GLIMPSES OF AGRO-FORESTRY & SOIL CONSERVATION IN INDIA

Central Arid Zone Research Institute
Jodhpur-342 003 (Rajasthan) INDIA

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Pratap Narain
K.D. Sharma
D.C. Joshi
L.N. Harsh
J.C. Tiwari

CENTRAL ARID ZONE RESEARCH INSTITUTE
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INTRODUCTION

Out of 142 M ha net sown area in India, 97 M ha continues to be rain fed. Due to intrinsic features of natural resources and increasing human intervention the land resources of the country are exposed to different processes of land degradation. The wind and water erosion are dominant degradation processes on rain fed lands while waterlogging and salinisation are wide spread in irrigated areas. These processes are dominant in arid, semi-arid and dry sub-humid regions. Traditionally the natural resources have been managed with minimum deterioration in their quality. Traditional practices viz. planting trees and shrubs within the agricultural fields and on their boundaries, indigenous implements for soil working, current fallowing, low intensity cropping, green manuring and incorporation of legumes in crop rotations helped in maintaining land resources.

With the advent of new technologies to meet the needs of burgeoning population for food, fibre, fodder and fuel there has been undue exploitation of natural resources and consequently acceleration in land degradation. It has been estimated that in India about 107.12 M ha is degraded due to water erosion, 17.79 M ha is due to wind erosion, 16.13 M ha is under waterlogging and salinisation, and 3.97 M ha is under ravines. About 19.49 M ha forest is degraded. Technology packages have been developed in past few decades for rehabilitation of degraded lands and their sustainable management. Adoption of agroforestry on watershed basis has been the approach to combat degradation and sustainable production.

To address current problems of the nation this bulletin briefly presents agroforestry under different edaphic and agroclimatic regions on watershed basis for rehabilitation and sustainable management of land degraded due to water erosion, wind erosion, waterlogging and salinisation, and mine spoils. Promising agroforestry systems and priority MPTS in different agroclimatic regions have been identified and annexed.

SOIL EROSION ON MARGINAL CROPLANDS

In India 107.12 and 17.79 M ha is affected by water and wind erosion, respectively. The wind erosion is further aggravated by deep ploughing of sandy soils, particularly with tractor drawn implements which breaks the unstable clods and uproots the natural vegetation exposing the soil to wind action. About 30 to 40 % of the rainfall is lost through runoff causing loss of 5334 M tonnes of soil (16.35 tonnes ha^{-1} $year^{-1}$) and 5.4 to 8.4 M tonnes of nutrients annually.

A severe water eroded field

Wind erosion/deposition in crop field

Highly activated sand dunes

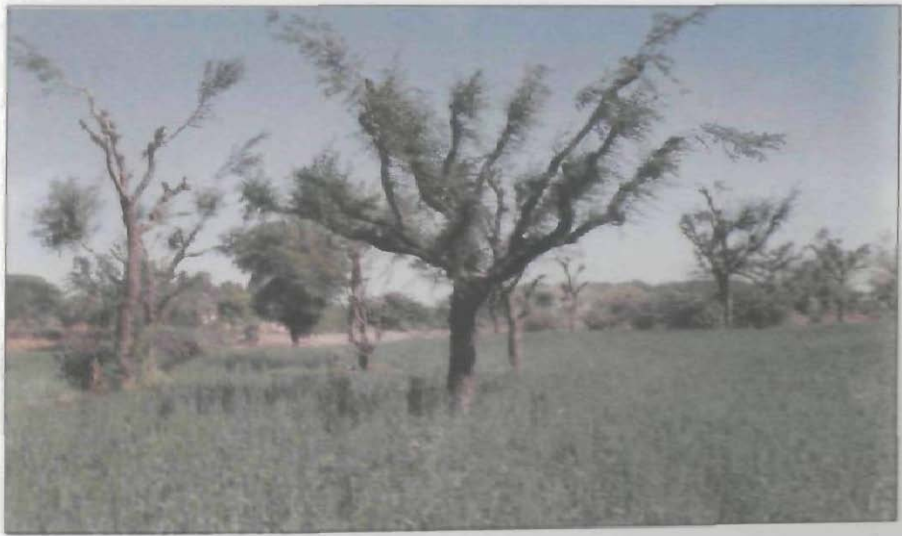
Sand dunes are most prominent features of the Thar desert in arid Rajasthan covering 58 % of the area. Height of these dunes vary from few metres to 100 m. These dunes are grouped into seven types viz. parabolic, coalesced parabolic, longitudinal, transverse, barchan, obstacles and shrub coppice. Because of extensive animal grazing and cultivation on dune flanks, many of these dunes have become highly active and create menace on agricultural fields, communication and transport network and human settlements.

