Rehabilitation of Degraded Lands

P. B. Shah, H. Adhikari, G. Nakarmi and B. Shrestha
Mountain Resource Management Project, International Centre for Integrated Mountain Development, ICIMOD, Kathmandu, Nepal

1. INTRODUCTION

Degraded sites, make up about 5% of the watershed, which are defined as surfaces that are dissected by gullies and rills, have minimal vegetation cover and are no longer under daily use except for collection of fodder and firewood. From the results provided by Carver et al. (1995) such surfaces are a major source of sediments and are likely the greatest single factor contributing to the annual sediment budget in the stream. Given the very intensive land use in the watershed these degraded sites represent the only land areas that do not contribute to consumptive biomass production. Agricultural intensification has led to shortages of cultivatable land and many marginal lands are being converted into agriculture. Until now there has been little emphasis on rehabilitating degraded lands because the task of stabilizing such sites, and returning the remaining soils into production is a formidable one. Few farmers consider the rehabilitation of such sites a viable option but pressure on the land, the continuous environmental problems caused by erosion originating from these sites, and the long term consequences on sedimentation downstream suggest that some innovative rehabilitation efforts are needed. The idea of a demonstration site was formulated in 1993 and a number of agro-forestry experiments have been initiated since that time.

The site chosen is located below Luitelgaun and covers an area of about 2.5 ha of very badly degraded land dominated by red soils. Over the past 20 years all trees were removed from the site and extensive and continuous collection of fodder and litter has resulted in massive rill and gully erosion. During every monsoon season massive headcutting and accelerated erosion occurs at the site and the off site impact on the stream and irrigation systems downstream are serious. A number of experiments were conducted in an attempt to improve soil fertility conditions, stabilize the gullies and introduce an agro-forestry system. An overview of the site at the time the experiments were initiated is provided in Figure 1.

2. EXPERIMENTS INITIATED BETWEEN 1993 AND 1994

There are no quick solutions to rehabilitate a site which is as degraded as that shown in Figure 1. A long term approach is needed because moving and redistributing the remaining soil material will not stabilize the soils and the nutrient status of all material at the sites is very depleted. The key issues are: (1) ameliorate soil nutrient conditions in the absence of large amounts of manure and fertilizer inputs, (2) stabilize the soils and eliminate or significantly reduce surface run-off, (3) provide a local supply of plant material that can be used for stabilizing the soils and improving the soil conditions and (4) improve the water availability at the site with appropriate irrigation systems that benefit the plants but minimize run-off.

The problem of site rehabilitation is not entirely solved by establishing a vegetation cover because farmers need production capacity, and there must be some economic benefits even early in the reclamation program. It is for these reasons that the following five experiments were initiated:

1. lime experiment using grasses and fodder trees,
2. gully stabilization project using checkdams and sisal,
3. establishment of a vegetable and fodder tree nursery,

Figure 1. Overview of demonstration site for agro-forestry experiments.

4. introduction of trickle irrigation and
5. development of an agro-forestry system with N-fixing fodder trees serving as hedgerows.

2.1. Lime Experiment Using Grasses and Fodder Trees

The problems of red soils, acidity and aluminum toxicity have been documented by Schreier et al. (1995). The pH of the red soils at the site range between 4.2 and 4.6, and in this range Al solubility is likely causing phosphorus deficiencies. The available P values at the site are all below 10 mg/kg, which is considered a very poor nutrient range. On a completely barren red soil surface and a 4x3 experiment was initiated in 1993 that included a lime/manure trial with grasses and fodder trees. The design of the experiment is provided in Table 1. A 40x3 m surface area was divided into 12 compartments of 10x1 m in size and a 40x1 m strip was used for the biomass trials. Segment A was used as a control, lime was applied to segment B, manure was applied to segment C, and a combination of manure and lime was applied to segment D. The third strip was left alone to determine natural recolonization rates.

Table 1. Design of plot experiment to improve soil acidity and determine plant response.

