Chapter 11

Rehabilitation of Degraded Lands in Mountain Ecosystems: A Technical Report of Plantation Establishment in Nepal

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Background

Situation of Degraded Mountain Lands

The world's future food supply is threatened because of the damage done by mankind to more than a tenth of the earth's fertile soil since 1945, an area the size of China and India combined. A report on the study 'World Resources 1992-93', released by the Washington D.C.-based World Resources' Institute, estimates that about 1.2 billion hectares of land (about 11 per cent of the earth's soil cover) have eroded in the last 45 years. A global assessment of soil degradation found two-thirds of all seriously eroded soils in Asia and Africa where most of the world's poor live. The vast majority of the damaged land is in Asia, with 45.3 million hectares, and in Africa, with 321 million hectares, where most of the world's poor subsistence farmers live.

According to Dr. Frank J. Dent, a soil scientist from the FAO, the unabated erosion of topsoil - the thin uppercrust of the earth's surface on which man plants his food crops - is most evident in the following countries of Asia.

Bangladesh - The total degraded land area is now 989,000 hectares, or 7.9 per cent of the country's total land area.

China - The average annual soil loss through erosion is estimated at five billion tonnes. Areas classified as degraded or "critical" are estimated to total 43 million hectares, or about 24 per cent of China's total land area.

Laos - The total degraded land area is estimated at 8.1 million hectares, or about 35 per cent of the country's land area.

Myanmar - The total eroded land area is approximately 210,000 hectares, or 3.2 per cent of Myanmar's total land area.

Pakistan - About 8.1 million hectares have been lost through wind erosion and another 7.4 million hectares through water erosion.

Sri Lanka - The total degraded land area is estimated at 0.7 million hectares, or 10.8 per cent of the country's total land area.

Thailand - Some 17.2 million hectares, or 33.7 per cent of the total land area, have been lost through water erosion.

The Philippines - Soil erosion has been identified as one of the most pressing ecological problems. About 60 per cent (8.25 million hectares) of the total agricultural land is severely eroded. In addition, 9.3 million hectares of hilly and mountainous land are highly susceptible to erosion.

Nepal is a country of hills and mountains which cover about 83 per cent of its total area. Only about 17 per cent constitutes the plains, also called the *terai* region. Some 240 million tonnes of soil are being lost annually. As a result, the bed levels of the *terai* rivers are rising by 15 to 30 centimetres every year. About

70 to 80 per cent of the slopes are cultivated to produce more food to feed the country's growing population. Farmers cultivate their steep lands on the hills without making terraces, thus increasing the slope length and accelerating soil erosion. Overgrazing is another cause of accelerating soil erosion. People keep a small number of unproductive cattle. They barely get one to two litres of milk from each cow. As they cannot feed the cows themselves they leave them in the forests for random grazing.

Degradation of mountain ecosystems is a global problem and the Himalayas constitute one of these threatened ecosystems. Environmental degradation in the Himalayan region is basically a result of human intervention in the use of various natural resources, namely, land, forests, pastures, water, and minerals. Land degradation has a serious impact on the economy and environment. On public land, the immediate impact is evident from the loss of forest cover, directly affecting fuelwood and fodder supplies, and also from changes in livestock output which influence household food and income levels. On private land, the impact is seen in terms of the lower output of different land-based products. The long-term effects on ecosystems are even greater, resulting in the irreversible loss of productive resources, options for survival, and habitable environments.

Approaches to the Rehabilitation of Degraded Mountain Lands

Rehabilitating degraded mountain land and making it more useful and productive is a big challenge. The different approaches to solving degraded land problems can be divided into three basic categories.

- Direct interventions on degraded lands, focussing on various types of land maintenance activities, changes in land use, and many other related, on-site activities affecting soil erosion and land productivity
- Indirect interventions such as those dealing with the development of suitable technology, reforms in land holding and tenurial structures, reducing population pressure, land-use planning, and policy-related incentives or disincentives for promoting positive land use
- Interventions outside degraded lands, focussing on off-farm employment, intensifying land use in other more suitable areas, and reducing off-site impacts

It is obvious that for on-site development direct interventions are important and will account for all the field work. This paper discusses the findings of two field-based case studies in Nepal.

The problems of degraded mountain land in different mountain ecosystems of the Hindu Kush-Himalayan Region are many and varied. Generally, there are four types of degraded land in this region.

- Bare sloping lands in temperate areas distributed throughout the trans-Himalayan mountains

  Basic characteristics: altitudes from 2,500-4,000m; cold and dry climate; precipitation from 300-600mm; scarce vegetation cover

- Bare sloping land in subtropical areas distributed throughout the middle Himalayan hills

  Basic characteristics: altitudes below 1,500m; warm and dry climate; precipitation from 800-1,500mm; scarce vegetation cover

- Degraded forest land in temperate areas distributed throughout the middle Himalayan hills

  Basic characteristics: altitudes from 1,500-2,500m; cool and wet climate; precipitation from 800-2,000mm; rich vegetation cover

- Degraded forest land in subtropical areas, distributed throughout the lower Himalayan hills

  Basic characteristics: altitudes below 1,500m; warm and dry climate (for six months in a year); precipitation from 800-1,500mm; rich or moderate vegetation

The methods are not the same for dealing with different types of degraded lands, but the principal measures can be summarised as follow:

- biological control measures which are primarily used and are sustainable and cheap,
- engineering control measures which are secondary, limited, and expensive, and
- agronomic control measures which are ordinary, limited, and cheap.

Biological control measures are commonly used and have achieved remarkable results in many countries, being the best way to rehabilitate degraded land in mountain ecosystems.

In order to test and demonstrate possible approaches to solving the problem of land degradation, a project entitled 'Rehabilitation of Degraded Lands in Mountain Ecosystems', funded by IDRC, Canada, was established in 1993 and two comprehensive case studies have been implemented in Nepal. Encouraging results have been seen which can be shared with other areas with similar problems.

Description of Trial and Demonstration Sites

Godavari Site

Location: Godavari is in the southeast of the Kathmandu Valley. It is under the administration of Lalitpur district. Its total area of 30 hectares varies in altitude from 1,550m to 1,800m. The whole site is located on a sloping catchment base (5°-30°) with a wide range of gradients, ridges, gullies, and many small watersheds and swamps.

Climate: Most of Godavari is in a warm, temperate area but its northern corner, situated at the lowest place on the site, is warm enough for growing subtropical plants. The mean annual temperature is 16.6°C, with a minimum of -1.7°C in January and a maximum of 23.9°C in May. The average annual precipitation is about 2,000mm and most of it is concentrated in the monsoon season (June to September). The relative humidity is approximately 76 per cent. Occasionally, there are hailstorms, normally in May or June.

Soil: The soil in Godavari is mostly brown-forest soil. This can be divided into three major groups: loam/silty loam over loam; loam over clay loam/silty clay loam; and clay and clay loam silty loam. (Soil classification is according to the United States Department of Agriculture [USDA] Soils Taxonomy). The soil depth at middle range is moderate to deep (approximately 25-100cm, more in some places) due to the fact that it is colluvial soil. The soils on site are generally fertile compared to those on land uncovered by vegetation. The chemical properties are: pH 4.6 - 7.6; organic carbon 0.1 - 6.4 per cent; nitrogen content 0.03 - 0.6 per cent; available phosphorus content 1-22ppm; and exchangeable potassium 0.1 - 0.8me/100g. The nutrient conditions on site are fairly good except for the deficiency of phosphorus due to the acidic soil.

