Water Scarcity And Degraded Ecosystems: Innovative Options For Managing Scarce Water Resources To Rehabilitate Degraded Rangelands In Semi-Arid Ecological Zone Of Pakistan

By

Sahibzada Irfanullah Khan

Sustainable Land Management Project (SLMP)
Ministry of Environment / Planning & Development Deptt. Pakistan
sahibzada.irfanullah@slmp.org.pk

Abstract

This paper depicts results of rehabilitation work initiated in 2003 under the SDC funded Farm Forestry Support Project in District Karak using rainwater harvesting and management techniques to strengthen silvo-pastoral system with hillside ditches and sand dune stabilization. The area lies in southern semi-arid region of Pakistan covering 75% of the land area with aridity index 0.05-0.65. Resided by poor pastoral communities, it is characterized by degraded rangeland ecosystem due to over-use and drought conditions.

The results recorded in 2008 showed profuse plant growth with a potential to provide timber, fuel wood and fodder for livestock. Maximum harvesting of rainwater and conservation of moisture resulted in enormous growth of natural grasses and shrubs. After 5 years, plant growth in height and diameter of 6 m and 20 cm respectively was recorded. Average vegetation soil cover of 45% and increase in soil organic mater and nitrogen content was also recorded.

Key words: Degraded rangelands, Semi-arid, Water Harvesting

1 Background

Drylands are generally defined as arid, semi-arid or dry sub-humid lands receiving less than 500 mm annual rainfall with an aridity index between 0.05 and 0.65 (the aridity index is the ratio Precipitation / Precipitation Evapotranspiration); UNCCD/UNEP (1999/7). There are more than 3 billion people globally living in drylands that cover 40% of earth's surface; ROBIN (2002). Drylands are generally defined in climatic terms as lands receiving less than 500 mm of annual rainfall. In Pakistan, the situation is severe with 75% of the country's area receiving less than 250 mm of annual rainfall; PMD (1998). Most parts of Sind and Balochistan, and Southern parts of Punjab and NWFP are falling within this dry zone.

Over 30 million people in Pakistan live in dryland areas. Their livelihoods depend heavily on the natural resource base in form of provision of food for human beings, fodder for livestock, and fuel for cooking and heating, and water for drinking. Some scanty income from the sale of medicinal plants and herbs, livestock and dairy products and wildlife also add to the meager earnings; FISCHLER (2006).

The poor in these ecologically fragile marginal lands are increasingly locked into patterns of natural resource degradation. Due to the low production and regeneration potential, drylands are not able to support an ever-increasing population of human beings and livestock. Most of the silvo-pastoral ecosystems in drylands are degraded due to overstocking beyond their carrying capacity, whereas rainfed croplands are increasingly being abandoned due to prolonged drought periods. These adverse factors are continuously undermining the livelihoods of poor farming families.

2 The study area

The study relates to joint activities of the Farm Forestry Support Project (SDC, IC), local NGOs and rural community organizations in Karak, one of 22 districts in the Southern part of the North West Frontier Province (NWFP) of Pakistan (Figure 1). District Karak is situated in southern region of NWFP, covering an area of 3372 square kilometers; GoP (1996). Total population of Karak is 430,000 heads; GoP (1998).

The area comes under tropical and sub-tropical climatic zone, characterized by arid and semi-arid conditions. It can be divided into three distinct geographical divisions: the dry hilly zone in north, sandy desert in south-west and sandy-loam plains in the eastern part. The northern hilly zone is famous for mining of various minerals like salt and gypsum. The south-western desert is characterized by shifting sand dunes, very dry and hot winds, and subsistence cultivation of gram, mustard, groundnut and wheat. The eastern region is famous for a number of agricultural crops (millets, wheat, maize) and vegetables (chilies, okra, egg-plant, tomato) mainly because of availability of some irrigation water. As a whole, 19% area is under cultivation out of which water is available for 2% area only; GoP (2000).

