Chapter 3.

Range Improvements

Range improvements involve special treatments or operations that will enhance agricultural productivity and allow multiple use of the rangelands consistent with sound ecological principles. Improvements increase the quantity and quality of forage production and facilitate grazing to maximise livestock production.

Most of the range management projects executed during the past 40 years have concentrated on the introduction of indigenous and exotic forage plants, range reseeding, planting of fodder trees and shrubs, stock water development, water distribution soil and water conservation, natural re-vegetation, sand dune stabilization, and regulating range use by fencing and control of undesirable plants. Some of these operations have significantly improved the range and can be helpful in developing rangelands in other countries of the Hindukush- Himalayan region with similar climatic conditions. The following is brief review of various range improvement practices:

PLANT INTRODUCTION TRIALS

Introduction trials of indigenous and exotic forage plants in the alpine pastures had been limited to a few sites. The Northern Areas Forest Department tested *Elymus junceus, Agropyron sp, Lolium perenne, L. multiflorum* and *Phalaris tuberosa* in the scrub alpines and reported that forage yield was significantly greater than native pastures (Mohammad, 1984). The selected grasses, however, were not seeded on large scale. Recently, the Agha Khan Rural Support Programme (AKRSP) has initiated a project to renew alpine pastures in the Northern Areas by reseeding *Agropyron desertorum, Elymus junceus, Trifolium repens, T. pratense* and *Medicago* *sativa.* Efforts are also being made to encourage desirable native flora by eliminating competition with undesirable plants. The Sub-committee on Range Management (1983) recommended some species for reseeding in the alpine areas of Pakistan (Government of Pakistan, 1983). These species include *Elymus junceus, Festuca sp, Lolium perenne, Poa sinaica, Phleum alpanicum, Medicago falcata, Trifolium pratense, Artemisia maritima, Indigofera gerardiana,* etc.

In the Trans-Himalayan grazinglands, plant growth is primarily restricted by low annual rainfall. Therefore, most of the adaptation trials of forage grasses and legumes have been done on the marginal lands under irrigation. Introduction trials conducted by FAO during the past 10 years indicated that some of the European temperate plants such as *Vicia sativa, V. dasycarpa, Avena sativa, Lolium perenne, L. multiflorum* and *Medicago sativa* were suitable in Hunza valley and Yasin which are located in the dry temperate zone. In this area, the *Medicago sativa* variety 'Punyal' is extensively cultivated for hay. A few grasses and legumes tested at the Agricultural Research Institute for Northern Areas, (ARINA), at Jaglote, performed well during 1985- 87 when irrigated. The adaptation trials of grasses, clovers and lucerne varieties from New Zealand conducted at Kalam (2500 m) and Jaglote (1500 m) (sponsored by PARC) the Coordinated Programme on Fodder Crops, revealed that *Trifolium repens* and *T. pratense* can significantly increase forage yield.

Suitable environmental conditions for plant growth, particularly high rainfall mean that it should be possible to increase forage yield in areas of the Himalayan forest wherever sufficient cover of desirable species is available. During the past 12 years, forage plants were introduced at various places in the Himalayas under the auspices of the National Forage and Pasture Research Programme. Based on the adaptation trials conducted at Khawarmang, Muzaffarabad, Jaba and Deerkot, a few species have been found suitable for seeding in the sub-tropical humid chirpine zone of Mansehra, Abbottabad, Muzaffarabad, Bagh, Kotli districts and Murree hills (Table 5).

Table 5. Forage and seed production of promising grasses at Muzaffarabad

Species	Dry matter yield T/ha.	Seed weight (kg/ha)
Dactylis glomerata	0.5	175
Festuca elatior	2.0	450
F. arrundinacea	1.8	150
Phalaris tuberosa	2.8	250
Lolium multiflorum	1.7	150
L. perenne	1.8	160
Trifolium pratense	1.7	30
Vicia sativa	0.9	28

Source: NARC Forage and Pasture Programme Annual Report 1984.

The Range Management Branch of Pakistan Forest Institute (PFI), Peshawar, tested a number of grasses and legumes at the Jaba Sheep Farm during the early 1970s. Noor (1983) recommended *Trifolium hybridum, T. incarnatum* and *T. pratense* for Jaba.

The Watershed Management Directorate, Rawalpindi, tested forage grasses and legumes at Deerkot to increase forage yield and selected suitable plants to conserve soil in Mangla watersheds during 1971- 72. *Phleum pratense, Trifolium pratense* and *Festuca elatior* had higher forage yields and provided good cover for soil conservation. Plant introduction trials have also been conducted at Dungian (2300 m) situated in the wet temperate zone. Adaptation trials of grasses and legumes have also been initiated in wet temperate areas under the FAO Regional Project on Himalayan Pasture and Fodder Research Network. Some species of grasses and legumes were recommended by Pathak and Jakhmola (1984) for the Indian Himalayan region which have the same climatic conditions as in the Himalayan forest grazinglands in Pakistan. These include *Agrostis sp., Capillipedium assimile, Chrysopogon spp, Dactylis glomerata, Eragrostis stolonifera, Festuca rubra, Hemarthria compressa, Paspalum dilatatum, Setaria glauca, Sporobolus indicus* and *Themeda anathera.* Some of the important legumes recommended are *Clitoria tornatea, Glycine javanica, Lupinus augustifolia, Lablab purpureus, Melilotus sp, Medicago sp, Phleum pratense, Vicia sp, Trifolium pratense* and *Vigna sinensis.*

During the past 13 years, the National Forage and Pasture Research Programme has tested over 600 species/varieties of grasses, legumes, shrubs

Plate 8. Forage germplasm evaluation trials at National Agricultural Research Centre, Islamabad.

and trees at the National Agricultural Research Centre (NARC), Islamabad, Lohi Bher, Missa-Kassowal and Bara Kau which are located in Pothwar scrub ranges. The dry matter yield of promising species/varieties introduced at NARC is presented in Figure 1.

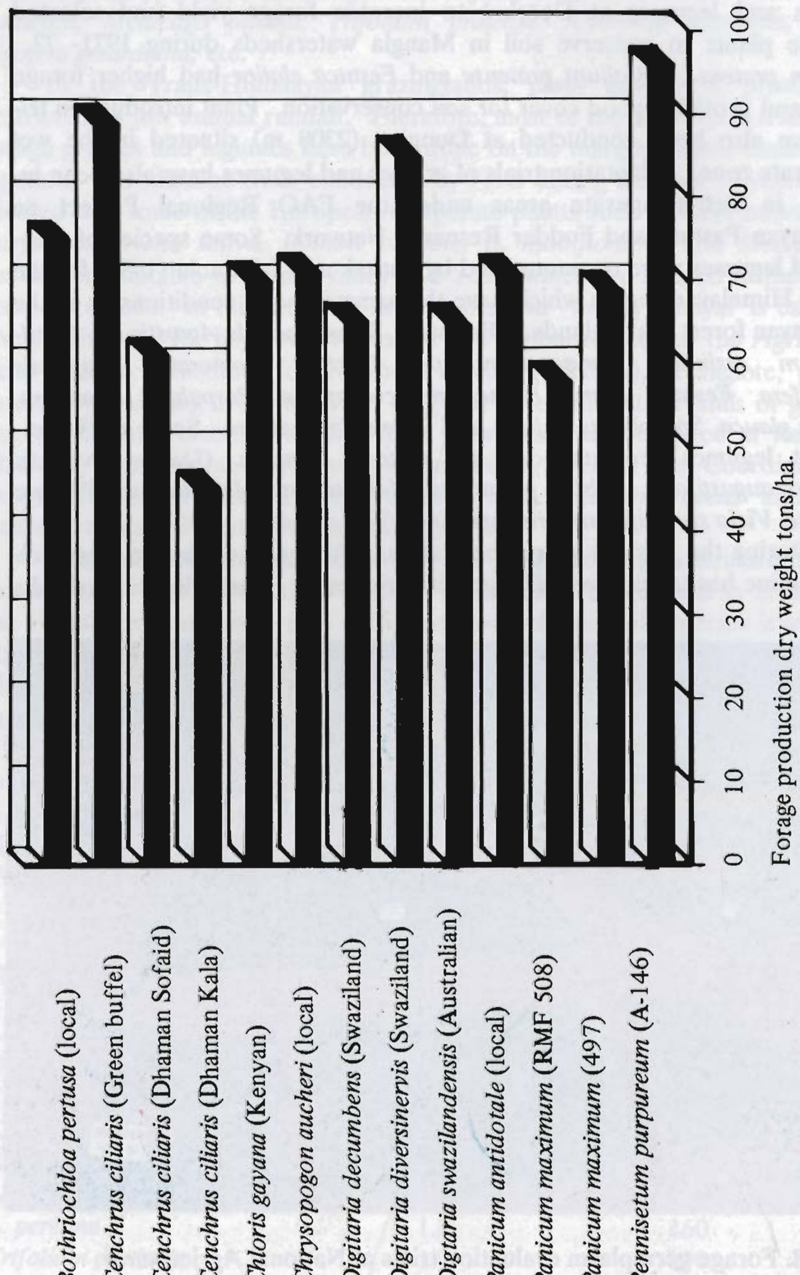

Figure 1. Average dry matter yield (t/ha) of grasses and legumes tested at National Agricultural Research Centre (NARC), Islamabad.

