RANGELAND MANAGEMENT IN PAKISTAN

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Foreword

Rangelands constitute an important component of the agricultural system in Pakistan. In addition to grazing support for the 93.5 million livestock, the rangelands are a major source of streamflow, natural habitat for wildlife and production of timber and fuelwood. Due to the arid and semi arid environment and limited irrigation facilities, these areas can not be converted into croplands. However this vast natural resource covering over 60 percent area of the country provides great potential for livestock grazing and dry afforestation.

Recognizing the importance of rangelands in the national economy, the Pakistan Agricultural Research Council initiated a National Forage and Pasture Programme in 1975 to establish a range research network in different range ecological zones of Pakistan. It is note worthy that most of the research work reported in this book was made possible by this programme. PARC institutions such as Arid Zone Research Institute (AZRI) and Agricultural Research Institute for Northern Areas (ARINA) also have mandate to enhance productivity of this vast arid and semi arid land resource. Recently, on the recommendations of the National Commission for Agriculture (1988) a Watershed and Aridland Development Authority (WALDA) has been created to further strengthen the research and development activities in the watersheds, rangelands and arid areas of the country.

This book embodies a comprehensive review of the range research and development activities conducted in Pakistan during the past 40 years. It provides innovative guidelines for the scientific management of rangelands. Much information attractively presented in this book provides a useful reference for the research workers, teachers and students. Range and aridland development agencies like WALDA, Sind Arid Zone Development Authority (SAZDA),

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It is my hope that this book will contribute significantly to the understanding of Pakistan's rangelands and prompt scientific management for their sustained productivity.

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Islamabad. February 1, 1989

Chapter 1

Introduction

RANGELAND DEFINED

In Pakistan, the local term for rangeland is "Chiragah," which is erroneously considered as wasteland and synonymous with desert or arid land. However, in 1973, the National Committee on Range Management defined rangelands as "Uncultivated areas (although sometimes disturbed by unthoughtful cultivation) that support natural or seeded herbaceous or shrubby vegetation with or without trees." The range ecosystem includes physiography, soil, vegetation, water, animal life and associated atmosphere. The above definition is in close agreement with the definition by Stoddart et al. (1975) who described rangelands as those areas of the world which by reason of physical limitations low and erratic precipitation, rough topography, poor drainage or extreme temperatures are unsuited to cultivation and which are a source of forage for free ranging native and domestic animals, as well as a source of wood products, water and wildlife.

Management of rangelands implies the application of ecological principles. Stoddart et al. (1975) defined range management as the science and art of optimizing the return from rangelands through the manipulation of range ecosystems. The American Society for Range Management (1964) defined range management as the art and science of planning and directing range use to obtain sustained maximum animal production consistent with perpetuation of the natural resources. Viewed within the ecosystem framework, range management has been defined as management of a renewable natural resource composed of one or more range ecosystems for the optimum sustained yield by the combination of goods and services (Vallen-

tine, 1971). In the past, the rangelands in Pakistan have primarily been managed for livestock production. However, the multiple use concept of rangelands also includes the protection of watersheds which drain into a number of big dams like Tarbela and Mangla, and providing of wildlife with a vast complex of natural habitats. These concepts have been recognized by researchers, planners and environmentalists.

SCOPE AND IMPORTANCE

The major land uses in the country are agriculture, forestry and livestock production. Of the cultivated area, about five million hectare (24 percent) is barani (rainfed) while 16 m ha (76 percent) is irrigated. About 60 percent of the total area of the country is rangelands. This area partly supports 93.5 million head of livestock.

Forests occur over 4.5 percent of the country, which produce only about 0.3 million cubic metres timber and about 0.4 million cubic metres of firewood. The estimated annual demand is 1.9 million cubic metres of firewood. The shortage is met from farmlands and by imports of wood and wood products worth about Rs. 1.7 billion per annum (Pakistan Economic Survey, 1986-87).

Forestry is the major land use in northern Pakistan followed by crop cultivation; livestock grazing is prevalent in the forest areas. Baluchistan, which covers about 40 percent area of the country, primarily depends on livestock production from its rangelands. In the provinces of Punjab and Sind livestock is also an important source of income in the arid and barani areas. In the arid rangelands of Baluchistan, Thal, Cholistan, D.G. Khan and Tharparkar, the main occupation is livestock production, which is their only source of income. At present, the sheep and goats obtain about 60 percent of their feed from rangelands (Zaffar Uddin, 1977) while the horses, donkeys and camels receive about half of their feed from rangelands. In Baluchistan, 90 percent of the required livestock feed is provided by range (FAO, 1983).

During the past 40 years, several range development/improvement projects have been implemented in various ecological zones of Pakistan. Range research conducted by National Forage and Pasture Programme and Provincial Forest Departments has yielded useful information. In this study, an attempt has been made to synthesize the available technology to develop comprehensive plans to manage and efficiently utilize vast national rangeland resources.

In the Hindu Kush - Himalayan region, livestock grazing is an important land use and the shortage of livestock feed and fuelwood are the major constraints. Forage and pasture technology in the region is at varying stages of development. Pakistan is blessed with a variety of range conditions, so successful rangeland management practices in Pakistan could be tested and utilized gainfully under similar ecological conditions in the countries of the region.

CONSTRAINTS AND PROBLEMS OF RANGELANDS

Most of the rangelands in Pakistan are overused due to certain practices, customs and problems peculiar to the Hindu Kush - Himalayan region. By and large, the rangelands are common tribal or village property not conducive to the regulation of proper grazing. The nomadic grazing also results in over-exploitation of the resource. Stockmen make little effort to improve their rangelands.

Khalil (1960) and Said (1961) also studied constraints of range and forest lands and identified the following biophysical factors as causes of the deterioration of rangelands in Pakistan.

Number Versus Quality: In the rural areas, the status of a man is judged by the number of livestock he owns, irrespective of their quality. This has led to the retention of useless unproductive, uneconomic animals, which adds to the grazing pressure on rangelands.

Land Tenure System: Most of the rangelands are common tribal or village property. Everybody in that group is allowed unrestricted grazing. But nobody is responsible for conservation, resulting in utter ruination of the area.

Migratory Herds: Another important factor contributing to over- grazing of rangelands in the western region is the seasonal influx of pawindahs (nomads) along with their livestock from Afghanistan. These nomads come to Pakistan at the start of winter and feed their animals in Pakistan ranges throughout the season. It increases the grazing pressure on rangelands which are already heavily grazed.

Arid Climatic Pattern: The major part of Pakistan lies in the arid and semi-arid zone, characterized by low precipitation, extreme temperature and low humidity. These conditions are very difficult for plant life. There are frequent droughts and the forage capacity fluctuates greatly with precipitation. Under such circumstances, stringent efforts are required to prevent overgrazing; as once vegetation is lost, it is difficult to restore.

Scarcity of Water: This is another limiting factor in the proper utilization of range resources. Many areas are not grazed because no facilities exist for stock watering.

Underground water supplies are limited and flooding has resulted in the destruction of low lands due to deposition of sterile sand and gravel on otherwise fertile fields. Wind erosion has also played havoc with this area by spreading sterile sand on good agricultural land and shifting sand dunes choke canals and lines of communication.

Some of the major constraints identified by Sub-Committee on Range Management are listed below (Government of Pakistan, 1983):-

- Absence of an independent range management agency vested with

authority, responsibility and accountability to undertake a range management programme.

- Lack of awareness, appreciation and encouragement on the part of senior administrators has discouraged those who have earned their post-graduate degrees in range management from advanced countries. The range management cadre has never been allowed to grow. This situation has forced most of the highly trained scientists to leave the country. Those still struggling within the country have little opportunity.
- In any range management/development programme, effective cooperation and participation of people is essential. Such participation by stockmen has been almost completely absent in all of the range management projects implemented so far.
- The funds available for range management/improvement are generally very meager and their impact is minimized by spreading them over large areas.
- Although livestock is the chief product of rangelands, very little attention has been paid to range livestock management.
- Range management research or development programmes launched and executed so far lacked necessary support, such as adequate resource analysis and surveys.
- Since range management activities were carried out by the Forest Department, it continued to be of secondary importance to forest development activities. Being both arduous and difficult, range management assignments were given to those outside the field of specialization, thus preventing the development of a cadre of professionals duly motivated and devoted.
- Exceptionally difficult and unfavourable working conditions and the absence of suitable incentives have dissuaded members of the Forest Service from accepting range management jobs in the Forest Department.
- Planning and development authorities generally give low priority to range management/development projects as these do not measure up to criteria involving direct economic returns.

Because of limited irrigation resources, the vast arid and semi arid areas of the country cannot be brought under crop cultivation. However, these areas have high potential for livestock grazing and dry afforestation. The recent prolonged drought prevailing in the country further warrants the necessity of developing a comprehensive master plan for the management of rangelands in Pakistan.

Chapter 2

Range Resources of Pakistan

Rangelands in Pakistan extend from alpine pastures in the northern mountains to temperate and mediterranean ranges in the western mountains and arid and semi-arid desert ranges in the Indus Plain. Elevations range from sea level in the south to over 8800 m in the northern mountainous region of the Himalayas. Extreme climatic variations are the result of extreme elevation range and summer monsoon rainfall. About 70 percent area of the country is arid to semi-arid. Summers are extremely hot while winters are cold. Rainfall varies from 100 mm in the south to over 1500 mm in the north. Northern snow-covered mountains of the Himalayas, Hindu Kush and Karakorum ranges are the main source of runoff for the mighty Indus River and its tributaries. Central and southern plains consist of fertile soils but annual rainfall is low, averaging less than 250 mm. As a result, water from the Indus and its tributaries is used to develop the largest canal irrigation system in the world.

Based on configuration of the land surface, relative elevation, mode of deposition of the sediments, and degree and kind of soil profile developments, Mian and Syal (1986) classified Pakistan into the following nine geomorphic units:

(i) Pleistocene river terraces, (ii) Subrecent level terraces, (iii) Flood plains, (iv) Indus Delta, (v) Loess plains, (vi) Sandy deserts, (vii) Piedmont plains, (viii) Weathered bedrock plains, and (ix) Mountains.

Recently, several attempts have been made to classify Pakistan into different agro-ecological zones. Rafiq (1976) delineated crop ecological zones on the basis of physiography and climate. Champion et al (1965) gave a comprehensive description of the forest types of Pakistan. However, range vegetation has never been given much emphasis. Pakistan Agricultural Research Council (PARC) in 1980 classified Pakistan into 10 agro-ecological zones, based on physiography alone. Agro-ecological zonation of

Pakistan by Baig and Ali (1986) has practical application in the rangeland rehabilitation and improvement operations. Khan (1971) divided northern Pakistan into alpine, sub-alpine, dry temperate, sub- tropical humid and sub-humid zones. A detailed eco-zonation of Pakistan is yet to be developed.

Due to bioclimatic variation, the range vegetation varies from one area to the other. Range condition of the areas also varies from site to site. Alpine pastures and northern mountain ranges are comparatively in fair to good condition. Forage production of desert ranges and aridlands of Baluchistan is low due to low rainfall. Estimated annual forage production of main grazing areas in the country is given in Table 1.

Table 1. Estimated annual forage production from rangelands of Pakistan

Rangeland	Area (m.ha)	Current production		Improvement potential	
		DM (t/ha)	Total DM (m.t)	DM (t/ha)	Total DM (m.t)
Alpine pastures	1.68	1.5	2.52	2.50	4.20
Trans-Himalayan grazing lands	3.50	0.6	2.10	2.00	7.00
Himalayan forest grazing lands	0.67	0.6	0.40	3.00	2.01
Pothwar scrub ranges	1.68	1.5	2.52	4.00	6.72
Desert rangelands	7.97	0.5	3.98	2.00	15.94
Kohistan ranges	2.38	0.4	0.95	2.00	4.76
Central Baluchistan ranges	8.00	0.5	4.00	1.00	8.00
Eastern Baluchistan ranges	5.00	0.4	2.00	1.50	7.50
Western Baluchistan ranges	18.50	0.3	5.55	0.80	14.80
Sulaiman mountain ranges	1.50	0.3	0.45	2.00	3.00
Total	50.88	0.66	24.47	20.8	73.93

Source: Mohammad (1987).

ALPINE PASTURES

The areas lying above an altitude of about 3000 and below the zone of perpetual snow constitute alpine pastures. Mohammad (1987) described in detail the alpine ecosystems. Alpine pastures are characterised by short, cool growing seasons and long, cold winters. The vegetation is mostly dominated by slow growing perennial, herbaceous and shrubby vascular plants and extensive mats of cryptogams (mosses, lichens, etc). Much of the landscape of the alpine pastures is rugged and broken with rocky, snow-capped peaks, spectacular cliffs and slopes. However, there are also many large areas, gently rolling to almost flat topography.

Khan (1971) discussed vegetation of alpine and sub-alpine zones in Hazara division. The forage production from various range types in alpine and sub-alpine zones is as follows:

Range Types	Forage Yield (DM kg/ha)
Meadows	1240
Shrub meadows	2660
Shrub	2400
Kail/fir forest range	1270
Birch range	Not sampled
Shrub-grassland	2300
Grasslands	2300

Hussain (1968) measured vegetation condition of alpine pastures in Kaghan Valley. The average plant cover, cumulative cover and soil protection percentage was 90.82, 119.25 and 97.79, respectively. Average forage production recorded was 700 kg/ha. Dry matter yield estimated during summer, 1987, in partially protected areas of Khunjerab National Park at altitudes of 3500, 4000, 4500, and 5000m was 380, 470, 585 and 370 kg/ha, respectively. Average dry matter production from Chaprot alpine pastures near Gilgit was 500 to 700 kg/ha. Champion et al. (1965) classified alpine vegetation into the following four major types:

i. Alpine scrub type consisting of moist deciduous alpine scrub, dry zone alpine scrub, moist alpine pasture, dry alpine plateau pastures, dwarf juniper scrub, and dwarf *Rhododendron* scrub forest.

ii. Moist alpine scrub comprises dry alpine scrub and moist alpine scrub.

iii. Alpine forests contain alpine fir birch forest, *Rhododendron* forest and high level bluepine forests.

iv. Sub-alpine forests consist of West Himalayan sub- alpine birch/conifer forest, sub-alpine birch forest, Hippophae - Myricaria river bed scrub, sub-alpine blue pine forest, deciduous sub-alpine scrub, sub-alpine scrub and sub-alpine pasture.

Hussain (1968) gave the following description of vegetation types in the alpine pasture in the northern mountains of Pakistan:

i. Alpine stony deserts are found just below the zone of perpetual

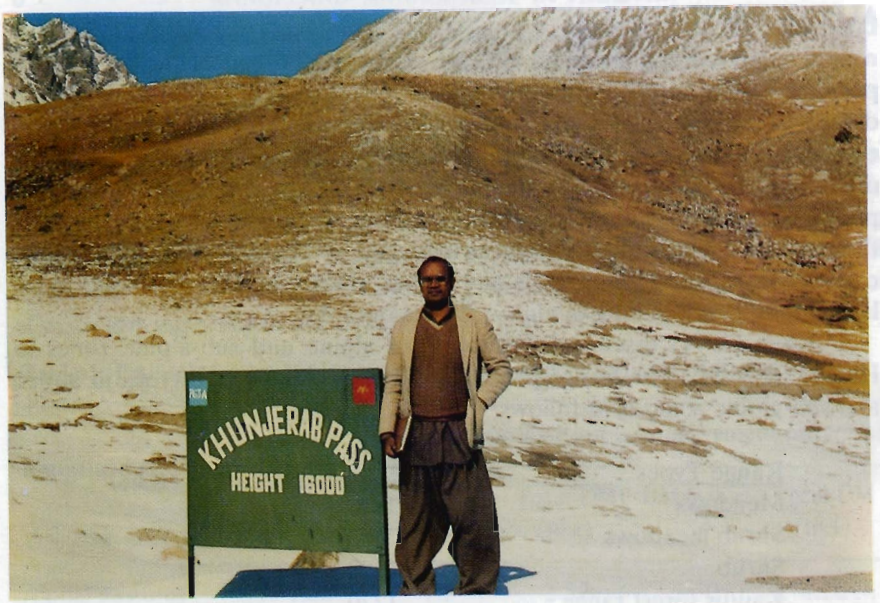

Plate 1. Alpine pastures in the Hindu Kush Range during early fall.

snow between 3500 and 5000 m altitude. The habitat is characterized by the presence of scree sand bits of rocks, heavily encrusted with lichens. *Saxifraga imbricata,* which is adapted to high winds, strong radiation and snow, is dominant. Alpine deserts have little value as grazinglands due to the absence of forage and difficult topography. However, the area provides excellent habitat for ibex and morcopolo sheep. Since most part of the year these areas remain under snow, they do not pose any watershed problem.

ii. Alpine meadows contain luxuriant ground flora. These alpine meadows have the greatest value as grazinglands. Trees are conspicuous by their absence in this type. Vegetation consist of perennial forbs, and grases belonging to the genera *Poa, Festuca, Stipa* and *Agropyron.*

iii. Above 3200 m elevation, the forest is replaced by scrub consisting of *Juniperus recurva* and *Artemisia maritima* which occupy exposed slopes in the interior valleys. *Ephedra jerardiana* occurs on gravel deposits in the bottom. This type does not have much value as a grazingland. The shrubs make up a close community and do not allow forage plants to occupy site.

iv. Alpine forests are dominated by *Abies pindrow* with occasional *Pinus wallichiana.* In the second storey, *Betula utilis* and *Quercus semicarpifolia* are sometimes present with many shrubs. Above the fir zone, *Betula utilis* is the only tree species with *Pyrus foliosa* and *Rhododendron sp.* in moist habitats. Alpine forests are subjected to

heavy grazing during summer. No planned grazing system is followed. Native flora of alpine pastures is given below:-

TREES/SHRUBS: Juniperus communis, Rosa webbiana, Berberis lycium, Berberis spp, Cotoneaster spp.

GRASSES: Phleum alpinum, Agrostis gigantea, Trisetum spp., Poa spp. Agropyron dentatum, Agropyron caninum, Festuca ovina, Alopecurus gigantea, Dactylis glomerata, Pennisetum lanatum, P. filaccidum, Clamagrostis pseudopharagmites, Oryzopsis spp, Carex spp.

FORBS: Plantago ovata, Plantago major, P. lanceolata, Trifolium pratense. T. repens, Fragaria vesca, Medicago spp, Potentilla spp, Rumex nepalensis, Polygonum alpinum, Anaphalis contorta, Thymus serphyllum, Astragalus spp., Taraxicum officinalis, Iris hookriana, Nepata spicata, Saxifraga jacquemontiana.

TRANS-HIMALAYAN GRAZINGLANDS

Landscape and Environment: Trans-Himalayan grazinglands spread over northern mountains in Dir, Chitral, Swat, Gilgit, Chilas and Skardu districts. Northern Areas became accessible by road in late 1970s following the completion of the Karakorum Highway (KKH). Most of the villages are connected with KKH by jeep. However, some are still approached by travelling on foot for several hours. Chitral and Swat valleys have an extensive road system. Gilgit, Skardu, Chitral and Swat are also linked by air with Islamabad and Peshawar.

The region constitutes a series of high mountain ranges of Karakorum, Hindu Kush and Pamir. The altitude varies from 1500 to 8600 m and includes 19 peaks over 7600 m, such as K2, Nanga Parbat, Rakaposhi and Trichmir. The area has rugged, steep and dissected slopes, and narrow valleys, subject to active geologic erosion. The terrain is naturally unstable. Landslides and rockfalls are very common. Mian (1985) recognised two main rock groups in the Northern Areas of Pakistan including i) igneous rocks consisting mainly of granites and diorites and ii) sedimentary and metamorphic rocks comprising mainly quarzite, slate, crystalline schist, marble and limestone. He further stated that most of the areas are without soil cover. They include (i) areas at high altitudes permanently covered with snow or glaciers, (ii) rock outcrops, (iii) recently deposited alluvium, scree materials and moraine, (iv) water bodies and the adjoining areas subject to periodic flooding.

The climate of the area is that of a mountain desert with bitterly cold winters and hot dry summers. The climatic variation in the area is greatly influenced by altitudinal differences. Lower altitudes (valley bottoms and hill slopes below 2300 m) experience marked diurnal as well as seasonal temperature variations and scanty precipitation. The areas between 2300 and 3300 m receive sufficient snow and enjoy a temperate climate. Areas above 3300 m are very cold with a limited growing season. Most of the area is beyond the reach of summer monsoon rainfall. Average annual rainfall (100-300 mm) in valleys is mostly received during winter and early spring.

Land Use: Crop production, livestock rearing and forestry are major land uses in the area. Maize, rice, wheat, and barley are important cereal crops. Double cropping is practised up to 2300 m while above that altitude only single, short-duration crops can be raised. Orchards of apricot, apple and mulberry are important components of the farming system. Due to low precipitation, crop cultivation is possible only in irrigated areas. Cultivation is practised on river terraces alluvival fans and scree slopes. As cultivable area is limited, considerable resources are being utilized for the reclamation of eroded lands. Mian (1985) enumerated the following steps in the reclamation of eroded lands:

i. Collection of stones and gravel from the surface and their use in demarcation of field boundaries and erection of 50 to 100 cm high stone walls around the fields.

ii. Minor levelling of hummocks and filling of depressions.

iii. Sowing of alfalfa seed and occasinal plantings of poplar, willow, Russian olive and mulberry.

iv. Frequent irrigation of fields every fourth or fifth day during summer.

v. After this, the fields are developed as irrigated pasture-cum- forest land. Fodder (alfalfa, thorny bushes) tree leaves and fuel and timber are produced.

vi. Pastures are irrigated for five to ten years, depending on the clay content of the soil. During the reclamation period, root mass, fallen leaves, twigs and branches decay to produce organic matter, which in turn provides nutrients and humus. The humus fertility improves water-holding capacity. Addition of organic matter and root action enhance the biological processes in the soil, thereby improving the overall soil environment. Alfalfa and other leguminous plants fix the atmospheric nitrogen in the soil. Irrigation water, which carrie a high amount of suspended material mainly silt and some clay, also improves the water-holding capacity of the soil.

vii. When alfalfa begins to disappear due to competition with other vegetation and shade, the land is cleared of all vegetation. Stones and gravel are collected from the upper metre of the soil and are used for construction and strengthening the houses as well as raising the field boundary walls.

viii. The field is levelled and made into a nearly level terrace for irrigated farming.

ix. Farmyard manure is applied before crops are planted and land is prepared.

Marginal and newly reclaimed lands are used for fodder production. Livestock grazing is done in alpine pastures, forests and along stream channels. Forestry operations include protection of natural forests, national parks, afforestation of marginal lands and wildlife conservation.

Range Types: Vegetation of Trans-Himalayan grazinglands can be divided into the following four range types:

i) Foothill ranges ii) Dry temperate ranges iii) Valley depression grazinglands and iv) Alpine pastures.

Sheikh and Khan (1982) described the forest and range vegetation of the Northern Areas. According to them, the areas are subject to heavy pressure by livestock as well as a shortage of fuelwood. Alpine pastures are in good condition but due to environmental limitations, the growth period is short. Low-lying ranges are in fair to good condition. The present forage production varies from 0.5 to 1.5 t DM/ha. Beg and Bakhsh (1979) distinguished eight plant communities in scree slopes in Chitral. Ahmed and Qadir (1976) conducted phytosociological studies along Gilgit to Gopis. The following range plants are found in the area:

Plate 2. Dry temperate grazinglands in Hunza valley.

TREES/SHRUBS: Juniperus macropoda, Quercus ilex, Pinus gerardiana, Cedrus deodara, Pinus wallichiana, Fraxinus xanthoxyloides, Artemisia maritima, Artemisia sacrorum, Indigofera spp. Ephedra spp, Daphne oleoides, Sophora spp., Cotoneaster spp, Parrotia jacquemontiana. Salix spp, Jasminum spp, Sorbaria tomentosa Caragana spp.

GRASSES: Chrysopogon spp, Cymbopogon spp, Dichanthium annulatum, Pennisetum orientale, Aristida spp, Oryzopsis spp. Poa spp, Bromus inermis, Agropyron dentatum, Agropyron caninum, Agrostis spp, Dactylis glomerata, Rottboellia exaltata, Phacelurus speciosus, Eragraostis spp.

FORBS: Iris spp. Tulips spp. Polygonum spp. Astragalus spp. Sambucus

ebulus, Lotus corniculatus, Medicago spp. Plantago lanceolata, Lathyrus spp. Thgmus serphyllum, Nepata spicata, Viola spp. Taraxicum officinalis, ferns, etc.

HIMALAYAN FOREST GRAZINGLANDS

Landscape and Environment: Himalayan forest grazing lands cover Siran, Kaghan, Neelam and Jhelum valleys. These areas can be ecologically divided into moist temperate and sub-tropical humid zones. The wet temperate zone occurs between 2000 m to the timber line. Kail, deodar, spruce and fir forests are abundant in this zone. Jammu and Kashmir and Hazara have extensive wet temperate areas. The areas receive plenty of snow during winter. About 3-4 m of snowfall has been recorded at Kaghan, Shogran, Naran and Nathiagali. Most of the areas in this zone receive more than 1000 mm during the monsoon which creates heavy soil erosion as the topography is steep and disturbed by unscientific cropping. Summers are cool but winters are very cold.

Plate 3. Saiful Maluk lake in Kaghan valley.

The sub-tropic humid zone is represented by 'chirpine,' but 'kail' forests also occur on higher slopes. The altitude varies from 1000 to 2000 m. Rainfall is usually more than 1000 mm. Flat and plain areas are fit for the cultivation of wheat, rice and maize cultivation with occasional irrigation. Most of the areas in this zone are subjected to soil erosion.

Land Use: Forestry, cropping and livestock grazing are the major land

uses. As the area receives monsoon rainfall, plenty of soil moisture is available for crop cultivation. Maize, rice and wheat are the major crops. Apple orchards cover a large area. Bluepine and 'chirpine' forests cover an extensive area throughout the tract. Grazing is done in forests and along water channels and on cropped areas.

Range Types: Khan (1971) prepared a detailed report about range management in Hazara. He recognized the following range ecological zones:

i) Sub-tropical sub-humid zone, ii) Sub-tropical humid zone, iii) Temperate humid zone, iv) Sub-alpine zone, v) Alpine zone, and vi) Glaciers or Snowfields.