Controlling Wind Erosion

- Reduced tillage after first shower of rains or no tillage maintains better clod size, which significantly reduces wind erosion.
- Crop residue @ 2-5 tonnes ha^{-1} and retaining pearl millet stubbles of 45 cm height is found effective in preventing wind erosion in sandy soils.
- Alternate strips of pearl millet, moong and moth beans, and cluster bean and erosion resistant grasses prevents wind erosion effectively. The optimum width of grass strips varies from 6 m in sandy soil to 30 m in sandy loam soils.

Strip cropping for wind erosion control

- Ber with clusterbean, cowpea, horsegram or other legumes is widely adopted in dry tracts of Andhra Pradesh, Maharastra, and Karnataka. The agri-horticulture system has a benefit cost ratio of 5.53.
- *Prosopis cineraria, Hardwickia binata* and *Tecomella undulata* are found most suitable for soil conservation in range lands.



Agri-silvicultural system

- Agri-silviculture including plantation of *Prosopis cineraria* and *Zizyphus rotundifolia* in crop fields is traditionally practised for soil conservation in arid region of Rajasthan.
- Shelter belts plantation of 3-5 rows of trees in pyramid shape check wind erosion significantly. Tree species such as *Calligonum polygonoides, Ziziphus nummularia, Acicia bivenosa, Acacia tortili* and *Prosopis juliflora* for the flank rows and *Eucalyptus camaldulensis, Hardwickia binata, Azadirachta indica, Albizia lebeck* and *Cacia siamea* for central row are recommended.

Shelter belt plantation to control wind erosion

- Protection against biotic interference, installing micro wind breaks of locally available brush-wood at 2-3 m interval at crest and at 5 m interval at middle/base of dune, and plantation of suitable tree species stabilised the sand dunes. Most suitable tree species for sand dune stabilisation in arid region are *Acacia tortilis, Prosopis juliflora, Colophospermum mopane, Acacia binosa, Acacia nubica, Ziziphus nummularia* and *Cordia rothii*. Suitable grasses and shrubs are *Lasiurus sindicus, Cenchrus ciliaris, Panicum antidotale* and *Citrullus colocynthis*. The State Government of Rajasthan has stabilised sand dunes in about 100,000 ha.

Stabilized sand dunes

Controlling Water Erosion

- Tillage combined with seeding across the slope reduced runoff and soil erosion by 10 to 20 % and could sustain crop for two weeks following intermittent failure of rainfall.
- On less than 3 % sloping land in 300-500 mm rainfall zone contour farming reduced soil loss from 5.5 to 3.6 tonnes ha^{-1} and improved crop yields.
- Modification of land configuration on Alfisols, Vertisols and Inceptisols led to 10-40 % increase in crop yield through on-farm rainwater management.

Contour farming for control of soil erosion

- Contour bunding and contour furrowing alone or in combination in less than 600 mm rainfall zone increased soil moisture storage from 26 to 39 % resulting in higher crop yield by 14 to 181 %.
- Variable graded bunds for annual rainfall greater than 600 mm in permeable soils and in less than 600 mm in impermeable soils disposed excess water safely.
- In red and laterite soils graded bunds reduced runoff from 20 to 13 % and soil loss from 4 to 0.1 tonnes ha^{-1}.
- In red lateritic soils graded trenches in 10-15 % sloping area in high rainfall regions reduced runoff by 26 to 28 % and soil loss from 4 tonnes ha^{-1} to zero.
- Contour vegetative barriers of locally adapted grasses such as *Cymbopogan jwarancusa, Cenchrus ciliaris* and *Cenchrus setigerus* transplanted 0.30 m apart on contours at 0.6 to 1.0 m vertical interval form a dense barrier within 2 years to control soil erosion.

CVB of Cenchrus cilliaris

The runoff reduced by 28-97 % and increased soil moisture storage by 2.5 times resulted in 20 and 50 % higher crop yield over control.

- In red soils the vegetative barriers of *Vetiveria zizanioides* at 11 m horizontal interval reduced runoff and soil loss to 35 and 62 %, respectively compared to the cultivated fallow. The two row vegetative barrier of *Vetiveria zizanioides* in sorghum crop reduced the runoff and soil loss to 68 and 80 %, respectively and enhanced crop yield by 7.6 %.

- In hilly region bench terracing with provisions of grassed water ways is effective. Agroforestry interventions are utilized to stabilise risers and sustenance of the terraces.

