IGFRI Approaches

REHABILITATION OF DEGRADED LANDS

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FOREWORD

Soil erosion and the consequent land degradation have been the primary cause for many of the ecological problems facing India today. The growing population of both human and livestock has aggravated the degradation process resulting in serious economic losses of soil productivity leading to deficiency of timber, fuelwood and fodder.

The International Development Research Centre, for over a decade, supported a silvipastoral research project at the Indian Grassland and Fodder Research Institute, Jhansi, which generated a series of technologies for different land and agroecological situations and ecorestoration and sustainable biomass production in the Bundelkhand region. The impact of this technology is visible through large programmes providing training and development skills and human resources in the field.

Based on extensive research and operational work in different situations, in and around Jhansi, several promising systems have been identified. These systems have varying production levels under identified conditions and are economically and socially acceptable. The technologies generated have helped in improving the livestock population, providing fuelwood and timber for local use and also conservation of land and water resources.

The efforts made by the IGFRI scientists in developing such technologies will go a long way in augmenting sustained production and meeting the serious shortfalls of fodder, fuel and timber. The application of this technology will go a long way in halting the process of land degradation and also will enhance the soil productivity.

We hope, the planners, policy makers, researchers, educationists, extension workers and farmers will appropriately utilize this publication for dissemination of information in different parts of the country.

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REHABILITATION OF DEGRADED LANDS

Background

Tropical countries face serious land degradation problems which have been aggravated by the pressure of unprecedented explosion of human and animal population on the land.

A typical degraded land

Large animal population left to open grazing on degraded lands

The attendant disturbance results in resource degradation and loss of myriad of ecosystem services adversely affecting the capacity of land to support the growth of useful plants on a sustainable basis. The world ecosystems, in addition to supporting five billion human population, have also to support three billion ruminants as its part.

Degradation Process

The mismanagement of biophysical environment leads to land degradation. The effect of deforestation, shifting cultivation, mining, dams and construction of roads, industriali-

A typical ravine showing erosion

Firewood transportation for sale, an activity helping resource depletion zation and resultant pollution, over grazing, uncontrolled fire, unplanned changes in land use pattern, urbanization and land encroachment activities has contributed to this process. India is losing forest cover at a rate of 1.5 million ha annually and the present 22.8 per cent forest cover has declined to only 10 per cent of the land area. About 64.2 million ha forest area has only 36 million ha under crown cover (more than 70%). The decline in forest cover has led to shortage of firewood which gets substituted by animal dung cake depriving the crop lands of organic manure so vital for sustaining crop productivity. The conversion of forest land into agricultural land and use by other development projects has led to soil

Animal dung cake making to meet the energy demands for cooking

Over grazing removes complete vegetal cover erosion, groundwater depletion, frequent floods and droughts further accelerating the process.

The problems of over grazing are acute throughout the country, specially in the north western part where pastoral communities (over 30) continue to move in the poor grazing resource area of arid and semi arid environment. The area for grazing is about 40.4 per cent in the country. Roughly, 117 million ha of grazing lands serve nearly 400 million domestic animals (3.3 animals/ha). The increased grazing pressure leads to replacement of the perennial grass cover by weeds and annuals. The reduction in cover helps accelerating erosion and loss of fertile soil.

The extent of degraded lands in the country is about 158 m ha. The operating factors are sheet erosion, water logging, salinity and alkalinity, wind erosion, stream erosion, shifting sand dunes, etc., which have resulted in hot deserts, exposed rocky and gravelly areas, cold deserts, ravines, saline sodic areas, swamps and wetlands, *cho* and river beds, culturable wastelands, etc. It is estimated that out of 90 m ha of uncultivated degraded lands, 35 m ha is with forest department, 20 m ha with government/community use for grazing and the rest 35 m ha either owned by individuals or encroached by them.

Arresting Land Degradation : Basic Need

In a predominantly agricultural economy like India, the basic dependence of more than 66% of its population is on agriculture and related activities. The need for more land to produce more food, fodder and cash crops is being felt for its growing human and animal population. While emphasis should be on vertical stratification and increasing per unit area productivity since it is hardly possible to stretch further the limited land resource, the utilization of degraded lands for this purpose can be another economical option.