Plate 4. Moist temperate forest grazinglands near Murree.

In the sub-tropical sub-humid zone, *Acacia-Olea* and *Dodonea, Imperata* are major range types. Forage production varies between 200 and 1800 kg/ha. In the sub-tropical humid zone, 'chirpine' forests, shrub savanna and grassland types are recognized with forage yields between 200 and 2000 kg/ha. Temperate humid zone has shrub grassland, shrub savanna and grasslands along with several forest types. Forage production ranges between 200 and 3000 kg/ha. Important plants in the Himalayan forest grazinglands are listed below:

TREES: Pinus wallichiana, Picea smithiana, Taxus baccata Cedrus deodra, Quercus incana, Q. dilatata, Q. semicarpifolia, Juglans regia, Aesculus indica, Acer pictum, A. caesium, Populus alba, P. ciliata, Pyrus sp.

SHRUBS: Vibernum nervosum, Indigofera spp. Rosa webbiana, Salix spp, Cotoneaster spp, Pistacia spp, Berberis lycium, Prunus cornata, Rhododendron arboreum, Sarcococca saligna, Rubus spp. Desmodium spp. Strobilanthus spp.

GRASSES: Dactylis glomerata, Agropyron dentatum, Phacelurus speciosus, Rottboellia exalatata, Alopecurus gigantea. Pennisetum flaccidum, Oryzopsis spp. Poa spp. Stipa sibirica, Bromus inermis, Bothriochloa paseudoischaemum, Chrysopogon echineulatus, Themeda anathera.

FORBS: Plantago ovata, P. major, P. lanceolata Senecio spp. Rumex nepalensis, Astragalus spp. Trifolium repens, T. pratense, Lotus corniculatus, Fragaria vesica, Medicago spp. Geranium collinum, G. nepalensis, Thymus serphyllum, Polygonum aviculare, P. parencoides, Phlomis bracteosa, Taraxicum officinalis.

POTHWAR SCRUB RANGES

Landscape and Environment: Pothwar plateau includes Islamabad, Rawalpindi, Chakwal, Jhelum and Attock districts, an area of 1.5 million ha. The tract lies between Jhelum and Indus River. Altitude varies from 300 to 1500 m. Ecologically, it is located in the sub-tropical semi-arid to sub-humid zone. Geomorphologically, the plateau can be classified into mountains, hills, rock plains, weathered rock plains, piedmont plains, loess plains and river plains (Beg et al. 1985). The soils of the area have developed from wind and water-transported materials consisting of loess, old alluvial deposits, mountain outwash and recent stream valley deposits; some are derived from shales and sandstones.

The climate is temperate in the northeast to sub-tropical semi-arid in the southwest. Annual rainfall varies from 250 mm in the southern part of Salt Range to over 1500 mm at Islamabad. Temperatures extremes are 45°C in June and often drop below freezing during January.

Land Use: Dryland farming is the dominant land use. Wheat, maize, sorghum, millets, groundnut, gram, mustard, sunflower and soybean are major cultivated crops. Livestock rearing is an important component of the rural economy. It is the home of the famous 'Dhani' cattle breed. The tract possesses scrub forests of Kala Chitta, Margalla Hills, Pabbi Hills and Salt Range which are gradually disappearing due to excessive exploitation for firewood and grazing by livestock. The Agency for Barani Areas Development (ABAD) in 1987 prepared a master plan for the development of the barani tract. The plan contains an extensive review of the natural resources and present land uses. Beg et al. (1985) delineated the ecological zones for maize and wheat. Land suitability evaluation for other cultivated crops, range livestock production and forestry is in progress.

Most of the tract is subjected to heavy soil erosion. Several government agencies, like Soil Conservation Directorate, ABAD, Water and Power Development Authority (WAPDA) and PARC, have an elaborate research network for soil and water conservation to increase productivity per hectare.

Range Types: Pothwar scrub ranges contain dry sub-tropical broad leaved, thorn-mixed forests. *Acacia modesta* and *Olea ferruginea* are dominant species. *Dodonea viscosa* has invaded most of the hills. *Prosopis juliflora* is in abundance in the Pabbi Hills. Some of the main grazing blocks under the control of the Forest Department are located in Khare Murat, Mari, Gullial, Lohi Bher, Pabbi, Kala Chitta, Margalla Hills, Sohawa and Salt Range. *Heteropogon contortus* and *Desmostachya bipinnata* are encroaching rangelands as well as cultivated areas. The northern part of the tract has a diverse. The vegetative cover of the protected Margalla Hills has increased markedly. The southern part of the tract is sparsely vegetated. Flat areas consist of *Aristida depressa, Eleusine flagellifera, Cynodon dactylon.* Said (1951) divided the vegetation of Salt Range into the following types:

i. Degraded zone includes the area with heavy soil erosion. Here, *Acacia modesta, Capparis aphylla, Salvadora oleoides, Cymbopogon jwarancusa* are dominant,

ii. The hotter sandstone aspect consists of *Acacia modesta, Gymnosporea royleana,* and *Zizyphus nummularia.* Among grasses, *Cenchrus ciliaris* and *Bothriochloa pertusa* are prevalent,

iii. The cooler sandstone aspect has occasional trees of *Olea sp, Celtis sp. Acacia modesta* are dominant,

iv. Limestone ridges consist of *Acacia modesta, Dodonea viscosa, Cenchrus ciliaris* and *Eulaliopsis binata.*

Ahmad (1964) also recognized the above-mentioned vegetation types. Beg et al. (1985) classified the range vegetation of Pothwar tract. Both of the workers recognized four major climatic regions, 18 bioclimatic zones and 36 ecological zones. The carrying capacity of the area was sampled by the government of Punjab (1974). Forage production varied from about 1 t/ha to 2.5 t/ha of dry matter. The tract consists of following important range plants:-

TREES/SHRUBS: Acacia modesta, Olea cuspidata, Zizyphus mauritiana, Salix tetrasperma, Dodonea viscosa Zizyphus nummularia, Sageretia theezans, Gymnosporia royleana, Carissa spinarum, Adhatoda vasica, Pistacia integerrima, Nerium oleander, Otostegia limbata.

GRASSES: Chrysopogon montanus, Chrysopogon aucheri, Themeda anathera, Bothriochloa pertusa, Bothriochloa intermedia, Dichanthium annulatum, Tetrapogon villosus, Aristida mutabilis, Cenchrus ciliaris, Digitaria nodos, Desmostachya bipinnata, Imperata cylindrica, Eleusine compressa, Cynodon dactylon, Panicum antidotale, Pennisetum orientale, Polypogon monspeliensis, Cymobopogon jwarancusa, Eulaliopsis binata.

THAL DESERT RANGES

Landscape and Environment: Thal range stretches over an area of 2.6 million ha. The tract is bound by the piedmont of the Salt Range in the north, the Indus River flood plains in the west and Jhelum and Chenab Rivers flood plains in the east. Ecologically, it is situated in the tropical

plains (sandy). The mean maximum and minimum temperatures recorded in the tract are about 44°C and less than 0°C respectively. The wind affects the amount and distribution of rainfall in the desert, most of which is received during the monsoon. It varies from 133 mm in the southern areas to 300 mm in the northeastern region of the tract (Government of Punjab 1974). The soils are alluvial with sandy textured sand dunes covering 50 to 60 percent of the area (Khan, 1966). Continued heavy grazing and ruthless cutting of trees and shrubs continue have resulted in the complete disappearance of several desirable species. The topsoil has been eroded by wind erosion and sand dunes have become unstable. The vegetative cover and forage production have declined substantially.

Accordingly to SSP (1968), the geomorphology of the area consists of the following landforms:

i. *Sand ridges:* Over the major part of the Thal Desert, the alluvium has been blown into sand ridges and hollows or valleys known as 'Pattis' in the local dialect. The soils of the ridges consist of very deep, structureless, fine sand of various degrees of calcareousness and colour gradations. All the sand ridge soils are excessively drained and have an average pH value of 8.3.

Fine material from the ridges has been washed into the hollows and where allowed to accumulate, has formed very deep, moderately calcareous, weakly structured soils. The soils of hollows are mainly well drained and have an average pH value of 8.4.

ii. *Abandoned channels:* The soils of the abandoned channels are water reworked and/or deposited material with a wide textural range (loamy fine sands to silty clays), usually have a 'kankor' zone and are moderately calcareous with a pH value of 8.3 to 8.8.

iii. *Flood plains:* Soils of sub-recent floodplains are moderately deep to deep dark, greyish-brown, silty clay loams and silty clays with weak to moderate structures and a weak lime profile, but no 'kankor' zone. In southern areas, reduced annual flooding, and a high water table have resulted in alkalinization. The soils are dense and strongly saline alkali, with a pH value of more than 9.

Land Use: Livestock grazing is the main occupation of the people. With the construction of Thal irrigation canal, about 1 m ha sand dunes have been converted into highly productive cultivated areas. However, about 1.6 m ha are still used as grazinglands. In a year of normal rainfall, sand dunes are cultivated. Gram, water melon, guar and millets are grown on a large scale. Persian wheel wells are quite common in the area.

Range Types: The following four major range types are recognized in Thal Desert (Government of Punjab, 1974):

i. *Dunes:* The soils of the dunes consist of coarse and loose sand. The dunes usually run in a northwest to southeast. On average, the dunes cover about 43 percent of the total area. The vegetation growing on

the dunes include (a) *Calligonum polygonoides,* (b) *Pennisetum sp.,* (c) *Aristida sp., and* (d) *Acacia jacquemontii*

ii. *Slopes and foot of dunes:* This range type is in between the dunes and flats. There is a gradual change in soil from dune to flat. The soil is comparatively less coarse. This area occupies about 5 percent of the total area. The vegetation includes *Pennisetum sp., Suaeda fruticosa* and *Aristida depressa.*

iii. *Flats:* The flats are generally sandy-loam and are ideal sites for the satisfactory growth of grasses. Artificial reseeding very successful here and this site offers great potential for range development. The flats occupy about 48 percent of the total area. In this range site, the most common flora consists of *Eleusine flagellifera, Suaeda fruticosa, Cymbopogon jwarancusa,* etc. Palatable species like *Cenchrus ciliaris* and *Lasiurus sindicus* also grow in this range type.

iv. *Kankor sites:* These are devoid of any vegetation. The seed of grasses cannot germinate and become established due to compact and hard soil. Boron is reported to be present in toxic levels that inhibits growth. About four percent of the total area is in this type of range.

The following plants are found in the Thal Desert.

TREES/SHRUBS: Acacia jacquemontii, A. nilotica, Calligonum polygonoides, Euphorbia caducifolia, Leptadenia pyrotechnica, Haloxylon recurvum, H. salicornicum, Kochia indica, Prosopis juliflora, P. cineraria, Rhazya stricta, Salvadora oleoides, Salsola foetida, Suaeda fruticosa, Tamarix aphylla, Zizyphus mauritiana, Z. nummularia.

GRASSES: Aristida depressa, Cenchrus biflorus, C. ciliaris, C. pennisetiformis, C. setigerus, Cymbopogon jawarancusa, C. schoenanthus, Cynodon dactylon, Desmostachya bipinnata, Dichanthium annulatum, Eleusine flagellifera, Lasiurus sindicus, Panicum antidotale, P. turgidum, Saccharum bengalense, S. munja.

FORBS: Aerva javanica, A. tomentosa, Crotolaria burbia, Indigofera cordifolia, I. oblongifolia, Tribulus terrestris.

D.G. KHAN RANGELANDS

Landscape and Environment: D.G. Khan rangelands lie between the Sulaiman Range and the Indus River over an area of 0.5 million ha. Average slope is gentle. A few sand dunes are also found. Soils are divided into two sub-regions. The piedmont plains called 'pachat' are formed in the local alluvium derived from adjoining mountains. These soils are deep, well-drained, calcareous, medium- textured and low in organic matter. The river plains locally known as 'belas' are formed in the mixed alluvium from the Himalayas. These are sandy clay, calcareous and low in organic matter.

The general climatic regime of D.G. Khan tract is typical of very arid sub-mountainous, sub-tropical areas. Ecologically, it is a tropical plain (non-sandy). Climate is broadly characterised by cold winters and very hot summers. Winter temperatures occasionally reach zero especially in

January and February, due to cold winds from the west. June and July are the hottest months with an average maximum temperature of 42°C. Average annual rainfall varies from 75 to 162 mm. Most of the rainfall storms from the high mountains (1540-3400 m) lose their moisture before reaching range areas which are at lower altitudes (150 m). Annual rainfall at D.G. Khan, Taunsa, Fort Munro, Jampur and Rajanpur is 132, 163, 202, 98 and 100 mm, respectively.

Range Types: Most of the forbs and annual plants start growing in early spring and complete their growth cycle within two to three months. *Saccharum spontaneum* and *Tamarix dioica* primarily colonise the recently formed soils along the Indus River. These are replaced by *Acacia nilotica, Prosopis cineraria. Salvadora oleoides* is probably the climax species of the area. In general, non-palatable forbs and shrubs tend to replace palatable grasses on all rangelands. Removing non-palatable plants may shift competitive advantage in favour of the palatable plants.

Forbs and secondary grasses usually increase as primary grasses decrease. Total cover may change very little, and occasionally may increase due to the invasion of non-palatable plants. In an advance stage of retrogression, growing cover is reduced and the reduction herbage yield becomes pronounced.

Deterioration of the rangelands has been associated with irregular grazing by nomadic and local livestock and illicit cutting of shrubs for fuel and fodder. Most of the rangelands are in poor shape. Estimated dry matter yields were 3 to 4 t/ha from *Lasiurus sindicus* seeded areas at Rakh Choti Dalana and only about 400-500 kg/ha from non-seeded areas.

Little information about the proper grazing of rangelands in D.G. Khan tract is available concerning forage availability, quality, quantity and palatability of range plants. Some of the factors that must be considered are livestock water points, grazing habits of animals, stage of plant growth, climatic conditions and management. A management plan based on a detailed resource survey may be required to determine development options.

Srubs, grasses and forbs are best used by different kinds of livestock. Cattle usually prefer areas with gentle terrain and where palatable grasses predominate. Areas with more rugged terrain and vegetation rich in forbs and browse are most suitable for sheep and goat. Camels relish saltish browse such as Salsola, sp. Except for operating and economic constraints, common use of the rangelands by sheep, goats, camels and cattle may be physically and biologically sound and effective means to maintain a desirable composition of plants.

CHOLISTAN DESERT RANGES

Landscape and Environment: The Cholistan desert is located in Bahawalpur, Rahim Yar Khan and Bahawalnagar Districts. It covers about

2.7 million ha. Its north and western boundaries are surrounded by areas irrigated by canals. On the east, it borders the Indian Rajasthan Desert. Ecologically, it is tropical arid sandy desert. The area is subject to wind erosion. Rainfall is erratic and ranges from 100 to 200 mm. Mean minimum and maximum temperatures are 20°C and 40°C, respectively. The soil survey of Cholistan has been conducted by the Soil Survey of Pakistan in 1974. The soils of the tract are saline, alkaline and gypsiferous. The area consists of shifting sand dunes. The inter-dunal valleys are locally known as 'dahrs'. The dunes reach heights of about 100 m.

The four major land forms recognised by Baig et al (1980) include: i. subrecent river plains, ii. the first sandy terrace above the Hakra River (late pleistocene) iii. the second sandy terrace above the Hakra River plain (late pleistocene), and iv. the third sandy terrace above the Hakra River plain (middle pleistocene).

The type of sandy landforms in the Cholistan is comparable to those in the Thal Desert. Mian and Sayal (1986) have distinguished three types of sand ridges. The transverse ridges occur in the western part (middle pleistocene). The longitudinal ridges spread over the northern and southern parts (the latest period of the late pleistocene) and the alveolar ridges occur in the centre (the earlier period of the late pleistocene).

Land Use: Livestock production is the major occupation. Wildlife are hunted during the winter. A shortage of drinking water is a serious problem as underground water is saline (Rasul, 1966). Aridity precludes dryland farming. The current drought is seriously affecting fauna and flora. Heavy losses of livestock are expected due to a shortage of natural browse and grasses.

Plate 5. Cholistan Desert-a natural habitat for blackbuck (*Antelope cervicapra*).

Range Types: The vegetation of Cholistan consists of xerophytic trees, shrubs and grasses. In their description of the grass cover types of Pakistan, Johnston and Hussain (1963) characterized the Cholistan vegetation as *Dichanthium-Cenchrus-Lasiurus* type. Sheikh (1986) categorized Cholistan vegetation as sand dune, desert scrub. The vegetation composition of Cholistan reported by Ahmed (1966) was *Calligonum polygonoides* (0.4%), *Haloxylon recurvum* (0.2%), *Haloxylon selicornicum* (0.7%), *Suaeda fruticosa* (0.4%), *Aristida depressa* (1.7%), *Cenchrus ciliaris* (0.7%), *Cymbopogon jwarancusa* (7.1%), *Eleusine compressa* (11.7%) and *Lasiurus sindicus* (9%).

The three major range types found in Cholistan are i) *Lasiurus sindicus/Haloxylon salicornicum.*, ii) *Eleusine compressa/Haloxylon salicornicum.* , and iii) *Haloxylon recurvum/Salsola foetida* and *Suaeda fruticosa* (Government of Punjab, 1974).

THARPARKAR DESERT RANGES

Landscape and Environment: The Tharparkar desert is situated in Tharparkar, Sanghar and Mirpur Khas Districts and covers 2.65 million ha. Ecologically, the tract can be categorized as tropical thorn desert. Hussain (1966) distinguished the following four major landforms:

i. Sand dunes are locally known as 'bits'. The sand dune ridges are from 15 to 200 m high and run parallel from northwest to southeast. The soil is sandy greyish and is derived from quartz and feldspar.

ii. Valleys lie between parallel rows of sand dunes and constitute about 30 percent of the total area. The soils are sandy loam. In many valleys, the sub-soil water has developed into large salt lakes.

iii. Flat alluvial plains are located in Nagarparkar. The soils are sandy loams with clay particles. Even with low rainfall the area is extensively cultivated with millets, sorghum, etc.

iv. Rocky hills known as Karunjar are found near Nagarparkar. They may be as high as 350 m, and consist of metamorphic rocks.

The Thar desert is subjected to heavy soil erosion partly due to dry land cultivation. In the northwestern and southwestern dunes wind- blown sand is a natural phenomenon (FAO, 1975). The landforms and soils of Thar are similar to that of Cholistan. The climate is arid. Rainfall is scanty and erratic, and most is received during the monsoon. The area has experienced a severe drought for the past four years. In a normal year, rainfall varies from 150 mm in the north to 400 mm in the south near Nagarparkar. Summers are hot (45°C) and winters are mild (5°C).

Land Use: Livestock production is the major land use in the region. Dryland farming is also practised wherever rainfall is adequate. Millet, sorghum and castor crops are cultivated in the dune valleys. Forestry is limited to irrigated and riverain forests. Small villages are located wherever watering ponds are available. The ground water is 200-300 m deep and

brackish. However, sweet water is found in Nagarparkar, Mithi and Diplo near Run of Kutch.

Range Types: Champion et al., (1965) described the vegetation of southern Sind,but did not describe the range vegetation of Thar Desert. Chaudri and Chuttar (1966) gave a brief summary of the vegetation and range flora of Thar. Hussain (1966) distinguished four vegetation types in this area: i. *Cenchrus-Panicum* dune type, ii. *Eleusine-Cenchrus* stands in valleys, iii. *Eleusine-Aristida* on flat alluvial plains, and iv. sparse desert thorn vegetation on hills. Vegetation is essentially dictated by the formation of sand dunes. The important range types found in Tharparkar are given in Table 2.

Table 2 Vegetation composition and dominant species at various range sites in Tharparkar desert.

Range sites	Grasses %	Forbs %	Litter %	Bare soil %	Dominant species
Malheojotar	22	11	21	46	*Euphorbia caducifolia,*
Khanore	23	6	19	52	*A. Senegal, Calligonum Polygonoides*
Pabuhar	14	–	14	72	*Panicum sp, Cenchrus biflorus*
Chilhar	21	5	13	61	*Prosopis cineraria, Lasiurus sindicus,*
Cabul-Jotar	16	4	7	73	*Panicum sp,*
Neplo	22	5	9	64	
Pathrio	25	6	10	59	*Prosopis cineraria. Eleusine flagellifera,*
Janhero	20	2	10	68	*Aristida sp,*
Adhigham	18	4	14	64	*Euphorbia caducifolia,*
Khipuri	17	6	19	58	*Acacia senegal, Zizyphus sp.Aristida sp Cenchrus biflorus.*
Loohior	23	9	22	46	*Tecoma undulata, Cenchrus ciliaris,*
Vakerio	20	4	16	60	*Panicum sp. Eleusine flagellifera.*
Bhalva	16	5	12	67	
Vingi	14	8	12	66	*Sporobolus sp, Aeluro-*

(continued)

Table 2 continued

Jattari	10	6	10	74	*pus villosus, Desmostachya bipinnata.*
Khambrro	13	4	7	76	*Prosopis cineraria,*
Hathango	13	5	11	71	*Cenchrus sp., Panicum sp.,*
Rar	11	2	9	78	*Lasiurus sindicus.*

Source : Khan and Baluch (1972)

Rangeland in Tharparkar desert ranges are in poor to fair condition. Desirable grasses have disappeared. However, shrubs still produce good browse. During winter, the desert does not support grazing, and most of the livestock migrate to irrigated areas.

KOHISTAN RANGES

Landscape and Environment: Kohistan ranges are situated in Karachi, Thatta, Dadu Districts and parts of Lasbela District. They cover about 2.3 million ha. Ecologically, the tract can be categorized as a tropical, arid thorn submountain zone. The following three land systems have been distinguished by FAO (1975):

i. *Kirthar Range:* A large uniform hill range culminating on the Kuttiyo-kabbar (2170 m), called the Kirthar Range, run north-south and forms the provincial boundary. It alternatively consists of smooth domes of Kirthar limestone, without any soil cover, and steep, broken outcrops of Nari shales and sandstone. At the foot of the mountain is a system of long, parallel outcrops of Munchhar and Nari limestones and shales that form a typical stone-desert landscape. Seasonal rivers descending from Kirthar (Khenji, Mazrani, Unnahar, Buri, Gaj, Nali, Angai and Bandni; some tend to be perennial) have deposited vast colluvial fans and silt flats, about 10 km wide, between the hills and the Indus Plain. Dunes have formed in some areas.

ii. *Central Kohistan:* South of Manohhar Lake, the Kirthar Range splits and tapers southward in a system of parallel ridges 500 to 1000 m high, of similar geological structure. The colluvial foot slopes of the ridges adjoin each other in a continuous piedmont system, almost as if there were no alluvial plains in-between. The most important of the well developed drainage systems is the Baran nulla and its tributaries, which join into a vast drainage zone around Thano Bula Khan.

iii. *Southeastern Shield:* Towards Karachi, Thatta and Kotri, Kohistan gently slopes down from 50 to 500 m in a system of stony plateaus

capped with Ranikot, Laki and Gaj limestones, which are occasionally dissected by Gaj sandstones and shales. The Mol, Khadeji, Malir, Ran Pathani and Liari rivers drain the area seasonally into the coastal plain.

Extremes of temperature of up to 45°C in summer and 3°C in winter. Mean annual rainfall varies from 150 to 200 mm, most of which is received during summer. Strong winds blow from the southwest to northeast during summer at 60km/hour. Relative humidity is fairly high and exceeds 80 percent during the monsoon. Due to severe wind erosion the top soil is thin. Most of the rocks contain limestone. Areas in the valley contain silt to loamy silt with a thick layer of sand.

Land Use: Land in Kohistan is used for livestock grazing, dryland farming and wildlife habitat. Dryland farming is done wherever adequate perched water is available. Small dams have also been constructed at a few sites. Plains, depressions and valley bottoms are cultivated with millets, sorghum and castor even when rainfall is moderate. Forestry is limited to testing of arid and salt tolerant plants such as mesquite, spineless cactus, *Zizyphus nummularia* and *Atriplex nummularia.*

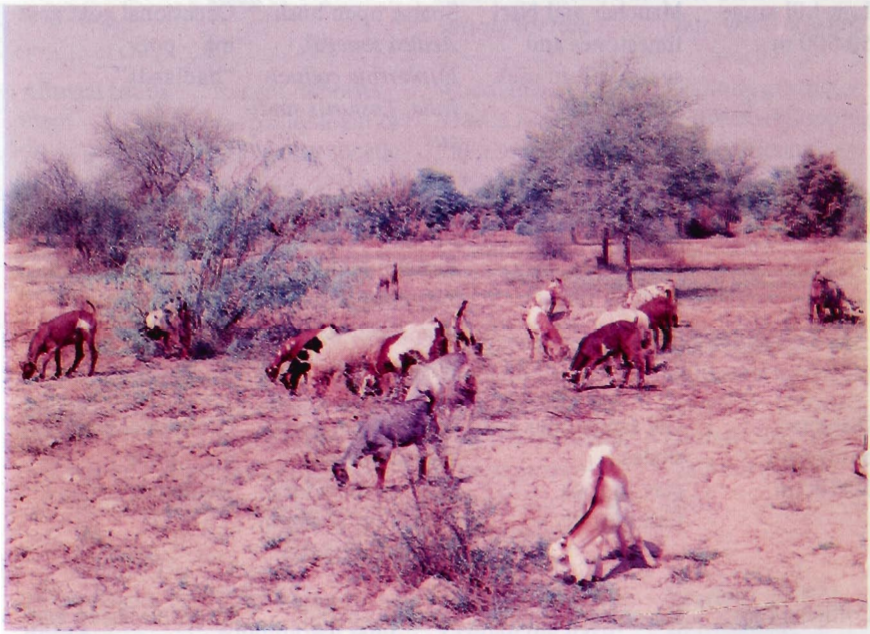

Plate 6. Depleted rangelands in Kohistan near Dhabeji, Sind.

Range Types: The vegetation of Kohistan is dictated by topography, soil type and relief. Hills contain open bushlands, footslopes have thickets of shrubs and trees, while plains are usually devoid of natural vegetation as

a result of dryland farming. A brief description of range types of Kohistan is given in Table 3.

