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Potential Strategies for Rehabilitating Degraded Lands in the Middle Mountains of the Hindu Kush-Himalayas

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Abstract

Long-term action research on the rehabilitation of degraded lands in the middle mountains of the Hindu Kush-Himalayas (HKH) has been conducted under the Rehabilitation of Degraded Land in the Mountain Ecosystems Project (1992-96) and the People and Resource Dynamics in the Mountain Watersheds of the Hindu-Kush Himalayas Project (1996 to the present). These important regional initiatives of ICIMOD and its regional partners have sought solutions to resource degradation in the HKH. The on-site trials have taken a number of approaches. Some have been monitored for more than eight years and provide important information on potential measures to combat land degradation. This paper reports on the vegetative and supporting technologies tried out in China, India, Nepal, and Pakistan.

Introduction

Rehabilitating degraded land has many benefits for local people and the environment. It helps local people to meet their needs for food, livestock feed, fuelwood, and timber, and often increases cash incomes and land values. This in turn increases social stability. The environmental benefits include less soil erosion and the preservation of biodiversity by alleviating the need to convert remaining natural habitats.

In 1993, the six land rehabilitation case studies in Table 13.1 were initiated by the Rehabilitation of Degraded Lands in the Mountain Ecosystems Project (1992-1996) of the International Centre for Integrated Mountain Development (ICIMOD) in the mountainous areas of China, India, Nepal, and Pakistan. These studies were later taken over for long-term monitoring by the People and Resource Dynamics in the Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP). These initiatives led on from work carried out by the Mountain Resource Management Project that ran from 1989 to 1995 in Nepal (Schreier et al. 1995).

This action research on land rehabilitation tested soil and water conservation technologies and approaches to rehabilitating lands in the midhills of the Hindu Kush-Himalaya (HKH). This research recognised that the problems of degraded mountain lands in the different ecosystems of the HKH are many and varied and require different solutions. The approaches taken to rehabilitating degraded lands have been (ICIMOD 1996):

- carry out baseline surveys and rural appraisals to identify local bio-physical and socioeconomic conditions;

Table 13.1: **Land rehabilitation sites under ICIMOD's projects**

Country	Village	Area	Land tenure	Other details
China	Damai village, Baoshan district, Yunnan	45 ha denuded forest land and 7.5 ha farming land; 1370-1750 masl	Community forest belonging to 136 households	Field survey in 1992 and implemented in 1993. Implemented by Kunming Institute of Botany, Chengdu Institute of Ecology, and Kunming Institute of Biology Village community of 136 households
India	Arah, Bageshwar district, Uttar Pradesh (now Uttaranchal)	9.5 ha abandoned farmland; 1490 masl	Belonging to 86 individual households	Field survey in January 1993; started in July 1993. Implemented by G.B. Pant Institute of Himalayan Environment and Development Arah village community and ban panchayat
India	Khaderiya, Bageshwar district, Uttar Pradesh (now Uttaranchal)	4 ha abandoned farmland; 1400 masl	Belonging to 45 individual households	Survey and implementation in 1997 Implemented by G.B. Pant Institute of Himalayan Environment and Development Khaderiya, Laubanj, Puniamaphi village communities and Puniamaphi Ban Panchayat
Nepal	Godavari, Lalitpur, central Nepal	30 ha degraded forest with bushes, 1600 masl	ICIMOD test and demonstration site	Field survey in February 1993; site developed by ICIMOD from March 1993
Nepal	Bajrepare, and Dhaireni villages, Kavre Palanchok district, Central Nepal	6.7 ha and 16 ha, respectively; 890-1000 masl	Community forest land	Field surveys in March 1993; sites developed from July 1993 Implemented with Department of Forest, Ministry of Forests and Soils Conservation, HMGN Forest user groups in two VDCs
Pakistan	Tarbela and Mangal catchment, Sinkari valley, Mashera district, Abottobad Hill Division, NWFP	15 ha abandoned farmland; 1400-1550 masl	Belonging to 18 individual households	Field survey 1993; site developed from October 1993 by Pakistan Forest Institute, Peshawar Village community of 18 households

Source: Shengji and Karki 1994

- apply technical components that increase biomass and improve soil-water management;
- incorporate indigenous knowledge and locally used species and practices; and
- do environmental monitoring to assess impacts on local ecosystems.

