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Agroforestry: An Integrated Land Management Option for Fragile Ecosystem

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ABSTRACT

Since 1965 the progress in Indian agriculture has been remarkable. However, what is being witnessed today are the changes which threaten to undermine future progress with several (ecological, economical, social and cultural) dimensions of un-sustainability and fragility to global and local ecosystems. Poverty, water and air pollution, soil degradation, loss of biodiversity, global warming and many other forms of environmental degradation have raised doubts about the wisdom of the pattern of development which is being currently pursued. The World Commission on Environment and Development [1987] hence stressed the importance of ensuring that today's economic progress is not at the expense of tomorrow's developmental prospects.Degradation of land is a vital issue throughout the world with the particular references to India as it a threat to agricultural productivity. Agroforestry, a land use system is being popular in many countries to protect the land from various types of degradation. Studies have proved that agroforestry can check soil erosion to some extent, increase soil fertility, reduce salinity; alkalinity, acidity and desertification etc. ultimately improve soil health which keeps the land suitable for agricultural production.

INTRODUCTION

The fragile areas / environments are considered to be very delicate, easily breakable, damageable and difficult to restore. Fragility in a system is opposite to the sustainability and is exaggerated by inequity and casual nature of technological implied. A fragile ecosystem land dominates arid, semi arid lands, wetlands, saline soils, acidic soils, waterlogged soils, mountains, small islands and certain coastal areas, deserts, nutrient deficient land, moisture deficit land, small islands and coastal lands, wetlands and bio-degraded land. These areas are limited by one or more land degradation processes.

EXTENT AND CAUSES OF LAND DEGRADATION

Land degradation is one of the major ecological issues of the world. Land degradation means loss in the capacity of a given land to support growth of useful plants on a sustained basis *[Singh, 1994]*. It is result of many factors or/and combination of factors which damage the soil, water and vegetation resources and restrict their use or production capacity. Considering its impact on food security and environment, it is being important in many corners of the world. The productivity of some lands has declined by 50% due to soil erosion and desertification of the world. Like other countries, India is not exception in facing threat of land degradation. The information on the extent of land degradation in the country has been assessed by various agencies. The estimates of these agencies vary widely (63.9 m ha to 187.0 m ha) due to different approaches in defining degraded soils and adopting various criteria for delineation. National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur of Indian Council of Agricultural Research (ICAR) in 2005 reported that 146.82 million hectare area is reported to be suffering from various kinds of land degradation. It includes 93.68 million ha under water erosion, 9.48 million ha under wind erosion, 14.30 million ha under water logging/flooding, 5.94 million ha under salinity/ alkalinity, 16.04 million ha under soil acidity and 7.38 million ha under complex problem *[Annual Report, 2009]*.

The primary cause of land degradation in India is the demographic pressure, leading to loss of vegetative cover due to deforestation. Harvesting of timber, collection of fuel wood, overgrazing, shifting cultivation, encroachment of forest areas and unscientific mining for minerals are some of the reasons for deforestation and desertification. Besides that, ignorance of proper soil and water conservation measures, non-judicious use of manures, fertilizers, insecticides and pesticides, faulty irrigation and water management practices, discharge of industrial effluents, sewage/sludge etc. are also responsible for land degradation to a considerable extent. Other causes of land degradation are diversion of arable land to other uses, viz., industrial development, urbanization, settlements, brick kilns, road construction, foods, water logging, climatic adversities, etc.