Table 3. Ecological characteristics of various land forms in Kohistan ranges

Land form	Geology and soil	Vegetation	Present land use-range condition
High mountain range 500-2170 m	Brahui, Borage and Kirthar limestone; silt in rock fissures only.	Open bushland *Acacia senegal, Zizyphus nummularia, Chrysopogon aucheri, Grewia sp*	Emergency goat grazing firewood -good, stationary
High mountain range 500-2000 m	Nari shales and sandstone; clay in rock fissures only.	Sparse open bush- *Acacia senegal, Commiphora* wightii, *Cordia gharaf, Grewia sp*	Emergency goat grazing, firewood fair, stationary
Low hill range 50-500 m	Manchar and Nari limestones and shales; silt in rock fissures only.	Sparse open bush- *Acaica senegal, Euphorbia caducifolia, Lasiurus sindicus*	Occasional goat grazing - poor, "badlands"
Stony plateau 50-500 m	Ranikot Laki limestones, Gaj limestones, very shallow film of silt.	Sparse open dwarf shrubland *Barleria acanthoides, Zizyphus nummularia, Lasiurus sindicus, Aristida sp*	Regular sheep and goat grazing, scattered fields in depressions poor, overgrazed
Dissected outcrops 50-100 m	Gaj sandstones and shales; clay in rock fissures only	Sparse open dwarf *Acacia senegal, Euphorbia caducifolia, Cordia gharaf, Lasiurus sindicus*	Occasional goat grazing - poor, "badlands"
Colluvial fans 100-200 m	Recent deposits unclassified boulders, gravel, sand and silt.	Open bushland *Saccharum spontaneum, Pterophyllum oliveri, Nerium indicum, Rhazya stricta*	Intensive sheep and goat grazing, firewood - fair, overgrazed

(continued)

Table 3 continued

Upper foot-slopes 200-500 m	Subrecent deposits and Manchar conglomerates; shallow, stony sandy loam.	Bushland *Aristida sp, Lasiurus sindicus, Cymbopogon jwarancusa, Zizyphus nummularia*	Regular sheep and goat grazing - poor, overgrazed
Lower foot slopes 100-200 m	Recent deposits deep, well-structured sandy loam or loamy sand.	Wooded bushland thickets *Prosopis cineraria, Cenchrus ciliaris, Indigofera oblongifolia, Cassia holocericea*	Yearlong grazing, all livestock; lopping widespread shifting cultivation - *fair,* wind erosion
Sedimentary Plain 50-100 m	Recent deposits deep, well-structured loam or clay loam	Woodland *Acacia nilotica, Prosopis cineraria, Eleusine flagellifera, Salsola foetida*	Yearlong grazing all livestock,lopping; widespread rainfed cultivation - fair, wind erosion
Alluvial Indus Plain 20-5- m	Recent deposits deep clay-loam or heavy clay-locally alkaline	Woodland *Salsola vermiculata, Capparis aphylla, Alhagi maurorum, Cynodon dactylon*	Yearlong grazing, all livestock;lopping; fodder cutting, marginal irrigated cultivation - no rangelands
Riverbeds and drainage zones 50-100 m	Recent deposits very heterogeneous gravel-sand to heavy clay; locally small dunes, locally alkaline	Riverine thickets and woodlands *Tamarix aphylla, Tecoma undulata, Acacia jacquemontii, Saccharum spontaneum*	Yearlong grazing all livestock,lopping, firewood, intensive rainfed cultivation - fair but heavily used
Recent sand dunes 50-100 m	Recent deposits wind-blown sand, not consolidated	Bushed grassland *Leptadenia pyrotechnica, Cenchrus pennisetiformis, Panicum turgidum, Calligonum polygonoides*	Yearlong grazing, all livestock; firewood - fair, but heavily used

Source: FAO, (1975).

Important range plants are given below:

TREES/SHRUBS: Acacia nilotica, A. senegal, Barleria acanthoides, Calotropis procera, Capparis aphylla, Commiphora wrightii, C. stocksiana, Cordia gharaf, Euphorbia caducifolia, Grewia villosa, Leptadenia pyrotechnica, Lycium depressum, Pterophyllum oliveri, Prosopis cineraria, Rhazya stricta, Salvadora oleoides, Tamarix dioca, Tecoma undulata.

GRASSES: Aristida adscensionis, A. mutabilis, Cenchrus ciliaris, C. biflorus, C. pennisetiformis, Cynodon dactylon. Cymbopogon jwarancusa, Digitaria sp, Eleusine flagellifera, Lasiurus sindicus, Saccharum spontaneum, Sporobolus marginatus.

FORBS: Aerva tomentosa, Cassia holosericea, Convolvulus glomeratus, Crotolaria bifolia, Fagonia critica, Heliotropium ophioglossum, Indigofera oblongifloia, Rhyncosia minima.

BALUCHISTAN INTERMOUNTAIN RANGES

Baluchistan province has a total geographic area of 34.73 million ha. Although about 93 percent of the area is classified as rangelands, about 10 million ha are unproductive, 12 million ha produce little grazing, and about 1.6 million ha are undergrazed due to the inaccessibility of the hills and lack of water. Fair to good producing ranges are limited to about9 to 10 million ha (FAO, 1983).

The climate of the province is arid to semi-arid with annual rainfall increasing from 50 mm in the west to over 400 mm in the east. Precipitation distribution is very erratic and irregular. Most of the rainfall is received during the winter. The temperatures are highly variable. The temperature in the Sibi plain can reach 50°C in summer and drop to 1 to 3°C in Kalat, Quetta and Muslimbagh, during the winter. About 80 percent of the area can be classified as intermountainous. The remaining 20 percent consists of flood plains and alluvial deposits with a high potential for cultivation. Geomorphologically, the rangelands in Baluchistan can be distributed into six types of landscape, including mountains, uplands, piedmont, desert, flood plain and coastal plains. Some of the important mountain ranges in the province are Sulaiman, Toba- Kakar, Central Brahui, Kirthar, Chagai and Raskoh Hills, Siahan, Pab, Central Makran and Makran Coast.

Vegetation composition, carrying capacity, and production potential of Baluchistan intermountain rangelands varies among areas. Precipitation, altitude and soil formation affect forage production. Dry matter forage yield of a few protected mountain ranges is given in Table 4.

Rangelands of Baluchistan can be divided primarily into the following three main categories:

Central Baluchistan Ranges: These ranges spread over Quetta and Kalat Divisions, a region with a mediterranean climate where annual precipitation varies from 100 to 400 mm, most of which is received during winter or early spring. Altitude ranges from 1000 to over 3000 m. The famous Maslakh Range Project, which was the first scientifically managed

Table 4· Gross dry matter production (herbage and forage) of the ungrazed mountain rangelands in Baluchistan.

Range	gms Wr/X	DM Kg/ha	Veg. Cover %	Plants
Shangaloona	9.8	49	10	*Cymbopogon*
Shangaloona	56.8	284	15	*Cymbopogon*
Dumas Kach	43.5	217	8	*Chrypogon with Aristida spp.*
Tomagh Forest	28.0	140	25	*Cymbopogon Chrysopogon*
Harnai to Ashgara	51.1	250	20	*Cymbopogon*
Gok Mt, Sharan	120.0	600	13	*Aristida*
Gok Mt, Sharan	73.0	370	15	*Chrysopogon*
Lakabad, Zhob	75.0	370	15	*Chrysopogon*
Malvi, Sliaz River, Zhob	99.9	500	15	*Chrysopogon*
Rigora Range, Chauter	16.4	82	5	*Cymbopogon*
Sulaiman, Mehtra	4.0	220	20	*Chrysopogon*
Sparangha	71.9	505	15	*Artemisia*
Ziarat Range	140.5	983	36	*Artemisia*
Killi Umarbad	40.0	218	15	*Haloxylon*
Kach	12.3	76	5	*Artemisia*

Source: FAO, (1983).

range project in Pakistan during 1954, is situated in this region. Most of the area contain mountains with interspersed with flat valleys. Wheat and orchards are cultivated wherever irrigation facilities are available. The 'karez' system of irrigation is prominent in the valleys.

A detailed soil and vegetation survey of the area was conducted by Pakistan Forest Institute, Peshawar and Soil Survey of Pakistan (1981). The following four plant associations were dominant:-

i. A high to moderate density of dwarf shrubland characterized by *Cymbopogon schoenanthus* and *Chrysopogon montanus.* This community is associated with the Juniper zone of the Toba Kakar and Central Brahui mountains and includes a tree layer of *Juniperus macropoda, Pistacia sp.* and *Fraxinus xanthoxyloides,* a shrub layer of *Caragana ambigua, Prunus eburnea, Othonnopsis intermedia,* low shrub layer of *Artemisia scoparia, Haloxylon griffithii,* and a layer of annual grasses and forbs.

ii. On the piedmont slopes, the vegetation is characterized by *Cousinia sp.* and *Haloxylon griffithii.*

iii. A loess rocky hill complex characterized by *Iris* and *Cousinia.*

iv. A salinas associated with *Salsola* and *Tamarix spp.* Vegetation of Kalat Division can be divided into following two range types:

a. Plant communities on the piedmont, bajada and flood plains on

large areas, particularly on the flood plains and bajada, have been intermittently cultivated and fallowed; areas are very sparsely colonized by *Alhagi camelorum, Acanthophyllum squarrosum.* South of Mastung, on the piedmont, there is a 5-10 percent cover formed by *Peganum harmala, Othonnopsis intermedia* and *Haloxylon griffithii.*

a. As one proceeds south, the vegetation of the piedmont slopes varying from 5 to 15 percent of low shrubs is dominated by *Artemisia scoparia* and *Othonnopsis intermedia.* In the southern part of Kalat, grassland becomes more frequent with a vegetative cover of 15-20 percent, dominated by *Cymbopogon schoenanthus, Withania coagulans, Acanthophyllum squarrosum, Calotropis procera* with scattered *Caragana ulcinia.*

b. The central core of the Brahui mountains consists of widely scattered *Juniperus macropoda,* some *Pistachia* sp. with *Olea Perruginea* and a 10-20 percent cover of *Artemesia scoparia, Perowskia abrotonoides, Nepto spps* and scattered *Caragana ulcinia.* As one proceeds south, the grasses become more dominant and the following genera are common: *Cymbopogon, Aristida, Pennisetum* with annual grasses of *Bromus tectorum, Bromus mollis, Agropyron squarrosum* and *Aristida depressa.*

Range in the area is depleted due to heavy influx of livestock of Afghan refugees and 'pawindas. A shortage of winter feed and watering points are main problems.

Western Baluchistan Ranges: These ranges cover the desert areas of Chagai, Kharan, Panjgur, Makran, Turbat, Gwadar and Lasbela Districts. Rainfall is erratic and scanty (50-200 mm). As a whole, the tract has low potential to sustain economical ranching. In Chagai District, vegetation on the piedmont slopes consist of *Cousinia alepidea, Haloxylon griffithii, Alhagi camelorum* with *Saccharum ravannae* in the nullah. In dune and sandy bajada, where livestock grazing has been excluded by the Forestry Department, there is a 1-5 percent plant cover with *Stipa plumosa, Aheagi camelorum, Tamarix* sp. and *Zygophyllum atriplicoides.* The extensive salinas have vast areas of sparse plant cover, interspersed with plant communities, which include species of *Suaeda fructicosa, Salsola* sp, *Panicum antidotale, Aeluropus repens* and *A. macrostachyus.*

In the Rakhshan Valley of Kharan District, sheep rearing is dominant. Here, the Afghan 'pawindas' have less influence. The grazing potential in Panjgur, Turbat and Gwadar is limited. Forage quality depends on rainfall.

On the piedmont, *Prosopis cineraria, Salvadora oleoides, Capparis aphylla, Zizyphus sp.* occur; *Tamarix aphylla* occurs in the core saline areas with *Suaeda fruticosa.* One important introduction to the Lasbela District is *Prosopis juliflora,* which has successfully colonized arid terrain, but has the potential of spreading into cultivated areas.

The main forage grasses, are *Cenchrus ciliaris, Eleusine flagellifera, Pennisetum orientale, Aristida adscensionis.*

Eastern Baluchistan Ranges: These are located in Zhob and Loralai Districts of Baluchistan. The bioclimate is influenced by summer monsoon rainfall.

Zhob and Loralai ranges have a high potential for range development. These are grass-dominated. However, the influence of Afghan 'pawindas' are very influential here. The protected areas support *Chrysopogon* grass communities. The area also has adequate watering points. Dryland farming is also practised at few locations. Vegetation is similar to that in the Sulaiman Mountain Ranges.

Plate 7. *Cymbopogon* dominated ranges in eastern Baluchistan.

SULAIMAN MOUNTAIN RANGES

Sulaiman mountain ranges cover about 1.5 million ha. The elongated area extends along Afghanistan border. The elevation of the Sulaiman Range is between 1540 and 3,400 m above sea level (SSP, 1976). Steep ridges of exposed bedrock with a relief of more than 150 m contain little soil material. The rocks exhibit characteristics of north-south trend. The younger rock formations occur in the eastern parts while the older rocks progress from the interior to the western side of the range. All of them represent a huge easterly dipping anticlock, the axis of which corresponds to the ridge of highest peaks culminating in the Takhti-Sulaiman.

The climate of the tract is arid mountainous, sub-tropical continental. Annual rainfall is low and ranges from 200 to 250 mm. About 50 percent of the total rainfall is received during July and August. May, June and July are the hottest months (mean maximum temperature of about 40°C) while

January is the coldest month (mean minimum temperature of about 3°C).

Livestock rearing is the major occupation of the tribal residents. Dryland farming is done in the piedmont plain and valleys of Sulaiman mountains whose water from flash floods is conserved and utilized (the 'Road-kohi' system of irrigation).

Natural vegetation consists of following species:-

TREES/SHRUBS: Acacia modesta, Acanthophyllum squarrosum, Berberis lycium, Caragana ambigua, C. ulcinia, Daphne oleoides, Olea ferruginea, Perowskia obrotonoides, Zygophyllum atriplicoides.

GRASSES: Aristida funiculata, A. adscensionis, Chrysopogon montanus, Cymbopogon schoenanthus, Dactylactenium scindicum, Desmostachya bipinnata, Dichanthium annulatum, Pennisetum orientale, Saccharum ravannae, Stipa arabica.

FORBS: Ebenus stellatus, Cassia holosericea, Indigofera oblongifolia.

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.

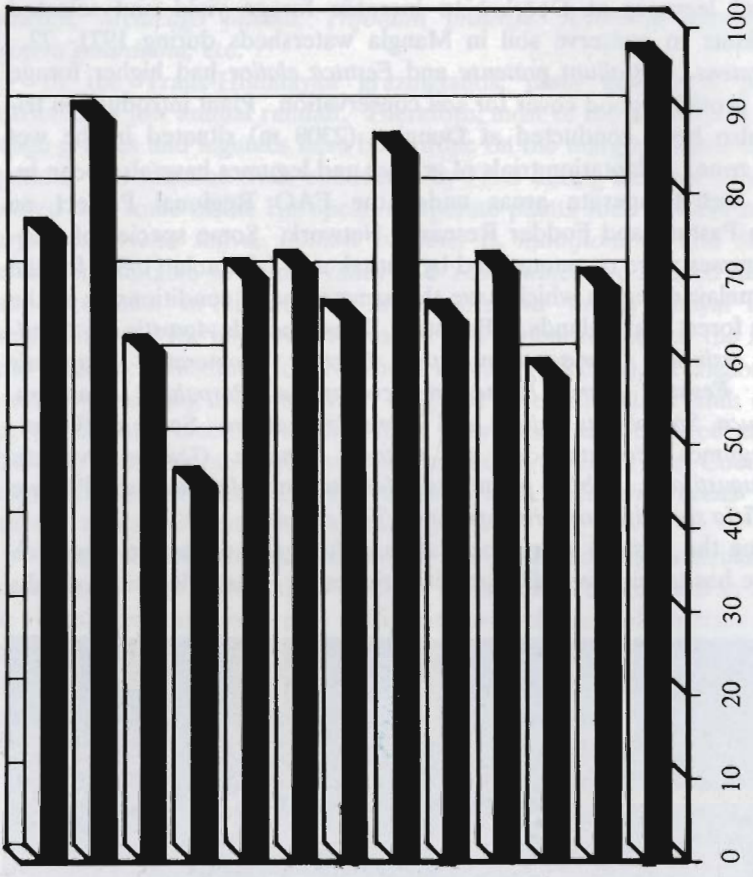

Figure 1. Average dry matter yield (t/ha) of grasses and legumes tested at National Agricultural Research Centre (NARC), Islamabad.

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

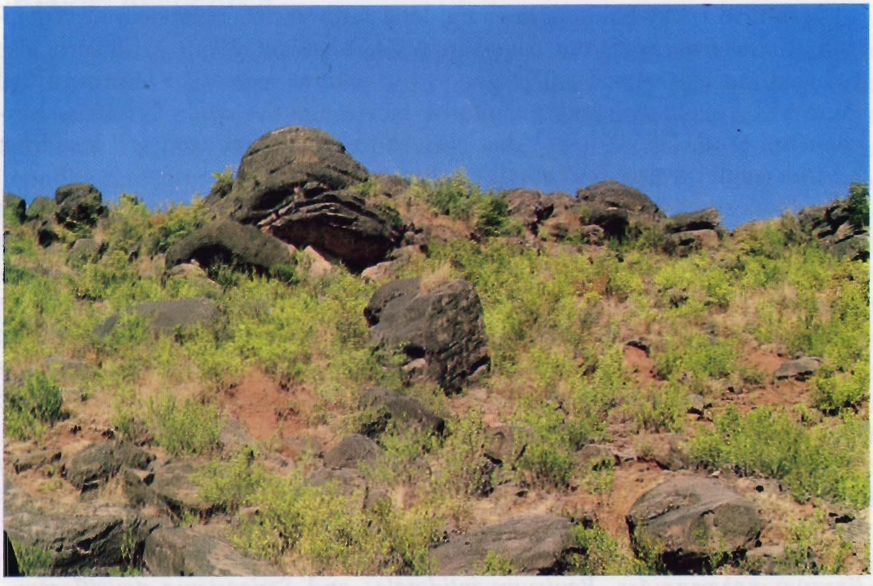

Plate 10 (a) Unprotected Margalla Hills in Islamabad.

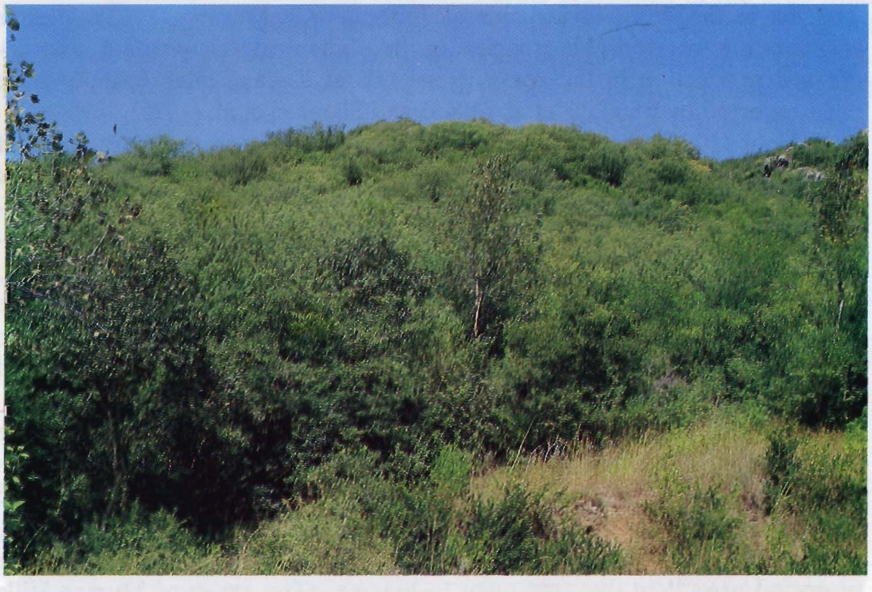

Plate 10 (b) Natural recovery of the same area by protection.

(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 *Ailanthus 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).

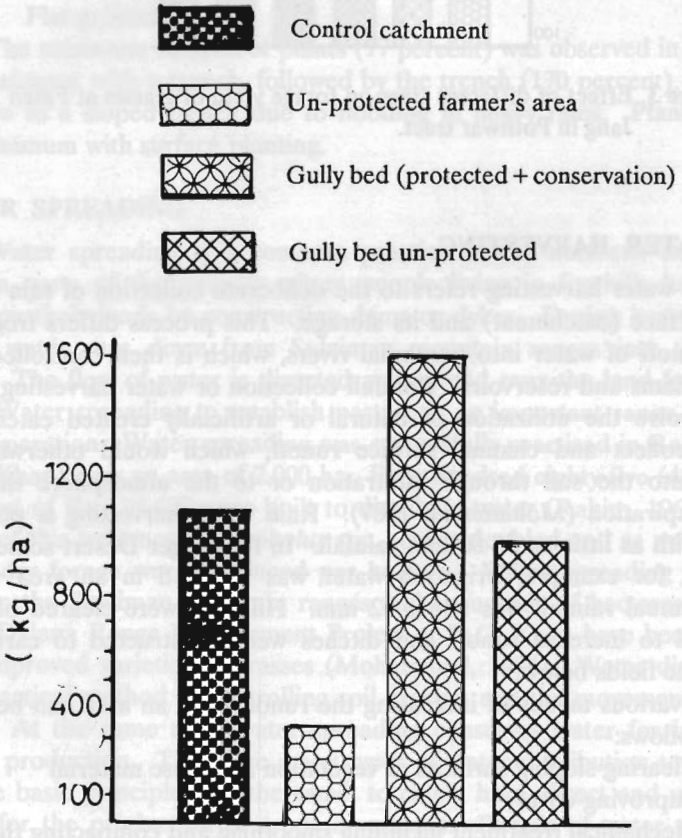

Figure 2. Impact of soil conservation structures on forage yield in Pothwar scrub ranges.

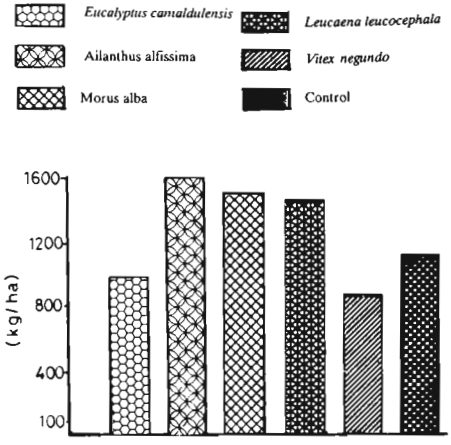

Figure 3. Effect of different trees on forage yield of grasses at Fateh Jang in Pothwar tract.

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

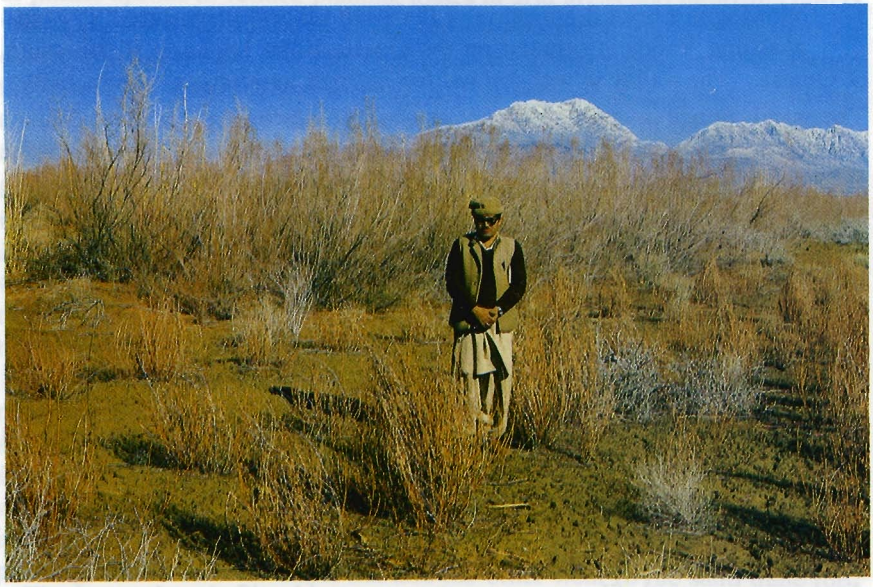

Plate 13. Sanddune fixation by afforestation in Mastung valley, Baluchistan.

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.

Chapter 4

Important Range Plants

PROMISING GRASSES

Reseeding depleted ranges with improved grasses has been extensively practised all over the world. Pasture establishment with cultivated grasses has involved millions of hectares in Australia, Europe, New Zealand and the western United States. A few indigenous and exotic grasses that have performed well in various range ecological zones of Pakistan can be recommended for large-scale reseeding in the relevant ecological zones of the Hindu Kush-Himalayan region.

Agropyron Cristatum (Crested Wheatgrass): This is a perennial tufted bunch grass with stems up to 1 m. Some stems are fine and have several leaves while other stolons are coarse with fewer leaves. Leaves are linear and are 5-15 cm long and 2-5 mm wide. Ligule is up to 1.5 mm wide membranous, often fringed or lanceolate. It produces very dense root system up to 2 m deep. Inflorescence is a dense spike 2-5 cm long and 0.7-2.0 mm wide. Each spikelet contains 3-8 flowers which are subsessile (Basel and Berlin, 1981). Seeds shatter soon after maturity and seedlings germinate readily so the initial thin stand soon becomes thicker. Seeds also remain in dry soils for a long period until the moisture is adequate for germination.

The species originated in central Asia, eastern Russia and Siberia and was introduced to Canada, USA, Europe and New Zealand. Crested wheatgrass is quite popular because it establishes and grows well under adverse conditions. It is adapted to dry conditions with 125-300 mm annual

rainfall. It has also been found in areas where there is less than 50 mm annual rainfall. It grows up to 2500 m. The grass is hardy and becomes dormant during prolonged dry periods and recovers soon after rainfall (Mohammad, 1981). It is also frost tolerant (Walton, 1983). It grows well on mostly good soils including light textured sandy soils and heavy clays. It tolerates only a short period of spring flooding and is intolerant of high water tables and is sensitive to salinity.