People in this area live on subsistence agriculture, livestock rearing and minor trade of daily use commodities. Literacy rate is surprisingly high (above 50%) as compared to the rate for Pakistan (44%); GoP (1998). Due to harsh living conditions and limited opportunities on land, people prefer to join civil and armed services that are mostly out of the area. The remittances they send back to their families are thus an important source of living.

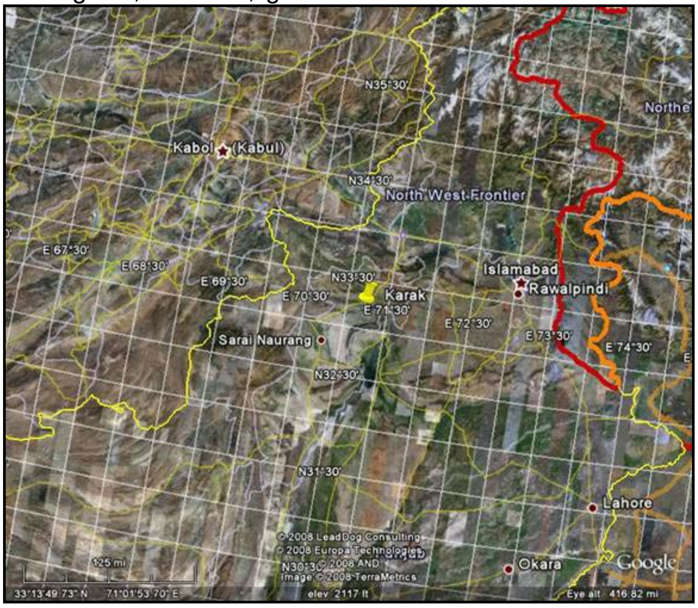

Figure 1: Location map of Karak (Source Google Earth)

3 The dryland ecosystems

The interplay between human beings, land resources, climatic conditions, natural vegetation and livestock constitute the ecosystem in most of the drylands in Pakistan. In all these, the climatic factors and availability of water for productive practices are limiting factors. Again, in most of the cases vast tracts of land are available but production systems are limited to only a few patches because of climatic conditions that limit the availability of water.

In the study area, mean maximum temperature can reach to 46°C in summer (May to September). The mean minimum temperature in winter months (November to February) goes down to 3° C. The extreme arid conditions prevailing in major part of Karak limit agriculture to a profit-less rather under-paying activity. Subsistence agriculture is totally dependant on rainfall that is sporadic, uncertain and does not exceed 350 millimeters per annum; GoNWFP (1998). Livestock rearing (mainly goats and sheep) is thus adopted as major source of livelihood that supports the family in terms of nutrition and income from sale of animals, wool and milk.

Figure 2: The drylands in Karak, Pakistan

These limitations lead towards a silvo-pastoral way of living where natural vegetation plays deciding role in the sustenance of the system. Sporadic grasses, shrubs and stunted trees are all what is required for grazing herds (Figure 2). The local tree vegetation in this area include *Acacia modesta, Prosopis cineraria, Capparis aphylla, Prosopis glandulosa, Tamarix aphylla, Zizyphus mauritiana, Olea ferruginea* and *Tecoma undulate*. Some of the important shrub species include *Zizyphus numularia, Vitex negandu, Saccharum munja, Callygonum polygonoides, Callotropis procera,* and *Nannorrhops ritchiana*. Among grasses, *Chrysopogon spp., Cenchrus spp*., and *Cynodon dactylon* are important. Whereas *Salsola foetida, Withania spp*., and *Erva javanica* are common herbs. The natural forest is limited to only 2% of the total area on distant hills; GoP (1996), comprising mainly *Acacia modesta* and *Olea ferruginea*.
Availability of water for drinking purpose is also not certain. The water table is as low as 500 feet and it costs high to drill and pump the water out. There were some natural springs in the hills that were providing drinking water to communities but dried out in recent droughts (1992, 1998, 2002).