The six types of sites provided a varying range of conditions. The Nepal sites, except for Godavari, are sloping degraded red clay (*rato mato*) dominated sites and involved working with local communities. The work at the Godavari demonstration site focussed on the natural regeneration of degraded ecosystems closed to human use. In China the village-level activities addressed issues to do with land management and economic and institutional constraints and installed vegetative and structural measures to overcome denudation (Box 13.1).

Box 13.1: **The rehabilitation of degraded lands in Damai village, China**

Existing problems:

- Forest denudation leading to surface erosion, mud and rock flows, flooding, and drought.
- Poor land management such as 'crude' farming practices, over-grazing and depletion of forest resources.
- Weak local institutions leading to weak regulation of natural resources.
- Low household incomes leading to increasing poverty and few farming inputs being applied.

Measures applied to overcome these problems:

- Engineering — building check dams and renovating degraded reservoirs;
- Revegetation — setting up local plant nurseries, community reforestation programmes, planting multipurpose hedgerow species, and promoting biogas stoves.
- Improving farming practices — introducing and promoting contour cultivation, alley cropping, organic fertilisers, improved crop rotations and soil-water conservation measures, and incorporating nitrogen fixing trees and crops in crop rotations.
- Improving incomes by introducing cash crops and trees and developing home gardens.
- Strengthening local institutions by addressing local people's land tenure needs and by involving communities in implementing the above measures.

Source: CAS 1995

In India the focus has mainly been on large areas of privately owned degraded and abandoned agricultural land. This work was facilitated by the local ban panchayats (village institutions for managing community forests). It involved extending a package developed by the G.B. Pant Institute of Himalayan Environment and Development for rehabilitating degraded lands called Sloping Watershed Environmental Engineering (SWEET; Kothyari et al. 1995). This includes recommended plant species and techniques for establishing them and for harvesting water. At the Pakistan site activities were carried out at sub-catchment level by establishing tree plantations on privately-owned abandoned farming land and on steep degraded community-owned areas. The strategy was to develop each land use under traditional practices keeping in mind the needs of local people and treating the watershed on a sub-catchment basis. The activities carried out in Pakistan have been:

- afforestation with *Pinus roxburghii* on steep slopes and ridges; and broadleaf species such as *Robinia pseudoacacia*, *Ailanthus alticima*, and *Eucalyptus camaldulensis* planted on mid-slope pasturelands; and

- improving agricultural land by incorporating perennial crops in the farming systems with robinia, hybrid poplar and fruit trees planted on terrace margins and grasses and legumes such as *Chlorus gyana*, *Lolium multiflorum*, *Sorghum almum*, *Pennisetum orientale*, and white clover planted on abandoned fields.

Lessons Learned about Rehabilitation

The outcomes of this work are presented here to document lessons learned and share PARDYP's experiences on the rehabilitation of degraded lands. This will be useful for land managers who work on rehabilitating degraded lands and researchers who measure and assess land degradation, particularly those working in the middle hills of the Hindu Kush-Himalayas.

PARDYP and its predecessor projects have found that rehabilitation should go ahead by:
- encouraging the participation of local communities and adopting approaches that encourage social cooperation and trust by way of participatory planning, execution and monitoring (Figure 13.1);
- transferring know-how to local people;
- strengthening local institutions;
- accounting for the inter-linkages between private, community and public land ownership in villages and the factors that cause their degradation; and
- monitoring the success of land rehabilitation measures.

Ground cover is crucial for stabilising slopes and controlling erosion. One particularly important area of concern in the HKH is the rehabilitation of the large areas of degraded red soils that occur extensively across the middle mountain areas in footslopes, furrows, and river terraces. Many such areas are found across Nepal (Figure 13.2). They are problematic to rehabilitate because of their low pH, low organic matter content, low available phosphorous,

Figure 13.1: **The opinions of land users govern whether new technologies and approaches are accepted (India)**

Figure 13.2: **Degraded red soil site in Nepal**

poor physical properties, and aluminium toxicity. The pronounced dry periods of these areas' climates makes them difficult to rehabilitate (Shah et al. 1995).

