PROCESS OF DESERTIFICATION AND CONTROL MEASURES TO IMPROVED LAND PRODUCTIVITY IN DRY AREAS

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Abstract

About 80% of the Indian desert, 'Thar Desert' falls in Rajasthan and Gujarat provinces of India. Its high population depends on rainfed agriculture and animal husbandry that is always vulnerable to climate shocks and climate change. A sustainable ecosystem management of agriculture/ pasture lands along with degraded forest areas in manner to address the resource requirement of the population will result in reduction in land degradation, increased biomass resulting in higher sequestration of carbon and in-situ conservation of genetic diversity of endemic tree and grass species. Tree based farming system is well recognized for its ecological and socioeconomic benefits in the form of food, fodder and medicinal products. Rainwater harvesting practices and conservation of biodiversity in sacred grooves are well acclaimed traditional practices. Intensification of agricultural production, reforestation and conservation of forests, management and conservation of soil and water, sustainable management of community land and control of sand drift are the best technological strategies to control land degradation and increase overall productivity. *Prosopis cineraria* along with some other species could be integrated in agricultural systems to diversify the farm income and sustain the livelihood in the area. This article specifies few of these strategies based on literature and the lessons learnt though field experiments.

Keywords: Desertification, land improvement, tree integration, surface vegetation, productivity

1. Introduction

Desertification and climate change are both global processes that lead to environment change. These processes are particular challenges to the poorer regions like Asia and Africa. Climate change refers to global warming of the atmosphere due to emission of green house gases from human activities such as industry, transport and land use change. Desertification refers to the land degradation in arid, semi arid and dry sub-humid areas resulting from various factors including climatic variations and human activities. The term 'Desertification' was coined first by the French Scientist Lavauden,

(1927) to describe the impoverishment of plant cover in the Sahara desert and latter by French forester Aubreville (1949) working in sub-humid Africa. Aubreville (1949) used this term to describe the process of land degradation initiated by deforestation resulting in the land being turned into a desert. Natural and anthropogenic factors are the driving forces of desertification. Cause of desertification can be divided into two categories like direct and indirect causes of desertification. Direct cause includes (i) climate affecting rural production system, and (ii) human activities like overgrazing, over-cultivation, deforestation without reforestation and inappropriate use of irrigation technology. Indirect cause of desertification includes (i) population pressure, urbanization, (iii) poverty, (iii) inequitable sharing of resources, (iv) conflict, national policies, and (v) globalization and new economic orders.

Desertification affects about one-sixth of the world's population, about 70% of all dry lands, amounting to 3.6 billion hectares and one quarter of the total land area of the world (United Nations, 1992). Desertification causes not only the deterioration of the environment and the productivity of the fragile ecosystems, but also the poverty of people living in the regions. It was estimated that the annual direct economics losses due to desertification amounts to more than $42 billion.

2. Consequences of desertification

Due to global climate changes and the over-exploitation of ecosystems resulted from increased human economic activities; desertification is accelerated in many parts of the world. For example, the land desertified annually in China was1560 km^2 in the 1960-1970's, 2100 km^2 in 1980's and 2400 Km^2 in 1990's (Di, 2003a; Chen *et al*. 2003). Desertification is more serious in developing countries where people are dependent on the surrounding environments or ecosystems for living, and resources are not available for restoring the over-exploited ecosystems. More than 80% of 50,000 to 70,000 km^2 of the land desertified annually are located in developing countries. Some consequences of desertification are given below:

- Accelerated soil erosion by wind and water
- Salt accumulation in surface horizon of soils
- Decline in soil structural stability
- Increase in surface crusting and surface runoff
- Reduction in soil infiltration capacity and soil moisture storage
- Replacement of forest or woodland by savanna grassland or scrub
- Reduction in species diversity and plant biomass in ecosystems
- Increase in flow variability of rivers and streams

- Increase in salt content of previously fresh lakes, wetlands and rivers

Because desertification changes the land surface characteristics, it also affect regional climate. Desertification not only threats the ecosystems health and human living within the region, but also affects areas far away from deserts. For example, dust storms from the Gobi desert have caused significant air quality and traffic problems in Beijing, Seoul, and parts of Japan, and even reached as far as the east coast of North America. Like wise storms from Sahara desert affects the air quality of Europe and some times crosses Atlantic Ocean.

3. Strategies for combating desertification

Because of the extreme threats of Desertification to environment and human living condition, combating desertification has become the top priority for government of many countries, international organizations, and non-governmental environment organizations in their environment agenda United Nations, in Agenda 21, specifically lists the steps to be taken to combat desertification (United Nations, 1992).