Vegetation: The natural vegetation of the whole Godavari Watershed Area is very rich. It is dominated by mixed forests with evergreen and deciduous forests. On the upper part of the site, there is a dense forest of *Schima wallichii, Castanopsis indica, Castanopsis tribuloides, Alnus nepalensis, Stranvaesia nussia, Machilus gamblei, Michelia champaca, Michelia Kisopa, Carpinus vimineu, Myrsine semiserrata, Rhododendron arboreum, Lyonia ovalifolia, Litsea oblonga, Lindera* sps., *Symplocos* sps., *Cleyera ochnacea*, and *Albizia mollis*. Unfortunately, parts of this forest have been destroyed through continuous and excessive removal of the most useful species by human beings for fodder, fuel, timber, and charcoal-making and also by forest fires. On the lower part of the site, natural forest species have been overwhelmed by the invasion of thorny shrubs, bushes, and weeds such as *Flacourtia indica, Pyrus pashia, Rubus* spp., *Rosa brunonii*, and *Eupatorium adenophorum* which are neither used by human beings nor eaten by cattle. The remaining coppices, stumps, and defaced scattered trees represent the natural vegetation of the Godavari site. In spring and winter the local people go daily to Godavari to collect fodder and fuelwood. As a consequence of human intervention, less useful species have gradually dominated the biomass on the site, i.e., they account for 79 per cent of the natural forest and 96 per cent of the shrubland on the slopes. The Godavari site is a

typical degraded forestland with poor biomass and less useful species, a landscape common in the Hindu Kush-Himalayan Region.

Dhaireni Site

Location: Dhaireni is located in Kavrepalanchok district about 45 kilometres from Kathmandu. The total area is 15.9 hectares and the altitude is from 900-1,900 metres. The whole site is on a south-facing slope (10° - 25°) with a wide range of gradients, ridges, and gullies.

Climate: Dhaireni is in a subtropical area. The mean annual temperate is 21°C, with a minimum of 0°C in January and a maximum of 35.5°C in May. The average annual precipitation is about 1,000-1,200m, mostly during the monsoon season (June to September). As this area receives no water apart from the monsoon rains, drought is the basic problem.

Soil: The soil on this site has been identified as mostly red earth soil, the same as in most degraded areas in the Jhikhu *Khola* watershed of Nepal. The main soil type is red clay loam, characterised by its poor organic matter and low infiltration due to a lack of vegetation cover. The soil pH varies between 4.4 and 6.6 and the cation exchange capacity (CEC) is fairly low. If the soil pH drops below 4, the low CEC inhibits the availability of nutrients to the plants. The organic carbon content of the soil is 0.02-0.89 per cent and the nitrogen content is 0.02-0.12 per cent. Both the carbon and nitrogen content are very low and cannot satisfy the needs of most plants. The available phosphorus content is 0.2-2.6 ppm. The soil under *sal* (*Shorea robusta*) trees and in mixed forests has a good phosphorus content (2.4- 2.6 [ppm]?).

Vegetation: On the Dhaireni site, natural vegetation is scarce and thriving natural forests are rare. About 3.8 per cent of the land is under chir pine (*Pinus roxburghii*) trees which were planted in 1973, 10 per cent of the land is under scattered chir pine, and 22 per cent of the land is barren with gullies. Seasonal streams account for eight per cent of the area and four per cent of the land is covered with stunted pines. The experimental study mainly concentrates on the barren land and gullies. Due to frequent intervention by felling wood, collecting fuel and leaves, and grazing, both natural and planted forests have been heavily damaged and thus vegetation types and species are poor. The main trees on the site are *Pinus roxburghii, Ficus semicordata, Lyonia ovalifolia, Shorea robusta, Castanopsis indica,* and *Terminalia* spp. The main shrubs are *Woodfordia fruticosa, Lantanu camara, Rhus parviflora, Colebrookia oppositifolia,* and *Euphorbia* spp. The main grass species are *Heteropogon contortus* and *Eupatorium adenophorum*. The soil condition and soil moisture in Dhaireni are so poor that very few trees and shrubs, useful or otherwise, can grow well. The total vegetation coverage, most of which consists of less useful species, is 10-15 per cent of the total land area.

Establishment of Plantation Models

The farmers in the hills and mountains of the Hindu Kush-Himalayan Region are small landholding farmers with very limited land for cultivation. Their daily subsistence, therefore, relies very much on community or public forests for fuelwood, fodder, grazing, and, sometimes, for generating cash income. The idea of establishing plantations is based on the farmers' own demands.

Farmers in the mountains have been practising terraced agriculture for centuries, but population pressure has forced mountain farming communities to encroach upon unstable and steeper sloping areas which are prone to soil erosion and slope failures. Sloping Agricultural Land Technology (SALT), developed in the Philippines, has proven to be effective for soil and water conservation, minimising runoff and soil erosion, and enhancing soil fertility to improve productivity. SALT methodology takes into consideration soil erosion control and provides opportunities for the optimal use of sloping land through bioterracing, e.g., using hedgerows to stabilise slopes without terracing. This technology is cost-effective and easy to operate and, therefore, in designing models for degraded land on the Godavari and Dhaireni sites the key concept of SALT has been used and tested.

The following models have been established for trial and demonstration.

Model 1 - Multicrops and Hedgerows

The area of Model 1 on the Godavari site is approximately one hectare with a slope of 10°-20°. The purpose of the model is to set up a 'multicrops' system in alleys between hedgerows in order to produce as many crops as possible to meet farmers' daily needs. The crops include various cereals, legumes, vegetables, and fruit trees. The crop rotation system has been introduced in different alleys in order to maintain the soil fertility level. Ten hedgerow species have been tested, out of which five are promising.

Model 2 - Fruit Trees, Fodder Crops, Timber Trees, and Hedgerows

The area of Model 2 covers about 0.7 of a hectare with a slope of 20° - 30°; it is on the Godavari site.

The model aims to set up a tree crop-dominated plantation to meet farmers' needs for fodder, timber, and cash income as the slope is steep and unsuitable for cereal and vegetable cultivation. The fruit trees planted include apples, plums, pomegranates, grapes, chestnuts, and walnuts and the fodder crops include Napier grass (*Pennisetum purpuream*), *Crotalaria, Sesbania, Cajanus*, Jack beans (*Canavalia ensiformis*), Velvet beans, Oats, Vetch, *Bauhinia,* and Mulberry. Hackberry (*Celtis australis*), *Lapsi* (*Choerospondia axilliaris*), Soapberry (*Sapindus mukorossi*), and Michelia (*Michelia champaca*) were selected as timber trees. Most of these trees and fodder crops performed very well. Eight hedgerow species were tried, out of which five were successful.

Model 3 - Vegetation Cover and Hedgerows

The Model 3 area covers about 5.5 hectares with a slope of 10° - 25°; it is on the Dhaireni site.

The model's purpose is to cover the severely-degraded land with as much vegetation as possible and try out some useful plants to meet farmers' demands for fodder, fuelwood, and cash income. The trees selected were Jackfruit (*Artocarpus lakoocha*), *Tanki* (*Bauhinia purpurea*), *Lapsi* (*Choerospondia axilliaris*), *Mashala* (*Eucalyptus camaldulensis*), *Kangiyo* (*Grevillea robusta*), *Bakaino* (*Melia azedarach*), Mulberry (*Morus alba*), and Guava (*Psidium guajava*). The fodder crops selected were Napier grass (*Pennisetum purpuream*), *Rahar* (*Cajanus cajan*), Jackbean (*Canavalia ensiformis*), and Velvet beans (*Mucua pruriens*). Some trees such as Jackfruit, *Bakaino*, and *Mashala* performed very well but the rest of them did not due to the poor soil conditions and lack of water. Four species of fodder grew well and farmers especially preferred Napier grass and *Rahar*. Four species of hedgerow were tested of which *Tephrosia candida* and *Dalbergia sissoo* grew vigorously, producing more biomass. They also exhibited tolerance to drought.

Model 4 - Subtropical Fruit Trees and Fodder Grass

The Model 4 area covers about one hectare with a slope of 5° - 10°; it is on the Godavari site.