Segment A	Segment B	Segment C	Segment D
No additions	Limestone addition (rate: 20 T/ha)	Manure addition (rate: 20 T/ha)	Lime and manure (rate: 20 T + 20 T/ha)
Grasses	Grasses	Grasses	Grasses
N fixing fodder trees	N fixing fodder trees	N fixing fodder trees	N fixing fodder trees
No planting	No planting	No planting	No planting

To make the experiment realistic, the treatments were only applied once at the beginning. *Bauhinia purpurae, Litsea monopetala, Artocarpus lakoocha* and *Melia azedarach* were the main fodder trees, and *Desmostachya bipinnata, Typha angustifoloa, Imperata cylintrica, Eulaliaopsis ninata,* and *Saccharum spontaneum* were the main grass species used in the experiment.

During the first year we had significant insect and disease problems, and plant production was small because the soil surfaces desiccate significantly during the dry season. The plant response was much better during the second year, and the results so far indicate that for the grasses the combined treatment was the best while the fodder trees did slightly better in the manure treated plot. The lime application did increase the soil pH between 0.2 and 0.4 pH units two years after the treatment application. No natural revegetation occurred on the control plots or those reserved for natural regeneration with treatment, suggesting that the soil and site conditions are very difficult for the support of plant growth.

2.2. Gully Stabilization

Two headwater gullies were selected for a paired gully system study. One was left without modification and the other was stabilized using simple check dams, sisal and grasses. Each gully was surveyed with a theodolite in the field before the 1994 monsoon season and after the monsoon season . The same survey will be conducted at the end of the 1995 monsoon season. This will allow us to determine how much change has occurred in the gully headwalls and how much sediment was lost during the rainy season between unaltered and slightly modified conditions. Some 300 control points will be used to model the surfaces and erosion rates using 3D plotting routines.

2.3. Establishment of a Fodder Tree and Vegetable Nursery

As shown in the paper by Shrestha and Brown (1995), native nitrogen fixing fodder trees have been identified as appropriate trees for afforestation in the watershed. In order to rehabilitate such a large degraded area, a constant supply of plant material is needed. We decided to use an agro-forestry system where native nitrogen fixing fodder trees are planted in hedgerows and vegetables and other marketable crops between the rows to produce food, fodder and litter.

A nursery was set up near the Andheri Khola stream, and seeds and seedlings were collected from many sources over a two year period. The reasons for the establishment of the nursery were three-fold: (1) to make available a large number of native nitrogen fixing fodder trees for constructing hedgerows and for future distribution to farmers, (2) to provide a constant supply of marketable crops, and (3) to provide a centre for bio-diversity in native species.

It is often difficult to obtain the seeds of native nitrogen fixing fodder trees since the pressure for fodder is intense, and excessive lobbing of trees prevents blooming and seed generation. With the help of Mr. Batta and his group at ICIMOD, we were able to obtain an initial set of trees and grass species and subsequent efforts have yielded the results shown in Table 2.

The second focus was on vegetable production because growing basic staples between hedgerows is not an attractive proposition in these degraded sites. Since the site is in close proximity to the Kathmandu market it was decided to grow selective vegetables in the nursery for transplanting. This included cauliflower, zucchini, cucumbers, watermelons, sweet pepper, tomatoes and eggplant. Annually some 500 plants were produced, and at least half were distributed to the farmers as an incentive for collaboration in future on-field trials.

The idea is to demonstrate that if a crop with high market value can be grown the need for crop intensification (several crops rotations per year) is not as high. This would allow degraded sites to be at least partially productive while the process of soil amelioration is taking place.

2.4. Introduction of Trickle Irrigation

Since the soils are desiccated during the dry season and surface plant cover is minimal, it was felt necessary to introduce some irrigation capacity. As shown by Carver and Nakarmi (1995), surface cover at the end of the dry season is critical for erosion control, particularly when the first monsoon rains occur. This requires water, and the only way to bring water to the site is by pumping water from the stream to the various planting sites. To solve the elevation problem, a solar pump was installed and storage reservoirs were constructed to provide a constant water supply during the dry season.