About 30 promising species/varieties of summer grasses and legumes were selected for large-scale seeding in the Pothwar scrub ranges. Several agronomic studies on seeding rate, planting techniques, defoliation intervals, fertilizer requirements and seed production techniques were conducted at NARC to develop a package of technology for farmers.

The Pothwar area experiences acute shortage of fodder during winter. NARC is attempting to produce forage and fodder crops capable of higher forage yield with the low rainfall received during winter. Several indigenous and exotic grasses and legumes were introduced at NARC. Out of 35 winter grasses, *Lolium perenne, L. multiflorum, Dactylis glomerata, Phalaris tuberosa* and *Agropyron desertorum* were selected. Agronomic trials are underway for large scale reseeding operations in the Pothwar tract.

At PFI, Peshawar, a range plant nursery has existed since 1966. Where over 600 varieties/species of grasses, legumes and fodder trees and shrubs have been tested primarily under irrigated conditions. Seeds of promising varieties/species of forage were collected and distributed among various organizations and institutions. Field adaptation trials conducted at the Jamrud Target Area under semi-arid rainfed conditions led to the selection of a few promising forage plants, such as *Cenchrus ciliaris, Panicum antidotale, Medicago sativa, Atriplex canescens* etc.

Grasses were also field tested in Kohat, Kala Chitta and Kharemurat (Fateh Jang), which led to large-scale seeding of *Cenchrus ciliaris* and *Panicum antidotale* at Gulial and Kharemurat. Sowing in pits or along the berms of trenches was very successful in highly eroded areas of the Pothwar Plateau. Plant introduction trials conducted by the NARC Gully Land Management Project revealed that proper water distribution and moisture conservation techniques, such as reverse terracing, contour trenching and pitting, enabled *Pennisetum purpureum, Cenchrus ciliaris, Chloris gayana* and *Panicum antidotale* to increase forage yields in gullied areas.

Field trials of 37 exotic grasses were conducted at Maslakh located in the western mountain ranges (Rafi, 1965). Due to prolonged drought and desiccation, only plants that survived were *Atriplex canescens.* Several species such as *Agropyron desertorum, Elymus junceus* and *Artemisia maritima* can be successfully planted in Maslakh area by using various rainwater harvesting techniques. The Arid Zone Research Institute (AZRI) at Quetta established a few grasses and legumes with occasional irrigation. Winter forage adaptation studies conducted by AZRI in the mediterranean climatic conditions of Quetta Valley revealed that *Vicia sativa* and *V. dasycarpa* can be raised with winter rainfall (AZRI, 1987). At the Forage Research Station, Mastung, several local and exotic species of grasses and legumes were tested during the past 10 years. *Glycyrrhiza glabra* proved a good forage and medicinal plant (Mohammad and Rehman, 1986). It was successfully planted in sand dunes along with *Tamarix aphylla, Arundo donax* and *Calligonum polygonoides* Mastung area. *Atriplex canescens, Agropyron elongatum, A. intermedium, A. desertorum,* and *Elymus junceus* were also well suited to the environment.

RANGE RESEEDING

Natural Revegetation: Natural revegetation is the cheapest but slow process of rehabilitating depleted rangelands. In this process, the availability of sufficient number of desirable plants, adequate soil moisture and nutrients and suitable climatic conditions are necessary to restore range condition. Natural revegetation can be achieved by reducing stocking rates, changing season of use, initiating special grazing systems, proper distribution of livestock, additional water development and protecting of the area from livestock grazing for longer periods (Vallentine, 1971).

In Pakistan, the rehabilitation of deteriorated range sites has involved protecting the areas from livestock grazing. In most of the rangelands barbed wire fencing is common. In the Maslakh range, 40,000 ha were protected by erecting barbed wire fence during 1956. Baig (1978) reported a significant increase in forage yield, species composition and plant cover in the protected areas. Rafi (1965) recommended a minimum period of five years of complete protection before initiating proper grazing management practices.

Repp and Khan (1958) studied the effect of protection in the Maslakh area. Exclosure significantly improved the native vegetation. Khan and Hussain (1960) evaluated the effect of protection on the natural recovery of native vegetation in Hazarganji forests. Partial protection of the area from livestock grazing, increased the vegetative cover by 30 percent over a period of 10 years. Baig (1978) compared the condition of vegetation in the well-protected Hazarganji National Park with the areas open to grazing. Several desirable grasses and legumes were present in protected areas that were not found in the areas subjected to continuous yearlong grazing.

Plate 9. Natural revegetation in Hazar Ganji (Quetta).

In arid rocky habitats in India, long term exclosure improved vegetation (Shankarnarayan and Shankar, 1984, Shankar, 1980). Closure also reduced the loss of soil and water as the natural vegetation improved and there was a qualitative and quantitative increase in the yield of grasses. Mirchandani et al. (1958) found that closure to grazing reduced soil loss from 3.3 t/ha (under overgrazed conditions) to only 0.6 t/ha.

Exclosures have been studied in all the major range areas of Pakistan during the past 30 years. On an average, the vegetation improved slowly in Cholistan, Tharparkar and Kohistan desert range areas. Pothwar scrub ranges have a high potential for natural revegetation because the area receives at least 500 mm rainfall. Rasul (1966) studied the effect of one year closure on forage production in Cholistan Desert. Four times as much forage was produced in the area closed to grazing. Natural reseeding increased the density of grasses by 15 percent.

Shankar and Dabadghao (1977) studied changes in natural vegetation in an 18-year exclosure near Bikaner. The botanical composition, relative frequency and relative cover of herbs and shrubs improved dramatically. Protected dunes were rich in species of higher ecological status, i.e., *Calligonum polygonoides, Panicum antidotale* and *Sericostema paucifloram.* Singh et al. (1970) reported a dry herbage yield of 3.5 t/ha by protecting grasslands at Jhansi. Production through protection increased from 0.35 to 2.63 /ha in the desert grasslands at Jodhpur (Chakravarty, 1963). Faster regeneration of desirable species in the botanical composition and increased production in the rocky grasslands at Kailana near Jodhpur have been reported by Bhimaya et al. (1965) and Shankar et al. (1975).

Noor (1981) observed about 30 percent increase in the plant cover of *Agrostis gigantea* and *Potentilla sp* after a year of protection from livestock grazing in Paya alpine pastures which could be attributed to more soil moisture. Khan (1977) reported that 27 years of protection in a Bastargi exclosure at Ziarat, meant that forage species such as *Prunus eburnea, Lonicera hypoliuca* and *Berberis baluchistanica* were found only inside the exclosure. After a year of protection the forage yield increased by five times in Himalayan forest grazinglands at Muzaffarabad (Ashfaque and Amin, 1982).

After 20 years of protection, the plant cover and forage yield of native vegetation in Margalla Hills National Park increased substantially (Mohammad and Ahmed, 1987). With three years of protection at Banda Daud Shah, grass, forb and shrub cover increased by 64, 35 and 11 percent, respectively (PARC 1981). The forage yield was 10 times more in the protected area than the area open to grazing. The range of Murree Hills produced 20 times more forage when protected.