Crested wheatgrass is best suited to pasture production. It can be grazed heavily without reducing its productivity. It is of special importance because it is ready for grazing from early spring (Hughes et al., 1969). It grows very rapidly in May and June, so it produces grazing material when feed is in short supply and responds well to early grazing. During its early vegetative stage, it may contain 14-17 percent crude protein but at maturity the plant contains only 8 percent crude protein. Its quality and palatability also decreases during hay-making (Walton, 1983). After flowering, it does not meet the nutritional requirements for protein. Regrowth after hay cutting is also poor. About 5 cm of the growth should be left ungrazed at the end of the season.

It can produce forage for as long as 40 years. Plantings of 1913 in the USA still exist. Seed production of 1000 kg/ha has frequently been recorded. The species is quite variable in terms of seed size and germination percentage because its inflorescence is cross pollinated (Hughes et al., 1969).

In Pakistan crested wheatgrass is inter-cropped with many winter legumes, e.g. alfalfa and vetch for pasture and hay. It has been introduced at NARC, Islamabad, Peshawar, Mastung, and in the Northern Areas. It is well adapted to the mediterranean climate of Baluchistan. At Mastung, it has yielded 4.2 t DM/ha (Muhammad and Bhatti, 1983). It has a high potential for reseeding in the high mountains of Baluchistan and the Northern Areas.

Bothriochloa Pertusa (Palwan): It is commonly known as 'Palwan' or Hurricane grass. It is a tufted perennial with stolons and rhizomes. Culms are erect or geniculate up to 1 metre tall. Basal diameter is about 7 mm with 8-12 tillers. The leaves are linear and mostly basal. The flowering stems terminate in 6-10 radiating brownish seed spikes.

Palwan' is well distributed in South East Asia, tropical Africa and Arabia. In India, it occurs all over the country up to 2100 m (Dabadghao and Shankarnarayan, 1973). It is a native grass of Pothwar Plateau and Himalayan forest grazinglands. It is adapted to a wide range of climates from sub-tropical sub-humid to humid ecological zones with annual rainfall range of 500-1300 mm. The grass is drought tolerant and can be successfully grown on dry areas. It grows on a variety of soils from coarse to fine textured and moderately acidic to slightly alkaline with a pH of 5.8 to 7.5. It prefers fertile soils and can be successfully grown in the dry areas (Pathak and Jakhmola, 1984). Seed is sown along contour trenches, pits or on flat

lands at a rate of 3 kg/ha. It is a good soil binder.

Tufts are planted in the highly eroded hilly areas in Pothwar Plateau and Tarbela watersheds. It can withstand heavy grazing and short dry spell. Tufts planted at 50 cm intervals can cover soil within a growing season. Planting is done at the beginning of monsoon rainfall season.

At NARC, forage production upto 10 t DM/ha was obtained from two cuttings. Under natural conditions in Islamabad about 4-8 t DM/ha are cut for hay. It is a palatable grass grazed by sheep, cattle, buffaloes and goats. It has considerable potential for soil conservation in the Pothwar area.

Cenchrus Ciliaris (Dhaman): Locally known as 'Dhaman' or Buffelgrass, it is a summer growing perennial; culms 20-50 cm tall are erect or decumbent, and branch from the base. Growth forms vary from rosette or procumbent to erect. The stems reach up to 1.5 m height at maturity, and have typical foxtail seed heads; leaves are 10-25 cm long, 3-7 mm wide, glaborous or hairy, ligule narrow, ciliate membranous. Inflorescence is a dense cylindric raceme 3 to 10 cm long, pale or purplish. The seeds are dimorphic, differ in size and weight, and are enclosed in clusters of bristles which are dispersed by wind at maturity. Seeds remain dormant for a period of 9-12 months. Buffelgrass has fairly a deep root system, which is dirty brown in colour and thin. The number of rootlets increases with age. The root system is well distributed in the surface and middle zones. Das et al. (1963) reported that about 50 percent of the roots penetrated below 1 m. By virtue of its deep root system, it is highly drought resistant and can withstand heavy grazing or burning.

Buffelgrass is native to tropical and sub-tropical Asia, Africa and Latin America. It has been extensively seeded in Australia. Some of the prominent cultivars developed in Australia are 'Biloela' 'Molopo' 'Boorara' 'Lawes' 'Nunbank' 'Tarewinnabar' 'Gayandah' 'American' and 'West Australian'. Buffelgrass is also common in the southeastern part of the United States. In Pakistan, local cultivars 'Dhaman Sofaid' and 'Dhaman Kala' are extensively found in Pothwar scrub ranges, Salt Range, Pabbi Hills, Thal, Cholistan, D.G. Khan, Kohistan, lowlands of Baluchistan and Tharparkar Desert. A new cultivar 'Blue Buffelgrass' developed by the author at NARC, Islamabad, yields about 30 percent more than 'Dhaman Sofaid' in Pothwar scrub ranges. For Indian Rajasthan Desert, varieties '358' and '3108' have been recommended by Shankarnarayan and Shankar (1984). Some other species of this genus, such as *C. biflorus* and *C. setigerus*, also occur in the arid and semi-arid tropical areas of Pakistan and India (FAO, 1975).

Buffelgrass is suitable for areas with rainfall of 350-800 mm and an alltitude of 1000 m. It prefers light textured sandy loam soils but is also adaptable to harder and heavy textured scrub soils. Seeds of *Cenchrus ciliaris* sown during spring do not do well as the growth season is very short. Seeds germinate well but due to very hot season, the plants cannot get established, and die. Seeding is recommended immediately before the onset of

Plate 14. Blue-Buffel (*Cenchrus ciliaris*) - a new selection for Pothwar scrub ranges.

monsoon season (Mohammad et al., 1984). Seeding at the rate of 3-5 kg/ha is done on disked and cultivated land. In Thal, sowing at the beginning of summer monsoon rainfall season was very successful (Khan, 1965). Broadcasting is preferred over drilling because fluffy nature seeds tend to clog in seeding drills. Seeds are covered with 0.5 to 1.0 cm soil by dragging brush drawn either by a camel or tractor. seeds germinate within 10 days, provided soil moisture is adequate. Another 30- 40 days are required for seedling establishment.

Tuft planting and transplantation of seedlings has also been successful on sand dunes in Thal and eroded lands in Pothwar Plateau (Khan, 1968, Mohammad, 1984). In Peshawar rangelands buffelgrass was interseeded with *Eucalyptus camaldulensis* while in Thal rangelands, there are huge pastures of *Cenchrus ciliaris* and *Lasiurus sindicus* mixture. These seedings increased productivity from 300 to 1800 kg DM/ha per year (Khan, 1970). Buffelgrass is also intercropped with different legumes to improve forage quality (Sultani et al., 1985). Mixed seeding with *Lasiurus sindicus* is quite desirable in desert rangelands (Government of India, 1981). Buffelgrass has been interseeded with *Leucaena leucocephala, Atriplex nummularia* and *Zizyphus nummularia* on thousands of hectares in Kohistan rangelands (Mohammad, 1987). Under heavy grazing, the reseeded area can be invaded by *Cymbopogon* jawarancosa. About a year is required for stand establishment before livestock grazing can be allowed. Buffelgrass is highly palatable and relished by sheep, cattle and goats.

Buffelgrass remains productive for a long period. Pastures reseeded with this grass during 1965-66 in the Thal area still yield about 3.5 t DM/ha, although seasonal grazing has been done every year since their establishment. Mohammad and Naqvi (1987) obtained forage yield from buffelgrass during an 8-year study at Dhabeji. The annual fluctuation in forage yield was primarily due to variation in annual rainfall. During the past 10 years, intensive adaptation trials of more than 40 cultivars collected from different countries of the world have been carried out in various areas. The cultivars selected for different areas are RM 269 in Peshawar Valley, Blue Buffel in Pothwar Scrub Ranges, Sofaid Dhaman in Thal, Cholistan and D.G. Khan Ranges and Kala Dhaman' in Kohistan Ranges and Baluchistan lowlands.

Quality of buffelgrass varies with the stage of growth. In a study by the Range Research Project Lohi Bher, crude protein was 9.62 percent at pre- bloom 7.87 percent at flowering and 4.37 percent at maturity (Mohammad et al, 1986). Production was substantially increased by the application of nitrogenous fertilizer. Application of N-fertilizer at 100 kg/ha produced 5.42 t DM/ha and 44.14 kg/ha of seed whereas only 3.35 t DM/ha and 4.25 kg/ha of seed were produced when the fertilizer was not applied (Mohammad and Bhatti, 1983). However, fertilization during the spring did not increase forage production. Forage production of buffelgrass is also affected by the frequency of cutting. At NARC, buffelgrass yielded 13.5 t DM/ha when 100 kg N/ha was applied during the summer and cutting interval was 20 days compared to 7.8 t DM/ha with only one final cutting and no fertilizer. In a sheep grazing trial at Lohi Bher Range in the Pothwar Plateau, sheep gained 3.7 kg (live weight) on improved pasture and 1.9 kg on open/depleted range (Mohammad et al., 1986). Dabadghao and Shankarnarayan (1973) reported that a well established buffelgrass pasture could carry about 450 sheep per 100 ha in Rajasthan Desert ranges. Buffelgrass is the most suitable for the tropical desert areas where forage production can be substantially increased with improved cultivars.

Chloris Gayana (Rhodesgrass): This is a tufted perennial that grows during the summer. Its stem is 50-150 cm tall and it has a linear leaf blade 20-40 cm long and 3-9 mm wide, that tapers to a fine point. Its ligule is up to 6 mm wide and has a hairy membranous ring. Inflorescence is composed of 7-15 brownish green spikes, sometimes in two whorls, each 8-15 cm long. Each spikelet is 3-4 mm long, sessile and ciliated (Basel and Berlin, 1981).

Although native to Africa, rhodesgrass is widely adapted to sub- tropical and temperate areas. It is common in Australia, Pakistan and India. In Australia, Katambora', Callide' and Samford' are promising cultivars, grown on large areas (O'Rielly, 1975). In Pakistan, Kenyan cultivars are grown in the Pothwar scrub ranges. Several species of *Chloris* genus occur naturally in Indian Punjab, Rajasthan and Utter Pradesh. The annual rainfall requirement is 600-1200 mm with an altitude up to 1500 m. It has a wide adaptation to soil types, from light to heavy textured sandy loams but prefers fer-

tile soils. It can be established from seeds and is also propagated vegetatively from root shoot. Although summer growing, it has moderate tolerance to frost. The grass disappears after three years of establishment in Sind arid areas (Mohammad and Naqvi, 1987). Adaptation trials conducted by the National Forage and Pasture Programme at Islamabad and Peshawar indicate that rhodesgrass can be seeded in sub-tropical sub-humid Pothwar scrub rangelands. Seed is sown in the beginning of the monsoon in a disked and cultivated seedbed. Line sowing is preferred over broadcast seeding. About a full summer growing season is required for plant establishment.

Rhodesgrass is palatable and can withstand heavy grazing and trampling. It is also used as hay but it is not recommended for silage. Digestibility and crude protein decreases as the grass matures and becomes old and stemmy. Seed rate for *Chloris gayana* is 6 kg/ha. Herbage yield up to 7.5 t DM/ha was recorded at NARC under rainfed conditions. It is intercropped with a number of legumes like lucerne (Gohl, 1981). The grass is also intercropped with *Atriplex canescens* which increases forage yield (Mohammad and Bhatti, 1983).

Rhodesgrass also responds well to N-fertilizer and more intensive clipping. With 100 kg N/ha and clipping at 20-day intervals the forage yield doubled. Winter fertilization, however, did not increase forage production. The grass is also salt tolerant. Mohammad et al. (1987) subjected plants to different levels of salinity. The grass tolerated up to 9.0 dS/m. Percentage survival of plants, plant height, number of tillers, leaf length, leaf area and dry weights of shoots and roots decreased with salinity. Uptake of Na, K, Zn, P and M increased and uptake of Fe decreased. There was an antagonistic effect between Na and K.

The grass can be reseeded over large areas in Pothwar and Himalayan foothills. It forms a good soil cover and may be used to control soil erosion. Its potential for silvi-pasture establishment needs to be explored.

Cynodon Dactylon (Bermudagrass): This is also known as Khabbal'. It is a summer growing perennial with extensive stolons and rhizomes that rapidly colonize bare ground and form a dense mat. Leaves are grey to bluish green, short and flat. Its leaf blade is 5-16 mm long and 2-5 mm wide. The emerging blade is folded in the bud shoot. Its ligule is 0.2-0.3 mm wide and is membranous with ciliated elm. Its inflorescence is composed of a whorl of 3-7 digitally arranged spikes radiating from the top of a slender peduncle, sessile flowers are 3-10 mm long; stems are erect and up to 12 cm tall (Basel and Berlin, 1981). The seed is very small and 1 kg may contain 3-4 million or more seeds. Germination percentage is quite low (Walton, 1983).

Bermudagrass is found in many tropical and temperate countries of Asia, Africa, America and Australia. It is native to the Pakistan-India subcontinent, and is found in Pothwar, Thal, D.G. Khan, Cholistan, Kohistan, Tharparkar and Baluchistan lowlands. It grows on all types of soils, abandoned cultivated lands, paths, roadsides and depressions. Growth is better

on heavy soil than on light soil because of fertility and soil moisture. However, well fertilized stands give good yields on sandy soils. It can withstand flooding but does not grow well in water-logged areas. It is not much affected by soil reaction and grows well both on acidic and alkaline soils (Hughes et al., 1969). It is adapted to areas with more than 600 mm annual rainfall and a mean daily above 24°C (Gohl, 1981). The grass can tolerate temperatures above 24°C (Gohl, 1981). The grass can tolerate grazing and trampling. It can withstand prolonged drought and remains dormant in cooler months. Regrowth is rapid in spring and summer. It is a good soil binder and is used extensively for soil conservation and for lawns.

Bermudagrass is very palatable and nutritious. Leaves at vegetative stage contain 12-14 percent crude protein. Weight gain in livestock is relatively higher (Hughes et al., 1969). However, it is a problem weed in arable cultivated land (Gohl, 1981). It is sown during spring or summer on well prepared seedbeds. Due to low germination percentage a seeding rate of 9-11 kg/ha is recommended. The grass can be established vegetatively by tufts, plugs or springs. For high yielding varieties, seed is sterile; therefore, only stem cuttings are planted (Walton, 1983).

At maturity, forage production declines and herbage becomes unpalatable. Summer and winter legumes, such as vetches and clovers can be intercropped to sustain year-round forage production. It also produces excellent hay. The grass responds well to fertilizers, especially nitrogen. This fertilizer should be applied when new stolons are 12-13 cm long. Digestibility of bermudagrass is 65 percent or higher.

Bermudagrass may be used to control soil erosion in Pothwar scrub ranges. Economical methods of planting tufts of the grass are needed. Selection of fast spreading cultivars may be given priority.

Dichanthium Annulatum (Murgha): This is locally called Hindigrass', 'Delhigrass' or 'Murgha' in India. The stems are erect or ascending, 45-120 cm long, with nodes that are usually bearded. Leaves are linear about 8 to 30 cm, finely acuminate, glaucous, glabrous, more or less sparsely hairy above with small bulbous based hairs; the margins are scabrid, with ligules nearly 0.3 cm long, oblong, obtuse membranous or shortly ciliate. Racemes are 2-3.5 cm long and subdigitate, fascided, pinkish or nearly white (Dabadghao and Shankarnarayan, 1973). The flowering stems terminate in 4-6 radiating brownish seed spikes. The root system is characterized by dark brown hairy roots which increase with age. The roots penetrate to a soil depth of 120 cm. However, most of the roots are concentrated in the surface zone.

Murgha' a native grass of Pakistan, India, Nepal, Bangladesh and Burma. It also occurs in tropical Africa and Australia. A selection of *D. annulatum* ('Marvel-8') has been released in India for medium and low rainfall areas (Dabadghao and Shankarnarayan, 1973). It is extensively grown in Murree foothills, Pothwar Plateau and D.I. Khan. This grass prefers fertile loams but also grows on rocky grounds wherever sufficient soil moisture

is available. It has great potential in the Indus flood plains of D.G. Khan and D.I. Khan. It is sown during the summer. Germination occurs within a week. The plant matures within 60 days and can then be grazed or cut for hay. With irrigation, green forage yield up to 30 t/ha was obtained in six cuttings in India. Indian strain 'Marvel-8' yields about 13t/ha of dry matter under rainfed conditions. This strain is also suitable for protecting bunds and terraces in areas where rainfall is heavy.

Murgha' is palatable and leaves at vegetative stage may contain up to 10.4 percent crude protein; protein in mature grass decreases to only 2.7 percent. (Gohl, 1981). The grass has a great potential in the flood plains of the Indus in Rakh Miran (D. I. Khan). This is also a recommended species in the sub- tropical humid rangelands of the Pothwar Plateau of Pakistan (Mohammad and Bhatti, 1983).

Elymus Junceus (Russian Wildrye): This perennial grass is large, dark green, and is mostly basal with large ligules. The spike is borne on very long leafless culm up to 1 m long. The heads are dense terminal spikes with seeds that shatter readily on maturity. Therefore, seed collection is quite difficult. It has an extensive fibrous root system, which enables it to tolerate drought. The roots may penetrate to a depth of 3 m. About 75 percent of the roots are in the surface area (15 cm) but they can draw water horizontally from 1.5 m. Seedlings are small and very slow growing and establishment is quite difficult. However, germination percentage is high and seed remains viable up to 5-6 years. The plants should be allowed to mature and set seed before grazing.

Russian wildrye is native to Siberia, Russia and was introduced to Canada, the United States and Europe. It is well adapted to dry areas with annual rainfall of 125-300 mm. It is a very hardy species and is resistant to drought, frost and salinity (Walton, 1983). It can be grown on a fairly wide range of soils but does well on fertile loams. On sandy loam soils in the dry areas, the root system penetrates enough into the soil before the moisture is depleted. Mohammad (1979) has described it in detail. It has a very long growth period which starts early in the spring and continues until late fall.

Although grazing can continue from early spring to winter, it is better to graze the grass lightly in the spring and save most growth for summer and fall. It is very tolerant to grazing and regrows quickly after clipping. It is a highly palatable and nutritious grass with relatively high crude protein. It provides an excellent forage during August to November. It is the best cool season pasture grass to supplement the forage during winter (Hughes et al., 1969). Best forage and seed yield is obtained by the application of N-fertilizer. For seed production, wider spacing and heavy N-fertilizer application are recommended. The grass is mainly used as a pasture plant and is not recommended for hay.

For increased forage production, Russian wildrye is seeded in mixtures with legumes. In the United States, it is grown in combination with crested wheatgrass and winter fodder shrubs (Mohammad, 1982). It is also

intercropped with alfalfa for better feed quality (Walton, 1983). Yields are also increased by seeding mixtures with legumes. Seeding the legume in alternate rows or cross seeded rows also decreases competition. Winter introduction trials at NARC have been promising. It has also been introduced in Mastung (Baluchistan) where forage production is 1.5 t DM/ha (Mohammad and Bhatti, 1983). However, it has not been seeded on a large scale.

Russian wildrye needs to be introduced as winter forage crop in Pothwar. It appears to be suited for large-scale seeding in Northern Areas and high mountainous areas of Baluchistan.

Lolium Multiflorum (Italian Ryegrass): This tufted annual has cylindrical stems that are 30-100 cm tall and often erect branching at the base. It produces abundant dark green leaves. The leaves are rolled in the bud and are smooth. The leaf blade may be 6-20 cm long and 4-10 mm wide; linear with narrow auricles at the base. Its inflorescence is a slender spike, 10-40 cm long, composed of 5-8 spikelets, arranged on opposite sides. Spikelets are sessile, each with 10-20 flowers. The seeds have awns of various length (Basel and Berlin, 1981).

Italian ryegrass is native to the mediterranean region of southern Europe, north Africa and Asia. Now, it is grown in almost all parts of the world. The grass is adapted to a wide range of soils but produces best on soil of medium to high fertility. It also grows well on soils of low fertility but heavier seedings are necessary for good cover. It grows best on irrigated lands and in areas where annual precipitation is 500- 1000 mm. It can grow on wet soils, with good surface drainage. However, it is sensitive to waterlogging. The grass does not withstand drought or hot dry weather. It is also frost sensitive and does not survive severe winters.

It is an excellent grass for forage, soil improvement and erosion control. However, its primary purpose is forage. For pasture, it is grown alone or in combination with winter grains, thus allowing earlier grazing than Italian ryegrass alone. Intercropping of annual or perennial clovers improves both production and the nutritional value of the forage.

For seeding land is disked and the seed is broadcast. The seed is covered with 1-2 cm of soil. Seed is also drilled in rows into existing pastures at a seeding rate of 4-8 kg/ha. For soil conservation purposes, the seeding rate should be doubled. Mature seeds shatter readily and fall on the ground. They remain dormant during summer and germinate in the fall.

It is a very palatable and nutritious grass with forage yield of 5-10 t/ha of hay or 25 t/ha of silage. Mixed cropping with grain resulted in live weight gains in cows of over 500 kg per hectare in 6 months (Hughes et al., 1969).

Italian ryegrass responds well to nitrogen fertilizer. Herbage yield increases significantly by applying 30 kg N/ha. Quality and quantity of forage is also increased if legumes are intercropped. The grass is generally cut for

hay when the spikes are formed. Because of fine stem and abundant leaves, it makes an excellent hay. It should be cut at a stubble height of 7.5 cm. On a good soil and with adequate moistures, the pasture may also be grazed after hay cutting. It provides good grazing during winter and spring.

The grass has been introduced at Jaba, Muzaffarabad, in sub- tropical humid zone where it has yielded 1.5-1.7 t DM/ha and 100- 150 kg/ha of seed (Amin and Ashfaque, 1983). There are introduction plots in the Swat and Hunza Valleys, in a dry temperate zone. At NARC, it has proved a good winter forage with a dry matter yield of 2.9 t/ha.

Lolium Perenne (English Ryegrass or Perennial Ryegrass): This short lived perennial bunch grass species has shallow fibrous root system. The stem is 30-60 cm tall and leafy. Leaf blade is 3-20 cm long and 2-6 mm wide. The leaves are linear, smooth and quite stiff, often with small auricles at the base margin. The leaves are folded in the bud. The membranous ligule is 1-2.5 mm long. Its inflorescence is a slender spike, 5-30 cm long, composed of 5-35 sessile spikelets. These spikelets are arranged on opposite sides of the stem. Each spikelet may contain 2-10 awnless flowers (Basel and Berlin, 1981).

Perennial ryegrass is native to temperate Asia and north Africa. It was the first perennial grass grown in pure culture for forage production in Europe. Now, it is grown for pasture all over the world. It is a winter hardy grass and requires 750-1250 mm of annual rainfall. It is adapted to a wide range of soils including heavy clay but prefers medium to high fertility soils. It is not a dryland grass and generally not adapted to areas with extremes of cold, heat or drought. It requires large amounts of water but is sensitive to waterlogging.

Perennial ryegrass can be seeded in early spring or fall. In areas where winters are severe, spring sowing is recommended; in areas where winters are mild, early fall sowing is recommended. Germination is better if it is sown in the late fall. Winter forage yield is low if severe freezing occurs, especially on heavy soils. Early spring seeding may be successful when summer is mild and rains are frequent. The seedbed is prepared with a light disc and seed should be broadcast. Optimum seed rate is 4- 8 kg/ha. However, when grown in mixture with small grain crops for annual forage, 2-4 kg/ha seed is recommended. For erosion control, the seeding rate can be doubled.

Forage production is substantially increased if 30-50 kg N/ha is applied or when grown in mixture with legumes. Fall, spring and fall-spring applications are made according to the requirements. Perennial ryegrass is generally cut for hay after pollination or when the seed is soft. Because of its leafiness and medium fine stems, it makes a high quality hay. Under favourable conditions after hay cutting, the pasture can be grazed. Heavy pasturing is desirable to keep the grass in succulent condition (Hughes et al., 1969). This grass has been introduced in the Neelam Valley, yielding

1.6-1.8 t DM/ha and 125-175 kg seed/ha (Amin and Ashfaque, 1983).

Panicum Antidotale (Bluepanic): This erect summer-growing perennial grass is up to 3.0 m tall. Leaves are linear and blue green, leaf blades are 25-50 cm long and 5-12 mm wide. Its ligule is membranous and 0.5-2.0 mm wide. Seeds are produced in large panicles 20-45 cm long and 6-15 mm wide composed of many flowered ascending branches. Spikelets are 2.5-3.5 cm long (Basel and Berlin, 1981). Seeds shatter at maturity so seed collection is usually difficult. Seeds remain dormant for about a year.

Bluepanic is native to Pakistan, India, Nepal, Afghanistan and Sri Lanka. It is now extensively grown in several tropical countries in Asia, Africa, Latin America and Australia. Several other species such as *P. maximum, P. coloratum*, are also used for pasture establishment. It is well-suited to the sub- tropical sub-humid Pothwar Plateau, Salt Range, Pabbi Hills, Kharemurat and Gulial forests. It is also adapted to the Thal and Kohistan ranges (Mohammad and Naqvi, 1987).

Adaptation trials were conducted at NARC, Islamabad, Peshawar, Thal and Dhabeji during the past 13 years. Forage production in t DM/ha was as follows: Peshawar (5.3), Lohi Bher (8.8), Kherimurat (6.5), Pabbi Hills (7.0), Thal(5.2) and Dhabeji (6.2). Bluepanic sustains forage production for 5 years, before it should be replaced.

Bluepanic is best suited to fertile sandy loam soils in areas receiving 500-800 mm of precipitation and an altitude up to 1000 m. It is sown at the beginning of monsoon. The seeding rate is 2.5-3.0 kg/ha. The seedbed is disked and cultivated. Drilling is preferred for a uniform stand. In Pakistan, most seed is broadcast. Tuft planting is also common in hilly areas for soil conservation. The seeds need to be covered by a thin layer of soil. Germination starts within 8-10 days of seeding. A full season of growth required for plant establishment. Grazing is normally allowed in the second year. It is a palatable grass and can withstand heavy grazing by sheep and cattle. At late flowering stage, it acquires a bitter taste and accumulates oxalic acid, which can cause kidney disorders.