Bench terracing on sloping land

- Soil and water conservation treatments (bench terracing and contour bunding) in mountainous watersheds reduced runoff from 42 to 14 % and soil loss from 11 to 2 tonnes ha^{-1}.

Bench terracing and contour bunding in mountainous watersheds

- Bench terracing in 16 to 35 % slope of red and lateritic soils reduced runoff from 15 to 3 % and soil loss from 45 to 0.5 tonnes ha^{-1}

Bench terracing in red and lateritic soils

SALINISATION AND WATERLOGGING

Natural salt affected soils are wide spread in arid and semiarid regions of India covering about 16.13 M ha. These lands are barren supporting only scrub vegetation of salt tolerant species. Irrigation with saline and sodic water causes saline and sodic conditions in the region. Fast rising water tables in the canal command areas create waterlogging and salinisation. The reasons are faulty irrigation systems and improper on-farm water management. Consequently, India alone has 12,428 km^2 under soil salinity and alkalinity and 4,266 km^2 under waterlogging.

Salinisation in irrigated crop fields

Management of Salt Affected Soils

- Technology for sustainable management of brackish water by treatment with gypsum as amendment has been developed for wheat, mustard, and cumin crops. The technology is cost effective with benefit cost ratio of 3:1. The programme has been adopted in the region.

Reclamation of brackish water irrigated soils

- It is not possible to reclaim these lands because of paucity of good quality water for leaching the salts. The augur hole, and ditch and mound techniques have been developed for identified tree plantation on such lands. Silvi-pastoral, silvi-agriculture and silvi-horti-pastoral practices for vegetating such lands have been adopted.
- *Prosopis juliflora, Acacia nilotica, Casurina equisetifolia, Tamarix articulata, Tamarix arjuna* and *Pongamia pinnata* together with grasses such as *Leptochloa fusca, Chloris gayana* and *Sporobolus sp., Prosopis juliflora* produced 46.5 tonnes ha^{-1} in 15 cuttings over a period of 50 months. In the silvi-horti-agricultural model growth rate of guava and eucalyptus+subabul was faster resulting in higher production.
- The subsurface drainage at 25-50 m spacing, depending on the soil texture and drainage requirement, not only improved the yield of crops but also facilitated the growing of a wide variety of crops by controlling the water table and reducing salinity. The benefit and cost ratio was more than 1. Feasibility of subsurface drainage technology for waterlogged saline soils has been demonstrated and adopted in canal command areas of Punjab, Haryana, Rajasthan, Gujarat, Karnataka and Andhra Pradesh.

Area reclaimed by bio-drainage

- Tree species namely *Eucalyptus camendulensis, Delbergia sisoo, Prosopis cineraria* and *Tecomela undulata* plantation in the IGNP command revealed that in a period of 6 years water table has gone down by 14 to 15.7 m.
- Agroforestry with commercial trees suitable for bio-drainage viz. poplar *(Populus deltoides)* Eucalyptus *(E. tereticornis)* and babul *(Acacia nilotica)* with rice-wheat, rice-berseem, pigenpea/sorghum-mustard rotation. The benefit cost ratio was highest (3.30) in case of poplar with rice-wheat rotation.

GULLIED AND RAVINOUS AREAS

Gully erosion is the removal of soil by running water, with the formation of channels, which cannot be obliterated by normal cultivation. Concentration of surface runoff through cattle paths, cart tracks, dead furrows, tillage furrows, or other small depressions down a slope is a potential source of gullying. During every rain, the runoff rushes down these gullies, increasing their width, depth and length. A network of gullies is known as ravines. Large areas of contiguous fertile lands, once giving good crop yields, thus get swallowed by the ever increasing gullies and are rendered uncultivable. Roads, bridges, buildings and fences are often damaged by the development of ravines. Gullied and ravinous areas occupy 3.97 M ha within the States of Uttar Pradesh, Madhya Pradesh, Rajasthan and Gujarat along the Chambal, the Mahi and the Yamuna Rivers.

Land turned barren due to severe gullying

Reclamation of Gullies

- Reclamation of small gullies by levelling and provision of safe disposal of water is though recommended but not cost effective for rain fed agriculture. Protection from biotic interference, peripheral bunding, safe disposal of runoff, terracing and gully plugs with plantation of locally adapted tree, shrub and grass species lead to excellent silvi-pasture development.
- Clearing and levelling the bed, constructing a series of composite earth and brick masonry check dams at 1.2 m vertical interval, and terracing the side slopes can reclaim a medium gully. The terrace

Reclamation of deep gullies by permanent vegetation faces, grassed outlets and earth check dams are stabilised by growing suitable grasses such as *Cenchrus ciliaris* and *Dichanthium annulatum*.