AGROFORESTRY TECHNOLOGIES FOR FRAGILE ECOSYSTEM

In a scenario of decreasing availability of good lands for agriculture, degrading soil and water resources, increasing pollution hazards and threats to the environment and ecosystem, new approaches in farming systems will be required to meet food, fodder, fiber, firewood and timber targets fixed for the future. New agricultural technologies must assure sustainability while optimizing productivity and improving soil health. Inclusion of trees in the existing farming/cropping systems and adoption of agroforestry on wastelands is one option to achieve sustainability which optimizes productivity. With the growing realization that agroforestry is a practical, low cost alternatives for food production as well as environmental protection, forest departments of many countries are integrating agroforestry programmes with conventional silvicultural practices *[Swaminathan, 1987]*. Most agroforestry systems constitute sustainable land use and help to improve soil in a number of ways. Some of these beneficial effects are evidence in a number of experiments carried out in different parts of the world *[Young, 1989]*. Through agroforestry, many countries could not only minimize the land degradation but also increased the production *[GTI, 1995; Mishra and Sarim, 1987; Swaminathan, 1977]*. Overall, India is estimated to have between 14,224 million and 24,602 million trees outside forests, spread over an equivalent area of 17 million ha which are more in numbers than trees in side the forest. There are various fragile ecosystems where specific agroforestry systems are required to combat for the degradation.

1. WATER EROSION

Water erosion is the most serious degradation problem resulting in loss of top soil in 130.5 million ha and terrain deformation in 16.4 million ha. In India, there are nearly 3.67 million ha ravine lands of which about 72 per cent are confined in Uttar Pradesh, Madhya Pradesh, Rajasthan and Gujarat states only. In addition, due to faulty agricultural practices more than 8,000 ha of land are converted into ravines every year. The best use of ravine land is to put it under suitable permanent vegetation cover. Medium and shallow gullies can be utilized under silvipastoral and hortipastoral and deep gullies under tree plantations. The recommended species for ravine areas are as under in Table 1.

Production of different tree species in ravines has shown that *Acacia nilotica* is the most promising fuel wood tree species. The main grasses suitable for gully stabilization in Rajasthan, Uttar Pradesh, Madhya Pradesh and Gujarat are *Dichanthium annulatum, Cenchrus ciliaris* and *Sehima nervosum.* By planting and protection of these grasses, reasonable green fodder yield can be achieved in 2-5 years. This practice also reduces run-off and soil loss considerably to the tune of 6-10 t ha^{-1} yr^{-1}. Vegetative barriers are cheap and effective as compared to mechanical measures on mild slopes. Live bunds of Guinea (*Panicum maximum*), Bhabar (*Eulaliopsis binata*) and Khus grass (*Vetivera spp.*) reduced the run-off by more than 18 per cent and soil loss by more than 78 per cent as compared to cultivated fallow on 4 per cent slope in Doon valley *[Bhardwaj, 1990-91]*. *Grewal [1993]*, reported soil loss under different land use options and found minimum loss when trees and grass was grown together in a silvipastoral system (Table 2).

Table 1: Some suitable agroforestry species for salt-affected ravine areas

Trees and shrubs	*Acacia tortilis, Albizia amara, Bambusa bambos, Dichrostachys cinerea, Leucaena leucocephala, Acacia nilotica, Dendrcalamus strictus, Dalbergia sissoo, Albizia lebbeck, Prosopis juliflora, Terminalia arjuna and Azadirachta indica.*
Grass and legumes	*Chrysopogon fulvus, Cenchrus ciliaris, Pennisetum pedicellatum, Saccharum spontaneum, Dichanthium annulatum Phaseolus atroperpureus and Stylosanthes species.*

Source: Pathak and Solanki, 2002

Table 2: Soil and nutrient loss from different and land use systems in Shivaliks.

Land use systems	Soil loss (t ha^{-1})	Run-off (%)	Nutrient loss	
			N (%)	K (%)
Eucalyptus-Bhabar grass	0.07	0.05	0.46	0.90
Acacia catechu-for age grass	0.24	2.00	6.97	0.52
Leucaena-Napier grass	0.28	4.40	6.60	1.20
Teak-Leucaena-Bhabar	0.43	3.30	2.08	0.55
Eucalyptus-Leucaena-Turmeric	0.59	2.60	2.47	0.73
Poplar-Leucaena-Bhabar	1.54	4.80	5.90	1.10
Sesamum-rape seed	2.69	20.50	42.50	3.00
Cultivated fallow	5.65	23.00	51.30	5.00

Source: Grewal [1993]