- In order to effectively combat desertification and sustain economic development, monitoring modeling and prediction of desertification are important.
- The Agenda 21 calls for strengthening the knowledge base and developing information and monitoring systems for region prone to desertification and drought, including the economic and social aspects of these ecosystems.
- Use of appropriate and site-specific technology dovetailed with indigenous knowledge in natural resource management, control of land degradation like sand drift and salinization, intensification of agricultural production through tree integration with more emphasis on indigenous species etc.
- Local community involvement is pre-requisite for any effective long-term solution to desertification. The local community needs to be aware of the benefits for them and to have a full role in the design and implementation of the anti-desertification measures.
- Appropriate form of environmental education must go in hand to reduce poverty and ensure food security among the poorest communities.

3.1. Drought Proofing and Common Land Management

Variability in the monsoon influences the risk in crop production. A severe drought is preceded by a consecutive drought for 3- 4 years followed by unfavorable monsoon conditions, which fails to support cropping system. Availability of community land varies from 4% to 93% of the total village area in arid districts of Rajasthan and Gujarat. A 62-

100% household is totally dependent upon these lands for getting fuel, fodder and even food. To meet the requirement of 3.46 tons of fuel wood and 2.07 ton of fodder per house hold per year on sustainable basis, productivity of these common lands needs to be maintained at 4.2 tons per ha per year.

3.2 Intensification of Production

3.2.1 Tree on Farmland: Research indicated that 30-40 trees of *Prosopis cineraria* in a field increase crop production by 40-50%. This is due to soil nitrogen enrichment with its root nodules and faster mineralization of tree litter. In general, density of this species range from 1 tree ha^{-1} in Jaisalmer to 100 trees ha^{-1} in Jhunjhunu (Rajasthan), however up to the age of 10 year it can be increased to 200 trees ha^{-1} (Malhotra, 1984). In an experiment, density of *Prosopis cineraria* (Linn), which did not affect crop production adversely, was 417 stem ha^{-1} (4 m x 6 m spacing) at the age of 5 year. It reduced further to 278 (4m x 9 m) at 7 years and 208 SPH (8m x 6 m) at 10-11 years. *Vigna mungo* (mungbean), *Penisetum gluocum* (pearl millet) and *Sesamum indicum* (L.) were sown during 1995 to 2001. Height and collar diameter increased with decreasing stem density (Table 1). However, when compared with the growth data at the age of 5 year, the increment in height and collar diameter was 2.5 and 1.9 fold in D_1 compared to 2.0 and 1.8 fold in D_3 (Singh et al., 2002).

Table 1. Growth, biomass and crop yield in *Prosopis cineraria* based agroforestry model.

Tree ha^{-1}		Tree height (cm)		Tree girth (cm)		Percent yield reduction in 2001	
5 year	10 year	5 year	10 year	5 year	10 year	Grain	Straw
1667	417	178	439	5.1	10.3	19	21
833	278	223	459	6.0	12.7	15	19
417	208	278	534	8.3	14.9	4	1

3.2.2 Windbreaks and Shelterbelts: These consist planting trees/ shrubs at the periphery of agricultural fields. These provide the advantage of reducing wind speed and water runoff speed, increasing water infiltration, mineralizing the litter or fixing nitrogen and protect crops against free grazing animals if the windbreak is sufficiently dense (Sharma et al., 1997). Windbreaks and live hedges also provide multiple uses depending on the species and can produce fruit, forage, gum, and oil for sustainable income.

3.2.3 Live Hedges: Hedges protect house/hut or kitchen garden and restricts movement of livestock and are a lining tract through agricultural lands. These living barriers are also raised to demarcate boundaries of agricultural fields and to protect home controls runoff, facilitates the infiltration of rain water to the soil, conserve moisture and increase the production of agricultural crops. The fodder and fuel wood demands are also fulfilled by the living barriers. Farmer earns additional revenue from sale of Pala (dry leaves of *Zizyphus* species), Munj (*Saccharum bengalense*) and firewood from these hedge plants. The most commonly used species for live fencing are *Prosopis* spp. *Acacia* spp. *Zizyphus* spp, *Saccharum* spp, *Euphorbias*, and *Opuntias*, *Leptadenia spp.* etc (Singh and Gupta, 2000).

3.3 Reforestations and Conservation

3.3.1 Forest Regeneration: Experiences show that local species are better suited to regenerate the ecosystems of which they are natural components providing habitat and food for the fauna. These multiple use local species are competitive over the long term and are drought resistant while the exotics can be harvested much sooner, and 2 or 3 times for the same tree owing to stump regeneration.