The purpose of the model is to establish a high yielding and good quality subtropical orchard in order to improve the cultivation level of existing orchards in hill areas. Citrus is the main staple fruit species with a potential for domestic and foreign markets, but the yield per unit area and the quality of citrus, unfortunately, cannot meet international standards. Some high quality (internationally appreciated) varieties of citrus have been introduced to the site from Pakistan, China, and other areas of Nepal.

An intensive experimental citrus plot has been established on the Godavari site and all the trees are growing well. Poor soil management is one reason why citrus orchards in Nepal have been unable to produce high quality fruit products. A high standard orchard-establishing technology (including making big pits, applying enough basic organic fertiliser, and high density planting) has been adapted to the orchard in Godavari. White clover has been introduced to improve soil fertility. All saplings and fodder grass are growing well.

Model 5 - Improving Plantation on a Degraded Forest Site

The Model 5 area, on the Godavari site, covers about 0.5 of a hectare with a slope of 25° - 30°

The model aims to improve the degraded forest which has been frequently felled or lopped and make it more productive in terms of producing timber, high quality fodder trees, and other useful trees. The site being very steep, it is impossible to grow hedgerows and carry out alley cropping. Improvement measures must include strictly controlling lopping, collecting, and grazing and the transplantation of useful trees, at proper distances, from adjacent degraded forests and nurseries on to the site. The trees selected were *Schima wallichii, Castanopsis tribuloides, Juglans regia, Prunus cerasoides, Quercus lamellosa, Myrica nagi, Pinus roxburghii, Pinus armandii, Rhododendron arboreum, Alnus nepalensis, Choerospondias axillaris, Sapindus mukorossi, Cedrus deodara,* and *Paulownia elongata*. In order to create a suitable environment for these trees, most of the useless trees, bushes, and weeds were removed. After two growing seasons, the trees are growing well, faster than those trees for which a proper growing environment was not initially created. This cost-effective measure needs minimal investment and labour.

Preparation of Planting Materials

Establishment of the Nursery

To establish various plantation models, plenty of planting materials, such as seeds, seedlings, cuttings, and saplings (grafted and non-grafted), are needed. These planting materials come from various sources.

Seeds are obtained from local forests, the District Forest Office (DFO), local NGOs, the Nepal Agricultural Research Council, the Royal Nepal Botanical Garden, China, Pakistan, and The Philippines.

Seedlings are mainly obtained from the ICIMOD nursery in Godavari. Some also come from the DFOs in Godavari, Banska, and Kavre.

Saplings of fruit trees come mainly from horticultural stations in Dhankuta and Kirtipur in Nepal; many come from India, Pakistan, and China.

To meet the requirements for plantation seedlings from outside is impossible, so a standard nursery was established in Godavari, on an area of 0.3 ha, in February, 1993. Within two years (1993-1994) more than 60,000 seedlings were raised, most of which were planted in Godavari and Kavre.

Technology for Raising Seedlings

To raise the standards of existing hill nurseries, strong and sufficient seedlings are required. Based on two years' practice, the following technical points were seen to be necessary for nursery management.

1. The seed bed should be carefully prepared and soil collected preferably from a nearby forest. If the soil is not fertile, 10-20 per cent organic fertiliser should be mixed with the soil in a proportion of 10-20 per cent to provide enough nutrients for young seedlings.
2. Watering is important for seed beds, especially in the crucial early stages. A plastic net cover, semi-pervious to light, has been used for covering seed beds. It has proved to be very effective for retaining moisture and providing enough sunlight to young seedlings.
3. Pre-treatment of seeds is a must. More than 40 species of plants were tried at the Godavari nursery, of which about 75 per cent belonged to the legume family and had a lower germination rate when sown in beds without pre-treatment. In order to increase the germination rate, all seeds should be soaked in water for two to 72 hours. Soaking increases the germination rate by 10-50 per cent. Tables 1 and 2 show the results of some experimental plants and their features. From these two tables we can see that the germination rates of most of the plants are from 30-90 per cent. The germination rate of plants such

as *Albizia, Leucaena, Flemingia, Acacia,* and *Tephrosia* could not be increased even after soaking the seeds for many days. Careful observation showed that the seeds had very hard coats which prevented them from absorbing water. When scoured with abrasive paper the germination rate increased by 90-100 per cent.

Table 1: Experimental Plants and Their Basic Features
Godavari, Kathmandu

Names of Plant	Seed Weight (gramme/100pc)	Germination Rate (%)	Collected Places
Hedgerow species			
Acacia decurrens var. dealbata	1.90	20.0	Yunnan, China
Acacia mearnsii	1.40	5.0	Yunnan, China
Acacia auriculaeformis	2.50	5.0	Yunnan, China
Amorpha fruticosa	0.93	10.0	Pakistan
Alnus nepalensis	0.07	25.0	Nepal
Albizia lebbeck	3.10	50.0	Nepal
Albizia esticulate	3.25	60.0	Nepal
Calliandra calothyrsus	5.00	55.0	Philippines
Cassia siamea	2.14	3.0	Yunnan, China
Caesalpinia sappan	65.70	30.0	Yunnan, China
Delonix regia	56.50	20.0	Yunnan, China
Desmondium rensonii	0.22	98.0	Philippines
Desmondium sp.	0.24	95.0	Nepal
Flemingia macrophylla	1.80	80.0	Nepal
Flemingia macrophylla	2.02	85.0	Philippines
Hippophae salicifolia	1.05	70.0	Nepal
Indigofera dosua	1.02	60.0	Nepal
Leucaena leucacephala	6.00	30.0	Philippines
Leucaena leucacephala	7.00	90.0	Nepal
Leucaena pallida	4.80	50.0	Nepal
Leucaena diversifolia	1.20	70.0	Nepal
Robinia pseudoacacia	2.12	35.0	Pakistan
Tephrosia candida	2.30	48.0	Yunnan, China

Table 2: Experimental Plants and Their Basic Features
Godavari, Kathmandu

Names of Plant	Seed Weight (gramme/100pc)	Germination Rate (%)	Collected Places
Fodder Bush Species			
Bauhinia variegata	32.60	80.0	Nepal
Cajanus cajan	8.45	75.0	Yunnan, China
Crotalaria pallida	2.40	60.0	Yunnan, China
Canavalia ensiformis	120.00	85.0	Nepal
Mucuna pruriens	110.00	86.0	Nepal
Sesbania rostrata	1.08	38.0	Nepal
Sesbania cannabina	1.85	75.0	Nepal
Fodder Grass Species			
Astragalus sinicus	2.05	80.0	Sichuan, China
Amaranthus caudatus	0.10	90.0	Sichuan, China
Lolium multiflorum	0.28	30.0	Sichuan, China
Trifolium repens	0.05	95.0	Sichuan, China
Tree Species			
Camellia sinensis	58.30	9.8	Yunnan, China
Juglans regia	-	70.0	Shaanxi, China
Pinus armandii	8.50	40.0	Shaanxi, China
Paulownia tomentosa	0.04	0.5	Shaanxi, China

Performance of Plantations

Establishment of Hedgerows

Hedgerows are the main component in the establishment of plantations; they play a multifunctional role. Hedgerow functions are broadly: minimising runoff and reducing soil erosion; enhancing soil fertility to improve productivity; conserving soil moisture within the cropping alleys and making them conducive to plant growth; and providing biomass for fodder, green manure, and mulching materials.

The characteristics necessary for good hedgerow species are fast growth, strong root systems, nitrogen-fixing ability, tolerance to lopping and quick coppicing, and resistance to diseases and pests.

Keeping these requirements in mind, 23 plant species have been introduced at the Godavari nursery for raising seedlings (see Table 1).

Of these species, half are local and the rest are exotic. All seedlings of the 23 species grew when they were in the nursery, but they performed differently when they were transplanted in the fields. After one growing season's observation, it could be seen that three species of *Acacia*, two of *Leucaena*, one of *Calliandra*, and one of *Cassia* did not perform well in Godavari; their growth was slow and they were intolerant to frost. In 1994, 11 species of hedgerow were found to grow well and they were placed under observation. Table 3 shows the growth rate of 11 hedgerow species in Godavari.