Young [1989], reported that trees and shrubs have several functions to control erosion like (i) to increase soil cover, by litter and pruning (ii) to provide partly permeable hedgerow barriers (iii) to lead to the progressive development of terraces, through soil accumulation upslope of hedgerows (iii) to increase soil resistance to erosion, by maintenance of organic matter (iv) to stabilize earth structures by root systems (v) to make productive use of the land occupied by conservation works. Alley cropping or hedgerow cultivation is very helpful in controlling of soil erosion in the hilly area. Nitrogen fixing trees species like *Leucaena leucocephala, Gliricidia sepium, Indigofera tysmani*, *Fleminigia* spp. and *Desmodium rensonii* etc. and grass species like *Vetiviera zizanoides* and *Thysanolaena maxima* are very effective for controlling run off and erosion in the hilly region. *Singh et al., (1993)*, found that runoff and soil loss were substantially reduced when small watersheds with agriculture were replaced either by trees and grasses (silvipasture) or with mechanical measures.

2. WIND EROSION

Wind erosion is a serious problem in the arid and semi-arid regions including the states of Rajasthan, Haryana, Gujarat and Punjab. It is also prevalent in coastal areas where sandy soil predominate and in the cold desert regions of Leh in extreme north-western India. Wind erosion is moderate to severe in arid and semi-arid regions or north-west, covering an area of 28,600 km^2 of which 68 per cent is covered by sand dunes and sandy plains.

• Degraded Lands In Arid Regions

Most suitable species for restricting the movement of sand-dunes and checking the advance of desert identified are *Acacia planifrons*, *Acacia albida*, *Acacia tortilis*, *Prosopis juliflora*, *Prosopis cineraria*, *Tecomella undulata* and *Zizyphus mauritina*, Promising grasses identified for growing in association with trees are: *Cenchrus ciliaris* and *Cenchrus setigarus*. For Tamilnadu situations, species like *Acacia senegal* and *Albizia mellifera* are reported suitable to check shifting of the sand dunes.

Sand Dunes And Their Stabilization

The Indian desert is situated in the north-west covers about 2.86 m ha area. About 68% of this area is covered with sand dunes and sandy plains. Techniques of stabilization of Sand dune developed by CAZRI include two processes - sand dune fixation and sand dune afforestation *[Anonymous, 2007]*.

Sand Dune Fixation - It is based on the principal of reducing the threshold velocity of wind by establishment of wind breaks at the dune surface and fencing the area by establishing a pre-planting mechanical system. The technique includes:

(a) Parallel hedge system (5 m)

(b) Checker-board or chess board system with brushwood material like *Leptadenia pyrotechnica* (Khimp), *Ziziphus nummularia* (Pala), *Crotalaria burhia* (Sania) and *Panicum turgidum* (Murath)

(c) The fore dune system

(d) Mulching

Table 3: Suitable forage and fuel wood species for sand dune afforestation

Trees	*Prosopis juliflora, Prosopis cineraria, Acacia tortilis, Acacia radiana, Zizyphus mauritiana, Acacia senegal, Parkinsonia articulata* and *Tamarix articulata* etc.
Shrubs	*Colligonum polygonoides, Exotolaria burhia, Aerva javanica, Zizyphus nummularia,* etc.
Grasses	*Lasiuruss indicus, Panicum turgidum, Panicum antidotale,* and *Cenchrus ciliaris,* and among creepers *Citrullus colocynthis* etc.

Source: Pathak and Solanki, 2002

Sand Dune Afforestation – After fixation, sand dunes can be permanently stabilized with vegetations. The recommended species for stabilization are indicated in Table 3.

- **Semi Arid Regions Degraded Lands**

The most promising trees, grasses and legumes which can be combined in a silvipastoral system identified for rehabilitation of degraded lands are

Trees : *Albizia spp., Hardiwickia binata, Dalbergia sissoo, Leucaena leucocephala, Azadirachta Indica, Acacia nilotica*

Grasses: *Chrysopogon fulvus, Dichanthium annulatum, Cenchrus ciliaris, Panicum maximum, Panicum pedicellatum, Heteropogon, Bothrichloa* etc.

Legumes: *Stylo, Clitoria, Sirato* etc.