3.3.2 Assisted Regeneration: Strong regeneration capacity of the species in dry areas is viewed as a form of adaptation in a highly variable environment. *Azadirachta indica*, *Prosopis cineraria*, *Ziziphus* sp. and *T. undulata* have been explained by their ability to produce through stump/ root sucker sprouts. Soil working/ site preparation practices have been found to be useful to increase the soil water availability and sprouting vigour of the species. Trenching around the root zone of these species influence sprouting through the incised roots increasing plant population and productivity of the area.

3.3.3 Direct Seeding: This is one of the low cost alternatives to re-vegetate dry areas. However, success of direct seeding depends upon selection of suitable species and site conditions. A field study indicated that germination percent of *C. mopane* was 94.2 under direct seeding under ploughing of the area and seed broadcasting (Singh, 2003). At the age of 9 months, root of *C. mopane* seedlings was more than two fold larger as compared to that in *A. indica*. Shoot and root dry biomass of *C. mopane* was 5.4 and 6.6 fold than that in *A. indica* seedlings (Table 2). High survival in *C. mopane* seedlings was due to their deep rooting behaviour thereby extracting water from the deeper soil layers as compared *to A. indica*, the roots of which confined in top 0-60 cm layer. Natural regeneration in field condition suggests that this species is best to rehabilitate dry area rather than its introduction in agriculture land as it competes with agriculture crops.

Table 2: Seed germination, survival and growth of germinated seedlings under direct seeding. (Source: Singh, 2003)

Parameters	**Unit**	*A. indica*	*C. mopane*
Seed		1530	955
Germination	25 July 01	825 ±1.5	903 ±1.0
Survival	8 April 02	21 ±1.16	91 ±10.21
	17 July 02	9 ±1.00	87 ±9.29
Height	8 April 02	11 ±1.2	18 ±1.5
	17 July 02	23 ±3.2	28±4.6
Collar dia.	8 April 02	0.28 ±0.03	0.42 ±0.03
	17 July 02	0.31 ±0.01	0.49 ±0.08
No. leaves	8 April 02	14 ±1.2	7 ±1.5
	17 July 02	17 ±2.1	24 ±5.6
No. branches	8 April 02	1	1
	17 July 02	1 ±0.00	3 ±0.6
Root length	8 April 02	60 ±4.4	121 ±3.6

3.4. Rainwater Harvesting and Conservation

3.4.1 Traditional Water Harvesting Measures: Village ponds (*Nadi*) and *Bawadi* are in use in this region for ages. It is a tradition methods used by the villagers of the Thar Desert. Many structures like *Kunds,* local name given to a covered under ground tank developed primarily for tackling problem of drinking water, village ponds *(nadis), Kundis and layikas*, *virdis*, *Khadins* etc. Earthen dam/ check dam are the important technical know how in hilly/ ravenous areas to improve water regime, recharge ground water and enhance the productivity.

3.4.2 Micro-catchments for Plantation Establishment: The studies at AFRI demonstrate the dramatic impact of " Micro-catchments rain water harvesting technology " on tree growth, which improved by 4 to 5 folds on micro-catchments when compared with control. The structures - ring pits, big saucers and ridge and furrow have been found beneficial (Gupta, 1995). Based on growth, cost benefit analysis, employment and social conditions trench and mound and saucers of 2.5 dia have been recommended. The water harvesting techniques as they prevent runoff losses (30-50 %) maintain higher soil moisture regime and facilitate better tree establishment and growth owing to better development of root system, improved water use efficiency, improved nutrient use efficiency (4-7 times), thus give a good start to young plantations.

3.4.3 Mulching and Weeding: Moisture conservation practices such as mulching, soil tillage and intercultural operations in dry zones adequately demonstrate their utility in plantation establishment and early growth of trees (Gupta, 1995). This impact is attributed to the prevention of evapo-transpiration losses and consequently high soil moisture regimes and moderation of thermal regimes in the vicinity of roots and consequently maintaining better microbial activities resulting in transformation and availability of nutrients. A study carried out on partitioning in water use by tree irrigated at 3.6.2 mm per meter during March to June 2002 indicated 34%, 46% and 61% loss of water through evaporation under *E. camaldulensis*, *D. sissoo* and *A. nilotica*, respectively (Table 3).

Table 3. Partitioning of water loss between surface evaporation from soil and transpiration by plants of different tree species. *PET: potential evapo-transpiration (evaporation + transpiration). Source: Singh and Rathod, 2004.