Forage production is significantly increased if nitrogenous fertilizer is applied. Application of 100 kg/ha of urea increased dry forage yields by 50 percent (Mohammad and Bhatti, 1983). Reseeding with bluepanic increased range productivity 12 times compared to depleted/open range in the Jamrud area of North Western Frontier Province (Mohammad and Bhatti 1983). The optimum seeding rate is 2.5 kg/ha which gave 1120 kg/ha of dry forage and 20 kg/ha of seed. Seeding 1 kg/ha produced 1015 kg/ha of dry forage while seeding 0.5 kg/ha produced 372 kg/ha during the first year. Almost same results were obtained in the Neelum Valley (Mohammad and Bhatti 1983). Livestock weight gain increased substantially on pasture reseeded with Bluepanic (Mohammad et al. 1986). In Kohistan ranges, bluepanic yielded the second largest amount after buffelgrass (Mohammad and Naqvi, 1987).

Planting tufts of bluepanic is more successful. However, further re-

search is needed to determine economical planting methods. Pothwar ranges and Murree foothills are highly suitable for large scale seeding. Research on better methods of seed collection is needed.

Pennisetum Purpureum (Elephant or Napiergrass): This summer-growing, tall perennial grass grows in clumps with 2-20 tillers. Tillers are canelike and may be 1.5 m tall and 2.5 cm thick. It has strong and erect stems; branches are produced from the axil of the leaf of main stem. It has a deep root system and is fairly tolerant to drought but is susceptible to frost. It also withstands acidity and may tolerate a pH of 4.0 (Walton, 1983). Its leaf blade is 60-120 cm long and 20-40 mm wide. If allowed to grow to maturity, it produces an inflorescence 8-20 cm long. Flowers may be solitary or in groups of 2-4, sessile in bisexual flowers and pedicellated in male flowers (Basel and Berlin, 1981).

Elephantgrass is native to tropical Africa and is grown in many other countries such as America, Brazil, Australia, Pakistan and India. In Australia, the cultivar Capsicum' is high yielding with thick succulent stems and a strong crown and has vigorous stooling ability. Elephantgrass has long been introduced in the irrigated areas. Bajra-Napier Hybrid is extensively cultivated for fodder. Variety A-146' from Taiwan has provided good forage yields at NARC and has been grown in the subtropical humid northern mountains of Pakistan. *P. orientale* is the only other species of this generation that naturally occurs in Pothwar Plateau.

Plate 15. Elephant grass (*Pennisetum purpureum*), A-146 recommended for Pothwar scrub ranges.

Due to absence of viable seeds, elephantgrass is propagated vegetatively by root shoots or stem cuttings that have a few nodes. It is planted during early monsoon in a well prepared deeply ploughed bed. Establishment is better if planted during rainfall at 50x50 cm spacing. Variety A-146' is most suitable for Pothwar Plateau where rainfall exceeds 500 mm. It grows best on deep soils of moderate to fairly heavy texture. It can tolerate short drought but does not withstand waterlogging.

Elephantgrass is of considerable importance in high rainfall areas of Pothwar. It is excellent for dairy cattle because of its rapid, tender growth and relatively high protein content. With fertilization and proper management, dry matter yields up to 40 t/ha has have recorded at NARC. It provides one cutting during the spring and 2-3 cuttings during the summer growing season. Forage production remains constant up to 4 years and declines later. Occasional fertilization with N, P and K is necessary to maintain soil fertility. Nitrogen fertilizer also improves the crude protein content. Applying of l20 kg N/ha under rainfed conditions produced 39.35 t DM/ha forage compared 18.22 t DM/ha for the control. Percentage of crude protein increased from 6.98 to 12.63 following application of 120 kg N/ha. However, the crude fibre content was not affected by N fertilizer (Mohammad and Bhatti, 1983). Frequency of cutting also affects forage production. During summer, more forage was produced at 20-day harvest intervals than at 40-day intervals or final cutting. Elephantgrass is also intercropped with legumes. Cowpeas intercropped with elephantgrass improve forage quality, especially the crude protein content (Mohammad and Bhatti, 1983).

As planting of elephantgrass is highly labour intensive, economical procedures need to be developed for stem cutting or tuft planting. Intercropping of winter vetch or annual medics with this grass may result in year-long forage production.

FODDER TREES AND SHRUBS

Trees and shrubs are an important source of feed for livestock. They offer certain advantages because of their productivity, palatability and nutritional quality; they also provide cover for wildlife, conserve soil, stabilize sand dunes, have considerable aesthetic and recreational values and have beneficial role in the ecosystem. However, they have always been viewed as of secondary importance by land managers. Range managers in Pakistan are generally interested in replacing shrublands with grasses. Foresters primarily emphasize the development of timber forests. Agriculturists want to replace shrublands with cash crops that offer earlier returns. They have succeeded in some areas but could not replace shrubs on large tracts of arid and semi-arid lands, which constitute over 60 percent of the area of the country.

An ecological review of the arid land vegetation indicates that morphological and physiological flexibilities,allow trees and shrubs to survive in 'he harsh environment of the desert and to survive ruthless exploitation by

man. Shrubs of the arid and semi-arid regions usually possess small, leaves which reduce transpiration losses. Large cell size, thick cell walls, a dense vascular system, high stomatal density and proportionally greater palisade tissues also reduce water losses. The volume of intercellular space is less in xeromorphic than mesomorphic leaves, but the ratio between the internal exposed surface area of the leaf and the external surface area is higher in xeromorphic leaves.

Plants shed their leaves to maintain the water balance. Leaf shedding usually begins with the oldest leaves and progresses toward the apical meristems. Shedding of leaves is correlated with seasonal changes in soil moisture. In the desert, leaves are often replaced by brachyblasts, reduced to stipules or shed completely during the dormant season. Certain desert shrubs reduce the weight of their young shoots through desiccation. Most of the shrubs continue photosynthesis through their stems and branches. Desert shrubs also develop a wide cortex that protects vascular tissues from desiccation. Shrubs also have an extensive root system that penetrates deep into the soil. Rooys as long as 55 m below the soil surface for Prosopis cineraria were reported in the (Government of India, 1981). Some of the native shrubs and grasses are highly salt tolerant and drought resistant and may be svited to irrigated as well as arid range areas. Most of our desert rangelands have a very deep ground water table. Deep root systems allow shrubs and trees to this water efficiently. Water utilizing efficiency of shrubs with respect to the depth of ground water (Dakshini, 1972) is given in Figure 4. Several shrubs have the ability to utilize very saline water. The salt tolerance of various plant communities native to the Pakistan-India subcontinent were studied by Chatterji and Gupta (1969) and is diagrammed in Figure 5. Such shrubs can be successfully planted in desert areas of Thal, Cholistan and Tharparkar. Juneidi and Huss (1978) have recommended large scale planting of *Atriplex nummularia, A. canescens, Salsola foetida, Indigofera oblongifolia, Zizyphus nummularia,* and *Prosopis cineraria.* in the semi-arid areas of the Arabian Peninsula.

A FAO report (1975) on Range Management in Sind strongly recommended planting of fodder trees and shrubs in the arid rangelands of Kohistan and Tharparkar. Among the native species, *Prosopis cineraria, Acacia nilotica, Tecoma undulata, Acacia senegal, Zizyphus nummularia, Calligonum polygonoides,* and *Indigofera oblongifolia* are suggested for the revegetation of arid areas of Sind. Planting of exotic species such as *Acacia aneura, Atriplex nummularia* and *Opuntia spp.* was also recommended.

During the past few years, fodder plants such as *Leucaena leucocephala, Atriplex nummularia* and *Opuntia spp.* have been successfully planted in the Kohistan tract. *Zizyphus nummularia, Z. mauritiana* and *Prosopis cineraria* were planted by Khan (1968) over large areas in the Thal ranges. The National Forage and Pasture Research Programme is dry planting fodder trees and shrubs at Dagar Kotli. These fodder trees and shrubs are *Tecoma undulata, Cordia mixa, Prosopis cineraria, Parkinsonia aculeata, Acacia modesta, A. aneura, A tortilis, Zizyphus mauritiana.* Spac-

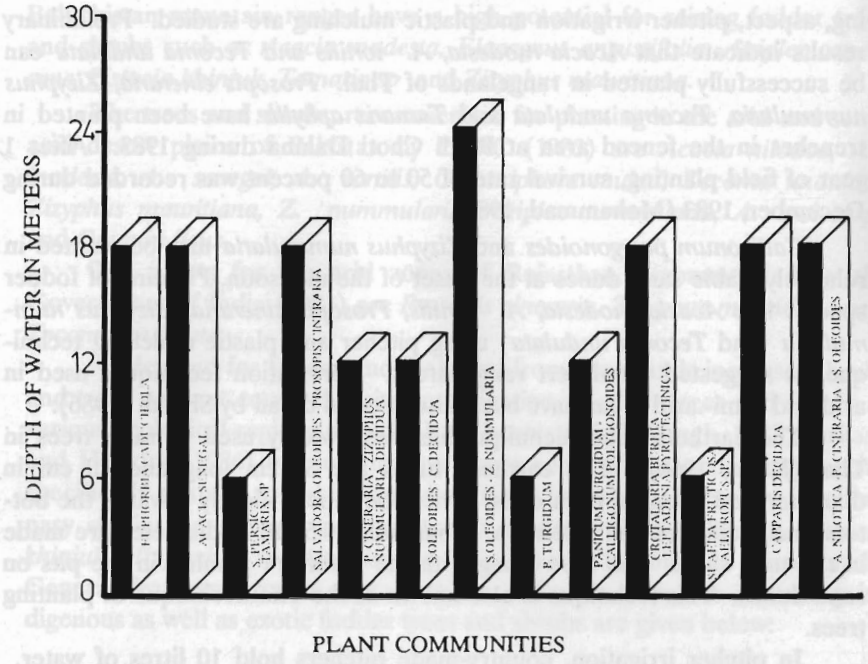

Figure 4. Gound water utilization efficiency of desert shrubs (Dakhshini, 1972).

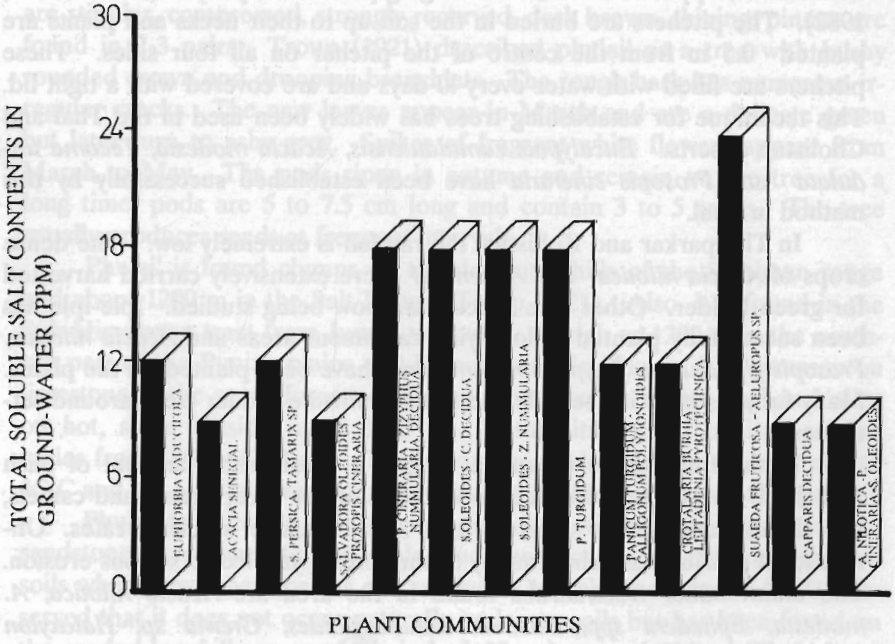

Figure 5. Salt tolerance levels of desert shrub communities (Chatterji and Gupta, 1969).

ing, aspect, pitcher irrigation and plastic mulching are studied. Preliminary results indicate that *Acacia modesta, A. tortilis and Tecoma undulata* can be successfully planted in rangelands of Thal. *Prosopis cineraria, Zizyphus nummularia, Tecoma undulata* and *Tamarix aphylla* have been planted in trenches in the fenced area at Rakh Choti Dalana during 1983. After 1 year of field planting, survival rate of 50 to 60 percent was recorded during December, 1983 (Mohammad, 1984).

Calligonum polygonoides and *Zizyphus nummularia* may be planted in relatively stable sand dunes at the onset of the monsoon. Planting of fodder species like *Acacia modesta, A. tortilis, Prosopis cineraria, Zizyphus nummularia* and *Tecoma undulata* using pitcher and plastic mulching techniques is suggested for desert range areas. Forestation techniques used in arid and semi-.arid areas have been discussed in detail by Sheikh (1986).

The earthern tube technique has been widely used to raise trees in Thal (Khan, 1966). The earthern tubes are 30 cm long and 10 cm in diameter and open on both ends. The tube tapers slightly towards the bottom and facilitates soil retention. Four holes 0.5 cm in diameter are made in the tube shell. The tube along with the plant are planted in the pits on sand dunes. This technique is also known as the Thal technique of planting trees.

In pitcher irrigation, country-made pitchers hold 10 litres of water. To reduce the percolation rate of water, the pitchers are usually coated with paint or charcoal along all the sides except for circular areas of 3 cm diameter on opposite sides on the bulging part of the pitcher (Sheikh et al., 1982). The pitchers are buried in the soil up to their necks and plants are planted 0.5 m from the centre of the pitcher on all four sides. These pitchers are filled with water every l0 days and are covered with a tight lid. This technique for establishing trees has widely been used in the Thal and Cholistan deserts. *Eucalyptus camaldulensis, Acacia modesta, Tecoma undulata* and *Prosopis cineraria* have been established successfully by this mathod in Thal.

In Tharparkar and Kohistan, the rainfall is extremely low. The dense crops of *Acacia nilotica* and *A. senegal* were extensively carried harvested for green fodder. Other tree species are now being studied. Iple-iple has been successfully planted in low lying catchment areas and *Acacia nilotica, Prosopis glandulosa, Zizyphus nummularia* have been planted on the plains. Many farmers both in the hills and plains cultivate fodder trees around settlements.

In the Baluchistan mountain ranges, a considerable amount of bush and shrub growth has provided good browsing for sheep, goats and camels, but these stands have suffered from the excessive stocking rates. Unrestricted grazing has ruined many of the forests and led to serious erosion. The main fodder trees/shrubs found in the area are *Acacia nilotica, A. modesta, Ephedera spp, Fraxinus xanthoxyloides, Grewia sp, Haloxylon grifithii, Pistacia khinjuk, Prunus eburnea* and *Zizyphus mauritiana.*

The Trans-Himalayan grazinglands, Sulaiman mountain ranges and

Baluchistan mountain ranges have a high potential for raising fodder trees and shrubs such as *Acacia modesta, Elaeagnus angustifolia, Atriplex canescens, Pistacia khinjuk, Tamarix sp* and *Zizyphus mauritiana.*

The trees and shrubs, recommended for planting in the arid and semi-arid desert plains of Pakistan by PARC (1983) are *Acacia nilotica, A. modesta, A. senegal, A. tortilis, Commiphora mukul, Tecoma undulata, Zizyphus mauritiana, Z. nummularia, Atriplex nummularia, A. polycarpa* and *Opuntia ficus.*

The plants for the arid zones of Rajasthan, recommended by the Government of India (1981) are *Prosopis cineraria, Zizyphus mauritiana* and *Tecoma undulata.*

As demand for fodder and fuelwood from rangelands increases shrubs and trees warrant comprehensive investigation. Fodder trees and shrubs in various ecological regions of India have been studied (Singh, 1982; Parkash and Hocking, 1986) but information about some of the promising species specifically adapted to Pakistan environments is limited. Therefore, preliminary studies on species such as *Acacia modesta, Olea ferruginea, Pistacia khinjuk, Hippophae sp, Artemisia sp.* etc., should be initiated immediately. General features, growth characteristics and uses of a few promising indigenous as well as exotic fodder trees and shrubs are given below:

Acacia Modesta (Phulai) : Family: Leguminosae; Common name:'Phulai. It is a medium-sized deciduous, slow-growing tree which attains a height of 6 to 9 m. Young shoots are glabrous or nearly so. Prickles are stipular, compressed, strongly recurved, dark brown, shining; pinnae are found in 2-3 pairs. Troup (1921) described phulai' as a tree with bushy rounded crown and drooping branchlets. The rough bark has numerous irregular cracks. The new leaves appear in March and are a delicate green but later turn to ashy grey. Spikes of fragrant white flowers appear from March to May. The pods ripen in autumn and remain on the tree for a long time; pods are 5 to 7.5 cm long and contain 3 to 5 seeds. The tree usually produces seeds at frequent intervals.

Phulai' is found clumps on the dry outer hills of the Sulaiman range and about 1200 m in the Salt Range (Troup, 1921). Also, it is found in the Sub-Himalayan tract from Jumna westward, as high as 1200 m in the northern part of the Punjab plains and Baluchistan. In Hazara, it is common on limestone in the scrub forests of Khanpur and occurs in the Kaghan Valley on hot, shale hillsides upto 1466 m. Within its natural habitat, rainfall varies from 380 to 1270 mm. The maximum shade temperature may rise to 45°C and the absolute minimum may drop to well below the freezing point.

Phulai' is found on various geological formations, including limestone, sandstone, conglomerate and shale, and can grow in infertile dry, shallow soils where few other species can survive. Quraishi and Ahmed (1973) observed that it does not occur naturally on loamy soils but has been found on the eroded low hilly areas of Khairabad, Nowshera and Chitral (Shahid and Qayyum, 1977). Troup (1921) found that phulai' may occur in pure stands

or in association with *Olea ferruginea, Acacia catechu, Tecoma undulata, Prosopis cineraria, Bauhinia variegata, Zizyphus mauritiana, Ehretia laevis* and various other species, often with an undergrowth of *Dodonia viscosa, Carissa* italics *Adhatoda vasica* and other shrubs.

The distribution of phulai' extends into the lower limits of *Pinus roxburghii* in some parts of outer Punjab hills. On poor dry locations at low elevations it is sometimes associated with *Salvadora oleoidies* and *Capparis aphylla.*

Champion (1935) classified phulai' as a component of the sub- tropical dry evergreen forest, in which kau' and 'phulai' are two typical tree species. He explained that the development of forest was arrested due to the severe biotic influences of the past and would not return to climax conditions without sufficient protection. Phulai' has been regenerated on thousands of hectares in Punjab. Its seed is generally sown in trenches, pits, troughs, etc., With standard dry forestation techniques, Sheikh (1986) found that it could be successfully planted where the average rainfall was 350 mm with or without mulch.

Troup (1921) observed that the tree is drought resistant. It coppices well and is usually managed by a silvicultural system known as "coppice-with-standard". The coppice shoots, as well as seedlings, must be protected from browsing, as they damaged by goats, sheep and camels.

Champion (1935) said the dry deciduous scrub forest is a seral type of the northern thorn forest. He believes that those forests have been subjected to long continued grazing, lopping and felling to the extent that they probably never attained climax status and never will. In another study, Said (1951) mentioned that, in the normal succession cycle, phulai' seemed to be sub-climax species, whereas kau' was more characteristic of a stable climax stage. Natural forests of phulai' are worked on 30-year felling cycle and 60-year rotation when trees reach a diameter of 20 cm and a height of 7 m (Sheikh, 1986).

Phulai' is one of the most valuable forage species due to its palatability and nutrional value. It is relished by all classes of livestock and many species of wildlife. It is also used for timber and fuelwood. It provides excellent flowers for honey production. Khan (1965) found that phulai' forage is rich in nutrients and also liked by wild ungulates, such as Nilgai in the Changa Manga forest plantations.

Acacia Nilotica (Babul): Family: Leguminosae; Common names: 'Babul' and 'Kikar'. It is a moderate to large sized, almost evergreen tree with a short trunk, a spreading crown and feathery foliage. Bark is dark brown, nearly black and hard inside with regular deep longitudinal fissures, which often run spirally up the tree. Young branches are green with white stipular spines, as long as 6 cm (Khan, 1965).

Babul' forests are mainly confined to the lower Sind though sporadic trees are found over the Indus Plains, Pothwar Plateau, Sulaiman foothills, in the lowlands of Baluchistan, Rajasthan, Haryana, Punjab and semi-arid

and arid parts of Deccan Plateau. It is as, high as 600 m on flat, gently undulating ground or ravines. The maximum shade temperature of its habitat ranges from 40 to 50°C and the minimum temperature is from -1 to 15°C; the mean annual rainfall is from 400 to 800 mm. In areas with less rainfall, it can grow only with artificial irrigation or river inundation. In Sind, the species grows on riverain alluvial sandy loam soils subject to inundation. It is damaged by frost and is not found in areas where frost is a regular feature (Hussain, 1977). It is salt tolerant but does not tolerate water-logging for longer periods.

There appear to be two varieties of the tree **In Pakistan,**:

i. Telia': This variety has spreading crown and long pods. This is the variety found mostly in the riverain forests of Sind, Punjab and NWFP.

Plate 16. Babul (*Acacia nilotica*) - a fodder and fuelwood tree of the Indus Plains.

ii. 'Cupressiformis': ('Kabuli Kikar') This variety has broom-like ascending branches. It occurs sporadically along roadsides and in cultivated fields in Sind and Punjab.

Babul' is semi evergreen though on very poor soils it is sometimes bare for a short time in April-May. The young leaves appear from March to May; the old leaves commence to fall before they appear and continue to full while the young leaves are sprouting. Flowering is generally in the rainy season, from June to September or October, but trees may be found in flower as late as December to January. The young fruit develops rapidly and ripens according to locality, but usually ripens from April to June. In Sind, the tree flowers twice a year; once in June-July and again in November-December. The pods from the first flowering ripen around October, but are usually poor in quality and quantity. Pods of the second flowering ripen in May and give a better crop. The pods are 5-15 cm long and 1.27 cm broad and each contains 8-12 seeds. Seeds retain their viability for some years if carefully stored. Trees start bearing fruit at an early age, usually at about 5 to 7 years. They seed annually as a rule. Under favourable conditions, the plants germinate in July and are 1-1.5 m high by December. Factors conducive to rapid growth appear to be adequate soil moisture, full sunlight and friable soil free from weeds. Seedlings produce a long tap root reqiure full sunlight and are tender to frost.

Babul' is typically a gregarious tree. It coppices poorly and can be propagated by seed. Broadcasting is the cheapest and most effective method of sowing in the riverain forests of Sind. Direct sowing in pits, along contour trenches, furrows, dribbling of 3-4 seeds in lines, patches and mounds has also been successful in Pothwar. To ensure plant establishment, 1-year old seedlings raised in polythene bags are planted during the monsoon. Plantations are managed by clear felling a 20-25 year rotation followed by artificial regeneration, (Parkash and Hocking, 1986).

Leaves and pods of babul' are largely used as fodder for cattle, goats, sheep and camels. Annual pod yield has reached 4.2 t/ha of pods from riverain forests of Sind (Gori 1957). Singh (1982) reported 8-10 t of pods/ha per year from well stocked plantations. He further reported that forage yield of 5.27 DM t/ha were obtained from its leaves. Pods contain as much as 15 percent crude protein. The tree is also used for fuelwood. The timber is of good quality. Its bark contains as much as 27 percent tannin. Babul' gum is used for manufacturing matches, inks, paints and in confectionery (Parkash and Hocking, 1986). The tree is planted by farmers in compact blocks to reclaim salt- affected land (Sheikh, 1986).

Acacia Senegal ('Khor'): Family: Leguminosae; Common name; 'Khor'. It a small to medium sized thorny tree that grows up to 13 m in height. Bark is pale greenish grey, smooth on older stems, and falls off in thin flakes. Leaves are pinnate with pinnae in 3-5 pairs; stipular spines 3, compressed slightly recurved. Flowers are fragrant; if produces flat pods 2-

3 cm by 3 cm that are straight (Khan, 1965). It is found in dry rocky hills of Sind, Punjab and Baluchistan (Khan, 1965). The species is also found throughout the Sahelian zone from Senegal to Somalia. It is cultivated in Pakistan, India and Nigeria (NAS, 1983).

Khor' grows under sub-desert conditions where annual rainfall is as low as 200 mm, with 8-11 dry months in a year, but prefers 300-450 mm rainfall. In the Tharparkar Desert the tree grows where temperatures range from -4 to 48°C. It can survive the most adverse conditions; hot, dry winds and sand storms on the poorest soils of rock and sand. This species is ideal for the reclamation of refractory sites and shifting sand dunes (NAS, 1983).

Khor' is easily raised from seed. Its natural regeneration in existing stands is often poor but it regenerates easily in fallow lands and some degraded soils, often from stump coppicing. Planting of 2-year-old nursery raised seedlings is quite successful. For effective germination, seed should be soaked in water for 12 hours before sowing.

Khor' provides excellent firewood and charcoal. Average production of wood from natural forests is about 5 m3 per ha (NAS, 1983). It provides gum used in feeds, beverages, pharmaceutical preparations, confectionery products and other industrial applications. The species fixes nitrogen and improves soil fertility. It is highly suitable for agro-forestry systems. Mohammad and Naz (1985) recommended this species for planting in the arid and semi-arid desert plains of Pakistan. The foliage and pods of Khor' are rich in protein and are an important feed during the rainy season and early dry season for camels, sheep and goats (NAS, 1983).

Acacia Tortilis ('Jangli Babul'): Family Leguminosae; Common name Jangli babul. It is a small thorny tree 4-20 m high; its evergreen forage has white to creamy flowers. Fruiting starts at the age of 6-8 years. It is native to North Eastern African deserts, the Middle East, and southern Arabia. It grows in savanna formations or as a single tree on the edges of the depressions where water collects from the hillsides. It has been extensively planted in the arid lands of India (Parkash and Hocking, 1986). Sheikh (1986) reported successful forestation of jangli babul' in the desert rangeland of Thal at Dagar Kotli and at Dhabeji by applying special rain-water harvesting techniques. The plants can also be established by the pitcher irrigation technique (Sheikh, 1986). The tree is found in extremely dry climates receiving less than 100 mm rainfall. Sheikh (1986) reported that *A. tortilis* is a valuable addition to the known tree species that can be planted in desert areas where rainfall is 200 to 350 mm. It can survive maximum temperature exceeding 50°C and minimum temperature of close to 0°C. It regenerates from seed and coppices. It grows up to an altitude of 900 m. It favours alkaline soils with a pH of 7.95 to 8.30 (Parkash and Hocking, 1986). It is sensitive to frost and even 3-year-old trees around Peshawar died due to exceptional frost during the winter of 1982-83 (Sheikh, 1986).

