilizers and increase cash return by enhancing crop yields. It should also be noted that the current conventional slope farming leads to severe soil degradation and abandonment of land. Application of Contour Hedgerow Technology provides an option for farming on a sustainable basis.

In terms of time needed for management, mainly for pruning hedgerows for green manure, it should be compared with the time taken to carry farmyard manure to the farmland. Hence, providing green manure *in situ* saves labour.

The HKH region is known for is diverse climates, biophysical background, and rich biodiversity. There are rich germ plasms of nitrogen-fixing plants in the region that have potential as hedgerow plants. The diverse conditions in the region also make it possible for the introduction of appropriate hedgerow plants from other regions. Wide application of Contour Hedgerow Technology will prevent agricultural lands from further degradation on a sustainable basis.

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**Dr. Tang Ya**
*Agroforestry/Soil Conservation Specialist*
Mountain Farming Systems
ICIMOD

e-mail: tangya@icimod.org.np



Established in 1983, ICIMOD is dedicated to the cause of poverty alleviation and environmental conservation in the Hindu Kush-Himalayan range of Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. ICIMOD is a focal point for documentation and information exchange, training, applied research, and demonstration on a wide range of issues affecting mountain people.

Editors: **Shahid Akhtar/Archana S. Karki**
ICIMOD, P. O. Box: 3226, Kathmandu, Nepal
Tel. (977 1) 525313 or Fax (977 1) 524509, e-mail: dits@icimod.org.np