Artificial Reseeding: Artificial reseeding is prescribed when natural vegetation cannot recover within a short period and there are few desirable species. Since artificial seeding is usually expensive, careful planning and management are needed to make the operation successful. Vallentine

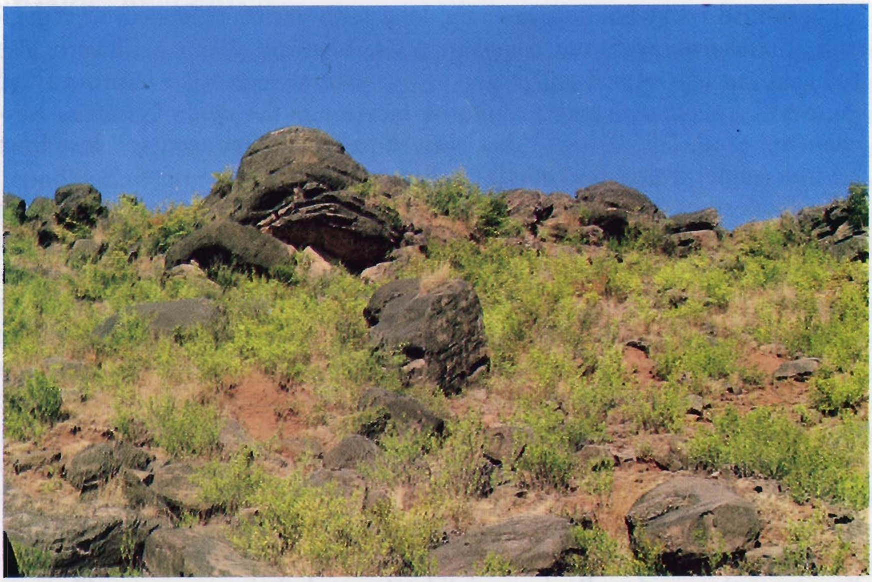

Plate 10 (a) Unprotected Margalla Hills in Islamabad.

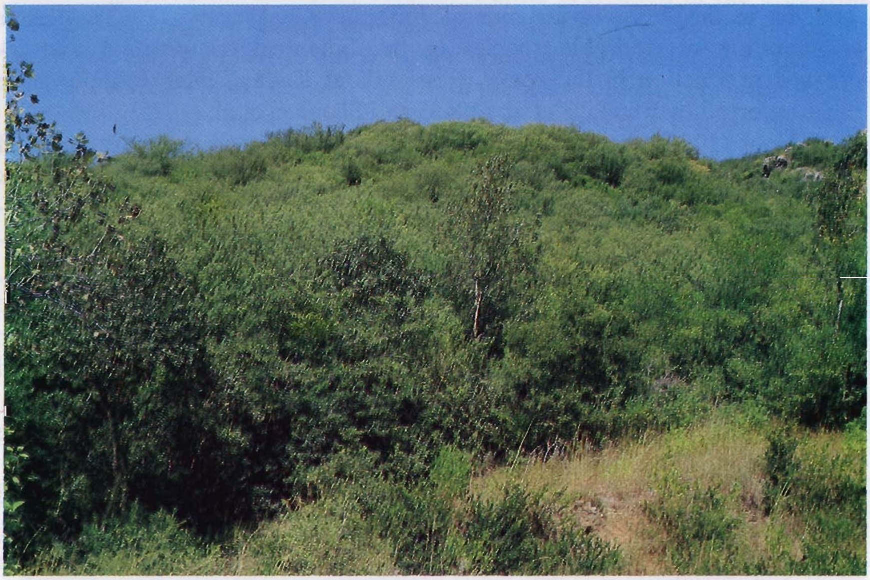

Plate 10 (b) Natural recovery of the same area by protection.

(1971) has discussed the factors to be considered before deciding to reseed range sites. Hussain and French (1963) recommended the following principles and procedures for reseeding of desert rangelands in Pakistan.

- Proper selection of range sites,
- Choice of ecologically suitable species,
- Use of a mixture,
- Elimination of plant competition,
- Proper seed bed preparation,
- Proper season and time of sowing,
- Correct seed rate,
- Distribution of seed and seed coverage,
- Contour sowing along slopes,
- Seeding method.

Reseeding is generally successful on the sites where soil moisture and nutrients for plant growth are adequate. Reseeding is not likely to be successful on areas receiving less than 300 mm rainfall. Abandoned farmlands, marginal lands for cropping, brushlands, and well-drained wetlands can be converted into productive pastures by artificial reseeding.

Before the seedbed is prepared, undesirable plants should be eliminated. Most of the rangelands in Pakistan have been invaded by poisonous and unpalatable plants. Desert rangelands are infested by *Cymbopogon jawaruncosa, Panicum turgidum, Calotropis gigantea, Prosopis juliflora. Opuntia Spp.* Pothwar scrub ranges are invaded by *Desmostachya bipinnata, Heteropogon contortus, Sorghum halepenses* and *Lantana camera.*

The Himalayan forest grazinglands are invaded by *Dodonea viscosa, Delphinium sp. Aconitum sp., Bromus sp.* and *Stipa pinnata.* Western mountain ranges contain a high percentage of *Salsola sp.* and *Paganum hermala.*

In most cases, brush ia controlled by manual uprooting and grubbing, which involves digging out plants and roots to prevent sprouting and regrowth, cutting plants above root crown or trimming off green leaves or branches and girdling, which consists of completely removing a strip of bark and outer xylem around the tree. Undesirable grasses are automatically removed during land preparation (PARC, 1983).

The highly mechanized equipment such as pipe harrow, mouldboard plough, pitting, railing, chaining and cabling, bulldozing, brush land plough, offset disc and root plough have not been used in land preparation in the rangelands of Pakistan. In certain areas controlled burning is also employed to remove undesirable plants. The desert range areas are generally ploughed with a disc, followed by a cultivator. Vallentine (1971) gave the following general characteristics of an ideal seed bed:

i. Very firm below seeding depth,
ii. Well pulverized and mellow on top,
iii. Not cloddy or puddled
iv. Free from plant competition,
v. Free of seed of competitive species, and

vi. Have a moderate amount of mulch or plant residue on the soil surface.

In desert rangelands, grass is often seeded in strips (Mohammad, 1984). In the Thal area, planting tufts of *Cenchrus ciliaris* and *Lasiurus sindicus* on shifting sand dunes dramatically increased forage yield (Khan, 1966). The tufts of old plants were dug out and transplanted on sand dunes at a spacing of 1.5 x 1.5 m. The All of the tufts planted during rainfall or within 24 hours of rainfall grew. Transplanting of grasses has also been extensively practised in India. In the hills, transplanting is more applicable than seeding. In India, nurseries are prepared during May-June to produce grasses and legume seedlings. After about a month, the seedlings are uprooted and transplanted while the soil is wet. In the Lohi Bher Range, planting tufts was highly successful on eroded areas. The forage yield was also about 50 percent more than in sown pastures (Mohammad et al. 1986). Most of the watershed ranges in the Himalayas have been reseeded by tuft planting. However, planting tufts in the vast desert ranges is not economically feasible due to the large amount of labour required.

Cenchrus ciliaris and *Lasiurus sindicus* have been reseeded successfully over thousands of hectares in Thal and Dhabeji rangelands primarily due to timely monsoon rainfall immediately after seeding although average annual rainfall in these areas is less than 300 mm (Mohammad and Naqvi, 1987) (Table 6). Reseeding of *Cenchrus ciliaris* and *Lasiurus sindicus* in D.G. Khan rangelands was not successful during 1983-84 due to prolonged drought in the area (Mohammad, 1984a). Except at a few sites, most of the reseeding work in the Cholistan Desert did not improve range condition. Reseeding is likely to be successful in Pothwar Plateau and Salt Range where annual rainfall exceeds 400 mm. Large tracts of scrublands in Gulial (Pindi Gheb), Kharemurat (Fateh Jang), Pabbi (Kharian) and Lohi Bher

Table 6. Average dry matter yield (t/ha) of 10 tropical grasses at Dhabeji, Sind, during 1976–83.