4 Statement of the problem

Most of the people in Karak live below poverty line. Their livelihood is dependant on rainfed subsistence agriculture and livestock. The livestock is then dependant on natural range vegetation in the form of low trees, shrubs and grasses. However, due to increasing drought conditions and scarcity of rainfall, the agriculture is not more a productive activity and croplands are increasingly abandoned. To fill this gap in livelihood, the number of livestock per household is increasing with time. This exerts great pressure on natural vegetation of the rangeland area that gets grazed more intensively and more frequently. This leads to the degradation of ecosystem and depletion of natural vegetation. The scanty rainfall condition, hot weather and sustained grazing pressure restricts recovery potential of natural vegetation. The phenomenon thus adds to desertification that compounds the problem of poverty and makes communities utterly vulnerable to the situation.

The net effect of the problems stated above is observed in the form of increase in poverty and vulnerability of the poor. The droughts leave negative effects on their capacity to survive. In the efforts to survive, they become heavily indebted, their health is badly affected and most of them migrate to urban areas.

5 The rehabilitation of degraded ecosystems

Keeping in view the importance of natural vegetation and the support it does provide to local livelihoods, the Farm Forestry Support Project (FFSP) started the dryland management and rehabilitation program in 2003 in District Karak. The purpose was to rejuvenate the productive capacity of degraded lands so that the support these lands were providing to livelihoods previously could be restored.

The FFSP has already been working in this region since 2000 as a support to farmers in rainfed regions of NWFP to promote their farm forestry related initiatives by providing an enabling environment. The project is funded by Swiss Agency for Development and Cooperation (SDC) and executed by the Intercooperation-Pakistan Delegation Office, Peshawar.

Detailed surveys were conducted in the region to identify problems and suggest rehabilitation measures. The surveys were jointly conducted by technical experts from FFSP, local NGOs and community members in different villages. Based on results, the activities were suggested and thoroughly discussed in the communities for feasibility, and specifying roles and responsibilities. Following rehabilitating measures were adopted on selected sites to see the outcome.

5.1 The development of silvopastures

Vast tracks of land were lying as wastelands because of degradation by over-grazing and water shortage. These lands were previously providing a number of goods and services to the human and livestock population in past. For example, the scattered and stunted trees were a source of fuel wood and timber for households, and bushes and grasses were browsed by animals to fill their stomach. However, these types of outputs were no more available due to depletion of vegetation. The degradation was evident in form of depletion of vegetation cover, loss of soil fertility and soil erosion. Within the Karak region, 5 sights were selected for applying the “Hillside Ditch” technique to recover the fertility of soil, productive potential of the land and hence the vegetation cover; FFSP (2008).

Figure 3: Lay-out of hillside ditches

5.1.1 Suitability

The Hillside Ditches were especially designed for these silvo-pastoral lands. Keeping in view the gentle sloping topography of the sites, interventions were so designed where machinery (tractors) could be used to reduce labor cost (Figure 3).

5.1.2 Description

Continuous ditches along the contour line having plant pits at regular interval were excavated. The ditches were 66 centimeters wide and 30 centimeters deep, with excavated soil from ditch placed on downhill side making continuous ridge of 30 centimeters. The soil excavated from plant pits was placed within the ditch on one side of plant pit to impound water. Spacing of ditches and plant pits was kept as 7 meters and 5 meters respectively (Figure 4). The size of the ditches and spacing of plants and ditches was fixed keeping in view the rainfall of the area.

The plant pits were planted with tree species that were fast growing and having fodder value. The inter-spaces between plants were sown with seeds of grasses and fodder shrubs to have maximum utilization of space. The species used on different sites included *Acacia albida, Dalbergia sissoo, Acacia nilotica, Melia azadarich,* and *Acacia Victoria* in trees, *Dodoneae viscose* and *Acacia modesta* in shrubs, and *Sorgham almum* and *Cenchrus ciliaris* in grasses.