The rehabilitation of such sites should begin by assessing their soil characteristics and the existing vegetation cover. Stocking and Murnaghan's 2001 handbook provides many useful pointers for rapidly assessing land degradation. The following technologies and approaches have been successful in rehabilitating the project sites.

Vegetative measures for stabilising gullies

Gully stabilisation has been an important strategy for rehabilitating badly degraded land in all of PARDYP's watersheds. PARDYP and its predecessor projects have found the following to help stabilise gullies.

- The species *Agave americana*, *Dendrocalamus strictus/hamiltonii*, *Thysanolaena maxima*, *Pennisetum purpureum,* and *Vitex negundo* are good bio-engineering species for gully plugging.
- Establish nitrogen fixing trees such as *Alnus nepalensis* in combination with any of the above mentioned species on more shady and less compacted soils. These shade surrounding areas to reduce moisture loss thus encouraging natural regeneration.
- Where vegetative measures alone are not enough to stem degradation, build check dams made from soil-filled bags or stones (Figure 13.3) and then plant on them.
- Plant trees on sides of small gullies to conserve moisture and facilitate grass growth.
- Dig diversion drains, as shown in Figure 13.4a, and stabilise them by planting hedgerow species on their sides to reduce the amount of topsoil washed into gullies. This also allows runoff water to be harvested.
- Build earth-filled dams (Figure 13.4b) near the outlets of these drains and at other places to trap sediment and collect water for local use.

Figures 13.3a & 13.3b: **Gully stabilisation using bio-engineering and structural measures (Nepal)**

Figure 13.4a: **Diversion drains, Nepal**

Figure 13.4b: **A pond built to collect water diverted from a rehabilitation site, Pakistan (PFI 1994)**

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Vegetative measures for rehabilitating degraded slopes

The following measures have proved successful for rehabilitating degraded slopes.

- Establish contour lines of hedgerow species (preferably nitrogen fixing) on exposed and bare sloping areas using a modified Sloping Agriculture Land Technology approach (Pratap and Watson 1994). This involves lightly cultivating the surface of a narrow strip about 30 cm wide and then seeding the area with a few of the species in Box 13.2.

> Box 13.2: **Recommended species for planting in contour lines:**
>
> *Flemingia macrophylla*, *Desmodium intortum*, *Tephrosia candida*, *Leucaena diversifolia*, *Crotolaria juncea*, n-fixing *Indigofera species;* *Stylosanthes hamata*, *Melinis minutiflora*, *Vetiveria zizanoides*, *Sorghum alum*, *Pennisetum orientale*, *Thysanolaena maxima*, *Medicago sativa*, *Amorpha fructicosa*, *Pennisetum purpureum* (NB 21), *Cajanus cajan*, *Agave americana*, *Cotoneaster spp.*, *Ficus tikoua*, *Mucella laciocarpa*, *Pueraria lobata*, and *Vitex negundo.*
>
> Amongst species tried in Pakistan, *Sorghum alum* gave the best results. *Medicago sativa*, white clover and *Chlorus gyana* did not perform so well due to competition from naturally occurring grasses.

> Box 13.3: **Recommended species for planting on slopes:**
>
> *Cassia siamea*, *Diospyros kaki*, *Phyllanthus emblica*, *Punica granatum*, *Zanthoxyllum bungeanum*, *Betula alnoides*, *Camptotheca acuminata*, *Melia azedarach*, *Schima wallichii*, *Toona ciliata*, *Toona sinensis*, *Trachycarpus fortunei*, *Trema orientalis*, *Acacia richii*, *Albizia mollis*, *Atylosia scarabaeoides*, *Bauhinia variegata*, *Bauhinia faberi*, *Caesalpinia decapetala*, *Albizia lebbeck*, *Robinia pseudoacacia*, and *Ailanthus alticima.*
>
> *Dalbergia sissoo* often suffers from die-back problem at maturity in Nepal and is no longer considered suitable for large-scale planting;