Common name	1976	1977	1978	1979	1980	1981	1982	1983	Total
Buffelgrass	4.0	6.9	4.8	4.9	5.0	5.1	4.6	4.6	39.9
Bluepanic	6.0	4.0	5.3	5.1	5.4	5.5	3.2	2.9	37.4
Gorkha	2.5	4.6	3.1	3.1	3.3	4.0	3.2	2.8	26.6
Love grass	1.5	2.3	3.1	3.1	3.1	3.1	2.5	1.8	20.5
Rohdes grass	1.0	1.6	0.7		--	–			--
Sorghum	2.4	2.4	2.3	2.8	2.7	2.7	2.4	2.4	20.1
Saba	3.0	2.9	3.0	2.8	3.9	2.3	3.6	3.5	25.0
Hyperrhenia	1.1	1.0	2.0	–		--			--
Green panic	2.5	3.4	3.6	3.6	3.9	2.3	3.6	3.5	26.4
LSD (P=0.05)	1.0	1.1	0.8	0.8	0.8	1.1	0.6	0.8	1.4

Source: Mohammad and Naqvi (1987).

(Rawalpindi) have been converted into pasturelands by reseeding *Cenchrus ciliaris* and *Panicum antidotale*. Shankarnarayan and Shankar (1984) reported that *Lasiurus sindicus* did well in sandy soils where annual rainfall was as much as 350 mm. The establishment and performance of this grass was highly impressive in sandy soils of Rajasthan Desert in India. *Cenchrus ciliaris* can be reseeded on all types of rangelands with sandy, sandy loam, stony and deep and red soils. These grasses perform well in the areas with annual rainfall between 150 and 750 mm. With proper water distribution *Dichanthium annulatum* was seeded over a large area in Rakh Miran (D. I. Khan). It naturally occurs on heavier soils with higher rainfall and performs well in regions where rainfall exceeds 400 mm per year. Mohammad and Naz (1985) indicated that flatlands with medium textured soil were very suitable for seeding *Cenchrus ciliaris* in Thal.

Range reseeding operations in most of the areas have significantly improved. Large scale reseeding of selected grasses and legumes can be undertaken immediately in comparatively high rainfall areas of Pothwar, Himalayan forest grazinglands and the Salt Range. Reseeding of grasses coupled with water distribution in Sulaiman ranges requires further study. Due to the higher rate of ecological recovery in Pothwar Plateau, natural revegetation can also be practised.

Plate 11. Buffelgrass (*Cenchrus ciliaris*) pasture in Pothwar scrub ranges.

STOCK WATER DEVELOPMENT

The availability of drinking water in rangelands ensures proper distribution of livestock which leads to optimum utilization of range sites. As most of the rangelands in Pakistan are located in arid and semi-arid areas, the conservation and planned use of water is extremely important. Inadequate or too much water in the grazing area may result in improper utilization of the resource, especially in the already heavily over-grazed arid rangelands. The amount of water needed by livestock differs with the type of range, climate, season, and kind of animals. Generally, cattle drink up to 10 gallons of water per day while sheep and goats need about a gallon per day. Cattle like to drink every day while sheep can go without water for days. Most of the desert rangelands in Pakistan contain brackish or saline water. Although both cattle and sheep can tolerate a fairly high salt content (upto 7000 ppm), ponds to harvest rain water are needed in Cholistan and Tharparkar where the subsurface ground water is highly saline.

Alpine pastures, Trans-Himalayan ranges, and Himalayan forest grazinglands have plenty of rivers, perennial springs and seepage water for livestock. However, at certain locations in the northern region temporary ponds, ditches or water channels are constructed in the valleys to provide water for livestock when they are moved to alpine pastures. In the Pothwar Plateau scrub ranges, small dams are constructed to accumulate monsoon rainfall water. At certain locations perennial water channels and springs are also available. During drought periods the southern part of the Plateau experiences shortages of drinking water for humans and livestock. There are shallow persian wheel wells at different locations.

Although the desert rangelands of Thal, Cholistan, D.G. Khan and Thar are within the reach of monsoon rainfall, occasional droughts have resulted in heavy livestock losses in Cholistan and Tharparkar areas. Therefore, development projects in the desert rangelands focused on the construction of ponds to harvest rain water (Mohammad, 1984, Government of Punjab, 1974). Due to highly brackish underground water in Cholistan, ponds to collect rainwater were constructed about every 20 km. There are 478 ponds in a 15000 square km area. Rasul (1966) described stock water development work in Cholistan. In the Thal area, hand pumps were installed at a regular distance of 7 km to provide drinking water for humans and livestock. In D.G. Khan rangelands, water from flash floods of Sulaiman mountains has been conserved by constructing several small reservoirs (Mohammad, 1984a). Persian wheel wells were also dug at a few places. Because of high wind velocity during most part of the year, wind mills have been successful in Kohistan, Thar and Baluchistan rangelands.

Baluchistan mountain rangelands experience shortages of water throughout the year. The nomadic livestock grazing is primarily controlled by the availability of watering points. The area has only a few seeps and springs in the foothills and brackish underground water in the valleys and plains (Baig, 1977; and FAO, 1983). The area has centuries-old underground water channels, locally known as karez canals, which are quite efficient for irrigation. With the extension of electricity in the province, tubewell irrigation is possible over extensive areas. Every range development project has a water development programme. In the Maslakh range

Plate 12. Windmill-a reliable water source in Maslakh Range, Baluchistan.

management project, the following water development works were carried out over an area of 40000 hectares from 1954 to 1964 (Rafi, 1965).

Springs	7
Surface wells only	9
Surface wells with wind mills	3
Surface wells with Persian wheel wells	5
Earthen bunds	12
Water tanks	7
Pipelines	3 km
Surface drains	10 km

Some of the important sources of stock water development in the desert ranges are briefly described below:

'Karez': Water is taken from its original source (spring) to the low-lying areas for human as well as cattle consumption. An underground channel 1.5 to 2 m deep is dug with holes at suitable distances, wide enough to maintain the channel. At the end of the channel, an underground tank is built to store the water. The upper surface is covered except for a hole to remove the water from the tank to minimize evaporation.

Springs: These are not common in arid and semi-arid rangelands so wells are the most satisfactory source of stock water. They are dug, driven or drilled according to the site and depth of sub-soil water. On state lands with range projects these wells are power- driven. In some cases, water is removed with pack animals like bulls or camels. A rope is passed through a pulley, one end of the rope is fastened to the bucket and the other end to the animals. A man unloads the bucket and the other takes care of the animals. This practice is very common in deserts like Tharparkar, Cholistan and D.G. Khan.

Desert Sand Tank: In the arid regions, a small but dependable water supply is essential for human life and activity. Low rainfall coupled with extreme heat does not make it possible to conserve water in any type of open pond or reservoir and a unique type of water bed or reservoir, known as the desert sand tank, was introduced more than a century ago and is still used.

Essentially, a sand tank consists of a dam or other impervious structure built across a stream bed or large desert "sand wash," preferably where there is rock-outcrop or where the stream bed is within a rock bound channel in a small canyon. The dam is built on to the bedrock and channel walls to reduce evaporation losses and to keep water free of contamination from animals and insects because water is retained in a relatively deep bed of sand. It is the most important means of water development. A number of reservoirs constructed at Range Development Project, Maslakh (Quetta) are fairly successful. The disadvantage is that surface runoff is required. To reduce the evaporation losses the reservoir must be deep and with a small surface area. The following points should be considered in the construction of reservoirs.

i. The ground should be properly tested.
ii. The embankment is properly constructed.
iii. A proper spillway should be provided.
iv. The embankment should be fenced.
v. Moderate cost.
vi. Minimal loss due to evaporation and infiltration.

The major cause of failure of earth dams is probably inadequate spillway. No matter how a dam or reservoir has been constructed, the dam will be destroyed during the first shower if the capacity of the spillway is inadequate.

Where it is not possible to construct a dam, a dugout can be built to collect and hold surface runoff. It is merely a hole dug to provide adequate storage. It can be constructed in any place on fairly flat land where water can be collected and impounded. A dugout has one or more sloped entrances so that livestock can utilise the water at any depth. The other sides are made as steep as possible. A dugout should be fairly deep to compensate for evaporation.

Tobas: These depend on rains for their water supply. Good rains, may provide water for several months. If not, the tobas go dry quickly and are of no use to livestock. Tobas have a definite place for water development. They are cheap and can be placed on any clay area where there is some runoff. In general, they must be 3-4 m deep to hold water for any length of time. Shallow tobas less than 3 m deep lose their water through evaporation very quickly. Tobas must be constructed in heavy clay soil or be lined with impervious material to make them watertight. Tobas have sloping sides so that livestock can have access to the water. They must be desilted every two to three years. The size of the tobas will depend on how many livestock will use the area for how many months. Storage must always be at least double the actual calculated need to allow for seepage and evaporation.