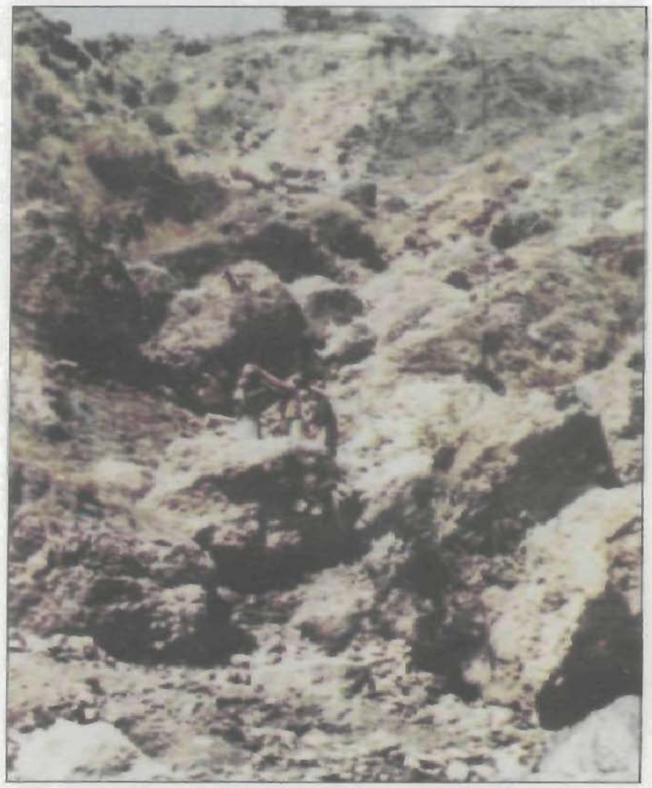
- For deep ravines the best land use is to put them under permanent vegetation, comprising locally adapted grass, shrub and tree species.

Landslide Control

- Effectiveness of integrated measures of gabion toe walls, spurs, drop structures, mulching, contour wattling, plantation and protection proved successful for stabilisation of landslides. A reduction in runoff by 31 % with negligible sediment load resulted from landslide control over a period of 30 years. An increase in vegetation cover from 5 to 95 % resulted in longer dry weather flow from 100 to 250 days.

MINE SPOILS

In the arid, semi-arid and dry sub-humid regions of India, mining is second only in economic importance to agriculture. The important minerals surface mined in this zone are limestone, gypsum, lignite/coal, heavy metals, rock phosphate, clay, building stone, etc. It is estimated that about 700,000 ha area is "spoiled" due to surface mining in India. Within the Indian desert about 184,000 ha are disturbed due to mining.



Havoc caused by limestone mining

The natural resources of an ecosystem are seriously altered and disrupted when disturbed by surface mining. Surface mining creates both the on- and off-site environmental degradation. Traditional mining practices, absence of environmental protection measures and lax regulations cause destruction of land resources viz. denudation of vegetative cover, loss of level and uneven topography, depletion and contamination of water resources, poor soil conditions

Havoc caused by strip mining of gypsum

and loss of soil fabric, loss of fertile land, surface crusting, soil erosion, etc. It is estimated that 2 to 2.5 ha additional area is degraded from each ha of effective mining. Fugitive dust from mining operations often degrades air quality. Release of gases into the atmosphere such as hydrogen sulphide, methane, ammonia and nitrous oxide can occur. Biological systems at all scales are altered or destroyed. Rehabilitation of such drastically disturbed land is a challenging task in drylands due to the harsh environmental conditions and the lack of a suitable technology.