- Plant a mixture of some of the tree and shrub species listed in Box 13.3 alternately at one metre intervals throughout degraded areas.
- As much as possible, plant locally occurring species that are suitable for the sites and preferred by local people. For example, in the PARDYP watershed in India where the land degradation problems were not so severe, villagers preferred *Grewia optiva*, *Bauhinia retusa*, *Thysanolaena maxima*, *Quercus incana*, *Quercus glauca*, *Ficus macrophylla*, *Ougenia delbergioedes*, *Debregeasia longifolia*, and *Diploknema butyracea* as they find these most useful. Their fast rate of growth is shown in Table 13.2. Table 13.3 shows the high success rates of the tree planting at the Damai China rehabilitation site.
- Select species for planting on degraded sites according to, and in order of importance, species that: 1) grow on poor sites, including hot, exposed and dry conditions; 2) grow fast and establish quickly; 3) require less inputs; and 4) are preferred by local users.
- Encourage the natural regeneration of vegetation on degraded sites. The results of studies at Arah in India (Table 13.4) and Godavari in Nepal (Figure 13.5) show how sloping areas that are not too seriously degraded can be re-greened by natural regeneration. The data from Arah shows how 26 new species came in to the site between 1993 and 2000. Although the pioneer species *Imperata cylindrica* – a C4 pioneer species – remained dominant, its dominance had decreased by 2000 and the proportion of C3 type species that prefer better soils and moist conditions had increased. The species richness and

Table 13.2: **The growth of trees planted at Arah, Uttaranchal, India**

Species	Height (cm)	
	1993	2001
Quercus incana	12	245
Quercus glauca	19	296
Grewia optiva	28	389
Ficus macrophylla	21	369
Ficus nemoralis	25	356
Debregeasia longifolia	25	396
Ougeinia delbergiodes	25	345
Bauhinia retusa	40	421
Albizia lebbeck	36	369
Dalbergia sissoo	30	496

Table 13.3: **Survival and plant canopy area of species planted at Damai, China two years after planting**

Species	Survival (% in 1995)	Canopy area (cm^2 in 1995)
Flemingia macrophylla	100	1,525
Crotalaria assamica	90	758
Tephrosia candida	95	141
Cajanus cajan	95	8,153
Cassia siamea	90	14,427
Acacia richii	95	2,057
Acacia mangium	20	not available
Acacia meansii	70	364
Albizia mollis	95	1,398
Leucaena leucocephala	95	1,612
Eucalyptus robusta	90	286