3. SALT-AFFECTED SOILS

Out of nearly 146.82 million ha wastelands in the country, about 5.94 million ha is constituted by the salt affected soils. A sizeable chunk of salt lands in the country is present in the Indo-gangetic alluvial plains. Silvipasture system is considered an option of great promise for the rehabilitation of such soils. Salt affected soils in the country can be grouped into two categories, alkali/sodic and saline soils.

- **Alkali/Sodic Soils**

Sodic soils of the Indo-gangetic alluvial plain are characterized by high pH, higher exchangeable sodium (ESP), low infiltration, dispersed soil, low organic matter content and poor fertility. In most cases precipitated $CaCO_3$ layer exists in the profile. This layer offers severe mechanical impedance for root penetration of perennial vegetation particularly the trees. Because of high sodicity, such soils do not support any kind of vegetation except the growth of some salt tolerant indicator plants. Promising agroforestry species identified for planting in salt affected soils are listed in Table 4.

AFFORESTATION TECHNOLOGY FOR ALKALI/SODIC SOILS

Special planting technology has been developed for raising multipurpose tree species (MPTS) in sodic soils. The planting technique for sodic soils involves digging holes of 30 cm diameter and 100-140 cm deep with the help of a tractor mounted post-hole digger. These auger holes are filled back with the mixture of original alkali soil + 3-4 kg gypsum + 8-10 kg farm yard manure (FYM) + 10-15 kg river sand. This technique ensures more than 80% tree survival even after 10 years in highly alkali soils (pH>10.0). This auger hole technology has become a

Table 4: Promising MPTS for salt affected soils

Alkali Soils	Saline Soils	Promising Grasses
Prosopis juliflora, Acacia nilotica, Tamarix articulata, Casurina equisetifolia, Eucalyptus tereticornis, Pithecelobium dulce, Pongamia pinnata, Terminalia arjuna, Prosopis alba, Dalbergia sisso	*Prosopis juliflora, Tamarix troupii,Tamarix articulata, Pithecellobium dulce, Acacia farnesiana, Acacia nilotica, Acacia tortilis, Casuarina glauca, Eucalyptus camaldulensis, Leucaena leucocephala*	*Leptochloa fosca, Cynodon dactycon, Braciaria mutica, Panicum spp., Chloris gayana*

Source: Singh et al. (1993)

common practice with the Forest department, farmers and others engaged in afforestation programmes on alkali soils in our country. For saline soils, sub surface planting method gives better survival and biomass of multi purpose tree species (MPTS). In this case, saplings are planted in 30 cm deep trenches.

SILVIPASTORAL MODEL

As mentioned above the most promising woody species for alkali soils are *Prosopis juliflora*, *Acasia nilotica,* and *Tamarix articulata.* Highly salt tolerant and high biomass producing grass species include *Leptochloa fusca*, *Chloris gayana*, *Brachiaria mutica* and species of *Sporobolus & Panicum*. Mesquite *(Prosopis juliflora*) and *Kallar* grass (*L. fusca*) silvi-pastoral practice has been found most promising for firewood & forage production and soil amelioration. *Kalla*r grass in association with mesquite produced 46.5 t/ha green fodder in 15 cuttings over a period of 15 months without applying any fertilizer and amendment. Mesquite could produce 160 t/ha air-dried firewood in 6 years when planted at 2m x 2m spacing *[Singh et al., 1993]*. This system could improve the soil to greater extent after 6 years. More palatable fodder species such as shaftal (*Trifolium resupinatum*), berseem (*Trifolium alexandrium*) and senji (*Melilotus parviflora*) could be grown with mesquite after harvesting *kallar* grass even after a period of 4 years.

AGRI-SILVICULTURE MODELS

This is suited to partially alkali/reclaimed alkali lands. *Poplar, Acacia* and *Eucalyptus* based agri-silviculture models have been developed for such lands. These have proved highly productive in terms of economics and soil properties when compared with crop based system as indicated in the Table 5.