Jangli babul' can be propagated by seed sown in pits during July-August. However, planting seedlings raised in polythene bags during the

monsoon is more successful. To stabilize sand dunes, 6-9 month-old seedlings are planted along mulched lines and watered 5-6 times during the first year (Parkash and Hocking, 1986). It yields about 15,000 seeds per kg. Germination is 40 percent, if seeds are not attacked by insects. Seeds are germinated in receptacles after soaking in water for 24 hours.

Leaves and pods of jangli babul' are fed to sheep, goats and camels. Foliage yield of 100 kg per tree has been recorded in Rajasthan at Central Arid Zone Research Institute, Jodhpur, India. It has a high calorific value. Its timber is used for fence posts, agricultural implements and building materials. It is extremely valued for sand dune stabilization, as wind breaks and for planting in the desert and arid lands of Pakistan. Highly eroded areas in Pothwar Plateau have also been planted to this species (Mohammad et al., 1985). In trials at CAZRI, Jodhpur, *Acacia tortilis* grew twice as fast as indigenous acacias and that the plant withstood arid conditions better than *Acacia nilotica, Acacia senegal* and the local *Prosopis species* (NAS, 1983). No insects or diseases in Pakistan attack the tree (Sheikh, 1986).

Albizia Lebbek (Siris): Family: Leguminosae; Common name: Siris'. It is a large deciduous tree, with dark-grey irregularly cracted bark. It produces a spreading umbrella of feathery foliage. It may reach 30 m in height and a diameter of 1 m. It produces whitish, very fragrant flowers in pedunculate heads with striking green stamens. Pods 15-30 x 2.5-5 cm are flat and rounded on both ends (Khan, 1965).

Siris' is one of the best known trees in Pakistan, India, Bangladesh, Nepal and Burma. It is also cultivated in North Africa, the West Indies and South America. There are extensive plantations in Nepal and in Central and South India (NAS, 1983). It grows to an altitude of 1200 m in Pakistan and is cultivated everywhere in the plains. Its pods are conspicuous during most of the year because thay hang on the tree long after they are ripe and throughout the hot weather when the tree is bare of leaves. When rattled by the hot winds, the pods sound like frying fish; hence, the tree is known in West Indies as the Fry Wood (Khan, 1965).

Siris' grow very fast but young plants are frequently killed by frost. It is frequently grown in the dry region on a variety of soils. Seedlings do not tolerate heavy shade and suppression and are drought and frost tender (Khan, 1965). It prefers moist conditions and grows best in well-drained loam soils. The trees tolerate salt spray and grow near the seashore (NAS, 1983). It is a prolific seed producer and is easily propagated by seed, even by direct sowing. Seeds remain viable for 4 to 5 years at ambient temperatures. It can also be propagated by stem cuttings or root-shoot cuttings. The root suckers sprout vigorously when roots are injured, (NAS, 1983). The growth of the tree during first year is exceedingly rapid. In Sukkur, a girth of 1.5-1.82 m was measured at 17 years (Khan, 1965). It produces 1-3 rings per 2.54 cm radius. Troup (1921) reports 3-4 rings per 2.54 cm. It can grow on calcareous as well as saline soils and has coppices well (Khan,

1965). Before sowing, seed should be immersed in boiling water and allowed to cool and soak for 24 hours. Germination is 50-90 percent (NAS, 1983). Misra and Singh (1981) found that seed scarification with concentrated sulphuric acid increased germination by 50 percent. Muthana et al., (1976) reported that transplanting 9-12 month-old seedlings increased survival and average tree height than direct sowing after 12 years.

Seedlings need to be regularly weeded during the first 2 years because they can be destroyed by browsing animals. The tree does not withstand wind as its roots are close to the surface. It is planted on avenues and to control erosion. In India, in a region receiving 400 mm of rainfall, siris' was successfully established in shifting sand dunes and in a shallow soil, 22.5 cm deep overlying hard calcareous pans (Kaul and Chand, 1979).

Young foliage of siris' contains 20 percent protein and is fed to livestock. One tree, may provide 20 percent of a buffalo's annual feed or 27 percent of the feed required by a cow (NAS, 1983). It is reported to be a well-known leguminous fodder tree with very palatable leaves (Negi, 1977). Chemical composition (percent of dry matter) and digestibility of its leaves has been rated by Prinsen (1986) as excellent. He reported that Indian siris' has potential in Queensland, Australia. It produces many leaves, which are shed during winter. Wood of siris' is dense (specific gravity, 0.55-0.6) and a good fuel. The calorific value of moisture free heartwood is excellent. Wood is also used for agricultural implements.

Artocarpus Integrifolia (Kathal): Family: Moraceae. Common name: Kathal'. It is a large evergreen tree with dense crown. It has dark brown bark and long, smooth leathery leaves. Fruits are long with a rough surface of conical tubercles. Other species are *A. chaplasha* and *A. lakoocha,* which are deciduous. Lakooch have small fruits, which are not tubercle. All the three species are found in northern Pakistan, India, Nepal and Bangladesh. They are propogated by fresh, perishable seed The species are fast although growing seedlings grow slowly. The fruits are eaten by wild mammals and birds and are heavily lopped for fodder.

Bauhinia Variegata (Kachnar): Family: Leguminosae; Local name: Kachnar'. It is a medium-sized deciduous tree with a spreading crown and reaches a height of 10 m and a diameter of 50 cm. Bark is grey. Young shoots are brown and pubescent. Leaves are 10-15 cm long. Flowers are large, white or purplish and appear when the tree is leafless. Pods are 6-12 2-3 cm long,hard and flat with 10-15 seeds. The tree is leafless for a couple of months during winter. Flowering takes place during spring (Khan, 1965).

Kachnar' grows in Pothwar Plateau and in the Himalayan foothills up to an altitude of 1500 m. It is also widespread in northern India and in the Terai areas of Nepal. The annual rainfall requirement is from 500 to 2500 mm with extreme temperatures (maximum 40-47°C and minimum below zero). It grows on a wide variety of soils; from gravelly soils on mountain

slopes to sandy loam soils in the valleys and plains.

Kachnar' can be reproduced from seeds. Natural regeneration is also common in eroded areas in the Pothwar Plateau. Nursery raised seedlings spaced a 3 m intervals can be planted during monsoon in pits. Seedlings are adversely affected when roots are disturbed. It is usually grown in cultivated areas. No compact plantations are found in Pakistan. It is also planted in cities as an ornamental tree.

Leaves, flowers and fruits are eaten by goats, sheep and cattle. Average annual fodder yield per mature tree is 15-20 kg dry matter (Parkash and Hocking, 1986). Its fruits and flowers are cooked for human food, and have a high calorific value. The timber is used for agricultural implements. The bark contains tannins. Its decoction is used for diarrhea control and as an astringent and tonic. Seeds contain 16.5 percent of a pale yellow fatty oil (Parkash and Hocking, 1986).

Celtis Australis (Tagho) : Family: Urticaceae; Common name: Tagho', Kharik'. It is a middle-sized deciduous tree that attains a height of 9-15 m. Bark is bluish-grey or brown, often with whitish streaks. Leaves are ovate sharply and coarsely serrate. It is found in the Sulaiman range, Trans-Indus, Salt- Range and Himalayas, at altitudes up to 2500 m from Indus to Bhutan. It is also found in Afghanistan, western Asia and the mediterrarean regions. It has been frequently planted in Punjab, N.W. Himalaya and in Sind and Baluchistan. Natural plants are common in Swat, Murree, Abbottabad and Neelam Valley. Tagho flowers in March to May, before leaves appear or with first the leaves. Fruits appear from July to September. Its trunk is short and straight and grows quickly (Khan, 1965). The tree is often planted to provide cattle and goat fodder. It is also cultivated for oars and tool handles.

Elaeagnus Angustifolia (Russian Olive): Family: Elaeagnaceae; Common name: Russian olive'. It is a medium-sized deciduous tree whose leaves drop late. Leaves are greyish on the upper surface with scattered scales and the free portion of the perianth tube is campanulate (Khan, 1965).

Russian olive is native to southern europe, western and central Asia and the Himalayas. In Pakistan, it is extensively cultivated in the northern areas and Baluchistan. It requires considerable sunlight and can withstand poor soils but is not suited to water-logged areas. It grows up to 3000 m. For propagation, 1-2 year-old rooted plants, produced in nurseries, are used. Cuttings are also planted. Recommended spacing is 2.15 x 2.15 m. Irrigation is needed for first 4 years of establishment. It is used for timber. Leaves are used as hay for winter feed. Fruit berries are edible. Bark is used for tannin.

Grewia Optiva (Grewia): Family: Tiliaceae. Synonym: G. oppositifolia; Common names: Grewia', Dhaman', Bihul'. It is a medium-sized

tree with a spreading crown that reaches a height of 12 m and about 30 cm in diameter. It is semi-deciduous and flowers during spring; its fruits ripen in early fall. The tree is common in the Himalayan mountains of Pakistan, India and Nepal. It occurs at altitudes between 100 and 2000 m. It grows in sub-tropical humid zones where temperatures are relatively low and annual rainfall is from 1200 to 2500 mm. It can grow on a variety of soil types. However, sandy loam with adequate moisture is more favourable for its growth. It is fairly drought resistant and tolerant to frost.

Natural reproduction in grewia' is rare and the tree is propagated by direct sowing of nursery raised seedlings in containers during the monsoon. It is not grown as a regular forest tree but is mostly cultivated along agricultural fields.

Leaves of grewia' are very palatable and the trees are heavily lopped during winter when there is a shortage of green fodder in the hills. Its leaves are as nutritious as berseem, alfalfa or cowpea (Singh, 1982). Foliage yields up to 30 kgs/tree can be obtained from 2-year-old plants; leaf fodder yields as much as 11 t/ha were reported by Singh (1982). However the wood is not usually burned because it has an unpleasant odour. However, it is hard and heavy (800 kg/m3) and good for agricultural implements (NAS, 1977). The inner bark is used for rope making. The wood can be used for pulp and paper.

Leucaena Leucocephala (Ipil-ipil): Family: Leguminosae; Common name: Ipil-ipil: It is either a tall tree or a many branched shrub. It is semi-evergreen with feathery leaves, white flowers and large bunches of pods. It is indigenous to Central America and has been introduced widely in many tropical countries such as Australia, Philippines, Indonesia, Pakistan and India. There are more than 100 varieties of this species (NAS, 1977). In Pakistan K-8', K-28' are extensively planted in the Pothwar scrub ranges, along highways in Punjab and under dry conditions at Dhabeji, Sind. It requires considerable rainfall (600 - 1700 mm) but with irrigation it has been successfully planted in low rainfall areas of Sind receiving less than 300 mm of rainfall. With irrigation, the plants can be established in very dry areas. It can survive in high temperatures (45°C) and is found at altitudes up to 1000 m, grows well in neutral to slightly alkaline soils (pH up to 8) and is frost tender.

Ipil-ipil can be propagated by seed and coppice. Coppice growth is faster than that of seedlings. Its seed is broadcast in raised beds or in containers. Seedlings are planted during spring or summer rains. In a fuelwood plantation, a 2-3-year rotation is maintained. Shrubby plants are cut back to a height of 1 m for fodder production. By cutting close to the ground every 5 years it has remained in vigorous conditions for 55 years in the Philippines (NAS, 1977). At a spacing of 3 m it can contribute about 100 kg N/ha/year to the soil.

Because of its many uses, Ipil-ipil is known as a magic tree. Dry matter yield of 25-30 t/ha/year can be obtained by planting at 1 m spacing.

Leaves and pods are very nutritious. It is used for charcoal production. The timber is used for agricultural implements.

Morus Alba. (Mulberry): Family: Moraceae, Common name: Mulberry', Tut'. It is a medium-sized deciduous tree, which is both wild and cultivated. Teeth of leaves are uniform and usually blunt. The perianth of female flowers has four segments, which are glabrous or shortly ciliate. Fruits are ovoid, white or nearly dark red when not fully ripe (Khan, 1965).

Mulberry is native to China, central Asia and Himalayan region. Large irrigated plantations have been established in Pakistan, in newly reclaimed and cultivated areas in the Northern mountains and Baluchistan. It grows up to 3200 m. It is shade tolerant and a fast-growing species, usually planted as a under-storey in plantations. The tree can be easily established either from seeds or from cuttings. It coppices well. It is grown on shorter rotations of 16-20 years. For fodder and firewood, a spacing of 2.15 x 2.15 m is recommended (AKRSP, 1987).

Mulberry leaves yield a good quality fodder, which are dried for hay and fed to livestock during winter. Its fruit is dried and used as livestock feed and leaves are used for feeding silkworms. Its wood is used for furniture and sporting goods but it is not a good firewood. Wood yield from a 8-10 year coppice rotation is 7-l0 m3 /ha annually (AKRSP, 1987).

Olea Ferruginea (Kau): Family Oleaceae; Common name: Kau: It is

Plate 17. Ipil-ipil (*Leucaena leucocephala*) known for nutritious leaves and pods.

a medium-sized evergreen tree with grey bark. Leaves are 5-10 cm long, 1.27-2.54 cm wide and oblong. Flowers are whitish and bisexual.

Fruit is ovoid and 0.50 cm long (Khan, 1965). It grows in the foot hills of Himalayas, Pothwar scrub ranges, Kala Chitta hills, Sulaiman mountain ranges and in the Quetta-Pishin districts. It grows in association with *Acacia modesta* at altitudes between 500 to 2000 m with annual rainfall of about 500-1200 mm and prefers limestone rocky soils. The best growth is obtained on deep soils with sufficient supply of moisture (Singh, 1982). It is fairly drought resistant but susceptible to waterlogging and frost. It is propagated by direct sowing, rooted cuttings and root suckers. Its seed requires pre-sowing treatment of caustic soda or sulphuric acid to soften its hard endocarp. The leaves are valued as a nutritive fodder for cattle and they are believed to increase milk production.

Populus Spp. (Poplar): Family: Salicaceae, Common name: Poplar'. It is a medium-sized fast growing deciduous, single bole tree which reaches a height of 10 m. Bark is white, leaves are broadly ovate and green, and turn yellow before fall. New leaves appear in March. The Poplar' species present in the northern areas are *Populus nigra, P. alba, P. deltoides, P. euramericana* (hybrid poplar) *P. euphratica* and *P. ciliata.* The associated vegetation includes *Aesculus indica, Prunus padus* and *Cedrela serrata.*

Most of the poplars are native to Europe, China and the Himalayan region, including Pakistan, India, Nepal and Bhutan. These are also extensively cultivated in the irrigated plains of Punjab and NWFP and can grow up to 3200 m. The trees are mostly planted along water channels. For block plantation 2.15 x 2.15 m spacing is recommended. It can be propagated by cuttings made from 1-year-old wood preferably from stool or pollards (AKRSP, 1987). It is planted during the spring or summer rainfall seasons. Propagation of *P. alba* by suckers is more successful. Nutrient requirements are moderate but it can exhaust poor soil.

Poplars have moderate value as a fodder. Leaves are used for winter livestock feeding in the northern areas. Firewood quality is poor. Timber is high, soft and easily worked. It is used for furniture, packing material, matches and poles.

Prosopis Juliflora (Mesquite): Family: Leguminosae; Common name: Mesquite. This thorny semi-deciduous, large-crowned and deep rooted tree may grow to 10 m or more depending on the variety and site. The leaves are dark green. Leaflets (10-15 pairs) have mid-ribs near the centre. The long fleshy pods are straw-coloured when ripe. Flowers are pale cream-coloured in auxiliary spikes. It can grow upto 1500 m above sea level and thrives where annual rainfall is 200 mm (Sheikh, 1986). The species is native to Central and South America. The other species of mesquite is *P. glandulosa.* The tree has been planted in many arid zones of the world. It is widely propagated in Africa and Asia, particularly in India (NAS, 1983). It was introduced in Pakistan in early fifties, mainly for to stabilize dunes

and for fuelwood. Excellent plantation research has concerned its ability to stabilize sand dunes in Pasni and Gwadar in Baluchistan. The tree grows on a variety of soils but does well on sandy soils and can grow on rocky terrain provided its roots do not face competition.

Mesquite grows fast on a 15-year rotation with an expected yield of 75-100 t/ha which may be 50-60 t/ha with a 10-year rotation (Sheikh, 1986). It is reproduced easily by root-suckers and seed. The tree coppices readily. To overcome seed-coat dormancy, its seed must be mechanically scarified and either treated with 20 percent sulphuric acid for 1 hour or soaked in concentrated sulphuric acid in about 20 minutes, or covered with boiling water and allowed to cool and soaked for 24 hours in water (Sheikh, 1986). It is an aggressive invader and is a nuisance in irrigated plantations. This is a species to be tried only in very arid problem sites; elsewhere, may cause severe problems (NAS, 1983).

Mesquite wood is hard and heavy with a specific gravity of 0.70 or higher and is excellent for firewood and makes superior charcoal. Because of its high caloric value, the wood has been termed "wooden anthracite". It burns slowly and evenly and holds heat well (Sheikh, 1986). The tree is also valued for shade, timber and forage. The pods are eaten by livestock and may also be ground into flour for human consumption. It is planted where other more valuable forest species cannot be grown (NAS, 1983).

Prosopis Cineraria (Jand): Synonym: *P. specigera;* Family: Leguminosae; Local name: Jand, Kandi. It is a medium- sized thorny tree, 10-18 m high and about 60 cm diameter, with an open crown. It is leafless for a short period before flowering. Creamy white flowers appear in spring while leaves are light green. It grows in the tropical desert rangelands of Thal, Cholistan, Tharparkar, Kohistan and in the lowlands of Baluchistan and Pothwar Plateau. Scattered trees are also found in cultivated areas, along roads, canals and railway tracks (Mohammad, 1984). In India, it occurs in the arid lands of Rajasthan, Haryana, Punjab and the southern states. It also occurs in Iran, Afghanistan and Arabia (NAS, 1983). In Pakistan, it is associated with *Acacia nilotica, Salvodora oleoides, Zizyphus mauritiana* and *Calligonum polygonoides.* It requires 75 to 850 mm of moisture and tolerates high temperatures up to 50°C. Sheikh (1986) reports that jand' is found throughout the plains of Punjab and Sind in areas receiving less than 300 mm of rainfall. He further reports that in wild lands, 'jand' usually attains the girth of 1 m with an average height of 7-8 m. Jand' is a tropical tree growing in a wide range of soils with sufficient sub-soil moisture. It is drought, salt tolerant, and tolerates pHs as high as 9.8.

Propagation of Jand' is done by seed, root suckers and coppice. The seeds remain viable for 2 years, germinate after 10 days of sowing (Sheikh, 1986). Two to 3-year-old seedlings raised in polythene bags are planted during monsoon. Natural regeneration by seed is confined to moist depressions and along river and stream channels. Direct sowing of jand' in mixture with *Cenchrus ciliaris* has also been successful in Thal ranges at Dagar

Kotli (Mohammad, 1987). Since very few pure stands of jand' are maintained in Pakistan, no specific silvicultural system has been prescribed. In India, clear felling when trees are 30-40 years old is followed by coppice regeneration (Parkash and Hocking, 1986).

The tree is lopped for pods and fodder. Leaves and pods are browsed by goats, sheep, cattle and camels. Foliage yield data are not available in Pakistan. However, dry matter yield of 60 kg from leaves and pods per tree has been reported in India by Singh (1982).

Srivastava (1978) reported that annual lopping of trees results in maximum forage yield without detrimental effects on growth. It has also been observed that yield of forage from trees having girth less than 45 cm is lower, thereby suggesting a lower girth limit when trees should be lopped. Complete lopping significantly decreases leaf fodder yield compared to lopping two-thirds and one- third of the crown (Bhimaya et al., 1964). There is a substantial decrease in the forage yield as a result of recurrent lopping and trees should be given some rest between successive loppings to sustain forage yield (Srivastava, 1978). Its wood is an excellent fuel. Sheikh (1986) reported that the expansion of canal irrigation in the desert areas, is associated with a gradual disappearance of the tree as it is a good firewood and makes fine charcoal. Its timber is very strong and hard and durable and is used in construction, agricultural implements, tool handles and shafts (Parkash and Hocking, 1986).

Quercus Leucotrichophora (Banoak): Synonym *Q. incana;* Family: Fagaceae; Local name: Banoak. This medium-sized evergreen broad-leaved tree attains a height of about 10 to 15 m and a diameter of 60 cm. Leaves are 6-15 cm long, oblong or ovate lanceolate acuminate, sharply serrate, and dull green. Bark is grey to greyish brown, and is longitudinally and transversely cracked.

Banoak' is a common climax tree of the moist temperate and subtropical humid forests in the Himalayas. It occurs at altitudes between 1300 to 2600 m, with annual rainfall of 1000-1800 mm and moderate temperatures. It grows on a variety of geological formations, including shale, gneiss, mica schist, quartzite and limestone. It is frequently found on clayey soil. It usually grows gregariously on all aspects but attains its largest dimensions on cool northerly aspects with deep moist soil. The associated vegetation of 'banoak' includes *Cedrus deodara, Pinus wallichiana, Pinus roxburghii* and *Rhododendron sp.* of broad-leaved trees. Among its common companions are *Populus ciliata, Acer oblongum, Ulmus wallichiana, Alnus nepalensis,* etc. It is a very useful nurse tree to the deodar on hot slopes. Mixed forests of banoak' and chirpine are particularly common. It is sensitive to drought (Parkash and Hocking, 1986).

Banoak' is reproduced by seed, and coppice. Natural regeneration is possible if wildlife damage is prevented as acorns are relished by bears, monkeys, squirrels, rats and birds. Planting of 3-4-year-old nursery raised seedlings is quite successful during the monsoon. In Kangra (India), broad-

cast sowing after hoeing the soil without breaking the clods has also been successful (Parkash and Hocking, 1986). The silvicultural system followed for the management of the natural forests is coppice with standards (Singh, 1982). Establishment techniques for other species of the genera are similar. In Nepal, acorns are collected beneath the mature trees during October-November and sown immediately into a raised bed. These are pushed 1 cm into the soil with the point of the acorn facing upwards. The bed is then covered with a 1-2 cm layer of leaf litter or well-rotted compost. The seedlings are put into containers when the first leaves appear; then left to grow further for 18 months before planting out. The lopping of trees may not be allowed during plant establishment.

Oak trees are extensively lopped for fodder in all countries of the Himalayan region during the winter. Continuous lopping is harmful, so, rotational lopping on a 3-4 year cycle has been suggested by Parkash and Hocking (1986). A mature tree can yield about 20-25 kg of leaves annually. Banoak' is extensively cut for fuelwood (Parkash and Hocking, 1986). Timberwood is very hard and heavy and is used for construction, agricultural implements and furniture manufacturing. It contains useful tannins. Leaves provide material for rearing silkworm.

Robinia Pseudoacacia (Ain ul Asal): Family: Leguminosae; Common names: Robinia, Black locust. This short fast-growing deciduous tree has white and fragrant flowers that appear in April and fruit pods that mature in September-October. Leaves are 10-15 cm long; petioles are swollen at the base. Stipules become nearly straight or slightly curved with up to 2 cm long-leaflets, 9-20 opposite or sub-opposite. Flowers are white while pods are as long as l0 cm.

Robinia is indigenous to North America. In Pakistan, it has been planted in Tarbela and Mangla watersheds, in Kaghan and Neelam valleys and along the Karakorum highway. It grows well at altitudesbetween 1000 to 2000 m receiving 700 - 1500 mm annual rainfall in relatively cooler climate. It prefers well drained deep soils with adequate soil moisture and is capable of growing on soils with pH ranging from 4.6 to 8.2 (Singh, 1982).

Robinia is normally propagated through seed. Vegetative reproduction is also easy. About 8-10 month-old seedlings are planted out during the monsoon in pits. Naked root plants can also be planted (Singh, 1982) but it is preferred to have soil intact seedlings grown in polythene bags. No silvicultural system for this tree has been prescribed in Pakistan and India.

The leaves of robinia' are highly palatable. It is very useful for erosion control and coppices easily to form a protective hedge plant. It produces fuelwood of high quality. Timber is used for agricultural implements. The bark contains tannins. The tree has attractive flowers and is also grown as an ornamental plant along roadsides. It enriches the soil through nitrogen fixation. The tree is also used for shelterbelts and sand dune stabilization. In certain cases, roots, bark, sprouts, seed pods and

trimmings are reported to be poisonous for animals (NAS, 1983).

Salvadora Oleoides (Wan): Family: Salvadoraceae; Local name: Van, Piloo. It is a shrub or small-sized tree with drooping branches, an evergreen, which reaches a height of 4 m. Flowers are yellow to greenish white and its sweet fruit ripens in June. It is a tropical shrub indigenous to India and Pakistan and is extensively found in Thal, D.G. Khan, Cholistan, Tharparkar and the Salt Range scrub ranges. It is a climax species of the Indus Plain. It is also found along railway tracks and abandoned fields. It is associated with *Prosopis cineraria, Capparis aphylla* and *Tamarix aphylla.* Wan' is a species of the desert, highly drought resistant and can grow in saline areas. It withstands extreme temperatures and can survive with little rainfall (180 mm). It occurs at altitudes up to 900 m and performs well on

Plate 18. Black locust (*Robinia seudoacacia*) planted for soil conservation and fodder in the Himalayas.

medium and fine textured soils such as sandy loam and sandy clay loams (Parkash and Hocking, 1986).

Wan' is reproduced through seed, coppice, root suckers and by natural layers. However, natural regeneration is not very successful where rainfall is low. During seedling establishment, tree shade and protection from livestock grazing is desirable. *Capparis aphylla* acts as a mother plant for the establishment of seedlings.

No research has been conducted on its establishment procedures in Pakistan. The trees are being replaced by *Cenchrus ciliaris* and fast-growing trees such as Acacias. In India, forests containing wan' are managed by the coppice with standard system on a coppice rotation of 40 years (Parkash and Hocking, 1986).

Wan' is browsed by camels, goats and cattle throughout the year. It provides good foliage during the winter and a mature tree can produce as much as 20 kg/year. Although it is a poor quality fuelwood, it is being uprooted in Thal for use in brick kilns.