Table 2. Tree and fodder species produced since January 1994.

Plant Species (Nepali Names)	Number of seedlings produced	Number of seedlings planted at the site
Sissoo, *Dalbergia sissoo*	2093	207
Khayar, *Acacia catechu*	887	91
Nimaro, *Ficus auriculata*	441	7
Palowinia elengata		47
Flemengia, *Flemengia macrophylla*	342	623
Teprosia	1487	256
Sapan, *Cassia siamea*	57	509
Delonix	50	36
Sunhemp, *Crotolaria pallida*	1615	1000
Bakaino, *Melia azedarech*	399	156
Rato Siris, *Albizzia procera*		60
Tanke, *Bauhinia purpurea*		153
Kalo Siris, *Albizzia lebbek*		183
Kutmiro, *Litea monopetala*		82

The water is stored in oil drums and galvanized containers, and a very low cost trickle irrigation system was initiated below a number of storage containers. A network of many small 3-10 mm size hoses was connected to the tank, and a inexpensive flow controller was added to the end of the tube. The optimum rate is a 2 L/hour controller. The outlet is placed next to each plant, and water is applied by gravity for about 1-2 hours per day, depending on crops and time of the year. An example of the system is provided in Figure 2. The results obtained to date are encouraging because the method is water-conserving, and the problem with sediment inputs into the irrigation water was solved by including sediment filters in the irrigation system.

Figure 2. Example of a trickle irrigation system.

2.5. Development of an Agro-forestry System with N-fixing Fodder Trees Serving as Hedgerows

The experimental site was divided into 30 x 30 m sections, and simple 1 m wide terraces were constructed on top and bottom of each section. Hedgerows of native, nitrogen fixing fodder trees were planted on the terraces at the top and bottom of each segment. The terraces were built across the slope, and in order to improve tree survival, an initial treatment of 4 t/ha of manure was applied to each terrace, and in selective rows, lime was applied at a rate of 3t/ha. This was a once only treatment and will not be repeated. A plan view of the design is provided in Table 3, showing the location of the different hedgerows, species used, and treatment received.

The tree seedlings were planted in two rows in each terrace with 50 cm spacing between trees. The first year survival rate of the fodder trees was 86% and after one year we found that most hedgerows reacted more positively to the lime treatment than those without lime treatment.

The actual performance of the different species was variable, and the results provided in Table 4 showed that Sissoo was the most successful tree at the site with plant heights of up to 255 cm within one year. Siris performed significantly better in the lime treated site and Khayar did not respond to lime. After one year, the most successful colonizer was Sissoo and the poorest Kutmiro.

All land between the hedgerows was used for agriculture (mainly vegetable and fruits), and a number of pioneer crops were planted to establish organic matter, and use nitrogen fixers to overcome the nutrient deficiencies inherent in the site. The most interesting experiments are to be initiated in the upcoming season. Once the hedgerows are well established, they not only fix nitrogen, but their litter adds organic matter to the soil. Three sites were set up to incorporate the first hedgerow cuttings for augmenting organic matter in the soils. The hedgerows are designed to be cut back regularly so as to produce fodder and firewood and to minimize the shading effects for agriculture. The experiments are designed to measure the rate of fodder tree material decomposition, the rate of organic matter accumulation, and the rate of soil nutrient improvement from this composting and green manuring practice. The first input is scheduled for August 1995 since the hedgerows will be sufficiently developed at that time to survive cutbacks.

Table 3. Plan view of hedgerow experiments with nitrogen-fixing species.