Table 3: Growth Rate of Hedgerow Species
Godavari, Kathmandu

Species	Seedlings status and Growing Date			First Measurement June 22-July 5, 1994			Second Measurement Oct. 5-25, 1994		
	Growing Date	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)	Branches (pec)	Height (cm)	Diameter (cm)	Branches (pec)
Albizia lebbeck	July 13, 1993	18.5	0.41	128.9	1.15	23	184.1	2.40	20
Alnus nepalensis	July 5, 1993	15.5	0.35	185.8	2.04	22	356.6	3.49	18
Desmondium rensonii	July 6, 1994	10.0	0.30	110.5	20.95	20	245.0	1.53	21
Desmondium spp.	July 20, 1993	15.5	0.55	98.5	1.05	19	124.5	1.66	22
Flemingia macrophylla	July 20, 1994	19.0	0.38	121.0	1.13	16	196.4	1.82	14
Indigofera dosua	July 21, 1993	20.5	0.52	74.9	1.14	11	149.8	1.56	14
Tephrosia candida	July 7, 1993	17.5	0.41	102.9	1.18	17	180.3	1.53	10
Acacia mearnsii	July 25, 1993	12.5	0.31	59.0	0.53	8	86.7	0.76	8
Amorpha fruticosa	July 25, 1993	15.5	0.31	113.8	1.10	9	130.3	1.30	9
Dalbergia sissoo	July 14, 1993	20.0	0.65	30.4	0.99	9	52.0	1.15	9
Leucaena leucocephala	July 12, 1993	15.5	0.35	33.3	0.56	8	42.3	0.99	7

From Table 3 it can be seen that there were no great differences among the species when they were growing. After 15 months, big differences could be seen among the 11 species. *Acacia mearnsii, Dalbergia sissoo,* and *Leucaena leucocephala* had poor growth rates. The other eight species grew well, with average heights of 130.3cm to 356.6cm and average diameters of 1.30 to 3.49cm. Among the eight species the best was *Alnus nepalensis* in terms of growth and diameter; the second was *Albizia lebbeck;* the third, *Flemingia macrophylla;* the fourth, *Tephrosia candida;* and the fifth, *Indigofera dosua.*

In Dhaireni, four species of hedgerow were tested and the results can be seen in Table 4. The growth rate was expected to be better than that of Godavari because of Dhaireni's sufficient warmth and longer growing season. The data in Table 4 show the best species to be *Tephrosia candida* which reached 14.8cm in height and 1.68cm in diameter, the second was *Dalbergia sissoo* which reached 132.8cm in height and 1.25cm in diameter, and the third and fourth were *Leucaena leucocephala* and *Albizia lebbeck* respectively. It should be emphasised that Dhaireni is a typically degraded area with an arid climate and very poor soil conditions. In this environment, *Tephrosia candida* grew very well, resisting long periods of drought and producing more biomass than any other plants grown on the same site. The biggest *Tephrosia,* 172cm in height and 2.58 in diameter, bore fruit (35 pods) after only 16 months of growth. This is important as it signifies that the seeds can be produced locally instead of importing from outside the area.

Table 4: Growth Rate of Hedgerow Species
Dhaireni, Kavrepalanchok Dis.

Species	Seedlings status and Growing Date			First Measurement July 5, 1994		Second Measurement Nov. 30, 1994	
	Growing Date	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)
Albizia lebbeck	July 25, '93	17.5	0.45	42.3	0.71	90.0	1.43
Dalbergia sissoo	July 25, '93	21.6	0.60	58.6	0.83	132.8	1.25
Leucaena leucocephala	July 25, '93	15.8	0.32	62.8	0.59	117.7	0.81
Tephrosia candida	July 25, '93	16.5	0.35	77.4	0.72	148.0	1.68

As seen in Table 3, the height of eight hedgerow species of reached 100cm or more by July 1994. Since then, pruning experiments have been carried out on three plots ((plantations) in Godavari and the results are shown in Table 5. The results show that the biomass production of six hedgerow species varied from 5.41kg./100m to 86.36kg/100m at the first pruning. Two months later a second pruning was carried out and the biomass production from eight hedgerow species varied from 11.51kg/100m to 96.84kg/100m. *Amorpha fruticosa* and *Desmodium rensonii* in plot I were not high enough, so they were not pruned the first time.

In terms of biomass production, the hedgerow species, *Alnus nepalensis,* which produced 48.38-183.20kg/100m within the growing season, ranks first; *Albizia lebbeck,* with 48.24-58.88kg/100m, ranks second; *Indigofera dosua,* with 25.03-43.24kg/100m, ranks third; *Tephrosia candida,* with 31.31-36.83kg/100m (it can only be pruned once), ranks fourth; *Desmondium* (local), with 27.03kg/100m, ranks fifth; *Desmondium rensonii,* with 5.41-22.57kg/100m, ranks sixth; *Flemingia macrophylla,* with 15.57kg/100m, ranks seventh; and *Amorpha fruticosa,* with 11.51kg/100m, ranks eighth.

To summarise this result, six hedegrow species (*Alnus nepalensis, Albizia lebbeck, Indigofera dosua, Tephrosia candida, Desmondium* (local), and *Flemingia macrophylla)* can be recommended for hedgerow species in areas at altitudes of 1,500-1,800masl. Out of these six, *Alnus nepalensis* is the best in terms of fast growth, nitrogen- fixing ability, tolerance to lopping, and resistance to pests and diseases. All the fresh biomass (leaves and tender branches) pruned from the eight hedgerow species were fed to goats in Godavari.

Table 5: Biomass Production of Hedgerow Species
Godavari, Kathmandu

Plots	Name of Species	First Pruning* (June 30-July 3, 1994)			Second Pruning* (August 23 - Sept. 12, 1994)			Total Amount of Pruning (within a growing season)		
		Length of hedgerow (m)	Fresh weight of biomass (kg)	Fresh weight/ hedgerow length (kg/100m)	Length of hedgerow (m)	Fresh weight of biomass (kg)	Fresh weight/ hedgerow length (kg/100m)	Length of hedgerow (m)	Fresh weight of biomass (kg)	Fresh weight/ hedgerow length (kg/100m)
I	*Alnus nepalensis*	-	-	-	89.3	43.2	48.38	89.3	43.2	48.38
	Amorpha fruticosa	-	-	-	60.8	7.0	11.51	60.8	7.0	11.51
	Desmondium rensonii	-	-	-	113.4	25.6	22.57	113.4	25.6	22.57
	Flemingia macrophylla	-	-	-	406.4	62.6	15.40	406.4	62.6	15.40
	Indigofera dosua	-	-	-	91.9	23.0	25.03	91.9	23.0	25.03
	Tephrosia candida	-	-	-	49.5	15.5	31.31	49.5	15.5	31.31
II	*Albizia lebbeck*	223.9	16.0	7.15	223.9	92.0	41.09	223.9	108.0	48.24
	Alnus nepalensis	405.3	350.0	86.36	405.3	392.5	96.84	405.3	742.5	183.20
	Desmondium rensonii	120.2	6.5	5.41	-	-	-	120.2	6.5	5.41
	Indigofera dosua	161.4	28.0	17.35	161.4	29.5	18.28	161.4	57.6	35.69
	Tephrosia dosua	112.0	34.1	30.45	112.0	36.8	32.88	112.0	70.9	63.30
III	*Albizia lebbeck*	182.2	44.0	24.14	182.2	63.1	34.63	182.2	107.1	58.88
	Alnus nepalensis	448.3	212.8	47.47	448.3	161.8	36.09	448.3	334.6	83.56
	Desmondium (Local)	18.5	1.5	8.10	18.5	3.5	18.91	18.5	5.0	27.03
	Indigofera dosua	18.5	3.8	34.05	18.5	4.2	45.95	18.5	8.0	43.24
	Tephrosia candida	31.5	11.6	36.83	-	-	-	31.5	11.6	36.83

* Pruning height: 50cm above the ground.