Variables	Control		Planted		
	No mulch	Mulched	*E. camaldulensis*	*A. nliotica*	*D. sissoo*
Number of days	91	83	99	94	97
Total irrigation (mm)	144.8	144.8	470.6	325.8	253.4
Irrigation intervals (day)	22.8	20.8	7.6	10.4	13.9
PET* (mm day-1)	1.75	1.60	4.75	3.45	2.62
PET (lit day^{-1})	7.00	6.40	19.00	13.80	10.40
Transpiration loss (lit day^{-1})	-	-	12.60	7.40	4.00
Transpiration (lit kg^{-1} leaf dry-mass day^{-1})	-	-	3.00	1.83	0.71

3.5. Control of Sand Drift and Wind Erosion

Reactivation of sand drift and ripple formation is a common feature where only tree species are planted. This is because once the trees are grown up soil surface gets exposed. This situation could very well tackled by introducing surface vegetations like *Cassia angustifolia* and locally available grass species for faster stabilization of sand dune with additional benefits of biomass for fuel wood and fodder. Introduction of surface vegetation like *Cassia angustifolia* (medicinal plant) and locally available grass like *Cenchrus ciliaris* (for fodder production) along with the tree/ shrub species was found more suitable in early and effective stabilization of dune. It provides additional income for the local people (Singh and Rathod, 2002). Combination of *C. polygonoides* as compared to *A. tortilis* and *Prosopis juliflora* with *C. angustifolia* was found most suitable to control sand drift whereas the combination like *C. polygonoides* and *C. ciliaris* was beneficial in greater biomass production in terms of fuel wood and fodder (Table 4).

Table 4. Biomass of the 50 months old tree seedlings (kg seedling^{-1}) on a shifting dune. V type: vegetation type; CA: *Cassia angustifolia*; CC: *Cenchrus ciliaris*; CL: control; F wt: fresh weight; D wt: dry weight.

Tree species	**V type**	**Tree biomass (kg plant^{-1})**					**Tones ha^{-1} fresh weight from vegetation**		
		Above		Root		Total			
		F wt	D wt	F wt	D wt	D wt	1998	1999	2000
A. tortilis	*CA*	18.8	13.3	6.09	4.1	17.4	3.97	3.80	3.70
	CC	19.4	13.0	5.4	4.0	17.0	0.97	1.40	1.29
	CL	19.2	13.2	5.1	3.8	17.0	-	0.30	0.46
P. juliflora	CA	26.0	18.1	11.2	8.0	26.1	5.17	4.98	4.06
	CC	22.0	16.6	9.3	6.6	23.2	1.42	1.77	1.56
	CL	25.7	17.8	9.1	6.6	24.4	-	0.35	0.49
C. polygonoides	CA	26.4	18.0	18.8	9.8	27.8	7.28	7.35	6.46
	CC	29.9	18.7	16.6	8.9	23.6	1.93	2.57	2.19
	CL	23.4	16.9	17.6	7.8	24.7	-	0.58	0.60

Cassia angustifolia produced dry leaves of 0.76 tones ha^{-1} year^{-1} with *A. tortilis*, 0.96 tones ha^{-1} year^{-1} with *P. juliflora* and 1.39 tones ha^{-1} year^{-1} with *C. polygonoides*. Considering the economic return from *C. angustifolia* leaves, Rs 16720 ha^{-1} year^{-1} could be obtained from the plots in which *C. polygonoides* are integrated with *C. angustifolia* as compared to 9120 ha^{-1} year^{-1} from the plots in which *A. tortilis* was integrated (Table 5).

Table 5. Dry mass (tones ha^{-1}) of leaf of *Cassia angustifolia* and the economic benefits (Rs ha-1 @ Rs 12 kg-1) under different tree species in a shifting dune.

Tree species	Nov 1998	May 199	Nov 2000	Mean	Income (Rs ha^{-1})
A. tortilis	0.76	0.80	0.71	0.76	9120
P. juliflora	0.97	1.04	0.87	0.96	11520
C. polygonoides	1.39	1.56	1.23	1.39	16720

Conclusively there is still enough opportunity to enhance overall productivity in the region in addition to control land degradation or combat desertification. Incorporation of traditional knowledge in selecting suitable plant species, management of available natural resources and adoption of modern technology will not only control further land degradation but also produce substantial biomass to sustain the livelihood of the desert people. Therefore, we need to carefully select a set of strategies suitable for a particular situation for sustainable management of dry areas involving the local people and their traditional knowledge in endeavor of mankind.

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