Sesbania Sesban ('Sesban'): Family: Leguminosae; Common name: Sesban', Jantar'. It is a fast-growing, small to medium sized tree that reaches a height of 6 m. It is coppiously branched with pinnate leaves, pale yellow flowers and slender, slightly twisted seed pods as long as 25 cm long, containing 20-30 seeds (NAS, 1983). It is reported to be among the first garden plants grown in Egypt. It is now widespread in tropical Africa and throughout tropical Asia. It has three varieties and is commonly cultivated in the Punjab and Peshawar areas (Khan, 1965). A stem growth of 5 m in 12 months has been reported and a yield of 75 t/ha (10 percent moisture) in 1 year was recorded in India (NAS, 1983).

Sesban' grows at altitudes of 300-500 m in Pakistan. In India, it is grown throughout the plains and up to an altitude of 1200 m. It requires 300-1000 mm rainfall. In Pakistan, the tree tolerates temperatures from 10°C to 45°C. It tolerates a wide range of soil conditions and withstands acid soils, periodic flooding and waterlogging. It can endure 0.4-1.0 percent salt concentration in the seedling stage and 0.9-1.4 percent near maturity (NAS, 1983).

Sesban' can be grown either by direct sowing or by raising seedlings in polythene bags and then planting the afte 6 months. No pre-sowing treatment is required. However, the area under cultivation must be protected from cattle, because its forage is palatable and is subject to browsing. It has saveral uses. In Bihar, the flowers are eaten as a vegetable. The leaves are eaten in Thailand. The seeds, high in protein (33.7 percent), are eaten during famine in India. In Senegal, the stems are used for arrows and pipes. In India and Pakistan, stems are used as roofing for huts and the plant is cultivated as a substitute for bamboo. In India, Sesban is extensively planted as a windbreak and shade plant for vegetables, betel, vines, coffee, turmeric and cotton. In Pakistan, it is planted as an intercrop for soil improvement because it is usually rich in nitrogen. In India, it is often

grown as green manure in both dry and wet rice fields (NAS, 1983). It also provides a good fodder. Branches and leaves are fed to cattle.

Tamarix Aphylla (Frash): Synonym: *T. articulata;* Family: Tamaracaceae: Common names. Frash, Ghaz. This medium- sized, fast growing tree has an erect trunk and rough bark. Branches are articulate at the base of the sheath. Its leaves are sheathed and flowers are white during May-September (Khan, 1965).

Frash is native to the Indus plains in Sind, Punjab and tropical desert areas in India. It also grows in Afghanistan, Iran, Arabia and North Africa. It is a tree of the desert with high salt and drought resistance. It occurs as a pioneer species along river beds. It is associated with *Prosopis cineraria, Salvadora oleoides* and *Capparis aphylla.* It grows in areas receiving 350-500 mm rainfall and where temperatures vary from -5 to 50°C.

Frash can be reproduced from seed. Plants can be raised from seeds in polythene tubes. It coppices well. It is planted during the monsoon. For fuelwood, a 25-year rotation is practised. The species has been planted for sand dune stabilization in Mastung (Baluchistan). Roadside plantations are also found in Thal, near Peshawar and in Sind.

Frash is browsed by camels, goats and sheep. Timber is used for handicrafts, furniture and fruit boxes. It produces low quality firewood. The species provides excellent windbreaks in arid zones.

Zizyphus Mauritiana ('Ber'): Family: Rhamaceae; Common name: Ber'. It is a small to moderate-sized deciduous tree with a short bole, spreading crown and sweet fruits. It reaches a height of 10 m and a diameter of about 30 cm. The branches often droop and are armed with stipular spines. Leaves are velvety tomentose beneath and glabrous above. Flowers are greenish yellow, fruit a drupe yellow orange becomes red when mature (Khan, 1965). The old leaves fall after March-April and new leaves appear at the same time. Flowers appear from April to October and the fruit ripe from December to March (Sheikh, 1986).

Ber' is indigenous to Pakistan, India and Nepal. It grows at elevations up to 1800 m in Pakistan (Khan, 1965). It is a tree of tropical arid lands in the Indus plains and Baluchistan lowlands. It is associated with *Capparis decidua, Prosopis cineraria* and *Acacia nilotica.* It is highly drought resistant, needs little rainfall (125-500 mm) and can tolerate extreme temperatures in the range of -5 to 50°C. It can grow on a variety of soils but prefers deep sandy loam or slightly alkaline soil. Sheikh (1986) reported that ber' easily recovers from injury of any kind, including fire.

Ber' can be raised easily by direct seeding. Cultivated varieties are propagated by budding or grafting on to wild seedling rootstocks. Natural regeneration through coppice and root suckers is also quite successful and reliable (Parkash and Hocking, 1986). Normally, no seed treatment is needed for raising seedlings in the nursery. It is planted during spring, summer and monsoon seasons. It is readily browsed by goats and is a good

camel fodder. The branches and leaves are lopped for cattle fodder (Sheikh, 1986).

There are no large plantations of the tree in Pakistan. As soon as the tree starts growing it is lopped for fodder and very few young plants are allowed to mature (Sheikh, 1986). Ranjhan (1977) reported that ber' leaves are an important feed for goats and sheep in the arid lands of India and are more palatable than *Ficus religiosa* leaves. Young branches and leaves are lopped for cattle, goats and camels. Leaves are also used to feed silkworms. Bark contains tannin. The fruit is eaten fresh. The tree acts as a host for the lac insect. It is an excellent fuel with a high caloric value. Its timber is heavy and hard and is used for house building, agricultural implements, oil crushers, golf clubs, toys, tourney and pencils.

FORAGE LEGUMES

Legumes are an excellent source of feed for livestock. They also improve soil fertility by hosting nitrogen fixing bacteria. Potential of legumes as forages has not been fully explored in Pakistan. Promising forage legumes are being introduced in different ecological zones through the PARC sponsored National Forage and Pasture Programme. During the past 12 years, a few promising varieties of alfalfa, vetches, clovers, annual medics and cowpeas have been selected. A few important forage legumes are described below:

Medicago Sativa: (Lucerne or Alfalfa): This is an erect to sub- erect, widely grown herbaceous perennial legume. The plant is 30 to 60 cm high. The leaves are trifoliately pinnate and are arranged alternately on the stem. Leaflets are 3 to 10 mm broad. There are 5 to 25 or more stems per plant that arise from a woody crown, from which new stems grow when the older ones become mature or are cut. The inflorescence is a pedicellated raceme with various shades of purple, yellow and white flowers. The root is a distinct tap root system, which may penetrate into the soil up to 8.0 m. The fruit is a loose spiral of 2 - 4 turns, glabrous, with 10 - 20 kidney shaped seeds (Ali, 1977).

Cross pollination in lucerne is necessary to produce good quality seed. Harvesting is a critical problem because all the seed does not mature at the same time. Harvesting occurs when two-thirds of the flowers turn dark brown. The seed shatters readily, so the crop should be handled carefully.

Alfalfa has the highest feeding value and digestible protein of any forage. It has high mineral content and contains vitamins, especially vitamin A. For these qualities alfalfa is called "Queen of Forages" and is an excellent pasture for cattle. It generally intercropped with crops for pasture and hay. It is also improves the soil crop and is used in rotation for its beneficial effect on succeeding crops like wheat, barley and sorghum (Hughes et al., 1969).

Lucerne is found all over the world and is well adapted to a wide

range of ecological conditions and soil types. It is very well adapted to fertile soils in dry climates with adequate moisture. It is also adapted to humid climates with good fertilization and adequate cultural practices and is relatively tolerant of moderate alkalinity. However, it does not grow well on very alkaline soil. It also tolerates drought but becomes dormant during prolonged drought and resumes growth when more moisture is available.

Alfalfa is sown in the fall, preferably in October, at a seeding rate of 15 - 20 kg/ha. Seed should be about 1 cm deep in the soil. The crop should be cut at one tenth flowering stage. High quality hay is also produced at this stage. On the other hand, late cutting reduces the crude protein content. The number of cuttings per year varies from one in very dry areas to six under irrigated conditions. However, 3 - 4 cuttings is normal. Seed production of alfalfa has been a serious problem. For seed production, row spacing of 60 cm is better than broadcast.

Alfalfa is a major fodder crop of the irrigated belt. Alfalfa is produced under rainfed conditions in a limited area. In the Northern Areas, hay of alfalfa is used during the winter. It is also extensively cultivated in Quetta and Mastung valleys under irrigated conditions. The National Forage and Pasture Programme in collaboration with Utah State University and is testing 52 improved varieties of alfalfa from the United States and Canada along with eight Pakistani varieties at Khawarmong, Jaglote, Islamabad and Mastung areas to select suitable varieties for different ecological conditions.

Plate 19. Lucerne (*Medicago sativa*) adaptation trials at National Agricultural Research Centre, Islamabad.

Trifolium Pratense (Red clover): It is erect to decumbent perennial herbaceous plant. Leaves are trifoliate and leaflets are 1.5 - 30 cm long with a characteristic light coloured marking in the centre of each; leaves are obovate to broadly elliptic and stipules are ovate-lanceolate. Purple flowers are borne on compact clusters at the tip of the branches. The number of flowers per head is highly variable. Pods are single seeded, short and break open transversely (Ali, 1977).

Red clover is widely distributed all over the world and is an important forage crop in Central Asia, Europe, New Zealand, Australia, the United States and Canada. Fertile, well-drained soils with relatively high water holding capacity are most suited for red clover. It prefers moderate summer temperatures and adequate moisture throughout the growing season. Its tap root system is branched and most of the roots are concentrated in the top 30 cm of the soil. However, it does not resist to drought. It can grow on moderately acidic soils but shows best growth at a soil depth of pH 6 provided adequate calcium is available. The nitrogen fixation ability of red clover is enhanced with proper inoculation. With high levels of soil fertility and plentiful supply of calcium and phosphorus, it becomes the most effective legume in the fixation of nitrogen from the air.

Red clover is grown in the spring at a seed rate of 8 - 10 kg/ha. When grown in mixture with a grass, 4 - 6 kg/ha is the usual seeding rate. For first year, clipping should be done in late summer to avoid weed competition and damage by mice. Red clover should be cut for hay slightly before or at full maturity. Best results are obtained by harvesting the crop at half flowering stage. Its seed production is quite difficult and depends on pollination by insects. Bumble bees are quite effective pollinators but they are not present in sufficient numbers to ensure a good seed crop. Honey bees collect pollen and also pollinate the crop. If the second crop is to be used for seed, of the first crop should be harvested early. Seed is harvested when stems are yellowish brown and heads have turned brown.

Red clover is valuable for hay, pasture and soil improvement. It sustains yields for 4 - 5 years (Hughes et al., 1969). It has a crude protein content of 21.5 percent at the pre-bloom stage; hay contains 9.8 percent protein (Gohl, 1981).

Red clover has been introduced in the Trans-Himalayan and Himalayan forest grazinglands. Noor (1981) tested red clover at Jaba. It has also been sown at Kalam, Swat valley, the Northern Areas, Neelam Valley and near Murree. Annual forage yield at Jaba, Kalam, Jaglote, Khawarmong, Islamabad and Peshawar was 4.2, 3.5, 4.3, 5.2, 4.1 and 4.5 t/ha, respectively.

Trifolium Repens (White clover): This is is perennial, prostrate, herbaceous plant roots at the nodes. Leaves are composed of three sessile leaflets which may be broadly elliptic to obovate rounded at the apex. The petiole of the leaf is long and the stipule broad at the base and sheathing. The flower heads are on relatively long stalks composed of a globose

raceme, borne in the leaf axils at the nodes of the stems. These are 15 - 25 mm broad containing 40 - 100 flowers. They are normally white but may have a pinkish tinge. The seed pod of a single floret may contain 1 to 7 seeds. The florets are mostly self-sterile and must be cross-pollinated for seed setting. The seed matures in 23 - 28 days. It is very small and 1 kg seed may contain 1.5 million or more seed. Seed is bright yellow and round with a hard seed coat (Ali, 1977).

White clover is native to Europe. It probably originated in the eastern mediterranean countries or in West Asia. Now, it is one of the most widely distributed legume throughout the world. The small seed, the hard seed coat, the long period of flowering, high palatability and seed dispersal by birds are the factors enhancing seed dissemination. Generally, white clover is best adapted to the clay and silt soils in a humid climate. It can also be successfully grown on sandy soils with relatively high water table and in areas where mineral fertilizers are applied.

White clover is a very important pasture legume, due to its high nutritional value and palatability, it is liked by all classes of livestock. When intercropped with grasses, it increases the production and protein content of the herbage. White clover is widely used for hay and silage when grown in mixture with other legumes and grasses. It also makes a good cover crop in orchards (Hughes et al., 1969).

Environmental requirements of white clover are similar to those of red clover. Forage yield at Jaba, Kalam, Jaglote, Khawarmong, Islamabad and Peshawar was 3.5, 3.1, 3.6, 4.2, 4.1 and 3.7 t/ha, respectively.

Vicia Sativa (Common vetch): This semi-viney annual herb has a decumbent, erect or climbing plant body. The leaves are pinnately compound with petioles less than 1 cm long. Leaflets are 1 - 4 cm long, 2 - 15 mm broad, linear to lanceolate, oblong to obovate. Stipules are 3 - 8 mm long and tendrils are generally branched. There are usually 1-2 flowers, rarely 3, which are auxiliary, subsessile, or shortly pedicellate and violet or purple. The fruit is 2.3 - 6.5 cm long, 4 - 8.5 mm broad, narrowly oblong and contains 6-12 seeds (Ali, 1977).

Common vetch is native to Europe, Asia and the mediterranean region. It is best adapted to well-drained fertile loam soils and can be grown on sandy soils if well fertilized. It requires comparatively cooler season to develop a good stand, especially for seed production. However, it is less winter hardy than the other vetches and often suffers winter damage.

Common vetch seed is sown during October at 40 kg/ha. Inoculation of seeds improves results. Seed must be carefully harvested because seed shatters readily. Thus, it should be harvested when the lower pods turn brown. Cutting at night, early morning or a cloudy day reduces seed losses. The crop is cut with a mower and is threshed when dry. Common vetch is used as a cover crop to help protect the soil from erosion. By adding organic matter, it improves the physical condition of the soil when grown as a green manure crop. It is palatable to livestock. Early maturity, long

periods of bloom and more cuttings make it suitable as a forage crop. Reseeding and by deferring grazing, will maintain a good stand. It is also intercropped with a number of grasses, e.g., oats, to increase forage yield and crude protein content. It can also be used as hay (Hughes et al., 1969).

Chapter 5

Rangeland Evaluation and Utilization - A Case Study

THE STUDY AREA

The Pakistan Agricultural Research Council (PARC), initiated a research project at Lohi Bher Range in 1983 to evolve and test a package of technology for the Pothwar Plateau rangelands. During the past 5 years, improvements were made in accordance with the prescribed land uses. The management model developed at Lohi Bher can be modified and used elsewhere.

Bio-Physical Environment: The Lohi Bher Range, covering about 435 ha, is located about 20 km south-east of Islamabad, between the Rawalpindi - Lahore and Islamabad - Lahore Highways above the confluence of Korang and Soan rivers. It is situated between latitudes 33°.33' and 33°.35' north and 73°.6' and 74°.8' east. The project area lies in the sub-humid subtropical continental highlands (Khan, 1971). The climate is characterized by hot summers and cold winters with substantial frost in January. The mean maximum temperature of the hottest in June is about 40°C while the mean minimum temperature in January is about 30°C. The mean annual rainfall recorded at Rawalpindi varies between 880 and 1000 mm, about 70 percent falls in summer (July, August and September) and the remaining (30 percent) falls in winter (December, January and February). Summer rains are torrential while the light showers occur during winter.

Physiography: Physiographically, the area consists of the following units:

Main physiographic unit	Sub-physiographic unit
Active river plains	Nearly level sand bars
Recent river plains	Level to nearly level plains
Subrecent river plains	Level to nearly level plains
Subrecent outwash plains	Level to nearly level plains, nearly level, dissected plains, undulating, dissected plains
Subrecent erosional surfaces	Nearly level to rolling plains rolling to hilly plains
Old river terraces	Highest, steep, dissected terrace lower, steep dissected terrace
Subrecent channel infills	Un-shaped channel infills
Scarp slopes	Steep slopes
Hill slopes	Steep slopes
River bed	

Soils: The soils of the study area have developed from three distinct materials viz., river alluvium, local outwashes and water reworked loess deposited in three different ages: recent, subrecent and pleistocene. The soils vary in colour from brown/dark brown to dark reddish brown and pale brown. The textural range of the first two materials is high and varies from sand to silty clay whereas the third component contains silt loam to silty clay loam. The soils formed in recent alluvium are stratified without any sign of profile development. These are moderately calcareous and their lime content is uniformly distributed in the soil profile.

The soils developed in subrecent and pleistocene deposits are homogenized, humified and moderately to strongly calcareous with a weak to strong zone of lime accumulation. The degree and depth of homogenization and humification as well as the lime content depends on the age of the soil. In subrecent soils, homogenization is less than 90 cm deep. The B horizon is weakly structured. Calcareousness is moderate without a definite zone of lime accumulation. In pleistocene soils the depth of homogenization exceeds 90 cm. The B horizon is moderately structured, strongly calcareous and there is a strong zone of lime accumulation in the sub-soil. However, in subrecent erosional surfaces, the lime zone is exposed on the surface and contains many medium kankars and semi- consolidated rock fragments, thus giving a desertic look to the landscape.

All the soils are non-saline and non-sodic with pH values from 7.8 to 8.2. The organic matter content of the soil is about 1 percent. The organic carbon ranges between 0.10 and 0.55 percent, the nitrogen content is 2.5 percent and the soil contains P_2O_5 20 me/l00 g.

The project area is drained by the Soan and Korang rivers, the former

flows outside the area to the south while the latter flows through the northern tip. A number of seasonal streams also drain the project area and ultimately join the Soan and Korang rivers near Sihala. In the depressions of these streams, water remains and provides drinking water for animals. A few perennial springs are also found near Dhok Jabbi and Dhok Jhaliar. These are the permanent source of water for the human population as well as for livestock. The ground water table in the area is deep (30 m). However, near Dhok Maii Nawab, it is higher than the rest of the area. Persian wheel wells are found only where the water table is shallow. Crops are cultivated under rainfed conditions.

Present Land Use: The total land of the villages around Lohi Bher Range is about 435 ha, of which 60 percent is cultivated and about 3 percent is covered by residential buildings. The remaining 37 percent is uncultivated due to either lack of manpower, low and uncertain rainfall, poor soil, irregular relief or patches of good soil. The crops raised in the area are mung, mash, millets and maize in Kharif and wheat and mustard during in Rabi. In Kharif, about 30 percent of the area is put to grain and legumes whereas 70 percent is grown to coarse cereals. Among legumes, mung and mash are the main crops while millets, maize and sorghum are the major cereal crops. Wheat is the major crop in Rabi. Area sown under wheat is about 91 percent. The remaining 9 percent is oilseed, out of which 6 percent is sarson and 3 percent taramira. There is severe shortage of livestock feed during the winter.

Currently, the crop production is very low due to the following reasons:

i. small farm size,
ii. traditional farming system,
iii. low and uncertain rainfall,
iv. application of insufficient fertilizer,
v. use of poor quality seed and,
vi. no plant protection.

The cultivated and uncultivated land by villages is given in Table 11.

Sometimes too little food is produced to feed the family, so farmers purchase grain from the market.

Socio-economic data of eight villages surrounding the project area were collected to determine the impact and dependence of the local population on the project area. All families in the villages were sampled and interviewed. The data collected are summarized in Table 11.

SAMPLING PROCEDURES

Before initiating field work, enlargements of air photo (stereo pairs at scale 1:5,000) were scanned. The study area was delineated on the photos into various naturally occurring range sites, each with a distinct physiography and vegetation. The criteria used for categories included drainage

Table 11. Socio-economic status of Lohi Bher Range 1983.

Human Resources		
Population:	Total population	744
	Number of families	93
	Average family size	8
Education:	Literacy	22%
	Primary	59%
	Middle	27%
	Matric	13%
	FA/BA	1%
Professional:	Working members of total population.	66%
Income	Average income per month/family.	Rs.1129
Livestock		
Population	Total population	838
	Buffaloes:	8%
	Cows:	39%
	Goats:	35%
	Oxen:	13%
	Asses:	5%
Marketing:	In markets:	17%
	In villages:	83%
Farming		
Land:	Total area:	435 ha
	Cultivated:	60%
	Uncultivated:	37%
	Under buildings:	3%
Cropping pattern:		
i)	Kharif	30%
	grain legumes	30%
	Sorghum and millets	70%
ii)	Rabi	70%
	wheat	92%
	mustard	8%

pattern, elevation, slope, erosional features, texture and pattern of vegetation cover. To measure the variation of vegetation and the associated soils, field traverses were marked on the air photos on all the range sites.

Vegetation Sampling: To determine plant communities from vegetation stands, homogenous areas were sampled in each range site. The number of samples was calculated prior to sampling depending on the size of each range site. Within each sampling site 5-10 Adjustable Decimalised Collapsible (ADC) quadrats (Khan, 1974) of a square metre were placed at 5 m intervals in a randomly selected direction to cover the entire variation of vegetation. In hilly areas, transects were laid downhill. Normally, vegetation data included plant species composition, total and species cover, litter and bare soil. Information about the palatability of each plant species by season and animal type, presence of stock watering points and possibilities of their development were also collected.

To determine the plant communities of different range sites, the data about abundance, frequency and relative composition for each species were entered in separate tables according to class numbers. Then, these parameters for each species were added and arranged in a descending order to determine plant communities.

Carrying capacity of a range site was estimated with the help of a quadrat 1 m square. All the palatable species inside the quadrat were clipped to 2.5 cm. For browse the young twigs were clipped up to a browsable height. The clipped material was dried under shade and dry weight was recorded. The averages of air dry weight of all the quadrats of different range sites were calculated. Using proper use factors for browse and herbage separately, the forage production for each range site was expressed in kg/ha. Grazing capacities for each range site were calculated and expressed in terms of animal unit days per hectare.

Soil Sampling: Soil samples followed the methods and procedures of the Soil Survey Manual (USDA, 1951) and the Guidelines for Soil Description (FAO, 1969) . Soil properties such as colour, texture, structure, consistence, calcareousness and pH of all the horizons in a profile were recorded. Soils were classified and mapped in terms of soil series, the basic unit in the natural system of soil classification. External features such as drainage, relief, slope, erosion, dissection, stoniness, rockiness, etc., were also recorded. The soils were then correlated with one another and were named after the place where they were first recognized.

Socio-Economic Survey: Basic data on the human population, socio-economic conditions, livestock population dependence on the range area to be managed were gathered to develop management plan.

RESOURCE EVALUATION CRITERIA

The FAO (1976) framework provides useful criteria for the evaluation

of range resources. Following the biophysical approach, the suitabilities of each landscape ecological unit for specified land utilization types are determined qualitatively and quantitatively. The set of land qualities considered important for plant growth in the area include moisture, nutrient and oxygen availability in the root zone, adequacy of foothold of roots, salinity and sodicity, workability of soils and possibility of arable farming. The set of land qualities used to determine suitability for the natural grazing of domestic animals and wildlife are forage production, palatability of plant species, distribution of watering points, quality of drinking water, accessibility to grazing areas, erosion hazard, shelter and protection. Each land quality is quantified according to field data as well as data from available reports, literature and maps. The rating of land qualities depend on the degree of limitations. Each degree indicates the extent by which the land conditions fall short of the requirements for a given use. Most of the land qualities have been estimated by measurable land characteristics or from other sources. Resource evaluation procedures have been discussed in detail by Baig (1978). A brief description of the land qualities used in resource evaluation is given here.

Moisture Availability: The availability of moisture to the plant roots is determined by measuring the soil moisture tension of an undisturbed soil sample. Three levels of moisture tension are saturation, field capacity and wilting point. The difference between the soil moisture content at the field capacity and at wilting point is the amount of water that is available to the plants.

Available moisture content is further dependent upon the texture, structure and depth of the soil (its amount and distribution), potential evapotranspiration, topographic form, run off, infiltration rate and supply from the ground water. The ratings suggested by Zaidi (1970) are given in Table 12.

Table 12. Availability of soil moisture in different soil textures at Lohi Bher

Rating	Soil texture	Moisture availability mm/m
I	Clay loams, silty clay loams and silty clays	180
II	Loams, silt loams and very fine sandy loams	120
III	Sandy loams	90
IV	Loamy sands and gravelly sandy loams	60
V	Sands	60

Capacity to Supply Nutrients: The ratings recommended by Vander Javie (1976) that were used to evaluate land capacity to supply nutrients are given in Table 13.

Table 13. Nutrient capability in different soil textures at Lohi Bher

Rating	Land characteristics					Texture
	Nitrogen %	O. C. %	P2O5	me/100g. soil CEC	K	
I.	0.04	0.55	Very high	20	0.4	Loams, silt loams, silty clay loams silty clays
II	0.03-0.04	0.45-0.55	High	10-20	0.3-0.4	Sandy loams, fine sandy loams
III	0.02-0.03	0.35-0.45	Moderate	4-10	0.2-0.3	Loamy sands, loamy fine sands
IV	0.01-0.02	0.20-0.35	Low	2.5-4	0.1-0.2	Sand with effective soil material.
V	0.01	0.10-0.20	Very high	2.5	0.1	Sand without effective soil material

Workability of Land: Soil consistency varies with different moisture levels, and therefore, so does its workability. The criteria used for workability (Vander Javie, 1976), any one of which may influence land quality independently, are given in Table 14.

Possibility of Arable Farming: The cultivation of most crops is limited to a certain slope to allow tillage, harvesting and irrigation and to reduce soil erosion. The following slope classes have been distinguished and are rated for irrigated and dryland farming separately (Table 15).

Accessibility to Grazing Areas: Accessibility is an important land quality affecting the potential of the grazing areas. If livestock are unable to enter the grazing area, its rangeland potential will be nil, irrespective of its high nutritive value. Accessibility to the grazing areas is directly related to slope, number of gullies and their depth, stoniness, rockiness and sandiness and differs for different animals. Goats and sheep can use rough grazing areas even with very steep slopes. Cattle prefer to graze in the intermountain valleys. However, when they are given free choice, they spend

Table 14. Workability criteria of Rangelands.