	Plots of 30 x 30 m in size used for nitrogen-fixing fodder tree experiments				
Fodder Tree Species Lime Experiment Parent Material	Siris A1 No Lime Quartzite	Gully Experiment			
Fodder Tree Species Lime Experiment Parent Material	Sissoo B1 Lime appl. Quartzite				
Fodder Tree Species Lime Experiment Parent Material	Khayar C1 No Lime Quartzite	Field Camp, Vegetable Garden, Soil Rehabilitation Experiments			
Fodder Tree Species Lime Experiment Parent Material	Tanke D1 No Lime Quartzite	Siris D2 Lime appl. Red Soils	Kutmiro D3 Lime appl. Mixed	Bakaino D4 No Lime Saprolite	Sissoo D5 Lime appl. Red Soils
Fodder Tree Species Lime Experiment Parent Material	Siris E1 Lime appl. Quartzite	Bakaino E2 No Lime Red /mixed	Tanke E3 No Lime Saprolite	Kutmiro E4 No Lime Siltstone	Siris E5 No Lime Red Soils
Fodder Tree Species Lime Experiment Parent Material	Soil Rehabilitation Experiments	Sissoo F2 No Lime Quartzite	Khayer F3 Lime appl. Quartzite	Bakaino F4 Lime appl. Quartzite	Sissoo F5 No Lime Red Soils
Fodder Tree Species Lime Experiment Parent Material		Empty Plot		Paulowinia No Lime Quartzite	Paulownia No Lime Quartzite

3. CONCLUSIONS

The activities at the demonstration site have created significant interest and many curious farmers regularly visit the site. Initially there was much scepticism, and the idea of rehabilitating badlands was considered too daunting a task for the subsistence farmers. However, the successes during the first year have been sufficiently encouraging that some farmers are starting to rehabilitate other adjacent sites. The seedlings supplied by the project are freely distributed and this has created considerable goodwill with the community. It is hoped that this will lay the foundation for future collaboration in terms of on-farm trials with nitrogen fixing crops and fodder trees.

Table 4. Performance of hedgerow species.

Plot No.	Species	Treat-ment	Height (cm)	% Survival	Height (cm)	Diameter (cm)
			at planting	180 days after planting		
A 1	Siris	T 1	36	57	50	0.5
D 2	Siris	T 2	14	84	25	1.4
E 1	Siris	T 2	17	98	37	1.5
E 5	Siris	T 1	12	100	18	1.5
B 1	Sissoo	T 2	84	100	255	7
D 5	Sissoo	T 2	83	96	124	6.4
F 2	Sissoo	T 1	75	100	160	6.4
F 5	Sissoo	T 1	31	97	43	3.6
C 1	Khayar	T 1	37	100	79	2.4
F 3	Khayar	T 2	9	98	11	0.5
D 1	Tanki	T 1	46	87	79	3.4
E 3	Tanki	T 1	36	89	32	1.5
E 2	Bakaino	T 1	32	52	40	1.3
D 4	Bakaino	T 1	22	89	31	0.5
F 4	Bakaino	T 2	13	52	25	2.2
D 3	Kutmiro	T 2	11	89	11	0.5
E 4	Kutmiro	T 1	9	89	9	0.5

Treatment = T 1: 4 T /ha Manure only, T 2 : 4 T/ha manure and 3 T/ha lime

Although the experiments are only in the early stages some preliminary conclusions can be made:

1. The establishment of a tree nursery, which focusses on the production of native, nitrogen fixing fodder trees, has been very successful by providing a continuous source of seedlings needed to stabilize the degraded area but also by acting as a distribution centre while maintaining the gene pool of key N-fixing native species.

2. Sissoo (*Dhalbergia sissoo*) has proven to be the best pioneering species. It had the best survival and growth rates and responded well to lime treatment. This species appears to be best suited for the desiccated and nutrient-poor site conditions that exist at this low elevation site (800-900 m).

3. Soil amendments are necessary to ameliorate the overall physical and chemical conditions at degraded sites. The combination of N-fixing fodder trees, lime application and nitrogen fixing crops

appears to be an appropriate recipe for low input reclamation. The research today should be considered the first step in the long term program of stabilizing degraded sites, generating useful biomass early in the program and improving the depleted soil conditions.

4. REFERENCES

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