Small Dams: Small dams have a vital role in a range water development programme. Dams usually provide more water storage than tobas. There may be few sites suitable for dams and the sites may not meet the needs of the range management plan. Finally many small dams fill rapidly with silt. Dams for stock water should be of the main channel so they will not silt up readily.

SOIL AND WATER CONSERVATION

Except in the Himalayan forest grazing areas and Pothwar scrub ranges, most of the rangelands are located in the arid and semi-arid areas. Rainfall is low, erratic and infrequent. Prolonged droughts are common. Both human and livestock depend on rain water for drinking. Because range reseeding, planting of fodder trees and shrubs, regulation of livestock grazing and nomadic movement patterns are dictated by the availability of rain water, soil and water conservation has a very important role in the management of rangelands in Pakistan.

The northern mountains of Pakistan are subject to heavy soil erosion. Almost all the forms of water erosion, i.e., rain drop, splash, sheet, rill and gully erosion, are predominant in the Pothwar tract. In Pothwar Plateau alone, about 14,000 hectares of land are lost annually (Shafiq et al. 1987). These watersheds are the backbone of the national economy and are the main source of water for Tarbela, Mangla, Warsak, Rawal, Khanpur, Simly, and the proposed Kalabagh dams. The dams also provide water for the extensive canal irrigation system in the country, and generate 70 percent of the total electric power.

The life-span of these dams can be increased by 30-50 years by reducing the rate of siltation. It is estimated that about 18,000 square km of the catchment of the Tarbela Dam is silting. Proper land use practices can save the Government upto 2.5 billion rupees by reducing the losses incurred by siltation. Scientific management of the rangelands, which constitute about 20 percent of the area, can save 0.5 billion rupees annually (Government of Pakistan, 1983).

Soil and water conservation practices carried out by Provincial Forest Departments and Water and Power Development Authority (WAPDA) have been extensively reviewed in the proceedings of the First Pakistan Watershed Management Conference (1968) and the Seminar on Watershed Management (1977).

Khattak (1986) described forest operations conducted in Tarbela and Mangla watersheds. Cheema (1978) reviewed watershed research in Pakistan. Range management in the watersheds of Pakistan has been discussed in detailed by Mohammad (1986).

The achievements made under various agencies and through different projects/schemes are given in Table 7 and 8.

Chaudhry and Shafiq (1986) summarized the salient findings of the Soil and Water Conservation Directorate:

i. Different types of terraces were studied. It was concluded that the existing terrace system be improved because of small and scattered holdings of the farmers.

Table 7. Soil conservation operations conducted in various watersheds of Pakistan up to 1977.

Operation	Achievement
Tarbela	
– Terracing	317187 ha
– Reclamation of gullied lands	78724 ha
– Afforestation, range improvement and soil conservation measures.	38722 ha
– Channel training	50.5 km
Mangla	
– Area surveyed	5437 sq. km
– Area covered by field operations	3433 sq. km
– Afforestation, sowings, plantings soil conservation structures.	5.7 million pits/trenches, 20 million plants, 1.96 million cubic m.
– Engineering structures.	2534 (no.)

Source: Khattak (1977).

Table 8. Summary of watershed activities in Pakistan past, present and future.

(ooo ha)

		Punjab	Sind	Baluchistan	NWFP
A.	Area where work has already been completed				
—	Afforestation	37.0	--		93.8
				366.1	
—	Soil conservation	436.0			73.0
B.	Area where work is in progress				
—	Afforestation	3.4			30.7.6
				428.5	
--	Soil conservation	11.6	—		307.6
C.	Area where work is contemplated/required				
—	Afforestation	3.2	—		72.0
				10606.1	
—	Soild conservation	42.6			13.2
D.	Area with servere hazards of soil erosion.	N.A.	13.5	7400.0	400.0

Source: National Commission on Agriculture (1988)

ii. Two water collection ponds were constructed at the Soil and Water Conservation Research Station, Tarnol, which, in addition to collecting runoff water, also served as a sedimentation trap. There was a provision for the safe disposal of surplus water. These reservoirs were used to supplement irrigation water during drought. It supported good vegetable and maize crops.

iii. Comparative studies on various crops were also conducted. Cover crops and legumes were more effective in reducing erosion.

iv. Various check dams like brushwood, earthen, loose stone, wire netted, brick and concrete check dams were tested. Their suitability depended on the rainfall and catchment characteristics.

v. A number of tree species were planted at the Soil and Water Conservation Station, Tarnol to observe their performance and behaviour. The soils were shallow with 5-10 percent slope. Because of shallow depth, the growth remained stunted. However, those planted along the nullahs and on the banks of the ponds did well. For example, *Dalbergia sisso* and *Acacia nilotica* did well along the stream banks whereas *Salix tetra- sperma* showed better growth on the banks of the ponds.

vi. The performance of guava, citrus, apricot, plum, peaches and apple under dry farm conditions was tested. Deciduous fruits, citrus and guava could be grown in areas receiving 500- 1000 mm rainfall provided supplemental irrigation facilities are available.

vii. The water disposal outlets like grassy, loose stone, prefabricated brick work and concrete were tested. Brick work and concrete outlets were required where the amount and intensity of rainfall are high and field to field slope is larger. Others can be installed in the upper reaches of the catchment area and areas receiving little rainfall.

The PARC project on gully land management provided useful information about the effect of various planting techniques on vegetation status (Table 9).

Table 9. Effect of different management practices on ground cover/frequency distribution of grasses in Pothwar area.

Area specification	Total cover %	Cover of desirable grasses %	Average frequency of desirable grasses %	Average density of desirable grasses %
Gully bed unprotected	35	15	30	3
Gully bed (protected + conservation structure)	33	27	53	5
Unprotected farmers area	13	9	30	2
Control catchment	31	18	31	6
Catchment planted with *Ailnat..us altissima*	42	23	40	24
Catchment planted with *Morus alba*	43	30	44	5
Catchment planted *Leucaena leucocephala*	65	45	66	23

(continued)

Table 9 continued

Catchment planted with *Vitex negundo*	24	10	52	5

Source: PARC (1986).

Soil conservation structures improve forage production (Figure 2). Gullybeds with protection and conservation structures had the highest forage yields. Grass forage production under *Ailnathus altissima* plants was highest. *Vitex negundo* plantation produced the least grass yield (Figure 3).

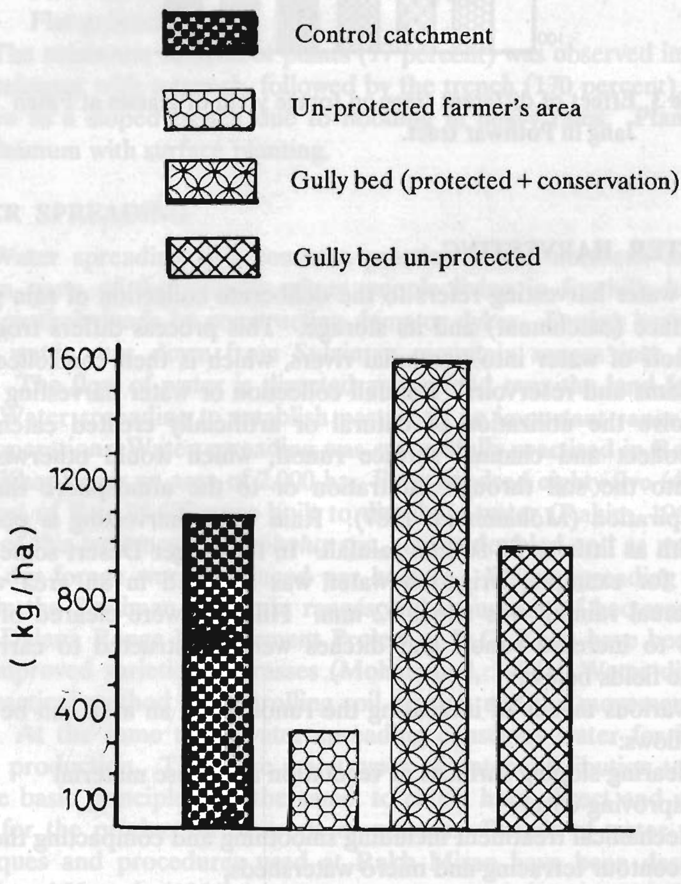

Figure 2. Impact of soil conservation structures on forage yield in Pothwar scrub ranges.