Horticulture

Growing Fruit Trees

Horticulture is an important component of mountain farming systems because they have a special role in generating cash income for farmer households. In Godavari, the area above 1,600m has a temperate climate that is suitable for various temperate fruit trees. In April 1993, 10 species of temperate fruit saplings were introduced into Godavari. Through two growing seasons (1993-1994) 10 species of temperate fruit trees adapted to the climatic conditions in Godavari and most of them grew well.

Table 6 shows the growth rates of six species of temperate fruit trees. It shows that three varieties of apricot, three of plum, three of peach, and three of pear grew from 118-186.6cm in height and 2.00-3.75cm in diameter; this means that all varieties had normal, standard growth rates. In addition, one-third of the fruit trees have blossomed and many trees are expected to bear fruit next spring.

The growth rate of persimmon (three varieties) and Chinese dates (two varieties) were not as good as expected. This could be due to the temperature in Godavari in summer not being high enough to meet the requirements of these two species. This point still has to be proven through further investigations.

As mentioned before, in the hill areas (1,000-1,500m) of Nepal, subtropical fruits, especially citrus, have potential for domestic and international markets. But the citrus produce sold in the markets is not as good as expected in terms of size, shape, and quality. For example, seedless navel oranges with high quality juice are predominant in international markets but they are not available in Nepal. In order to improve this situation, several varities of seedless orange and other high quality citrus fruits have been introduced in Godavari. This can be seen in Table 7. The Table shows that all citrus varieties grow well but the Pakistani varieties performed best with growth rates, in terms of height, diameter, and crown, much higher than other citrus varieties. This could be due to the large size of the saplings introduced from Pakistan. Many Pakistani plant varieties are expected to bear fruit next spring. It should be mentioned that there is a lot of concern about citrus virus diseases and that all citrus plants have been strictly controlled by the quarantine office of the Nepalese Government. After a minimum of three to five years, when the plants are confirmed as being free from any viruses, the good varieties will be propagated for farming.

The growth rates of guava, avocado, and macadamia seem good. Several guavas have been seen on the branches of the guava tree and it is expected that more trees will bear fruit in the coming spring. The temperature in Godavari may not be high enough for the avocado and macadamia, this still has to be proved.

Fodder and Green Manure

Fodder shortages are always a big problem and growing fodder is very important for plantation establishment. Soil nutrients on degraded land are very poor but can be improved through growing green manure (most species of legume are grown for both fodder and green manure). In the spring of 1993, a series of fodder species were introduced experimentally in Godavari and Dhaireni.

Table 8 shows the biomass and pod production of bush fodder species in Godavari. It shows that four species of legume (*Cajanus cajan, Sesbania cannabina, Sesbania rostrata*, and *Crotalaria pallida*) produced more than one kg/sq.m. of biomass. Of these, two species of *Sesbania* produced from 2.7-5.5kg/sq.m., which is more than *Cajanus cajan* and *Crotalaria pallida* produced. It can also be seen that biomass and pod production decreased with an increase in altitude. The temperature in Godavari may be too low for *Cajanus cajan* that could not bear flowers until the end of November, 1994. These four legume species originated from tropical areas. They are worth growing for fodder and manure because they are fast growing, nitrogen-fixing plants. They also provide a mass of forage to cover exposed land, reducing soil erosion during the monsoon season.

Table 6: Growth Rate of Temperate Fruit Trees
Godavari, Kathmandu

Species and Varieties	Saplings Status and Growing Date			First Measurement (October 16, 1993)				Second Measurement (October 15, 1994)			
	Growing Date	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)	Crown		Height (cm)	Diameter (cm)	Crown	
						N-S (cm)	E-W (cm)			N-S (cm)	E-W (cm)
Apricot											
Meixin (1-1)	May 22, 1993	35.3	0.50	72.5	1.12	25.4	22.5	118.4	2.00	52.8	57.8
Xinli (1-2)	"	30.4	0.45	52.5	1.16	24.5	24.4	129.6	2.15	79.4	77.0
Erzhaunzhi (1-3)	"	36.2	0.65	72.3	1.22	26.0	44.8	120.9	2.50	76.5	80.2
Plum											
Li - 3 (2-1)	May 22, 1993	32.3	0.65	59.3	1.32	23.5	20.7	145.8	2.76	82.6	97.8
Gaili (2-2)	"	35.4	0.70	70.3	1.35	35.9	34.6	146.6	3.73	110.8	112.2
Huahuanli (2-3)	"	31.5	0.55	56.8	1.04	40.0	32.8	130.5	2.50	81.5	95.3
Peach											
Yuhualu (3-1)	May 22, 1993	38.5	0.46	76.1	1.29	35.0	30.9	141.0	3.12	96.4	103.2
Youtao (3-2)	"	40.6	0.55	77.7	1.53	46.6	44.9	186.6	3.41	128.6	113.2
Beijing 8 (3-3)	"	40.2	0.60	72.6	1.57	36.7	33.0	139.5	3.50	95.4	102.1
Pear											
Suli (4-3)	May 22, 1993	55.3	0.61	70.0	1.26	20.5	20.5	152.0	2.43	38.8	62.6
Xueli (4-2)	"	52.1	0.65	56.0	1.24	20.8	14.8	142.6	3.20	43.6	51.4
Changxli (4-3)	"	48.5	0.59	52.0	0.96	15.3	15.8	149.8	2.10	55.5	61.0
Persimmon											
Songbenzhaosheng (5-1)	May 23, 1993	30.5	0.32	44.7	0.78	7.2	6.1	95.0	1.78	15.8	18.2
Quianchuancilang (5-2)	"	35.1	0.35	38.6	0.76	10.7	11.8	61.8	1.85	31.2	31.6
Cilang (5-3)	"	32.6	0.40	44.1	1.00	11.0	12.1	98.0	2.15	29.0	35.6
Chinese Date *(Ziziphus jujuba)*											
Jingzhao (6-1)	May 23, 1993	35.5	0.55	52.7	1.03	16.0	14.1	87.4	1.66	36.4	42.0
Cuizhao (6-2)	"	37.2	0.51	54.0	0.96	20.3	18.2	101.4	1.82	64.6	51.6

Table 7: Growth Rate of Subtropical Fruit Trees
Godavari, Kathmandu

Species and Varieties	Saplings Status and Growing Date			First Measurement (October 16, 1993)				Second Measurement (October 15, 1994)			
	Growing Date	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)	Crown		Height (cm)	Diameter (cm)	Crown	
						N-S (cm)	E-W (cm)			N-S (cm)	E-W (cm)
Citrus from Nepal											
Lime - *Kagati* lime	July 18, 1993	20.1	0.30	30.5	0.55	29.0	24.3	24.3	51.5	1.45	39.0
Mandarin - *Dhancuta suntala*	"	22.5	0.40	40.4	0.60	12.8	11.5	11.5	57.0	1.23	22.8
Sweet orange *Dhancuta junar*	"	25.0	0.42	29.0	0.63	9.8	14.5	14.5	38.3	1.26	19.8
Citrus from Pakistan											
Lime - *Kagati* lime	May 1, 1993	65.3	1.04	83.0	1.35	51.5	52.3	140.3	4.10	114.3	116.8
Sweet orange - Blood red	"	64.0	0.57	74.8	0.89	39.8	40.5	114.5	3.34	64.8	88.0
Sweet orange - Succari	"	62.0	0.92	93.2	1.47	37.4	37.4	103.0	3.66	85.2	69.2
Grapefruit - Shamber	"	68.3	1.35	109.8	1.63	47.5	41.8	151.8	3.82	102.5	90.0
Mandarin - Kinnow	"	53.4	1.22	86.3	1.55	35.3	35.3	126.5	3.46	98.8	93.3
Citrus from China											
Mandarin - Ponggan	Nov. 21, 1993	25.5	0.45	-	-	-	-	32.5	1.30	14.7	15.5
Sweet orange - Meishan	"	30.0	0.52	-	-	-	-	38.2	1.39	17.0	20.3
Sweet orange - New hall	"	30.2	0.55	-	-	-	-	33.5	1.52	19.5	19.3
Sweet orange - Skages Bonanza	"	31.5	0.60	-	-	-	-	48.0	1.78	18.2	19.8
Sweet orange - Delicious seedless	"	32.1	0.65	-	-	-	-	47.7	1.52	22.6	22.2
Guava *(Psidium guajava)*											
Allahab ad Sufeda seedless	Oct. 22, 1993	25.0	0.52	-	-	-	-	76.6	1.69	56.0	51.1
Avacado *(Persea americana)*											
Ethhinger	Oct. 22, 1993	28.6	0.65	-	-	-	-	84.4	1.77	61.1	60.0
Macadamia *(Macadamia integrifolia)*											
Keauhou	Oct. 22, 1993	18.5	0.35	-	-	-	-	44.9	1.28	40.4	32