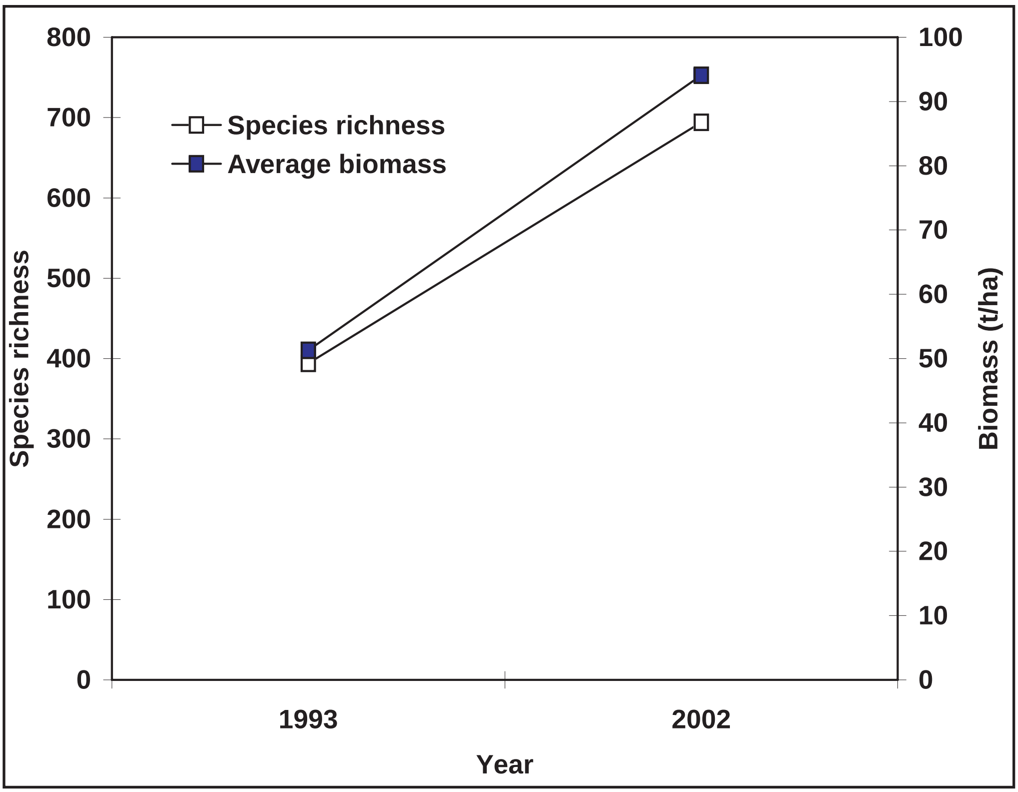

Figure 13.5: **Change in average biomass and species richness through natural regeneration of a degraded forest site, Godavari, Nepal** (Joshi 1994, 2002)

Table 13.4: **Changes in the importance of species growing naturally on the Arah rehabilitation site (India)**

Species Names	Importance value index	
	1993	**2000**
Imperata cylindrica	128.45	96.33
Indigofera dosua	38.76	45.60
Erianthus rufipilus	19.11	16.56
Chrysopogon serrulatus	21.27	9.67
Cassia mimosoides	7.60	9.56
Desmodium triquetrum	10.00	8.23
Oxalis corniculata	6.00	7.16
Micromeria biflora	8.00	5.63
Heteropogon contortus	0.00	5.20
Potentilla fulgens	4.06	4.86
Setaria glauca	0.00	4.57
Fimbristylis miliacea	0.00	4.12
Dicanthium annulatum	0.00	3.98
Begonia picta	3.56	3.78
Adiantum lanulatum	1.00	3.56
Crotalaria semialata	3.23	3.56
Polygala abyssinica	1.00	3.46
Bothriochloa pertusa	0.00	3.45
Erigeron canadensis	4.00	3.41
Scrophularia calycina	3.63	3.16
Arundinella nepalensis	0.00	2.93
Cyperus compressus	0.00	2.90
Calamintha umbrosa	3.00	2.65
Origanum vulgare	3.00	2.63
Valeriana wallichi	0.00	2.56
Zornia gibbosa	0.00	2.56
Barlaria cristata	0.00	2.52

Note: 1) only the 27 species recorded the most in 2000 of the total of 54 are listed here.
2) a 0.00 value for a species means that it was not present. 3) The importance value index is the sum of relative dominance, relative frequency, and relative density of a plant species in a community.

average amount of biomass almost doubled through natural regeneration over 10 years at Godavari. The low cost of this technique makes it appealing to communities.

- Plant tree species at intervals of at least 1m to avoid too much competition for water and nutrients. It is best to plant at least one-year-old saplings grown inside nursery bags to plant in 0.5 m^3 sized pits and to add farmyard manure or humus-rich forest soil into the pits.
- Set up on-site nurseries (Figure 13.6) to ensure a supply of healthy seedlings. This also helps generate a local pool of native and potential exotic species. The growth of nursery plants can be increased by raising them inside polypits (Vyas et al. 1999).

Figure 13.6: **An on-site nursery in Bheta Gad watershed, India**

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- Install low-cost water harvesting technologies such as simple polythene-lined ponds (Figure 13.7), to address short-term water needs. These ponds and the mulching of seedlings can overcome water scarcity problems. Where water is available all year round these ponds can be used for other purposes such as irrigating off-season vegetables and fish farming (Kothyari et al. 2002).

Figure 13.7: **Polythene lined water harvesting tanks in (a) Arah rehabilitation site (India) and (b) a rehabilitation site in Nepal**

- Make contour ditches or eyebrow 'terraces' (pits) (Figure 13.8) to help harvest surface runoff and conserve soil and increase the infiltration potential of land. Material planted along the bunds of these 'terraces' have a better chance of survival and good growth rates as they exploit water from the pits. Eventually the pits become filled with eroded soil.