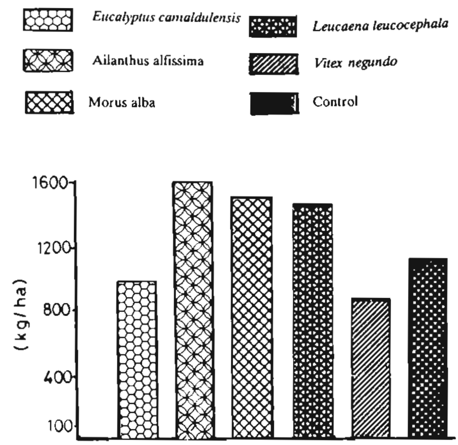

Figure 3. Effect of different trees on forage yield of grasses at Fateh Jang in Pothwar tract.

RAIN WATER HARVESTING

Rain water harvesting refers to the deliberate collection of rain water from a surface (catchment) and its storage. This process differs from the natural runoff of water into perennial rivers, which is then controlled and stored in dams and reservoirs. Rainfall collection or water harvesting techniques involve the utilization of natural or artificially created catchment areas to collect and channel surface runoff, which would otherwise be recycled into the soil through infiltration or to the atmosphere through evapotranspiration (Mohammad, 1987). Rain water harvesting is possible in areas with as little as 50-80 mm rainfall. In the Neger Desert some 4000 years ago, for example, irrigation water was supplied in an area where average annual rainfall was about 92 mm. Hillsides were cleared of rock and gravel to increase runoff and ditches were constructed to carry the water to the fields below.

The various means of increasing the runoff from an area can be classified as follows:-

i. Clearing sloping surfaces of vegetation and loose material
ii. Improving cover,
iii. Mechanical treatment including smoothing and compacting the surface, contour terracing and micro watersheds,
iv. Reducing soil permeability by the application of chemicals,
v. Surface binding treatment to reduce soil permexbality,
vi. Covering the catchment with a rigid surface and,
vii. Covering the catchment with a flexible surface.

An experiment in the Thal desert of Pakistan assessed the efficiency of different treatments to induce maximum runoff. Different treatments were compared and effects of individual treatments were studied. The results revealed that mud plaster (soil + wheat husk) was the best as it induced an average maximum runoff of 78 percent of total rainfall received by the catchment as compared to untreated catchment plots which captured only 49 percent of the runoff. The next best treatment were polythene sheet cover and sodium carbonate spray (Sheikh et al. 1982). Another experiment compared different rain water harvesting methods in the Thal desert rangelands in 1980 (Sheikh et al. 1984). The following five rain water harvesting methods were tested:

- Sloping catchment, 1 m slope, with a trench 1 m deep,
- Sloping catchment, 1 m slope with trench,
- Trench 0.3 m wide and 0.3 m deep,
- Pit of 0.5 m diameter and 0.3 m deep,
- Flat ground,

The maximum survival of plants (77 percent) was observed in the sloping catchment with a trench, followed by the trench (170 percent). Survival was low in a sloped trench due to flooding in heavy rains. Plant survival was minimum with surface planting.

WATER SPREADING

Water spreading is a common practice in the northern and northwestern parts of the country where people living in foothills hold flood water on their lands by constructing dams or dykes. During heavy rains, a lot of water runs down from Sulaiman mountain ranges into the Indus River. The flow of water is directed and spread over the land for cultivation. Water spreading to establish pasture is an important range improvement operation. Water spreading was successfully practised in Rakh Miran (D.I. Khan) over an area of 2,000 ha. Four hundred eighty five (485) dykes at a cost of Rs. 84,600 were built to distribute water (Rahim, 1966). As a result of this treatment, *Sporobolus spp.* cover doubled and as much as 2 t of air dry forage were produced per hectare. Water spreading has been done in the Sulaiman mountain ranges and thousands of hectares in Rakh Choti Dalana Range Management Project at D.G. Khan have been seeded with improved varieties of grasses (Mohammad, 1984). Water distribution is a practical method of controlling soil erosion and the movement of sediment. At the same time, water spreading conserves water for increasing forage production. There are many types of water distribution techniques, but the basic principles are the same: to catch, hold, direct and use runoff water for the production of crops or grasses. Details of water spreading techniques and procedures used at Rakh Miran have been described by French and Hussain (1964).

Pond System: This system has been practised in Pakistan for many years and is the simplest form of distribution. On relatively uniform slopes a "U"-shaped dyke is constructed below a piece of cultivated land to concentrate water for crop production.

Wild Flood System: The term wild flooding is generally applied to water distribution systems where water is diverted from drains and nullahs, then spread naturally over large areas. This require a specialized type of topography. The land must slope away from the stream channel. Where the stream channel is shallow, a series of plugs may effectively divert the water from the channel and spread it over a broad area of the flood plains.

Level Dyke System: This type of water spreading system consists of a series of long but level dykes. The alternate end of each dyke is turned up or closed so water flows towards the open end. The flood water moves in a zigzag pattern across the slope entirely through the system. This type of system is very effective but requires a reasonable accurate calculation of peak flows. The dykes must be long enough to force the water to flow along the face of the dykes.

SAND DUNE FIXATION

Sand dunes occur where sand accumulates or is deposited. Dunes are not enduring features; they soon change place and form. They may be isolated or occur in groups. Where sands are exposed to persistent winds, dunes march across the landscape in endless shifting ranks. Sand dunes are characterized by the lack of vegetation cover and are always exposed to winds. Thus, they migrate from one place to another, swept in the same direction. Longitudinal sand dunes move slowly at the rate of 10 metres per annum. Crescent sand dunes may be swept long distances within a few days.

Sand dunes adversely affect on communication, human health, cultivation, and animal health. Sand storms can affect the eyes and cause conjunctivitis. In the respiratory system, these fine sands may lead to acute or chronic bronchitis and even asthma. Chronic exposure of lungs may lead to silicosis, which is a disease that may destroy the lung parenchyma, leading to pulmonary fibrosis and ultimately, heart failure. Sand storms in northern Nigeria and Sudan visibly affect human health.

On cultivated lands, sand dunes may destroy nearby cultivated lands, roads and towns. Damage to plants as a result of soil drifting, wind pulling and sand lashing may at times be very substantial and in most cases, such damage is visible with the naked eye. Other disadvantages, which result from unchecked wind speeds, are not always visible but they often hamper plant growth and animal as well as human health.

Thal, Cholistan, Tharparkar and southwestern ranges in Baluchistan are subjected to heavy wind erosion. Mohammad et al. (1985) summarised desert rehabilitation research in Pakistan. Mohammad (1987) reported on recent Pakistan experience in rangeland rehabilitation and improvement. Pakistan has extensive experience in sand dune stabilization in the Thal and Baluchistan deserts. A brief description of the sand dune fixing techniques developed in Pakistan is given below:

Thal Techniques: Sand dunes in Thal area have been rehabilitated by reseeding with palatable grasses, tuft planting of grasses and bushes and plantation of fuel/fodder shrubs and trees.

Reseeding with palatable grass: A proper seed bed is essential for better seed germination. The soils are ploughed with disc plough which eliminates undesirable plants that use a large part of the available soil moisture and prevent the establishment of the reseeded species. Reseeding can be done from June 15 to July 31, during the monsoon rainfall. The incidence of a good rainfall with the sowing enhances germination. Germination, however, starts after four days of rainfall and is complete within 10 days. The seedlings should be protected from grazing. A little carelessness of the grazier or the manager may destroy all the efforts.

The availability of forage seed is a serious limitation. Seed is collected at maturity. Germination of immature seed is very low. Seeding rate is determined by its quality (germination percentage, size and germination habit). Five kg/ha of *Cenchrus ciliaris* and *Lasiurus sindicus,* separately or in mixture is the optimum seed rate for these species. The seed is broadcast manually and is covered with soil with the help of a 'Bush Drag' drawn by camels. The size and the weight of the drag is adjusted so seed is neither very lightly covered nor the soil is too compacted.

Tuft planting: A bunch of grass with a root system at least 20 cm deep and 10 cm above ground is called a tuft. Tufts should be planted at the top of a sand dune. Tufts of *Cenchrus ciliaris* and *Lasiurus sindicus* are suitable for the Thal area. Tufts are spaced 30 cm apart. Success of tuft planting depends on adequate rainfall. If rain falls within 24 hours of the planting, chances of success are up to 80 percent. This operation cannot be done on a large scale. This technique requires the careful management of labour and adequate rainfall.