Table 8: Biomass and Pod Production of Bush Fodder Species

Godavari, Kathmandu

Species	Altitude of Growing (metre)	Date of Sowing	Date of Harvesting	Area of Sowing (m^2)	Biomass Production		Pod Production	
					Total Fresh Weight (kg)	Yield per unit area (kg/m^2)	Fresh Pod Weight (kg)	Yield per unit Area (g/m^2)
Cajanus cajan	1550	Apr. 15, '94	Nov. 20, '94	30.5	61.3	2.01	-	-
Cajanus cajan	1615	Apr. 15, '94	"	31.0	51.2	1.65	-	-
Sesbania cannabina	1550	May 18, '94	Nov. 18, '94	15.0	64.5	4.30	12.9	860.0
Sesbania cannabina	1615	"	"	13.0	35.1	2.70	7.0	540.0
Sesbania rostrata	1550	"	"	10.0	55.0	5.50	10.0	1000.0
Crotalaria pallida	1615	"	Nov. 22, '94	30.0	30.3	1.01	9.0	300.0
Amaranthus caudatus	1615	Apr. 15, '94	Sept. 20, '94	22.5	19.6	0.87	-	88.8 (seeds)

Table 9 shows the biomass and pod production of Jack beans (*Canavalia ensiformis)* and Velvet beans (*Mucuna pruriens*)in Godavari. These two species are strongly recommended by World Neighbours and some tropical countries as very good cover crops for fodder and green manure. From Table 9 it can be seen that Jack beans produced 1.88-3.95kg/sq.m. of fresh materials (biomass and pods). The yield of Velvet beans seems to be a little higher than that of Jack beans but the yields of both decrease as altitude increases. Fortunately, the pods of both species can mature in the climatic conditions of Godavari. This means that the seeds can be produced locally. In addition, throughout two years' cultivation, these two bean species provided a dense forage which closely covered the land they grew on without any soil erosion. There were hardly any weeds under the plants. We may conclude that Jack beans and Velvet beans are worth growing for fodder and green manure in Godavari.

Table 10 shows the biomass production of fodder grasses in Godavari and Dhaireni. From Table 10 it can be seen that four species of fodder grass, namely, rye grass (*Lolium multiflorum*), *Symphytum peregrinum*, white clover (*Trifolium repens)*, and Napier grass (*Pennisetum purpureum*) produced 1.01-8.45kg/sq.m. of biomass which may not be impressive but is significant. For example, rye grass was harvested during April-June when very little fresh fodder could be collected for the animals (many wild animals such as deer and rabbits came to the rye grass fields to graze). The fodder grass *Symphytum* grows rapidly and regenerates. From April to October it can be harvested every two months. It is a highly productive fodder grass which can be harvested for several years without replanting. White clover is a nitrogen-fixing fodder grass which can be harvested three times every growing season. Because its dense forage closely covers the land, it not only protects soil from erosion but also improves soil fertility. Napier grass is a fast-growing fodder grass which has been proven to grow well and propagate easily in adverse places, so farmers accept it as a good fodder. From Table 10 it can be seen that Napier grass can be harvested twice in Godavari and three times in Dhaireni (the yield being much more than in Godavari because the Dhaireni site has sufficient heat and a longer growing season).

Table 9: Biomass and Pod Production of Jack Beans and Velvet Beans
Godavari, Kathmandu

Species	Altitude of Growing (metre)	Area of Sowing (m^2)	Biomass Production			Pod Production		
			Total Fresh Weight (kg)	Yield per unit area (kg/m^2)	Maximum Plant Weight (kg)	Total Fresh Pod Weight (kg)	Yield per unit Area (g/m^2)	Maximum Pod Yield per Plant (kg)
Jack Beans	1550	15.0	31.4	2.09	2.00	27.9	1.86	2.20
(Canavalia ensiformis)	1615	40.5	52.3	1.29	0.40	23.9	0.59	0.24
Velvet Bean	1550	15.0	24.9	1.66	1.70	35.6	2.37	2.40
(Mucuna pruriens)	1615	35.0	27.3	0.78	0.60	40.6	1.16	0.98

Table 10: Biomass Production of Fodder Grasses
Godavari, Kathmandu
Dhaireni, Kavrepalanchok

Species	Date of Sowing	Area of Sowing (m^2)	Yield per unit area (kg/m^2)	First Harvesting (June 26, 1994)		Second Harvesting (August 25, 1994)		Third Harvesting (October 4, 1994)	
				Total Fresh Weight (kg)	Yield per unit area (kg/m^2)	Total fresh weight (kg)	Yield per unit area (kg/m^2)	Total fresh weight (kg)	Yield per unit area (kg/m^2)
Rye Grass *(Lolium multiflorum)*	May 25, '93	28.0	1.01	28.2	1.01	-	-	-	-
Symphytum *(Symphytum peregrinum)*	May 20, '93	7.0	8.40	13.1	1.87	27.0	3.86	19.0	2.71
White Clover *(Trifolium repens)*	Jan. 10, '94	25.0	3.50	27.5	1.10	38.0	1.52	22.7	0.91
Napier Grass *(Pennisetum purpureum)*	May 25, '93	110.0	2.71	-	-	94.8	0.86	203.0	1.85
Napier Grass (Kavri, 1000m)	Jun. 30, '93	8.0	8.75	18.0	2.25	27.8	3.48	24.20	3.03

Paulownia elongata is a very well-known fast growing tree. In April 1993, 107 stump roots (10-15cm in length and 2-4cm in diameter) of *Paulownia* were introduced in the Godavari area. These stump roots were grown in three different places at altitudes of 1,400m, 1,550m, and 1,650m in order to investigate the difference in growth rate at different altitudes. The results have been shown in Table 11 where it can be seen that the average growth rate of *Paulownia* reached 197.5-644.0cm in height and 9.02-11.43cm in diameter after 18 months' growth.

Table 11: Growth Rate of Paulownia (*Paulownia elongata*)
Godavari, Kathmandu

Altitude of Growing (meter)	Date of Growing	Average Growth Rate in 1993		Average Growth Rate in 1994		Minimum Growth by Nov. 22, 1994		Maximum Growth by Nov. 22, 1994	
		Dia-meter (cm)	Height (cm)	Dia-meter (cm)	Height (cm)	Dia-meter (cm)	Height (cm)	Dia-meter (cm)	Height (cm)
1400	April 28, '93	3.22	233.5	11.43	522.8	8.59	490.0	13.68	651.0
1550	April 25, '93	2.81	116.1	9.02	644.0	7.15	510.0	12.90	800.0
1650	May 9, '93	2.90	114.5	10.66	197.9	8.30	138.0	13.60	360.0

The maximum growth rate of Paulownia was 800cm in height and 13.68cm in diameter. Lower altitudes were seen to be conducive to an increase in diameter of the tree but not to an increase in height. In general, all data from different altitudes show that *Paulownia* is a fast-growing tree species.