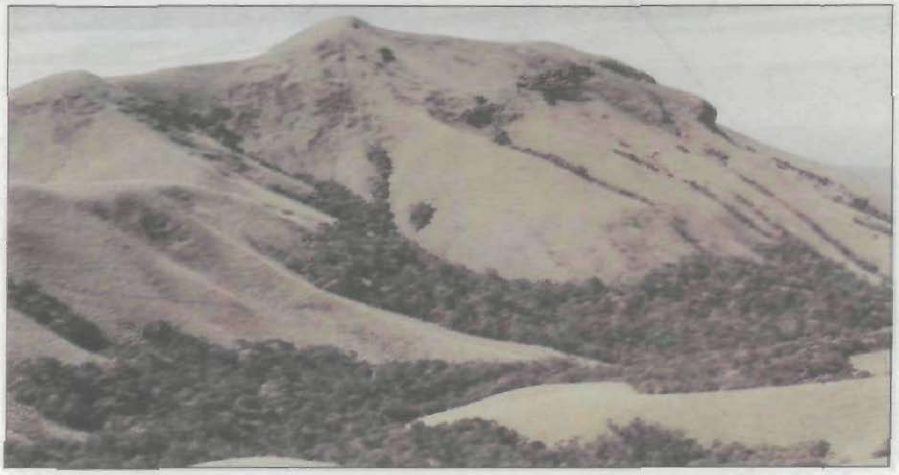
Rehabilitation of Mine Spoils

Stablisation of limestone mine spoils

- Stabilisation of limestone mine spoils through engineering and vegetative measures, and geo-jute reduced runoff losses by 35 % and debris outflow from 550 to 8 tonnes ha^{-1} $year^{-1}$. The vegetation cover increased from 10 to 80 % resulting an increase in lean period flow from 60 to 240 days within a period of 13 years. State PWD saved about Rs. 1.0 lakh per annum being spent for removing debris from the road.
- An optimum combination of rainwater harvesting, soil amendments, planting techniques and adapted plant species increased soil moisture storage in gypsum mine spoils by 37 %, organic carbon by 25 % and vegetation cover from nil to about 45 % within a period of 5 years creating a valuable grazing resource.

Reclaimed gypsum mine spoils

DEGRADED FOREST



Degraded Shola forest

The forest cover in India is reported to be less than 20 % of the geographical area of the country. About 26.13 M ha (8 % of total forest area) is degraded which has less than 40 % crown cover. In addition, 5.72 M ha forest area is scrub forest which is also highly degraded. It has been estimated that growing stock of forest is 4,740 M m^3 and the annual increment of growing stock is 87.62 M m^3 (1.3 m^3 ha^{-1} $year^{-1}$) which is very low as compared to global average of 2.1 m^3 ha^{-1} $year^{-1}$. This situation is mainly due to over grazing, fire, uncontrolled and wasteful logging, illegal felling, excessive fuel wood collection, poor natural regeneration, excessive litter removal and poor density of stock.

Rehabilitation Measures

Successful regeneration

- In recent past, efforts have been made to address the issue of forest degradation, deforestation and to improve the supplies of forest products.
- Since 1980, plantations have been established outside forest reserves on wastelands and on private lands. Since then 1.8 M ha is planted annually to regain the forest cover.
- Encouraging agroforestry in and around crop lands, farm houses and community land would meet needs of farmers and reduce pressure on forests and their illicit felling. In addition, joint forest management may further help in conservation of community as well as preserve forests in the country.

ANNEXURE

Promising Agroforestry Systems and Priority MPTS in Different Agroclimatic Regions

Agroclimatic Systems	Agroforestry Systems					
	Agri-silviculture	Agrihorti-silviculture	Agri-horticulture	Horti-pastoral	Silvi-pastoral	Priority MPTS
1. Western Himalayan Region	4	4	5	4	4	*Grewia optiva* *Populus ciliata*
2. Lower Gangetic Plains Region	5	-	3	2	2	*Eucalyptus hybrid* *Acacia auriculiformis*
3. Middle Gangetic Plains Region	4	-	2	-	-	*Populus deltoids* *Anthocphalus cadamba*
4. Upper Gangetic Plains Region	5	-	5	-	-	*Populus deltoids* *Eucalyptus hybrid*
5. Trans Gangetic Plains Region	5	-	5	-	-	*Populus deltoids* *Eucalyptus hybrid*
6. Eastern Plateau and Hills Region	5	-	4	3	4	*Gmelina arborea* *Tectona grandis*
7. Central Plateau and Hills Region	4	-	5	4	4	*Azadirachta indica* *Eucalyptus hybrid*
8. Western Plateau and Hills Region	4	-	5	2	4	*Azadirachta indica* *Acacia nilotica*
9. Southern Plateau and Hills Region	5	-	3	2	4	*Ailanthus excelsa* *Eucalyptus camaldulensis*
10. West Coast Plains and Ghats Region	4	5	4	2	2	*Casuarina equisetifolia* *Eucalyptus hybrid*
11. Gujarat Plains and Hills Region	4	2	4	3	5	*Prosopius cineraria* *Eucalyptus hybrid*
12. Western Dry Region	5	3	4	-	5	*Prosopis cineraria* *Acacia nilotica*

Number 1-5 indicates the priority practical model, 1 = least and 5 = highest.