Figure 13.8: **Eyebrow terracing at a PARDYP site in Nepal**

Benefits of Land Rehabilitation

The main benefits of rehabilitating the degraded sites have been:

- reduction in soil loss and runoff (Figures 13.9, 3.10), and increased soil fertility thereby maintaining the total stock of soil nutrients available to future crops; and
- increased biomass production (Table 13.5; figures 13.11, 13.12) and plant biodiversity meaning that women have to travel shorter distances to collect firewood and fodder, and making it easier for livestock herders to find dry season pastures.

Next Steps

Table 13.5: **Changes in grass production (dry weight), Khaderiya, India**

Year	Quantity of grass produced	Market value (US$)
1999	1.2	31
2000	4.3	131
2001	5.3	161
2002	7.0	213

Kothyari et al. 2003. Note: US$1:IR 46

The findings from the projects and other rehabilitation sites in the HKH suggest that there is a need to:

- carry out further trials to investigate the preliminary findings of Shah et al. (1995) suggesting that planting nitrogen-fixing fodder trees and grasses and applying lime on acidic red soils is a potential technique for rehabilitating these difficult sites;
- carry out in-depth studies across the PARDYP region of species growing naturally on degraded sites to identify other potential species for growing on dry, exposed, and degraded sites;

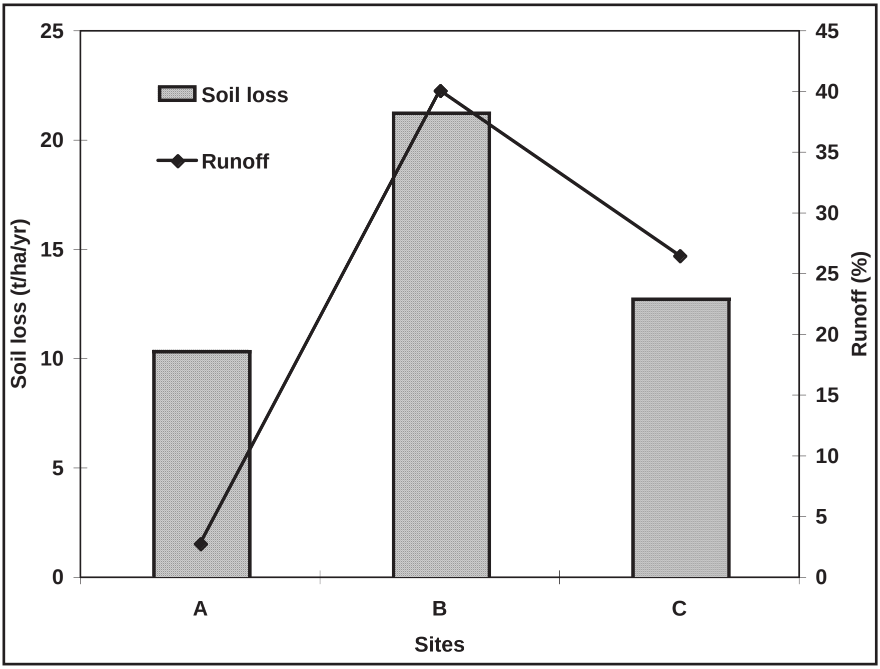

Figure 13.9: **Comparison of soil loss and surface runoff from three land use types in the Jhikhu Khola watershed, Nepal (A: sloping agriculture terraces, B: degraded red soils, and C: degraded plot in site B treated with broom grass)** (Mathema & Singh 2003)