Earthen tubes: Baked earthen tubes (30 cm long, 10 cm in diameter and 1 cm thick) open on both sides are used to raise fuel/fodder trees or shrubs on loose textured sand dunes. Holes in the tube provide aeration and drainage. *Zizyphus mauritiana, Z. nummularia, Prosopis cineraria* and *Tamarix aphylla* can be raised by this method. Planting occurs in the monsoon season (July- August) and spring (March-April). However, only monsoon plantings are successful in Thal. High temperatures after spring kill those planted in the spring. Planting is done during rainfall or within 24 hours after rainfall.

Transplanting trees and shrubs: In this technique, trees or shrubs raised in polythene tubes are transplanted on the sand dunes and are watered. When they are established, watering is stopped and they depend on rainfall.

Broadcasting seeds of shrubs along with grasses: Seed of some species (e.g. *Zizyphus mauritiana, Prosopis cineraria* etc.) is broadcast along with grasses, which germinate when it rains and the trees are established.

Plastic and grass mulching: In order to conserve moisture various types of mulching materials have been used. Sheikh (1986) designed various types of plastic aprons to reduce planting losses in arid areas and improve conservation of soil moisture to facilitate the establishment and growth of trees during the dry period. In the Thal Desert, an experiment in 1980 studied the effect of mulching on survival and growth of tree species. Plastic aprons, pitch stone and dry grass were used to mulch in the pits. Plastic aprons had the best effect on survival and growth of trees. Grass mulching attracted termites. Stabilization of sand dunes in Thal has been achieved with considerable success by planting species like *Calligonum polygonoides* and *Saccharum bengalense.* Cuttings of *Tamarix aphylla* have done very well on sand dunes when planted fresh from the tree. Where canal irrigation is available, *Acacia nilotica* and *Dalbergia sissoo* have been planted on rather stable sand dunes.

Drip irrigation: This system of irrigation has been tested in the Thal rangelands of Pakistan. Water was applied at 5, 10 or 15 day intervals on a sand dune top and on inter-dunal flat. For irrigation, a hand pump was installed on the top of the sand dunes and a water tank of 1.2 x 1.2 x 1.0 m was constructed with brick masonary and cement plaster. Two sheet pipes in the reservoir supplied water to the drip system. One pipe went to the planting site in the inter-dunal flat and the other went to the sand dune top. Two cross steel pipes 2 cm in diameter were fitted with nozzles and nipples rubber pipe could be fitted at 2 m intervals, with the supply lines. The plastic pipes, 1 cm in diameter, were fitted with the nipples and pin holes were made with a hot needle at 1 m intervals. The plastic pipes were placed in 15 cm deep trenches. Planting was done at 1 m intervals facing each hole in the pipe. The pin holes of the pipe were kept near the root zone of the plants. The pipes were buried in soil except for the ends to check the water flow. The water from full tank (140 litre capacity) was released in the pipes to irrigate 120 plants; each plant received approximately 1.2 litre of water each time.

The above system could be used to establish a green cover in arid and semi-arid areas. Apparently, the drip irrigation system seems to be costly but could be more efficient in desert areas like Thal, where sub-soil water is not deep and in the hilly areas where rain water can be collected and stored in artificial tanks. Several techniques of water harvesting have been practised in the Thal. These practices include spreading of asphalt, coaltar cover, cement cover, lime concretion, mud plaster and polythene sheet cover during the rainy season.

Maximum rain water was harvested from plots treated with mud plaster, followed by the polythene sheet cover and sodium carbonate spray. Different fodder/fuel trees like *Acacia nilotica, A. modesta, Eucalyptus camaldulensis, Prosopis cineraria* and *Zizyphus mauritiana* have been planted and are being irrigated by the rain water collected in the storage tanks.

Baluchistan Techniques: Rehman and Mohammad (1988) discussed the sand dune fixation work conducted at Mastung, Naushki and Pasni.

The following is a brief description of the methods and procedures:

Mastung Valley is situated on the Quetta-Kalat Highway 50 km south of Quetta. The valley is well-known for its high agricultural productivity. The sand dunes have developed at several places in Mastung Valley. During the summer season, high winds blow from the west or south west. By 1954, the dunes had spread over 10,000 ha of fertile land. The mobile dunes had buried six villages, 18 'karezes' and several orchards. The dunes threatened the Quetta- Kalat Highway and Quetta-Zahidan railway track traffic was often blocked. The following techniques were tested to halt the march of huge sand dunes on valuable agricultural and residential properties:

Mechanical stabilization: Construction of mechanical obstacles like walls, wooden barriers and spreading of brushwood on mobile dunes.

Chemical stabilization: Different soil binding materials used included spreading of fine clay soil on the sand surface, spraying mud and water mixed with a fine clay rich in carbonates.

Biological stabilization: This included planting of various local and exotic plant species in the dune area. First the local flora was studied and indicator species with fibrous root-systems were identified and tested. The area is within the mediterranean climatic zone and receives 125 mm of rainfall with some snowfall during the winter and occasional showers during the summer. Species were selected that could tolerate acute arid conditions. The species selected were *Tamarix aphylla, Arundo donax, Calligonum polygonoides* and *Haloxylon persicum.*

To plant these species on sand dunes, a trench of 25 cm depth was dug. The interdunal spaces on the leeward side were planted with rhizomes of *Arundo donax.* A trench parallel and 1 m from the first one was constructed at the same depth. Cuttings of *Tamarix aphylla* and *Calligonum polygonoides* were burried horizontally side by side. Again, a third trench was made parallel to the others and where *Haloxylon persicum* and *Calligonum polygonoides* were sown, to create shelterbelt or windbreak. All the operations were carried out during February and March. The technique was quite successful and the following total area has been successfully planted:

Sites	Hectares
Pringabad sanddunes	2790
Shamsabad sanddunes	2333
Teri sanddunes	234
Dund shelterbelt	34
Pitbagh sanddunes	179
Eidgah sanddunes	30
Total	5600

Plate 13. Sanddune fixation by afforestation in Mastung valley, Baluchistan.

To combat the movement of sand dunes, work was initiated in 1972 near Naushki in Chagai district. Two hundred ha were treated on an experimental basis. After plantings, the following natural vegetation was also planted:

i.	*Tamarix aphylla*	entire plant, branch cuttings root and shoot cuttings
ii.	*Calligonum polygonoides*	branch cuttings and seeding
iii.	*Haloxylon persicum*	branch cuttings and seed sowing
iv.	*Pennisetum orientale*	clumps planting

Planting occurred during the winter soon after rainfall, along the peripheral line of sand dunes. In the climate of Naushki, high summer temperature and low precipitation were coupled with desiccating winds, so the rehabilitation of sand dunes was not very successful. The seeding of *Haloxylon persicum and Calligonum sp* was successful, though growth was very slow. The natural regeneration of vegetation was quite encouraging in the treated area. Adequate moisture to a depth of moisture up to 0.5 to 1 m was required before the area was treated. Vital areas were rehabilitated where the movement of sand had threatened highways, railway tracks and villages. In 1983, the program was started in Kharan District where 2634 ha have been rehabilitated so far.

Low rainfall, greater evaporation, high temperature and nearness to the sea coast, means that the underground water is moderate to highly saline. Good quality water if available is not sufficient even for the human population. The whole coastline is affected by sand movement due to low moisture and loose sand. Strong sea winds have deposited sand in many urban and rural areas. For instance, a part of Pishkan town has been recently abandoned and a Pasni town has been endangered by the huge sand dunes. The old town of Pasni is buried under 5 m of sand. To plant the area to prevent sand movement the Baluchistan Forest Department selected mesquite *(Prosopis juliflora)* and used highly saline underground water for irrigation. The sand stabilization programme was initiated in 1970 in Pasni, Gwadar and Pishkan. The plants were mostly grown on loose sandy strata but occasionally on compact sand. The programme was initially undertaken to protect roads and houses from shifting sand and was subsequently extended to other areas.