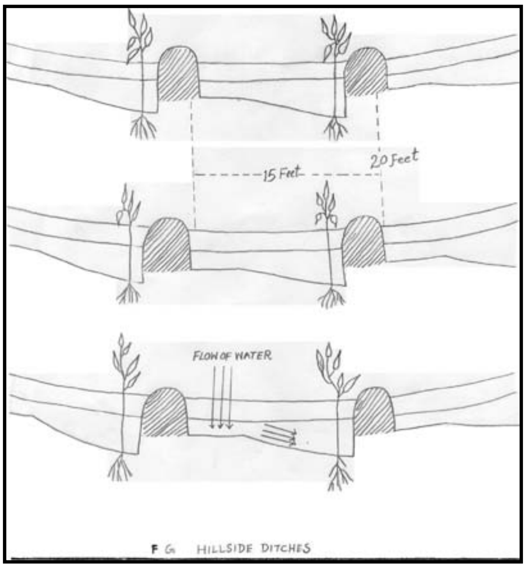

Figure 4: Design of hillside ditches

5.1.3 Instruments used

The hillside ditches were excavated with the help of a tractor driven “Ditcher” specially designed for the purpose to reduce cost. The ditcher that was fabricated in a local workshop, consisted a modified form of mould plough commonly used by farmers in hilly areas for cultivating hard gravelly soils. The front two blades were replaced with strong chisels and the rear blades by enlarging its length to 1 meter and depth to 0.6 meter (Figure 5).

For reducing the cost of manually excavated plant pits within the ditches, a pit excavator was designed and used (Figure 6). The front blade commonly used with tractor was modified to have a top-width of 1 meter and bottom width of 0.6 meter.

Fig 6: Ditcher, specialized instrument for ditch making

Figure 6: Figure 5: Pit Maker for making pits in ditches

The pit excavator was fitted with the tractor in front to excavate pits in hillside ditches. The pit excavator was so used that it produced a gently increasing slope towards the planting point from the middle of the space between two plant pits.

5.1.4 Functioning

Function of the whole arrangement of ditches and pitting was to take maximum benefits of rain water in arid zones by making maximum rain water available for plant growth for prolonged period. This was with the purpose to eliminate high establishment costs in arid zones involving labor in plantation and manual watering at frequent intervals.

By keeping the depths of ditch and pits within the ditch as 30 centimeters both plus the 30 centimeter high ridge, a 90 centimeter deep and 66 centimeter wide space at each planting site was available for storing run-off water coming from up-slope side. By keeping the space between ditches and plant pits as 7 meters and 5 meters respectively, rain water falling on 35 square meters land surface on uphill space was collected at each planting point.


Figure 7: Growth of grasses after one year

5.1.5 Effectiveness

The maximum on-site conservation of rainwater and its utilization for plant growth was the major effect visible on these sites. In an area arid to a limit that could not support the slow-growing vegetation, produced fast growing trees and obtained profuse growth of shrubs and grasses within a few years of time Figure 7).

According to the data collected from different sites, the average survival rate of trees planted was 40%, the average number of trees growing per hectare becoming 218. This number was manifold more than the number of trees growing on these type of lands without treatment (i.e. 14 trees per hectare; PFI (2005). The height and diameter growth rate on these sites recorded was also considerably higher. Maximum diameter and height growths were recorded in case of *Acacia albida* as 20 centimeters and 6 meters respectively, followed by *Acacia nilotica* as 15 centimeters and 5 meters respectively (Figure 8, Table 1).