Table 5: Change in soil properties (0-30 cm) under different tree-crop combinations

Land use systems	pH	Organic carbon (%)	Available N (kg ha^{-1})
Crop based system	-0.45	+0.07	+10
Eucalyptus based	-0.67	+0.12	+21
Acacia based	-0.63	+0.20	+31
Populus based	-0.80	+0.17	+25

Source : Pathak, 1989 - sign indicates decrease and + as increase over the original values

• **Saline Soils** Vegetation hinders the loss of water through evaporation and thus results in lower salinity in the area under vegetation. Plant species which can withstand high salt content and thrive under high water table conditions should be selected for planting. Species like *Atriplex, Prosopis, Tamarix, Casuarina, Kochia, Zizyphus, Salvadora and Acacia* are most tolerant to underground saline water situation. *Yadava and Prakash [1995]* found that *Termnalia arjuna, Albizzia procera*, *Eucalyptus* 'hybrid' and *Leucaena leucocephala* were more tolerant and survived up to electrical conductivity (ECe) 12.2 dS/m and *Dalbergia sissoo* were slightly tolerant as it survived up to ECe 6.70 dS/m. A study under *Acacia nilotica* and *Eucalyptus terticornis* in Karnal, India recorded that lowering of pH from 10.5 to 9.5 in five years and of electrical conductivity from 4 to 2 with tree establishment assisted by addition of gypsum and manure. *[Gill and Abrol, 1986.; Grewal and Abrol, 1986].*

Afforestation programmes for saline waterlogged soils require the proper selection of tree species and planting technique. As the main problems of these soils are: high water table, high salinity of soil and underground water, impeded drainage and less soil aeration for tree growth, tree species should be those which can tolerate these multiple stresses. It is equally important that suitable planting method is adhered for making successful afforestation of highly saline waterlogged soils. It has been observed that by way of furrow planting technique, it is possible to keep salt concentrations relatively low in the rooting zone of tree saplings such that they are able to escape the adverse effect of high salinity. Tree species like *Acacia farnesiana*, *Parkinsonia aculeata*, *Prosopis juliflora*, *Salvadora persica*, *S. oleoides* and *Tamarix sp.* could be rated the most promising which could be grown satisfactorily on waterlogged saline soils with ECe > 25 dS / m in their active root zone whereas tree species such as *Acacia nilotica* , *A . tortilis* , *Casuarina glauca* 13,987 , *C. glauca* 13,144 and *C.obesa* 27 were observed as moderately tolerant. The experimental observations indicated that the survival and growth of tree species were markedly improved with furrow planting when compared with sub - surface and ridge - trench planting methods. The biomass of *Prosopis juliflora* and *Casuarina glauca* was the highest (98 t/ha and 96 t/ha), followed by *Acacia nilotica* (52 t/ha—67 t/ha) and *A. tortilis* (41 t/ha) when planted with subsurface or furrow techniques, proving that these are the suitable species for saline waterlogged soils *[Tomar et al., 1998]*.

4. WATER LOGGED SOILS

The term 'water logging' refers to a condition of short/long term water stagnation caused due to changes in hydrological regime, landscape, silting-up of riverbeds, increased sedimentation and reduced capacity of the drainage systems. The physical deterioration of soil due to water logging or submergence flooding has affected around 14.3 million ha land in India. Suitable trees and grass species for such situations are:

Trees: *Eucalyptus tereticornis, Salix spp., Terminalia arjuna, Acacia auriculiformis, Syzigium cuuminii, Albizia lebbek, Bambusa nutans, Pongamia pinata*

Grasses: Para grass, Cold grass and Setaria grass

5. ACID SOILS

Agroforestry management is the appropriate management of acid soils because perennial woody vegetation can recycle nutrients, maintains soil organic matter and protects the soil from surface soil erosion, and runoff *[Nair, 2001]*. There are some multipurpose tree species which are highly adapted to acidity viz., *Alnus nepalensis, Parkia javanica, Parkia facataria, Michelia oblonga, Melenia arborea* etc. moderately adapted viz., *Acacia auriculiformis, Michelia alba, Michelia lenigata* etc. and less adapted viz., *Leucaena leucocephala, Robinea pseudoacacia, Cryptomeria japonica,Cryptomeria torulosa, Pinus kesiya* etc. *[Dhyani et al., 1995]*.