Seeds of *P. juliflora* were raised in polythene bags filled with coastal sand and irrigated with good quality water. Six-month to 1 year old seedlings were planted in coastal sandy belts at 2 m intervals. They were irrigated without any chemical amendment with sub-soil brackish water obtained from nearby wells. The plants were irrigated with 10-12 litre of saline water, weekly during the summer and fortnightly during the winter. Irrigation continued for 2 years untill plant roots were deep enough to survive. The mortality was up to 30 percent. Mesquite has successfully grown for the past 10 years. The Forest Department stopped drifting sand and it appears that the method could be improved with the use of appropriate scientific methodology. Total area covered with sand dunes afforestation along the coastal belts is given in Table 10.

Plantations of mesquite have totally stopped the movement of sand to the valuable residential installations; these activities were discontinued in

Table 10. Coastal sand dunes afforestation by Baluchistan Forest Department from 1972 to 1985.

(Hectares)

Year	Pasni	Gwadar	Ormara	Pishkan	Jiwani	Total
1972-76	84.5	84.5	–	–	–	169.00
1977-78	8.5	8.5	–	–	–	17.00
1978-79	2.0	2.0	–	–	–	4.00
1980-81	5.0	6.0	–	6.25	–	17.25
1982-83	33.5	40.0	–	4.05	–	77.55
1983-84	35.5	33.5	4.16	6.25	–	79.41
1984-85	23.0	25.0	4.16	2.00	6.25	60.41
Total	192.00	199.50	8.32	18.55	6.25	424.62

Source: Rehman and Mohammad (1988).

1984-85. The plantation, however, is being maintained. The Forest Department has formulated another project to fix coastal sand dunes on 500 ha during 1987-88. These plantings has significantly affected the sanitation and microclimate of the affected areas. The poineer work on saline areas of coastal belt by University of Karachi indicated the high potential of afforestation under saline conditions (Ahmad, 1987).

RANGE BURNING

Burning is the oldest known practice used by man to manipulate range vegetation for livestock grazing. In the Murree Foothills and chirpine zone, forest fires are frequent. Local people burn these areas to increase the regrowth of grasses. Because haphazard or accidental burning can be harmful or even disastrous, burning as a rangeland improvement practice has only recently gained the favour of range managers and researchers. Planned burning when weather and vegetation favour a particular method of burning that can be expected to maximise benefit, is known as prescribed burning. The most important factor is the proper time. Reasons for burning rangeland generally include the following:

- Increase the palatability of forages and removal of old, dead material, thus increasing utilization by grazing animals.
- Suppression of undesirable brush plants.
- Preventing invasion of inferior species and to start grass growth 1-3 weeks earlier on fresh burns.

The majority of rangelands in Pakistan is extensively overgrazed and as a result invaders or undesirable plants are prevalent in these areas (Mohammad and Naz, 1985). The plants are mostly coarse grasses and shrubs of low palatability. Due to excessive accumulation of organic matter and debris, some forest areas have become impenetrable and inaccessible for grazing by livestock.

The effects of controlled burning on the composition and production of forage were studied in three landscape ecological units at Lohi Bher Range in the sub-tropical, sub-humid Pothwar Plateau (Mohammad et al. 1987). Forage production increased by 200 kg/ha in spring on burned sites and by 425 kg/ha in the summer. Forage palatability and utilization also increased following burning due to tender and nutritious regrowth of grasses and forbs. Plant cover of deep- rooted perennial grasses like *Desmostachya bipinnata* and *Chrysopogon aucheri* increased following burning. Plant cover of annual forbs also significantly increased after burning, which substantially increased forage yield.

Burning significantly increases forage yield and palatability of coarse and some unpalatable grasses and forbs. Fire treatment in fall season is recommended because abundant litter and dead plant material which serves as fuel. In fall, most of the grasses are dormant and are thus not damaged by burning. Forage yield of grasses depends on soil moisture after burning.

In wet areas when there is enough precipitation after burning, forage yield can be increased by 50 percent. Burning should not be practised during extended dry periods. Controlled burning can be recommended for large tracts of humid and sub humid Pothwar rangelands of Pakistan as a management tool for controlling brush, improving palatability and increasing dry matter yield.

RANGE FERTILIZATION

Use of chemical fertilizer in rangelands is considered an uneconomical luxury. This is probably true in the arid and semi- arid rangelands. However, forage yields in the high rainfall zones improved substantially following fertilizer application. Khan (1981) obtained two- fold increase in forage yield with the application of phosphorus and nitrogen fertilizers in sub-tropical humid rangelands in the northern mountains.

At NARC, fertilization produced phenomenal results. Grass species, namely *Cenchrus ciliaris, Chloris gayana, Panicum antidotale* and *Pennisetum purpureum*, received 100 kg N/ha in different seasons. Summer yield in the fertilized plots was 13.0, 8.9, 18.9 and 26.1 t/ha DM compared to yields on control plots of 8.6, 5.1, 7.9 and 15.9 t/ha DM, respectively. Winter fertilization did not increase forage yield.

One-year-old plants of *Pennisetum purpureum* were subjected to four nitrogen fertilizer levels (0, 40, 80 and 120 kg N/ha) and three harvesting intervals (30, 45 and 60 days) at NARC. During the 6 month study period, nitrogen fertilization up to 80 kg/ha increased the dry matter yield of napier grass. Forage yield significantly increased as harvesting interval was lengthened from 30 to 60 days. Nitrogen fertilizer increased the percentage of crude protein and ash but did not affect crude fibre. Crude protein and total ash contents decreased with longer harvesting intervals. However, the percentage of crude fibre significantly increased in 45 and 60-day harvesting intervals. Dry matter yield and total of crude protein per unit area was higher from the moderately fertilized (80 kg N/ha) plants harvested at 60-day intervals than from heavily fertilized (0 to 120 kg N/ha) plants subjected to frequent clipping (30-45 days). These results indicate that better quantity and quality of napier grass can be maintained by harvesting at longer intervals (60 days) provided the plants are fertilized with 40 to 80 kg N/ha.

Cenchrus ciliaris and *Pennisetum purpureum* gave forage yields of 13.5 and 28.0 t/ha plots fertilized with 100 kg N/ha and harvested at 40-day intervals during summer compared to 7.8 and 12.1 t/ha respectively, from the control plots. Nitrogen fertilization level and length of harvesting interval also affected the nutritive value of grasses. The effect of fertilizing *Lasiurus sindicus* was studied in Thal. An application of 25 kg N/ha significantly increased growth and dry matter yield whereas phosphorus had no effect.

In a fertilization trial at Dhabeji, in the Kohistan ranges, the forage yield increased by about 20, 30, 25 percent in *Panicum antidotale, Cenchrus ciliaris* and *Lasiurus sindicus,* respectively compared to the control plots

(Mohammad and Bhatti, 1983). The forage production of napier grass increased with the application of nitrogen fertilizer (Stephens, 1967). Miyagi (1982) recorded a remarkable increase in the forage yield of napier grass with nitrogen application up to 600 kg/ha. Little et al. (1959) also reported higher forage yield in napier grass, guineagrass *(Panicum maximum)* and pangola grass *(Digitaria decumbens)* with nitrogen fertilization. However, the increase in yield was not as great as more nitrogen was applied (Miyagi, 1981, 1982). In the West Indies, applying more than 170 kg N/ha did not significantly affect forage yield of napier grass (Walmsley et al., 1978).

Nitrogen fertilizer significantly improved the nutritional quality of grasses (Mohammad, 1981). Colville et al. (1963) reported increase in crude protein of brome grass *(Bromus inermis)* from 8.9 to 14.8 percent by adding 160 kg N/ha. Hart and Burton (1965) concluded that crude protein was higher in plants receiving higher N fertilizer. Walmsley et al. (1978) did not find that nitrogen fertilizer (170-340 kg N/ha) increased the CP of napier grass. Nitrogen fertilizer reduced crude fibre in orchard grass *(Dactylis glomerata)* and Sudan grass *(Sorghum sudanense)*. (Ramage et al. 1958; Rusoff et al. 1961) but did not affect coastal bermuda grass *(Cynodon dactylon)* (Hart and Burton, 1965; Miller et al., 1961). Nitrogen fertilizer also significantly reduced the ash contents of bermuda grass and orchard grass (Burton and Devane, 1952; Ramage et al., 1958).

Fertilizer could successfully be applied in high rainfall areas of Pothwar and Himalayan forest grazing areas. However, the economic feasibility of fertilizer application in the arid rangelands needs to be further investigated.