Table 1: Growth data for trees, shrubs and grasses in Hillside Ditches: SAHIBZADA (2008)

S. No.	**Parameter**	**Species**	**Data recorded**
1	Average diameter	*Acacia albida*	20 centimeters
		Acacia nilotica	15 centimeters
2	Average height	*Acacia albida*	6 meters
		Acacia nilotica	5 meters
3	Av. no. of trees surviving / hectare	Overall	218 numbers
4	Average vegetation soil cover	Overall	45 %

Due to retention of run-off and percolation of run-off water into soil on the site, a profuse growth of local annual and perennial grasses was recorded, in addition to the *Sorgham almum* and *Cenchrus ciliaris* that was sown during plantation activity. The average soil cover on these soils recorded was 45%, considerably high over normal cover on these degraded lands (10-15% on the average). These grasses and shrubs were of high value as a feed for local goats and sheep. The farmers were advised not to allow animals for grazing in initial 2 years. They could, however cut grasses and stall-feed their animals during these 2 years.

The activity also contributed to the overall fertility status of soil. The laboratory analysis of soil samples taken at three sites each from treated and controlled plots showed a higher organic mater content and total nitrogen concentration in treated plots. A slight increase in phosphorus content and decrease in lime content could also be attributed to the treatment of site. No significant change in the electrical conductivity, pH and potassium content was however recorded. The treatment period of 5-6 years was too less to demonstrate any significant change in soil properties, except the content of organic mater that was recorded higher in treated plots (see Table 2 below).

In addition to increase in on-site productivity and soil fertility, the activity also contributed to the re-charge of ground water in down the slope areas. According to information provided by local community, 2 wells that dried out due to prolonged drought were rejuvenated near to the activity sites.


Fig 8: 6 years old trees of *A. nilotica*

Table 2: Soil properties in treated and controlled plots:

S.No.	Parameters	Control plot	Treated plot
1.	Organic mater (%)	0.65	1.01
2.	Total nitrogen (%)	0.13	0.20
3.	Phosphorus (mg / kg)	3.05	3.14
4.	Potassium (mg / kg)	155.13	114.1
5.	Electrical conductivity (d S / m)	0.10	0.13
6.	Lime content (%)	6.96	6.75
7.	pH (1:5)	8.29	8.38

Source: KHATTAK (2008)

5.1.6 Cost analysis

Due to use of specialized instruments and machinery, the cost was very low for applying hillside ditch technique to the development of silvo-pastures. The total cost including use of machinery, planting stock, seeds, and labor was calculated as US$ 82 per hectare (see Table 3).

Figure 9: 3 years plants of *A. nilotica*

It is important to mention that the extra cost involved in this activity was that of using specialized techniques. This, however, drastically reduced the cost of manual watering as implied in ordinary plantation activities by the Forest Department or other agencies. The usual cost per hectare plantation activity by the Forest Department was Rs. 19,800 or US$ 330 that was considerably higher than the cost on using hillside ditches; FATA (2007). The additional benefit of this silvo-pasture development was that it re-established the whole vegetation cover as compared to ordinary plantation work that considered only trees.

Table 3: Cost analysis of silvopastures development per 1 hectare of land: SAHIBZADA (2008)

Activity	Cost Description	Rate (Rs)	Amount (Rs)	Amount (US$)
Preparation of hillside ditches with tractor and ditcher	3 Hours	300	900	Total cost = **US $ 82** @ PK Rs. 60/$
Preparation of pits with tractor and pit blade	2.5 Hour	300	750	
Planting stock	540 Plants	2/plnt	1,080	
Planting with first watering	540 Plants	2/plnt	1,080	
Restocking (30%), including cost of plants and planting	160 Plants	4/plnt	640	
Grass seed	3 Kg	50/kg	150	
Seed of shrubs	2 Kg	100	200	
Sowing of shrubs' and grasses' seeds	1 Labor day	100	100	
Total Cost (Rs.)			**4,900**	

5.2 Sand dunes stabilization

Considerable portion in south-western part of Karak region is comprised of sandy desert. This is part of a greater “Thal” desert that is stretched on southern parts of NWFP and Punjab. The Thal desert is home to extreme poverty due to shortage of food and income sources. Gram, mustard and wheat are cultivated in sandy area but return very little or no yield due to prolonged droughts. The shifting sand dunes also cause hurdle to crop cultivation and infrastructure.