6. MINE SPOILS

It is estimated that nearly 3000 billion tones of mine overburden is dumped annually the world over. At present, about 3,86,000 ha land per annum is disturbed by mining which is expected to go up to 9,24,000 ha per annum. Mine spoils result in shifting mass of sand and rubble, denudation of forests, reduction in water holding capacity of reservoirs, rivers, streams etc. Such areas can be reclaimed by addition of soil amendments such as liming materials for acidic mine spoils, sewage sludge, paper mill sludge, fly ash, mulches, manures, compost etc for other mine spoils so that plant growth can be established. Suitable tree species for degraded mine spoils are listed in Table 6.

Table 6: Plant species suitable for re-vegetation of mine spoils.

Mine spoil category	Suitable plant species
Bauxite mined area of Madhya Pradesh	*Grevillea pteridifolia, Eucalyptus camaldulenis, Pinus, Shorea robusta, etc.*
Coal mine spoils of Madhya Pradesh	*Eucalyptus hybrid, Eucalyptus camaldulensis, Acacia nilotica, Dalbergia sissoo, Pongamia pinnata, etc.*
Lime stone mine spoils of outer Himalayas	*Salix tetrasperma, Leucaena leucocephala, Bauhinia retusa, Acacia catechu, lpomea cornea, Eulaaliop*
Rock-phosphate mine spoils of Mussoorie	*Pennisetum purpureum, Saccharum spontaneum, Vetex negundo, Rumes hastatus, Mimosa himalayana, Buddlea asiatica, Dalbergia sissoo, Acacia catechu, Leucaena leucocephela and Salix tetrasperma, etc.*
Lignite mine spoils of Tamil Nadu	*Eucalyptus species, Leucaena leucocephala, Acacia and Agave, etc.*
Mica, copper, tungeston, marble, dolomite, limestone, etc. minespoils of Rajasthan	*Acacia tortilis, Prosopis juliflora, Acacia senegal, Salvadora oleodes, Tamarix articulata, Zizyphus nummularia, Grewia tenax, Cenchrussetigerus, Cymbopogon, Cynodon dactylon, Sporobolus marginatus, D. annulatum etc.*
Iron ore wastes of Orrisa	Subabul, local plant species, etc.
Haematite/magnetite, manganese spoil from Karnataka	*Albizia lebbek*, local plant species, etc.

Source : Pathak and Solanki, 2002

7. COLD DESERTS

About 10 million ha in western Himalayas of Jammu and Kashmir and Himachal Pradesh, lying between the greater Himalayas and the mountains on the edge of the Tibetan plateau, are a cold desert. This is an unstable and ecologically fragile region situated in the rain shadow of the towering mountains ranges and experiences extremes of cold and dryness. The ever-increasing biotic pressures on the desert vegetation for fuel, fodder and grazing has led to serious ecological degradation. Tree species found suitable for these areas include poplar and willow. *Hippophae rhanmoides*, an important indigenous multipurpose shrub of the region is used as fuel and fodder by the local inhabitants.

8. ROCKY TERRAIN AND SHALLOW SOILS

A list of agroforestry species, which can be successfully planted for development of rocky and shallow soils, is given in Table 7.

Table 7: Suitable forage and fuel species for rehabilitation of rocky terrain/shallow soils