The process of erosion eats away the productive lands every year

The very process of land degradation is hazardous since it is eating away the most productive land every year. There is an urgent need to halt this process by proper techniques so that the process of reclamation could get initiated. The ravines engulfing cultivated lands; deserts advancing further; expanding rivers and flood plains; reservoir siltation; unwise land use, deforestation, etc., have to be immediately stopped to allow the process of building land resource before it is too late.

Conservation Assists Rehabilitation

The process of rehabilitation starts no sooner than the biotic forces stop operating. A highly degraded area after protection for only 2 years has shown increase of perennial and annual grass species and decrease of weeds. The total plant species also increased with protection (10 woody species with 800 plants / ha density). The process of succession sets in and the forage yield also increases.

Basic Objectives of Rehabilitation

- Ecological restoration, conservation of and improvement in soil, environment and biodiversity.
- Increasing land productivity for sustainable production of food, forage, firewood and other minor forest products.
- Optimizing economic gains, generating employment and enhancing social equity.

Conservation assisted regeneration of *Butea monosperma*

IGFRI Production Models

A. Plantation of grasses and legumes on shallow, rocky, and gravelly soils through assisted ecological development to protect soil, improve habitat and increase productivity.

B. Silvipastoral technology to give speedy repair to the system and augment production and utilization through feeding/grazing management.

Operational Sites

The models were tested on 54 ha area around Jhansi on four typical sites with following characteristics:

- Undulating rocky gravelly terrain with soil pH 6.4 - 7.7 (site I)
- Eroded plains with soil pH 6.4 - 7.3 (site II)
- Ravines with calcareous mounds and saline sodic basins having soil pH 6.1-9.8 (site III)
- Degraded hills with skeletal soils and no vegetal cover with pH from 6.5 to 7.5 (site IV).

Rehabilitation Processes

Protection

In the process of rehabilitation, the first step is the control of biotic pressure. There are three options, *viz.*, fencing, cattle proof trenching and social fencing. Considering the material cost, cattle proof trench (2 x 1 x 0.3 m) is being used where soil depth is negotiable; otherwise loose stone wall of the same dimension is being preferred. On the mounds, seeds

Cattle proof trench (left) and loose stone wall (extreme right) for protection against grazing

Cattle proof trench with *Prosopis juliflora* and *Acacia nilotica* grown on the mounds

of species like *Prosopis juliflora*, *Acacia nilotica* and *Dichrostachys cinerea* are sown to make a live fence to prevent damage by stray animals.

Conserving soil and water

Water has been identified as a trigger factor which accelerates the rehabilitation process. On impoverished sloppy lands, the first step is to check the run off, improve water percolation and increase soil moisture status of the soil. Staggered contour bunds/trenches

Contour trenches for checking run off and conserving soil and water

Termite activity consumes dry biomass and the resultant loss of soil needs protection

Loose stone gully plug to check the flow of rain water

(3 x .5 x .5 m) are made to arrest the flow of water. The soil is deposited along the contour and the trenches are dug facing the slope. 500 - 600 trenches/ha are recommended for semi arid region with rainfall up to 1000 mm. They retain 95% of the run off even from the rain storms of high intensities. In semi arid and arid regions, the dry biomass on the surface gets consumed by the termites during the summer and with the first showers of rain the loose soil gets washed away along with the nutrients. This method also assures arresting the loss

Pits prepared for plantation

of nutrients. On the soil mounds, seeds of woody species like *Azadirachta indica, Acacia tortilis, Acacia nilotica, Butea monosperma, Prosopis juliflora*, etc., and legumes like *Stylosanthes hamata* and *Macroptelium atropurpureum* are sown. It helps in soil enrichment and optimizing the soil moisture availability.

Plantation of tree seedlings and sowing of *Stylosanthes hamata* on berms to provide surface cover

Intervention of profitable species and population dynamics

By conservation, the dynamic process of building the natural population starts. This is often time consuming and tends to bring in the native species only. The natural ecological succession may take some time but assisting this process to get acceleration has been found more beneficial. Intervention of desirable species of grasses, legumes and woody perennials through seeding and planting helps building the resource. Pits of 45 cm^3 size at 4 x 5 m spacing are dug before the monsoon and 100 g fertilizers mixture (NPK) and 10 g BHC powder are mixed before planted with 3 - 6 months old seedlings of multipurpose trees. The inter spaces are sown with perennial grasses, *viz., Sehima nervosum, Cenchrus ciliaris* and a legume *Stylosanthes hamata.* Seeding of pelletized seeds or seed mixed with wet sandy soil is done before monsoon. Small amount of surface scratching through country plough at 1 m spacing helps in better establishment.