The Progress of Recovering Vegetation in Dhaireni

Dhaireni is a typically degraded area with barren land, poor soil fertility, and harsh climatic conditions. There are no water resources apart from the limited rainfall during the monsoon season. Before starting plantation, the average vegetation coverage was estimated at about 10-15 per cent, consisting of less useful species such as *Heteropogon contortus, Eupatorium odenophorum, Solanum khasianum, Euphorbia spp.*, and *Sonchus* spp. For the quick recovery of degraded land, the following measures have been adapted on the site

1. The land users' group made regulations for protecting the areas from open grazing and illegal encroachment on any kind of land for fodder, fuelwood, or timber.
2. *Agave sisalana*, a hardy, thorny, and drought resistant plant, was grown along the border of the protected area as a biological fence. It has been proven that this plant can keep buffaloes and cows away from the plantation area.
3. Twenty-two lines of hedgerows, with a length of 134.5 metres, have been established. Four species of bushes were selected for hedgerows of which *Tephrosia candida* and *Dalbergia sissoo* are very promising.
4. Since Napier grass can adapt to harsh climatic conditions and poor soil conditions it has been abundantly grown between hedgerows and in gullies. Most of it has grown well and has begun to reduce soil erosion.
5. Tree plantations were established on the site. Local farmers are very keen to grow some useful trees on degraded land, so eight species of these have been tried in Dhaireni. The results have been shown in Table 12. From Table 12 it can be seen that of eight species the growth rates of Jackfruit, *Lapsi*, *Mashala*, *Bakaino*, and Guava seem impressive in terms of height (61.3cm - 166.3cm) and diameter (1.12cm - 2.15cm). *Tanki*, *Kangiyo*, and Mulberry can survive but do not grow well. Taking into consideration the conditions, this progress is not so bad.

Table 12: Growth Rate of Tree Species
Dhaireni, Kavrepalanchok Dis.

Species	Seedlings Status and Growing Date			First Measurement (July 5, 1994)		Second Measurement (Nov. 30, 1994)	
	Growing Date	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)
Artocarpus Lakoocha (Jackfruit)	July 24, '93	25.0	0.50	79.2	0.94	101.0	1.31
Bauhinia purpurea (*Tanki*)	July 25, '93	18.3	0.35	41.1	0.52	37.9	0.64
Choerospondia axilliaris (*Lapsi*)	July 25, '93	22.4	0.41	61.1	1.04	90.0	1.67
Eucalyptus camaldulensis (*Mashala*)	July 26, '93	23.5	0.38	81.5	1.03	113.2	1.53
Grevillea robusta (*Kangiyo*)	July 20, '93	15.0	0.30	29.4	0.46	28.6	0.86
Melia azedarach (*Bakaino*)	July 27, '93	30.5	0.45	101.1	1.48	166.3	2.15
Morus alba (Mulberry)	July 30, '93	14.5	0.32	65.0	0.65	68.6	1.08
Psidium guajava (Guava)	July 28, '93	25.0	0.52	49.5	0.80	61.3	1.12

Through two years' effort the degraded land in Dhaireni site has been improved. The most obvious change is the increase in vegetation coverage from 10-15 per cent to 85-90 per cent. This is due to the planting of hedgerows, trees, Napier grass, and naturally regenerated native grass (*Heteropogon contortus*). This newly-increased vegetation coverage has laid an important foundation which is useful for further plantation. It is thought that this degraded land will be rehabilitated in three to five years and will become productive enough to meet farmers' demands for fodder, fuelwood, and cash income.

Discussions on Plantations

Functions of Hedgerows

As described earlier, the Godavari Watershed Area is very rich in vegetation. Unfortunately, during the past decades, most of the forests were destroyed, especially on the gentle slopes. This was through the excessive removal of the most useful species for fodder, fuel, timber, and other needs. With the increase in population, not only the people who live nearby but also those who live 10-20 kilometres away now come to Godavari to collect fodder or fuelwood. Such activities are greatly changing the composition of the forest which is gradually being dominated by less useful species. This trend will continue if proper measures are not adopted. This typical degraded forest land can be seen not only in Nepal but also throughout the Hindu Kush-Himalayan Region.

If human intervention on forests is stopped, the degraded forestland may recover naturally, but it will take many years. Under recent circumstances, this is not possible. One of the alternatives is to make degraded forestland more productive land, e.g., through establishing various plantations. Hedgerows play a multifunctional role in establishing plantations. As mentioned before, about 79 per cent of the forest species are less useful on the Godavari site. Among the useful species (21 per cent), most have less nutritional value

and slow growth rates (see Table 13). From Table 13 it can be seen that nine natural tree species are typical and representative of the Godavari site and are usually used as fodder by local farmers. The crude protein contents of these tree species are much lower than those of planted tree species (*Castanopsis indica* excepted). From the nutritional point of view planted tree species (in this case, hedgerow species) are much better than the natural species, being richer in nutrition, fast growing, and nitrogen-fixing. Once the hedgerows are established (normally it takes two to three years) they can serve as soil erosion binders, fodder, green manure, and fuelwood resources. But if farmers are determined to carry out afforestation with these natural forest tree species it will take more than 10-20 years to achieve this which, moreover, might not be possible under present circumstances.

Table 13: Comparison of Nutrient Compositions between Planted Tree Species and Natural Tree Species

Species Name	Dry Matter (%)	Chemical Composition on Dry Matter Basis (%)					Phosphorus (%)	Calcium (%)
		Crude Protein	Crude Fat	Crude Fibre	Nitrogen free extract	Total Ash		
Planted Tree Species								
Alnus cremastogyne	82	17.6	-	-	-	-	-	-
Albizia lebbeck	64	21.7	3.7	31.4	36.1	9.3	0.20	1.85
Amorpha fruticosa	88	24.3	14.6	10.0	45.8	5.3	0.28	1.31
Desmodium elegans	92	22.1	3.1	16.7	44.6	6.5	0.21	2.30
Flemingia macrophylla	91	13.4	2.0	46.9	27.3	10.6	0.18	2.78
Indigofera esquirolii	90	21.6	2.7	29.4	39.4	6.9	0.30	1.83
Leucaena leucocephala	89	23.8	4.3	20.2	43.1	8.6	0.17	3.14
Robinia pseudoacacia	88	26.9	3.0	17.7	44.6	7.8	-	-
Tephrosia candida	90	21.2	3.1	29.4	36.8	9.5	0.20	3.01
Natural Tree Species								
Castanopsis indica	35	14.8	2.6	29.4	47.9	5.3	0.12	0.43
Eugenia jambolana	37	7.9	2.6	20.7	61.7	7.1	-	-
Eurya acuminata	40	7.4	2.3	11.4	62.5	4.4	-	-
Machilus gamblei	35	10.9	2.9	26.9	55.4	3.9	0.67	0.31
Prunus cerasoides	48	6.4	3.7	13.0	60.7	4.2	-	-
Quercus glauca	50	8.6	2.6	29.8	42.7	4.3	-	-
Quercus lamellosa	51	10.0	3.8	26.2	42.9	5.1	-	-
Quercus incana	50	7.1	4.6	28.7	44.2	2.3	-	-
Schima wallichi	-	9.7	-	-	-	3.4	-	-

Source:
1. Compilatory Committee of "Fodder Plants in China", 1989.
2. Kong Qingfu et al. Chemical Compositions and Nutrients of The Fodder Plants in China, 1990.
3. K.k. Panday. Fodder Trees and Tree Fodder in Nepal, 1988.
4. K.G. Tejwani. Agroforestry in India, 1994.