FFSP conducted consultation with farmers and proposed the introduction of *Saccharum spontaneum* (locally called as *Kana*), in sand dunes for the purpose of stabilizing sand dunes, acting as wind-breaks for crop lands, and contributing to household income in the form of proceeds from sale of its stalks and leaves. The *Saccharum* plant was found most suitable for sandy land as it did withstand against prolonged droughts, lesser cost involved in its establishment and high return for its marketable products.

Figure 10: *S. spontaneum* in sand dunes

Local communities selected 9 sites for demonstration of *Kana*; FFSP (2008). *Kana* suckers were obtained from an adjacent district at the cost of Rs. 7 per sucker and planted at a spacing of 5 meter x 3 meter in straight lines Figure 10). Total cost per hectare of *Kana* establishment on sandy land including the cost of suckers and labour was Rs. 5,000 (US$ US$ 83). The average annual return from *Kana* site was Rs. 44,100 (US$ 735) that was profitably comparable with other land uses available for sand dunes, except wheat (see Table 4 below).

Table 4: Annual cost/benefit per hectare for various crops of sand dunes in Karak; ARS (2008)

Cost/Benefit	**Kanola (Rs.)**	**Gram (Rs.)**	**Mustard (Rs.)**	***Kana* (Rs.)**
Annual Cost	6,052	9,139	10,003	-
Annual Income	14,795	53,097	74,055	44,100
Net profit (Rs.)	8,743	43,958	64,052	44,100
Net profit (US$)	**146**	**732**	**1,067**	**735**

The investment cost for *Kana* was only one time as this was a perennial plant. It was cut each year and sprouted again Figure 11). Both the long stalks and leaves were sold in market (these were used for furniture making, as roofing material, sunscreens and making of decoration items). The outstanding characteristic of *Kana* was that its production did not depend on rainfall and even did well in prolonged droughts when all other crops failed.

6 Challenges and coping strategies

Fig 11: Harvesting of *S. spontaneum*

More than 60 percent land in Karak is not producing any agricultural crops, and hence is treated as wasteland where free and unrestricted herding and grazing of animals is practiced. Due to no or lesser productivity of economic goods, the use rights for livestock grazing are not reserved. Free, unrestricted and extensive grazing of animals is thus practiced by local communities, even by those who don’t own any land and totally depend on their livestock.

The rehabilitation measures however demand care of the land and protection from grazing for initial two years to provide relief to the recovering vegetation. Due to silvo-pastoral practices that have become a way of life, it is difficult for land owners to abandon grazing on their land. It is due to this reason that communities usually demand for fencing the area or keeping watchmen to protect the site which enormously increase the establishment cost of the activity.

Without attending to the protection parameters, activity in some places have resulted in no conspicuous results after the planted seedlings and shrubs were completely clean washed by roaming herds of goats and sheep.

On the other hand, it is a common concept among local people that investing on silvo-pastures is a profit-less venture. Failures due to water shortage in past and the lack of protection from free grazing animals have further strengthened this perception. The already marginalized communities therefore find it very difficult to invest on pasture development.

The interventions in silvo-pasture development have proved significant in overcoming the water shortage and rejuvenating the vegetation for the benefit of human beings and livestock. The cost of these activities is also very low and within the bearing capacity of farmers. These facts and results need to be spread wide through extension and mobilization of communities at regional level. The mater of free livestock grazing should be dealt with at regional and not at local level. Communities should be facilitated to reach a mutual consensus for protecting sites under treatment and keeping their animals grazing in other areas. A controlled grazing system in which area is divided into blocks, keeping one block under protection on rotational basis may also be one of the options.

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The cooperation extended by local farmers, especially those who offered their land for interventions and invested in planting cost and labor, and those other community members who cooperated in the execution of the activities, are highly adorable. It is considered that without their contribution, the activity would not have been possible.

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