Seedlings of *Acacia tortilis, Albizia lebbeck, Albizia amara, Leucaena leucocephala, Dalbergia sissoo, Dichrostachys cinerea, Azadirachta indica, Cassia siamea, Prosopis juliflora, Anogeissus pendula, Dendrocalamus strictus* and *Hardwickia binata* were planted at different spacings on the site, *viz.*, rocky gravelly eroding plain lands, rocky gravelly sloppy mounds, degraded forest areas and ravines with exposed *kankar* mounds and saline sodic basins. The sites represented typical wastelands available in central India.

Post planting survival of woody species at 4 years on different types of wastelands has been found to vary. *A. tortilis* proved to be the most promising species on all the sites followed by *L. leucocephala* on habitat 1, *A. amara* on habitat II and *D. cinerea* on habitat III. This shows the habitat specific behaviour of species at survival and establishment (Table 1). The survival is further accompanied by their growth patterns also. During the process of species dynamics, it has been found that dormant root stocks/stumps of trees start growth and some desirable species like *Anogeissus pendula* and *Butea monosperma* build up their colonies. An early assistance by trimming and thinning helps their becoming tree instead of a shrub.

Table 1. Survival rates (%) of seven tree species at 4 years

Species	SITES I	SITES II	SITES III
Acacia tortilis	68.0	90.2	81.0
Albizia amara	50.2	68.4	64.8
Dalbergia sissoo		46.5	31.8
Dichrostachys cinerea			72.2
Leucaena leucocephala	61.8	25.6	
Hardwickia binata	56.2		
Albizia lebbeck	28.3	4.5	45.1

Stylosanthes hamata, a pasture legume also works as a nurse crop

Use of nurse crops

The nitrogen fixing species like *Stylosanthes hamata* (a pasture legume) make an easy soil cover on the highly impoverished lands in the first year itself and work as a nurse crop for enriching the soil nutrients, build up soil due to its litter and give positive associative effect to the other tree species. Use of fast growing, nitrogen fixing woody perennials in planting mixtures also helps the process of soil amelioration while giving very high yield in the short time span. Such species are *L. leucocephala* and *Sesbania sesban* with nitrogen fixing capability, wide ecological amplitude and high productivity in the mini rotation. When they are planted with other species, they also serve as a nurse crop to encourage faster growth of the associated woody species.

Silvipastoral System

Planting of multipurpose trees with grasses and legumes in an integrated system and their utilization through cut and carry of forage in early years followed by *in situ* grazing is known as silvipastoral system.

This system aims at optimizing land productivity, conserving plants, soils and nutrients and producing forage, timber and firewood on a sustainable basis. It involves replantation, substitution or intervention in the existing vegetation by desirable species. The tree selection is based on its easy regeneration capacity, coppicing ability, fast growth, nitrogen fixing ability, palatable leaves (fodder), high nutritive value and less toxic substances, short rotation and high fuel value. The grasses and legumes should have easy colonizing ability, high production efficiency and high nutritive value.

Table 2. **Species planted on different sites.**

Name of species	SITES			
	I	II	III	IV
Acacia tortilis	*	*	*	*
Albizia amara	*	*	*	*
Albizia lebbeck	*	*	*	
Leucaena leucocephala	*	*	*	,
Hardwickia binata	*			
Dalbergia sissoo	*	*		,
Dichrostachys cinerea			*	*
Azadirachta indica				*
Prosopis juliflora				*
Cassia siamea				*
Anogeissus pendula				*
Dendrocalamus strictus				*
Cenchrus ciliaris	*	*	*	*
Chrysopogon fulvus		*		,
Bothriochloa intermedia			*	,
Stylosanthes hamata	*	*	*	*
Macroptelium atropurpureum	*	*	*	*

This model was tested on 54 ha land area spread over 4 places around the Institute with specific land degradation problems.