Alnus cremastogyne can be taken as an example from a study of China. Its leaves contain 2.5 per cent of nitrogen, 0.1 per cent of phosphorus, and 0.54 per cent of potassium. Traditionally, Chinese farmers collect the fresh leaves of *Alnus* and put them onto crop fields for green manure. By some statistics, 100kg of *Alnus* leaves have the equivalent of 5.4kg of urea, 0.70kg of calcium superphosphate, and 0.99kg of potassium chloride. A field study showed the use of *Alnus* leaves as green manure by 7,500kg, 9,750kg, and 14,062kg per hectare. Consequently, the crop yields increased by 15.9, 20.4, and 28.7 per cent, respectively.

From Table 5 we can see that, among the six hedgerow species, *Alnus nepalensis* grew the most within a growing season, producing 48.38-183.20kg of biomass per 100m. On an average, the biomass is 115.79kg/100m. If the leaves account for 80 per cent, it means 100m. of *Alnus nepalensis* hedgerow can produce 92.63kg of leaves which contain the equivalent of 5.0kg of urea, 0.65kg of calcium superphosphate, and 0.92kg of potassium chloride.

Alnus nepalensis is a local tree species and is found all over Nepal. From the results of the experiment in Godavari it can be recommended as the best hedgerow species for similar conditions in the Hindu Kush-Himalayan Region. Other species like *Albizia lebbeck, Amorpha fruticosa, Desmondium* spp (local), *Indigofera dosua, Tephrosia candida,* and *Flemingia macrophylla* can also be used as hedgerow species or even for afforestation because of their fast growth, nitrogen-fixing ability, and rich nutrition. All the leaves and tender branches of these species have proved to be good fodder; they have been fed to goats and rabbits in Godavari.

Fodder and Green Manure

Poor soil fertility on the Godavari and Dhaireni sites is the major constraint to improving the productivity of degraded land. According to soil survey reports, the nitrogen content of the soil is about 0.033-0.60 per cent on the Godavari site and about 0.02-0.12 per cent on the Dhaireni site. By any standards, these nitrogen contents are too poor for crop cultivation. To prove this point, in 1993, some crops were cultivated in the alleys between hedgerows when the experimental plots had just been established in Godavari. These crops were cabbage, cauliflower, radish, mustard, broad beans, and peas. None of them performed well unless they were provided with additional fertiliser.

Even the yields of leguminous crops like broad beans and peas were not impressive. Therefore, the improvement of soil fertility should be given priority when degraded land is cultivated. The effective and cheap way of improving soil fertility is through cultivating various leguminous plants.

From Tables 8 and 9 we can see that five leguminous bush and grass species have been tested on the Godavari site. *Crotalaria pallida, Cajanus cajan, Mucuna pruriens,* and *Canavalia ensiformis* produced biomass from 0.78-2.01kg/sq.m. Their nitrogen content is about 2.3 - 2.5 per cent indicating that they can produce 195-396kg nitrogen per hectare. *Sesbania cannabina* and *Sesbania rostrata* produced biomass from 2.7-5.5kg/sq.m. indicating that they can produce 918-1,870kg of nitrogen per hectare (nitrogen content is 3.4 per cent). White clover (*Trifolium repens*) can be harvested three times and its biomass production is 3.5kg/sq.m. per year indicating that white clover can produce 980kg of nitrogen per hectare (nitrogen content is 2.8 per cent). [These experiments have been conducted on small plots that need to be determined again in future]. All these results are encouraging. These five species are nitrogen-fixing plants which can serve as both green manure and fodder. Table 14 shows the data of some fodder bushes and grasses from which it can be seen that all leguminous species are very rich in nutrients and have been widely used by farming systems throughout the world. All species of fodder bushes and grasses have been fed to goats and rabbits in Godavari and they have proved to be good fodder for these animals.

How to Harness a Buffer Zone

There is a vast area between cultivated land and forest land in the Hindu Kush-Himalayan Region. We could call this area a buffer zone characterised by degraded forestland or bush land in which the resource bases are declining and soil erosion is increasing. This buffer zone will expand with the increase in both human and animal populations. Farmers or villagers are greatly relying on this buffer zone from where they have to collect fodder, fuelwood, and other materials. It is estimated that this buffer zone extends over more than millions of hectares?. How to harness this buffer zone is a big challenge and task for policy makers, government officers, and scientists. Ownership of land should be first thought out. In China, for example, bare land is given to the farmers by responsibility contract systems for more than 50 years; the farmers are then interested in investment, afforestation, or other farming activities. Some districts of Nepal have carried out a release system by giving community or buffer land to users' groups.

Table 14: Nutrient Compositions of Some Fodder Bushes and Fodder Grasses.

Species Name	Dry Matter (%)	Chemical Composition on Dry Matter Basis (%)					Phosphorus (%)	Calcium (%)
		Crude Protein	Crude Fat	Crude Fibre	Nitrogen free extract	Total Ash		
Amaranthus paniculata	93.1	12.7	2.6	31.3	41.4	12.1	0.22	3.24
Cajanus cajan	-	17.3	6.0	28.1	39.7	6.7	0.23	-
Crotalaria juncea	-	15.6	-	-	-	-	-	-
Lolium multiflorum	81.7	13.7	3.8	21.3	46.4	14.7	0.32	0.49
Pennisetum purpureum	91.8	10.5	2.0	33.0	44.7	9.6	0.04	0.07
Symphytum peregrinum	10.5	30.0	6.0	13.2	34.0	17.1	-	-
Sesbania gradiflora	-	34.8	4.2	7.5	48.7	12.5	0.33	2.33
Trifolium repens	20.0	24.7	2.7	12.5	47.1	13.0	0.34	1.72

Source:
1. Su Jiakai et al. Cultivation Technology of Improved Fodder Grass, 1983.
2. Kong Qingfu et al. Chemical Compositions and Nutrients of Chinese Fodder Plants, 1990.
3. Gan Shulong et al. Economic Animal and Plant Resources in Sichuan, China, 1988.
4. IRRI. Green Manure in Rice Farming, 1988.

Another issue would be the kind of technologies that could be transferred to farmers in order to gain more benefits when land is released to them. Five plantation models established on the Godavari and Dhaireni sites could provide some examples of how to make degraded land more useful and productive. Some of these experiments are successful, some cannot be copied by other areas, and some need to be further tested and modified.

Bibliography (not cited in the text)

Compilatory Committee of "Fodder Plants in China", 1989. *Fodder Plants in China*. Beijing: Agriculture Press.

Kong Qingfu, 1990. *Chemical Compositions and Nutrients of Fodder Plants in China*. Beijing: Agriculture Press.

Gang Shulong, 1990. *Economic Animal and Plant Resources in Sichuan, China*. Sichuan: Publishing House of Sichuan Academy of Social Sciences.

IRRI, 1991. *Sustainable Agriculture: Green Manure in Rice Farming*. Philippines: IRRI.

ICIMOD, 1993. *ICIMOD Methodology Workshop on Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayan Region, May 29 to June 3, 1993*. Kathmandu: ICIMOD.

K.k. Panday, 1988. *Fodder Trees and Tree Fodder in Nepal*.

Su Jiakai, 1987. *Cultivation Technology of Improved Fodder Grass*. Beijing: Agriculture Press.

K.G. Tejwani, 1994. *Agroforestry in India*. New Delhi: Oxford and IBH Publishing Co. Pvt. Ltd.

Zhang Xianwan, 1983. *A Study on Agro-Ecosystems in the Middle Hill Areas of Sichuan*, China: Chengdu Branch, Chinese Academy of Science.

D.P. Joshi, 1994. 'An Inventory of Flora and Fauna and A Biomass Study of ICIMOD Complex Site, Godavari, Nepal'. (unpublished).

G.B. Juwa, 1994. 'Soil Survey of ICIMOD Complex Site, Godavari, Nepal'. (unpublished).

M.N. Subedi, 1994. 'A Baseline Vegetation Survey of Bajrapareko and Dhaireni at Kavre Palanchok District, Nepal'. (unpublished).