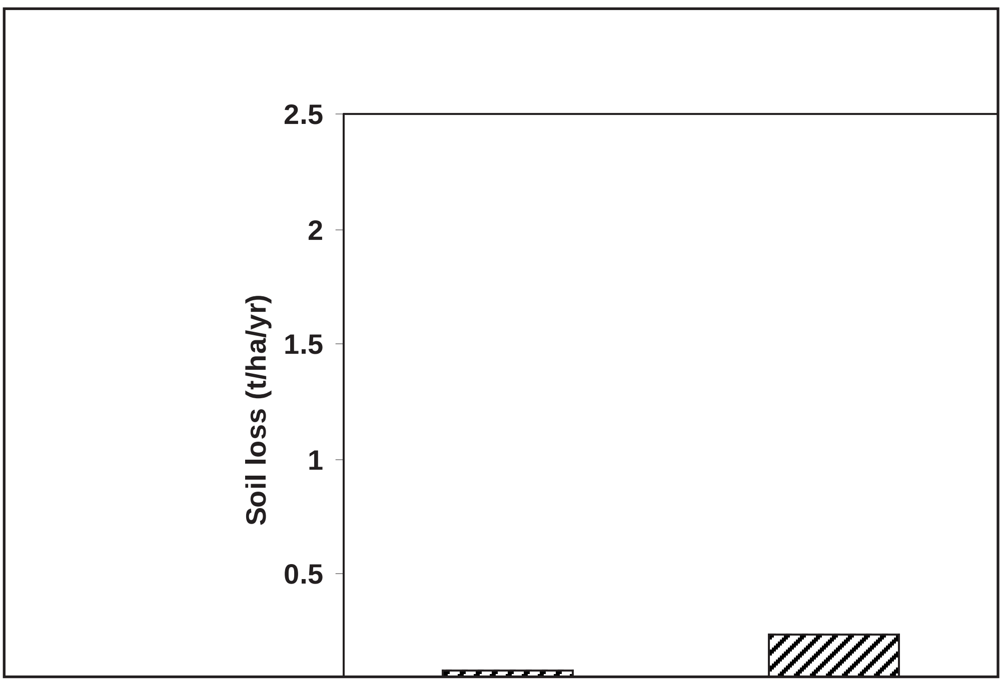

Figure 13.10: **Comparison of soil loss after 2 years of rehabilitation work showing treated and untreated (natural bare) areas, Damai, China** (Anonymous 1995)

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Figure 13.11: **In Arah (India) the rehabilitated site produced 5.5 t/ha of grass in 2001 compared to 1.2 t/ha in 1993 before rehabilitation**

Figure 13.12: **In Nepal, grass harvested from the rehabilitated site in the centre of the picture was 10 times more than from untreated degraded areas as in the foreground**

- identify species most preferred by local farmers. A case study from Nepal (Baral et al. 1999) found that a species of *Cassia* that grew well on degraded slopes was not liked by local users;
- identify where forest regulations hinder the planting of certain species. Some countries limit the right to harvest certain valuable tree species which dissuades people from planting them;
- carry out further tests of farm-based technologies, such as polypits and biofertilisers, to see if they help plant establishment in degraded areas;
- carry out further research on how to reduce the large amounts of stream sediment that Merz's 2003 study identified as coming from degraded surfaces. This could be done by identifying potential soil and water conservation species;
- prepare lists of organisations working on the rehabilitation of degraded lands in the HKH region to facilitate networking and share experiences; an
- further investigate the following non-technical issues:
  - **land tenure** is of crucial importance as farmers and communities with clear title to land are more likely to invest in conservation measures as they are assured of benefiting. For example, the government owns Nepali community forestry sites and so users are not assured of their continued tenure and are sometimes reluctant to invest in their improvement (Karki and Chalise 1995);
  - **poverty** affects how land users manage and develop their land. Poverty-stricken people are unlikely to carry out conservation practices that need too much investment of time, land, labour and capital;
  - **economic incentives** can have a negative effect as conservation measures that attract direct financial inducements that are later withdrawn can dissuade farmers from practising conservation without payment later on;
  - **economic and financial returns** as decisions made by land users are sometimes based on their particular perceptions of economic rationality; and
  - **off-site versus on-site costs** as few land users living upstream will invest in measures that benefit downstream communities unless they receive incentives.

Conclusions

Many of the above findings are site specific and need further testing to assess the conditions where they can be applied. Species choice is in many cases dependant on local soil and climatic conditions. However, the common occurrence of similar types of degraded areas across the HKH provides good scope for replication. Areas of red soils in Nepal are of special concern as they have estimated erosion rates of up to 200/t/ha/yr (Biot 1990). China also has many areas of degraded red soil (Zhang 1991). In the Indian central Himalayas large tracts of rainfed agriculture fields are abandoned and degraded. There is therefore a great potential for applying PARDYP's findings and more attention needs to be given to disseminating them to the main target audiences of community users and land managers.

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