The habitat specific organization of species mosaics in two or three tier systems involving trees, shrubs, grasses and legumes was tried during 1982 to 1990 (Table 2).

Production of forage

The forage production increased over years from 1-1.5 t/ha to 7.5 t / ha / yr (range 3.5 - 7.5 t / ha). Even in the second year of closure and management, 3 t / ha dry matter has been obtained on rocky gravelly soils. Upto 5 to 6 years, there was no decline in the pasture yield under trees. From the saline sodic soils, the adaptable species of grasses, *viz., Bothriochloa intermedia*, and *Dichanthium annulatum* have given high production. Thus on the top and slopes of calcareous mounds up to 2.8 - 3.0 t / ha and on the base up to 6.3 t/ha production has been obtained. This annual forage production when compared to open situation is more than five times in quantum and 7 times in quality besides providing total land cover throughout the year.

Acacia tortilis based silvipasture system

Albizia amara based silvipasture system

Dalbergia sissoo based silvipasture system

Dichrostachys cinerea, an ideal choice for silvipasture on ravines

Acacia tortilis provides a good cover on the ravine bottoms

Leucaena leucocephala based silvipasture system

Cut and carry forage during early years

Grass bales transported for storage

Organising a fodder bank

Top feed

After 6th year, the trees were partially lopped for fodder twice a year (during winter and the summer). The annual production of fodder from trees was up to 2.5 t/ha and was an additional input to the system.

Firewood

The firewood production from the system starts after 5 years. Some of the species can be harvested in 8 to 9 years while most of the species complete their cycle by 12 years. Based on studies of several years from the 3 sites, it has been observed that annually about 3.7 tonnes dry matter per ha could be produced from the trees which could be utilized as small timber and firewood. The trees coppice back after harvest and are ready for next cycle in 6 to 7 years.

Utilization and management

During the early stage up to 3 to 4 years, cut and carry system is operated. The forage harvested could be used for direct stall feeding

Lopping fodder trees in silvipasture during summer provides balanced food to the animal

Grazing in the silvipasture system by cows

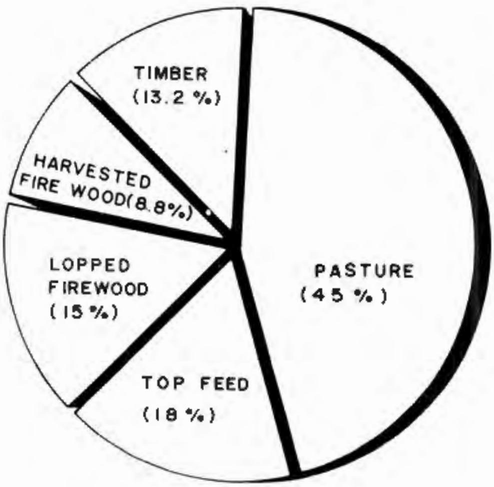
Mixed herd grazing in summer

Woody perennials, the first choice for goats and sheep in silvipasture

or conserved as hay, baled , transported and stored in a fodder bank for feeding during the lean months. On site baling in to 25 kg bales makes it easy to transport . After this period when the trees are beyond the reach of animals *in situ* grazing by deferred rotational methods is practised. Since the silvipastures are composed of grasses, legumes, shrubs and trees, a mixed herd grazing is more efficient and economical. In this study on year round grazing basis, 75 kg/ha/year animal weight gains were obtained. It was possible to check the animal weight loss during summers through the feeding of loppings and dry pods. This is possible only where the animals are introduced within the carrying capacity of the pasture.

Total productivity

The lands producing hardly up to 1 t/ha/yr have been improved to produce up to 10 t/ha/yr at a 10-year rotation through the system (Fig.1). Besides yield improvement by 8 - 10 times, the quality of forage has also improved by 6 - 7 times.



Annual production from silvipastures (10 t/ha/yr) on a 10-year rotation

Scope of the Present Work

The present work has shown a new technology dimension to many organizations dealing with improvement and rehabilitation of wastelands. The technology, if utilized and implemented even on half of the degraded lands, can solve the problem of land degradation and also of animal feed and firewood. The land productivity improvement could take care of increasing pressure of grazing animals and people for forage and firewood.