Herbaceous species			Woody species	
Habitat	Grasses	Legumes	Shrubs	Trees
1. Hilly terrain	*Chrysopogon fulvus, Sehima nervosum, Heteropogon contortus, Pennisetum pedicellatum, Thameda quadrivalvis*	*Stylo santheshamata, Atylosia scarbaeoides, Indigofera astragalina*	*Annona squasoma, Anogeissus pendula Dendrocalmus strictus*	*Butea monosperma, Anogeissus*
2.Base of Hillock	*Cenchrus ciliaris, C. setigerus, S. nervosum, H. contortus, Dichanthium annulatum, Bothrichloa pertusa*	*S. hamata, S. scabra, A. scarabaeoids, Macroptilium atropurpurium Lablab purpureus, Dolichos axillaris, Desmonthus virgatus*	*Dichrostachys cinerea, Acacta tortalis, Carrisa carandus, Zizyphus jujuba*	*Albizia lebbeck, Azadirachta indica A. nilotica, Hardwickia binata*
3. Dry plain	*C. ciliaris, C. setigerus, D. annulatum, B. intermedia, Panicum maximum, Setaria spacelata*	*S. hamata, S. scabra, S. humilis, Clitoria ternatea, M. atropurpureum A.excela scarobaeoides,*	*A. tortalis, Psidium guajava (guava), Emblica officinalis, Alianthus*	*A. indica, Dalbergia sissoo, A. amara, Leucaena leucocephala, Managifera indica, Tectona grandis*
4. Moist plain	*D. annulatum, Iseilema laxum, Brachiaria mutica, B. intermedia, Cynodon dactylon*	*M. atropurpureum, S. hamata, S. scabra, D. viragatus*	*E. officinalis, D. cinerea, L. leucocephala*	*D. sissoo*
5. Field bunds	*D. annulatum, H. contortus, C. dactylon*	*Rhynchosia inima, Indigofera linnae, M. atropurpureum, A. scarabaeoides*	*Carica popaya, C. Citrus aurantifolia*	*Eucalyptus sp., Phones sp.*

Source: Pathak and Solanki, 2002

Following steps are involved in rehabilitation of rocky lands

i. In the situations where some kinds of tree/grass stumps are present, assisted natural regeneration should be allowed. Efforts should be made to improve those three stumps for quality and value addition through *in-situ* budding/grafting. e.g. wild plants of ber, aonla etc. can be successfully budded/grafted with superior ones.

ii. In areas where such natural stumps are not available, woody species such as *Anogeissus spp., Dalbergia sissoo, Azadirachta indica, Prosopis spp, Leucaena leucocephala, Albizia amara, Albizia lebbeck* etc. can be introduced.

iii. Introduction of nurse crops like *Stylo*, *Clitoria* and *Sirato* to create a niche for the growth of other species.

iv. Sowing of grasses like *Cenchurus setigerus, Chrysopogon fulvus, Bothrichloa*, *Heteropogon* and *Dichanthium.* Some edible fruit, forage and vegetable clones of *Opuntia* can also be introduced.

v. Staggered contour trenching / bunding are pre-requisite for plantation of grasses, legumes and their mixtures.

CONSTRAINTS IN ADAPTATION OF AGROFORESTRY

In spite of significant impact of agroforestry on India's economy, it has not become as popular with the farmers as it should have been. There are certain inherent limitations with this land use system. Some of these constraints are listed below:

- Farmers in general, are reluctant to grow trees on their farm land owing to long gestation period in getting returns from trees, particularly in poor sites where return are even slower and lesser.
- Proven agroforestry technologies are available only for limited situations / locations / regions.
- Lack of quality seed / planting material sources of promising agroforestry species.
- Inadequate harvesting and processing techniques.
- Lack of value added product development protocols.
- Rigid legal laws restricting harvesting, transporting and sale of trees.
- Lack of assured financial support for popularizing agroforestry.
- Lack of proper transfer of technology, trained manpower, infrastructure and funds.

CONCLUSION

Land degradation and poor yields signify poverty, hunger and famine are pervasive, especially in the smallholders' farms. This coupled with the adverse effects of enhanced edaphic and environmental dangers increase the threat to the food security. Agroforestry emerges as a promising land use option to surmount the problem of land degradation and the imminent "food, fodder & fuel wood crisis". Diversified production and consequently greater food diversity and sustainability, as well as the potential for increasing the purchasing power of the rural people are intrinsic features of these traditional land use systems. Agroforestry practices are implicitly assumed to have higher productivity than monospecific systems, especially on degraded sites, because diverse assemblages have a greater likelihood of containing species with strong responses to resources compared to species-poor assemblages.

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