Technology Impact

Land productivity

At present, there is a wide gap between the demand and supply of forage and firewood in the country. This gap is expected to increase further with the increasing human and animal population and also land degradation. The deficit becomes acute in dry areas of arid

Table 3. **Expected production from degraded lands put to silvipasture technology on 50 million ha**

Products	Present		Expected	
	Productivity (t/ha/yr)	Production (m t/yr)	Productivity (t/ha/yr)	Production (m t/yr)
Forage	0.5 - 1.0	25 - 50	4.0 - 5.5	200 - 275
Top feed	Negligible	–	1.6 - 2.5	80 - 125
Firewood	Negligible	–	2.0 - 3.0	100 - 150

Prosopis juliflora, Acacia tortilis, A. nilotica and *Dichrostachys cinerea* provide vegetal cover to the eroding ravines and semi arid regions due to seasonal/annual drought cycles forcing large scale animal migration and loss of animal life. Even if just one third of the area under degraded lands (say 50 million ha) is put to this use, it could help bridge the gap in demand and supply to a large extent (Table 3).

Environment

The present situation of accelerating land degradation through soil, nutrient, and species losses could be reversed by this process. It has been estimated that 17.8 t / ha / yr soil loss under bare soil could be reduced to 1.3 t / ha / yr through this system. Thus on 50 million ha area, it could save 826 m t top soil annually. Similarly, 65 m t soluble salts could be annually protected through this technology. The improved infiltration rates further enrich the underground streams to improve the irrigation and drinking water resources. The adoption of this technology on degraded lands has further shown increase in the number of species of grasses, legumes, trees and also animals. It assists the process of rehabilitation assuring maximum conservation and biodiversity. Soil gets enriched under silvipasture system compared to intensively cultivated systems while annual herbage removal is common to both. Thus this system promises healthy environment and rich biodiversity which are essential for sustainable land productivity and human welfare.

Economics

The silvipasture models give high benefit / cost ratio (1.42) at 12 years rotation. The models tried on the three sites show more than 20% of Internal Rate of Return (IRR) at the farmers management level with more than 600 trees / ha density. For the ravine conditions, this technology shows >18% IRR whether managed by the Institute or by a farmer.

Visitors being explained the benefits of silvipastoral system on the sites

Silvipasture technology appraisal to visitors

Indirect benefits

Such programmes besides direct economic gains, also aim at development needs of the country, such as reducing regional imbalances, improving living condition of the rural people, maximizing employment and per capita income and enhancing social equity.

Regional development

This work has given a new technology dimension to many organizations dealing with wastelands development. The direct beneficiaries are forest department, soil conservation and watershed development agencies, non-governmental organizations, animal husbandry departments, etc. The utilization of research results on more than 500 ha wasteland areas in and around Jhansi by IGFRI has demonstrated the merit of this technology. Work of Development Alternatives (an NGO) on more than 500 ha in U.P. and M .P. and the forest departments of U.P. and M.P. to rehabilitate degraded lands has further been based on use of silvipasture models and species tested. The use of this technology in Bundelkhand region (12 districts) can meet the shortage of forage and firewood besides conserving the existing resources. The savings of animal dung manure for use in crop fields will result in cheaper grain production and farming system sustainability.

Employment generation

This system promises sustainable level of employment to rural people in the activities of animal breeding, collection, processing and manufacture of value added products from trees and grasses and collection and trading of quality seed and other materials. In an average 10-year cycle, establishment and management of silvipastures could generate 120 man days / ha / yr of employment. Thus, on 50 m ha it can provide job to 20 m people annually. Other ancillary activities could provide job to another 5 m people.

Technology Transfer

Technology transfer has been attempted through 4 workshops on silvipasture systems besides the Institute organized trainings of short and long duration. During this period, 12 Diploma Course programmes of 9 months each, 16 NARP trainings of 1 month each, 20 refresher courses, 2 micro planning and several planning workshops have been provided with a package of this technology input on the field and in the class room.

Technology demonstrations through Institute based and NGO based programmes have been on more than 1000 ha area around Jhansi. These programmes were funded by NAEB and NWDB, Govt. of India. The success of this programme has led to a realization of grass-legume seed production in bulk for meeting the country's demands for rehabilitating degraded lands. It has been further accelerated through the participation of government agencies, NGO's and the farmers.

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