Rating	Stoniness and rockiness, % of surface coverage			Consistence of upper 20 cm.	
	Coarse	Stones	Rockiness	Wet	Dry
1	<3	>0.1	<10	Very friable, non-sticky, non-plastic	Loose
II	3-15	0.1-3	10-25	Friable, slightly sticky, slightly plastic	Hard
III	15-40	3-15	25-50	Firm, sticky, plastic	Very hard
IV	> 40	>15	> 50	Very firm, very sticky, very plastic	Extremely hard

Table 15. Suitability of slopy areas for irrigated/dryland farming.

Rating	Slope Percentage	
	Irrigated Agriculture	Dryland Agriculture
I	0–2	0–8
II	2–4	8–16
III	4–6	16–30
IV	6–8	> 30

most of their time on the flat areas. Goats and sheep can climb more than 100 percent slopes whereas camels have been seen on slopes up to 50 percent.

The steepness and length of slope influence the use of forage by domestic animals. Experiments carried out in 38 bunch grass areas in southern Idaho showed that 75 percent utilization was attained 32 m above the foot of a 60 percent slope, while the same utilization occurred about half a mile above the areas with 10 percent slopes. As accessibility differs for different animals, potential grazable area in each unit also differs for different animals. The available areas for grazing directly affect the stocking rate.

Erosion Hazard: Soil erosion refers to observable erosion whether man-made, from natural factors or a combination of both factors (Table 16).

Table 16. Erosion susceptibility classification of slopy soils

Rating	Slope	Soil	Erosion susceptibility
I	Flat to gently sloping (0–6%)	Deep to moderately deep gravelly clay loam	Low
II	Sloping to moderately steep (6–25%)	Moderately deep gravelly clay to loams.	Moderate to high.
III	Steep (25--55%)	Shallow to very shallow gravelly loams.	High to severe
IV	Very steep 55%	Shallow to very shallow and patchy gravelly loams.	Severe to very severe.

Slope classes are made according to Guidelines of Soil Description (FAO, 1969). The different types of erosion under different classes of slope are described in Table 17.

Shelter and Protection: This land quality particularly concerns to wildlife, which need shelter and protection from the climate and humans.

Table 17. Level of soil erosion with respect to slope percent.

a) Without vegetation cover, the slope classes are rated as under:-

Symbol	Description
– Low	No apparent or slight erosion Moderate loss of top soil generally and/or some dissection by run-off channels or gullies.
– High to severe	Severe loss of topsoil generally and/or marked dissection by run-off channels or gullies.
– Severe to very severe	Complete truncation of the soil profile and exposure of the subsoil (B horizon) and/or deep and intricate dissection by run-off gullies.

b) Under vegetation cover (at least sparse), the slope classes are rated as below:

– Low	No apparent or slight erosion.

	Low to moderate	Slight to moderate loss of topsoil generally and/or some dissection by shallow run-off channels or gullies.
--	Moderate	Moderate loss of topsoil and some dissection by shallow run-off channels or gullies.
–	Moderate to high	Moderate to high loss of topsoil, dissection by shallow run-off channels or gullies.

Forage Production: Forage production of rangelands is an important composite land quality and is the result of the interaction of a number of components, including climate, rock lithology, parent material, altitude, physiography, soils, man and animal. The rating used for forage production in sub-tropical subhumid ranges is shown in Table 18.

Table 18. Range forage productivity rating for Lohi Bher Range

Rating	Palatable forage production (dry matter kg / ha)	
	Herbage	Browse
I	576–700	55–70
II	451–575	39–54
III	326–450	23–38
IV	201–325	7–22
V	< 200	< 6

Palatability: This refers to the plant attributes that determine its acceptability by grazing animals. Characteristics of plant species such as chemical composition, growth stage, external plant form and kind of plants affect the acceptability and may stimulate selective responses by animals or may prevent from grazing (Heady, 1964). Palatability of a given plant species for a given livestock type changes with the season or stage of maturity. Grasses in the early stage of growth are highly palatable due to their high nutritional content. When they become dry and yellow, their nutrient content decreases. Certain shrubs and trees that retain their foliage during the winter may continue to be highly palatable.

A number of plant morphological characteristics, such as spines, hair, stickness, coarse texture and unfavourable odour reduce palatability, as do the growth habit or position of various plant parts.

Palatability is a relative factor and depends on the availability of the plant species and the type of range animals. An absolute value in this respect is meaningful only when a wide variety of plant species are available. When few species are available, the animals have to depend on them

for their survival. Goats and camels accept a lower level of palatability than sheep and cattle. Sheep and cattle have definite preferences. The palatability of plant communities also varies by season.

Distribution of Watering Points: Drinking water is one of the basic requirements for grazing livestock and a lack of water may prevent the proper utilization of forage. In the evaluation of water availability for the livestock, four factors are important: (i) distribution of watering points, (ii) frequency of watering required, (iii) quantity of water, and (iv) quality of water.

Proper distribution of watering points plays an important role in range management. There is a significant relationship between watering points and grazing pressure. Poor water distribution is probably the chief cause of poor distribution of livestock over the range. Areas lacking watering points are not utilized and overgrazing occurs where watering points are closely spaced. The number of required watering points is variable and depends upon local conditions. The kinds of livestock differ in the distances that they can travel for water, and these distances vary with topography. Sheep and especially cattle normally do not travel long distances to watering points or go without water for long periods. Stoddart et al. (1975) observed that range use in plain areas decreases in almost exact proportions to the distance from water for long periods.

Vallentine (1971) correlated the degree of grazing and distance from water. To attain 50 percent use of forage, the appropriate distance from water should be one-fourth to one-half of a mile (depending on other factors such as slope and type of vegetation). Johnston and Hussain (1957) reported that the location of watering points varies with the landscape. In plains cattle can travel 3.5 km and sheep travel 6.5 to 8 km. Stoddart et al. (1975) suggest that in steep and very steep mountain areas cattle should not be forced to go more than 1 km for water. In flat area they should not be expected to travel more than 4 km to and from water points. In extreme cases they suggest that animals should not walk more than a total distance of 8 or 10 km a day.

A readily available water supply for livestock therefore, enhances conservation of the range. Livestock perform best when they have plenty of good quality water to drink and they are not forced to walk long distances. Animals that walk long distances for water gain less weight but also require more forage. The ratings used to determine distances that the animals can travel to and from water points are shown in Table 19.

Animals provided water daily are more contented, graze more quitely, eat a greater variety of feed and dry forage and utilize various plant species more uniformly.

In nomadic grazing, cattle are provided water every other day. Sheep and goats may go 2 to 3 days without water and camels may go 5 to 6 days. In the summer, sheep should be given water at least every second or third day but daily water is preferable. Grazing of sheep and goats for relatively

Table 19. Water points suitability for livestock in Pothwar tract

Rating	Distance to and from watering points and quality of water
I	Distance 1–2 km and water of very good quality
II	Distance 2–4 km and water of good quality
III	Distance 4–10 km and water of good quality or 3 km and water of medium quality
IV	Distance 10–20 km and water of medium quality or less than 6 km and water of poor quality
V	Distance 20 km and water of poor quality

long periods without access to water is possible and is a common practice where forage is succulent. Sheep grazing experiments conducted in Montana and on high mountain ranges in central Utah showed that (i) on succulent weed ranges in high mountains, sheep grazing without water gained weight comparable with those on well-watered ranges, (ii) on non-succulent grass ranges in high mountains, sheep can do well if they receive limited moisture from dew, fog or rain, (iii) it is rarely necessary to drive sheep long distances for water on mountainous summer ranges more often than every third day, (iv) where water is inadequate, open grazing and shading during the hot mid day is imperative. Sheep watered every day generally consume less water than those watered every second or third day and also gained more weight. Over a 40-day period, during January and February, Stoddart et al. (1975) reported that sheep watered daily gained 1.5 kg; sheep watered every second day gained 0.36 kg and those watered every third day lost 2.7 kg.

RANGE UTILIZATION MODELLING

Landscape Ecological Units: Based on detailed resource survey of vegetation, soils, and socio-economic conditions and the resource evaluation procedures described above, 15 landscape ecological units (LEU) were distinguished. The LEU is defined as an area that is homogeneous with respect to lithology/parent material, physiography (relief, slope and exposition), soils, pedoclimate and vegetation. The LEUs were delineated on

1:5,000 scale map and were named after plant communities associated with physiographic features and soils of the area.

The plant communities were characterised and assigned appropriate agronomic names. In the second step, the agronomic name was followed by its physiognomy and habitat. The physiognomic nomenclature of the plant communities was adopted from the East African Range Classification System (Pratt, 1964). Range plant communities were determined on the basis of percent cover and frequency data collected from each LEU. The general characteristics and 10 plant communities recognized in 15 LEUs in Lohi Bher Range are given in Table 20.

Grazing Capacity: Forage production of palatable grasses, forbs, shrubs and trees was recorded during the spring and summer growing seasons. Gross air dry forage production/ha along with the total forage yield for each LEU was recorded. Grazing capacity was calculated at the rate of 2 kg dry matter/sheep unit/day at 60 percent utilization level (Table 21).

Land Suitability Plan: To develop the range area and adjacent private land on a scientific basis, every LEU was evaluated to determine the most suitable land use. The parameters considered for the grazing of livestock and wildlife included forage production, accessibility to grazing area, availability of watering points, shelter and protection and erosion hazard. The rating of classes/criteria used for each factor are described in the range sampling and evaluation procedures. The suitability level for grazing by sheep, goat and cattle during spring and summer in each LEU during spring and summer growing seasons along with other land uses are given in Table 22. To facilitate range improvement operations, a land use map of the range was also prepared.

MAIN FINDINGS

Range development operations conducted during past 5 years according to proper land suitability plan significantally improved the range, livestock and cropland. The brief description of the salient findings which may help in assessing the usefulness of the model are given below:-

Grass Production: *Cenchrus ciliaris* sown during the spring did not perform well because growing season was very short. The germination was good but plants could not get established before the hot, dry period and died. Therefore, seeding should occur immediately before the onset of monsoon season. During the past 3 years, line sowing, trench sowing, pits and contour trench sowing techniques were used for large scale seeding/planting. Better results were obtained with line sowing along the contours. *Digitaria decumbens* performed well when planted in tufts. A few bunches of *Panicum antidotale* were established on raised beds and on

Table 20. General characteristics of landscape ecological units of Lohi Bher Range

No.	Landscape Ecological unit Name	Extent (ha)	Extent (%)	Physiography	Soils	Vegetation
1.	Barren active sandy bars	1.0	1.0	Nearly level sand bars (Slope 1–2 percent)	Light grey, deep, stratified sands, moderately calcareous, excessively drained.	Barren.
2.	CDA-SMU Rec. f/loamy river plans.	2.0	0.5	Level to nearly level plains. (slope 0–1 percent).	Brown/dard brown, deep stratified silt loams and very fine sandy loams moderately calcareous, well drained.	*Cynodon Saccharum* grassland
3.	DBI-HCO. Sub.c/ loamy river plains	26.0	6.5	Level to nearly level plains (Slope 0–1 percent)	Reddish brown, deep weakly structured fine sandy loams, moderately calcareous containing few fine lime nodules, somewhat excessively drained	*Desmostachya Heteropogon Acacia* wooded grass-land
4.	ICY-sub.c/loamy ouotwash plans	1.0 (20.0)	0.2	Nearly level to gently sloping outwash plains (Slope 1 3) percent)	Reddish brown, moderately deep, weakly structured fine sandy loams, moderately calcareous underlain by fine material imperfectly drained	*Imperata-Cynodon* grassland
5.	CDA-ECO dis.Sub f/loamy outwash plans. f/loamy outwash plans.	52.0	13.0	Level to nearly level dissected plains (Slope 0–2 percent)	Brown dark deep, weakly structured dissected plains loams and very fine sandy loams, moderately calcareous containing few fine lime nodules	*Cynodon Eleusine* wooded grass-

(continued)

6.	DBI-CAU.Sub.sandy Chann. infills	12.0	3.0	Nearly level U-shapped channel beds (Slope 3-8 percent)	Brown to greyish brown, deep, weakly structured loamy sands and sands, moderately calcareous excessively drained	*Desmostachya-Chrysopogon* grassland
7.	CAU-HCO diss.sub. gr.c/loamy plains.	101.0	25.4	Undulating dissected plains (Slope 3-8 percent).	Brown to greyish brown, moderately deep, weakly structured gravelly fine sandy loams and loamy sands over sand, moderately calcareous excessively drained	*Chrysopogon-Heteropogon* grassland
8.	ECO-HCO severely dissected fine-silty plains.	5.0	1.2	Nearly level subrecent erosional surface (Slope 1–2 percent).	Reddish brown deep, partly weakly structured dense silty clay loams silty clays,strongly calcareous with hard caliche pieces on the surface, imperfectly drained	*Eleusine-Heteropogon* grassland
9.	AMO-CDA diss.sub. gr.f/silty outwash plans.	8.0	2.0	Rolling subrecent erosional surface (Slope 8–14 percent).	Reddish brown deep, weakly structured clay loams strongly calcareous common gravel and hard caliche pieces on surface, moderately drained.	*Acacia-Cynodon* grassland
10.	ECO-CJA severely diss. redep. loess plains.	16.0 (17.0)	4.0	Nearly level to gently slopping dissected redeposited loess plains (Slope 2–6 percent).	Brown/dark brown, deep weakly structured silt loams, moderately calcareous, few gravel and common hard caliche pieces on the surface, well drained.	*Eleusine Cymbopogon* grassland
11.	AMO-DBI sub.c/ loamy outwash plains	13.0 (24.0)	3.2	Nearly level to sloping dissected outwash plains (Slope 2–8 percent).	Reddish brown, moderately deep, weakly structured fine sandy loams over sand, moderately calcareous, containing few gravel and lime nodules, somewhat excessively drained.	*Acacia-Demostachya* wooded grassland

(continued)

12.	DRO-AMO c/loamy old river terrace	31.0 (7.0)	7.7	Nearly level tops with steep to very steep side slopes (Top slope 1-2 percent side slope 30–40).	Reddish brown deep, weakly structured sandy loams, moderately to strongly calcareous containing few gravel and hard caliche pieces somewhat excessively drained.	*Dicliptera-Acaia* wooded grass-
13.	HCO-AMO diss.old f/loamy river terrace	33.0 (10.0)	8.2	Gently sloping top with steep side slopes (Top slope 2–4 percent, side slope 25–45 percent).	Brown/dark brown, deep, moderately structured loams and clay loams, strong calcareous with a Kankar zone in the sub soil, well drained	*Heteropogon-Acacia* wooded grassland.
14.	HCO-CAU steep sandstone hill slopes	53.0	13.3	Moderately steep to steep scrap slopes (Slope 13–55 percent)	Brown/dark brown shallow, patchy gravelly loams, mod. cal., common rock fragments on the surface, somewhat excessively drained. portunities to enhance their productivity in crop/livestock mixed farming and in other aforementioned disciplines.	*Heteropogon-Chrysopogon-Acacia*
15.	CAU-DBI scarp slpes	35.0	8.8	Moderately steep to steep scrap slopes (Slope 13–55 percent)	Variegated colours, deep variegated textures, moderately to strongly calcareous, common rock gragements on the surface moderately well drained.	*Chrysopogon-Desmostachya Acacia* wooded graddland.
	Riverbed	8.0	2.0			

Table 21. Grazing capacity in 15 landscape ecological units at Lohi Bher Range.

LEU	Grazing capacity sheep days/ha		Extent ha	Season-wise Grazing capacity and total (sheep days)		
	Spring	Summer		Spring	Summer	Total
1	–	–	4	–	–	–
2.	160	140	2	320	280	600
3.	125	280	26	3250	7280	10530
4.	105	350	1	105	350	455
5.	75	235	62	4650	14570	19220
6.	130	690	12	1560	8280	9840
7.	95	230	161	15295	37030	52325
8.	70	90	5	350	450	800
9.	135	130	8	1080	1040	2120
10.	60	105	16	960	1680	2640
11.	80	200	13	1040	2600	3640
12.	90	160	33	2970	5280	8250
13.	90	160	33	2970	5280	8250
14.	90	140	53	4770	7420	12190
15.	90	115	35	3150	4025	7175
Total	1395	3025	464	42470	95565	138035

Source: Mohammad et al., 1984.

Table 22 Land suitabilities of Lohibher range

LU No.	NATURAL GRAZING: SPRING (MAR–MAY) S	G	Ca	SUMMER (JUNE–SEP) S	G	Ca	SUMMER PASTURES: GRASSES CHAU	PAAN	CECI	PEPU	DIDE	SHRUBS CHGA	ACCY	ACAN	LELE	TREES ACMO	OLCU	RUPS
1.	N_f	N_f	N_f	N_f	N_f	N_f	N_{n2}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}
2.	S_1	S_{3p}	S_1	S_1	N_p	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
3.	S_1	S_{2fp}	N_f	S_1	S_1	S_1	S_{2m}	S_{2m}	S_{2m}	S_{2m}	S_{2m}	S_{2m}	S_1	S_1	S_1	S_{2mn}	S_{2mn}	S_{2mn}
4.	S_1	N_p	N_{fp}	S_1	N_p	S_1	N_o	N_o	N_o	N_o	N_o	N_o	N_o	N_o	N_o	N_o	N_o	N_o
5.	S_{2f}	S_1	N_f	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
6.	$S18_{2w}$	N_p	N_{fp}	S_1	S_1	S_1	S_{3mn}	S_{3mn}	S_{3mn}	S_{3mn}	S_{3mn}	S_{3mn}	S_{3mn}	S_{3mn}	S_{3mn}	S_{3mn}	S_{3mn}	S_{3mn}
7.	$S18_{2w}$	N_{3p}	N_f	S_1	S_1	S_1	S_{2mne}	S_{2mne}	S_{3n}	S_{2mne}	S_{2mne}	S_{2mne}	S_{3n}	S_{3n}	S_{3n}	S_{3n}	S_{3n}	S_{3n}
8.	S_{2fw}	S_{3p}	N_f	S_1	S_1	S_{3f}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}
9.	S_{12w}	S_1	N_{fp}	S_1	S_1	S_{3f}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}
10.	S_{2f}	N_{fp}	N_{fp}	S_1	S_{3fp}	S_{3f}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}
11.	S_{2f}	S_1	N_f	S_1	S_1	S_{2f}	S_{2me}	S_{2me}	S_{2me}	S_{2mne}	S_{2mne}	S_{2mne}	S_{2mne}	S_{2mne}	S_{2mne}	S_{2mne}	S_{2mne}	S_{2mne}
12.	S_{2fa}	S_{2a}	N_{fp}	S_{2a}	S_{2a}	S_{2a}	S_{2m}	S_{2m}	S_{2m}	S_{2m}	S_{2m}	S_{2m}	S_{2mn}	S_{2mn}	S_{2mn}	S_{2mn}	S_{2mn}	S_{2mn}
13.	S_{2a}	S_{2a}	N_{fp}	S_{2a}	S_{2a}	S_{2a}	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
14.	S_{2fa}	S_{2a}	N_{fp}	S_{2a}	S_{2a}	S_{2a}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	N_{nd}	N_{nd}	N_{nd}	N_{nd}	N_{nd}	N_{nd}
15.	S_{2a}	S_{2a}	N_{fp}	S_{2a}	S_{2a}	S_{2a}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}

LU No.	DRYLAND FARMING: Millets	Sorghum	Maize	Wheat	Oil-seeds	Oats	Medics	Cow-peas	TREE PLANTATION: CONSERVATION & FORAGE ACMO	OLCU	RUPS	CESI	FUEL & TIMB. LELE	ACNI	DASI	WILDLIFE: DEER & HARE	PATRIDGES	WATER FOWLS
1.	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_{ne}	N_f	N_f	N
2.	S	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	N
3.	S_1	S_{2m}	S_{2m}	S_{2m}	S_1	S_{2m}	S_{2mn}	S_1	S_{2mn}	S_{2mn}	S_{2mn}	S_{2mn}	S_{2mn}	S_{2mn}	S_1	S_1	S_1	N
4.	N_o	N_o	N_o	S_1	S_1	S_2	S_3	N_o	N	N	N	S	S	N	N	S_1	N	N
5.	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	N
6.	S_{2me}	S_{2me}	S_{3mn}	S_{3mn}	S_{2n}	S_{3m}	N_{mn}	S_{2me}	S_{3mn}	S_{3mn}	S_{3mn}	S_{3mne}	S_{3m}	S_{3mn}	S_{2mne}	S_1	S_1	N
7.	S_{2re}	S_{2mn}	S_{3me}	S_{2m}	S	S_{2mne}	S_{3n}	S_{2ne}	S_{3n}	S_{3n}	S_{3n}	S_{2mne}	S_{2mne}	S_{3n}	S_{2mne}	S_1	S_1	N
8.	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_{2k}	S_j	S_{2k}	N_f	N_f	N
9.	S_{2rke}	S_{2rke}	S_{2k}	S_{2k}	S_{2k}	S_{2rke}	S_{2drke}	S_{2drke}	S_{2nde}	S_{2nde}	S_{2nde}	S_{3de}	S_{3de}	S_{2nde}	S_{2nde}	S_1	S_j	N
10.	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	S_{2e}	N_f	N_f	N
11.	S_{2e}	S_{2me}	S_{3mne}	S_{2me}	S_{2mne}	S_{2me}	S_{2mne}	S_{2e}	S_{2mne}	S_{2mne}	S_{2mne}	S_{2e}	S_{2me}	S_{2mne}	S_{2e}	S_1	S_1	N
12.	S_1	S_{2mn}	S_{3mn}	S_{2mn}	S_1	S_{2mn}	S_{2mn}	S_{2mn}	S_{2mn}	S_{2mn}	S_{2mn}	S_1	S_{2m}	S_{2mn}	S_1	S_1	S_1	N
13.	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	N_a	S_1	N
14.				NOT RELEVANT					N_{nd}	N_{nd}	N_{nd}	N_{nd}	N_{nd}	N_{nd}	N_{nd}	N_a	S_1	N
15.				NOT RELEVANT					S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	S_{3e}	N_a	S_1	N

ABBREVIATIONS FOR TABLE 20 AND 22

TREES

ACMO	=	*Acacia modesta*
ACNI	=	*Acacia nilotica*
DASI	=	*Dalbergia sissoo*
EU	=	*Eucalyptus sp.*
OLCU	=	*Olea cuspidata*
PO	=	*Populus sp*
RUPS	=	*Rubinia psuedoacacia*
CESI	=	*Ceratonia siliqua*

SHRUBS

ACAN	=	*Acacia aneura*
ACCY	=	*Acacia cynophylla*
CADE	=	*Capparis decidua*
LELE	=	*Leucaena leucocepnala*
ZINU	=	*Ziziphus nummularia*

FORBS

CASA	=	Cannabis sativa

GRASSES

CECI	=	*Cenchrus ciliaris*
CHAU	=	*Chrysopogon ancheri*
CYDA	=	*Cynodon dactylon*
DEBI	=	*Desmostachya bipinata*
HECO	=	*Heteropogon contortus*
IMCY	=	*Imperata cylindrica*
PAAN	=	*Panicum antidotale*
CHGA	=	*Chloris gayana*
DIDE	=	*Digitaria decumbens*

SUITABILITY CLASSES

S_1	=	Highly suitable
S_2	=	Moderately suitable
S_3	=	Marginally suitable
N	=	Not suitable;

LAND QUALITIES RELATED TO PLANT GROWTH

d	=	Adequacy for foothold
n	=	Capacity to supply nutrients
m	=	Capacity to supply moisture
o	=	Capacity to supply oxygen
s	=	Salinity and sodicity
r	=	Possibility of arable farming

LAND QUALITIES RELATED TO NATURAL GRAZING AND WILDLIFE

f	=	Forage production
p	=	Palatability of plant species
a	=	Accessibility to grazing areas
w	=	Availability of watering points
t	=	Shelter and protection
e	=	Erosion hazard
c	=	Coarse
diss	=	Dissected
f	=	Fine
gr	=	Gravelly
Rec	=	Recent
Redep	=	Redeposited
Sub	=	Subrecent
S	=	Sheep
G	=	Goat
Ca	=	Cattle

Plate 20 (a) Pre-improvement condition of Lohi Bher Range.

Plate 20 (b) Improved pasture by reseeding blue panic grass (*Panicum antidotale*).

sandy and slopy areas. Sixty percent of the plants grown on slopes and ridges survived. Bajra Napier Hybrid did not perform well on slopes and sandy areas. However, it grew well along channel banks and beds where more soil moisture was available. *Pennisetum purpureum* usually planted on sandy and low moisture soil areas did not perform well. However, it was established in low lying areas where sufficient soil moisture is available. Forage yield of the grasses tested at Lohi Bher is given in Table 23.

Table 23. Forage production of important forage species during 1984-85 at Lohi Bher

Grass	Seed rate kg/ha	Dry yield t/ha	
		1984	1985
Cenchrus ciliaris	5.0	4.8	5.0
Chloris gayana	6.0	5.4	4.8
Chrysopogon aucheri	5 5	6.0	6.0
Digitaria decumbens	Vegetative propagation	10.8	5.9
Panicum antidotale	5.0	8.1	8.2
Pennisetum purpureum	Vegetative propagation	12.5	9.5
Native range	Self regeneration	1.8	1.3

Source : Mohammad et al (1987).

Fodder Trees: During the past 4 years, the following six forage trees/shrubs were tested and their percentage survival was recorded. The percentage survival of *Acacia modesta, Olea ferruginea. Ceratonia siliqua* and *Leucaena leucocephala* was 88, 76, 40 and 67 respectively.

Based on the above findings, nearly 10,000 plants of ipil - ipil were planted in the project area on slopes, ditches, banks and level sites. Maximum growth was recorded on the slopes with eye-brow terraces and in the ditches. Ipil -Ipil yielded 413 kg/ha of green forage 1 year after planting, 1212 kg/ha after 2 years and 4,000 kg/ha after 3 years if planted at 5 m x 5 m interval.

Forage Utilization: The study was conducted at four range sites with three replications; three clipping levels were 50, 60 and 70 percent, based on weight of the forage clipped. Forage production data recorded during 1981, 1982 and 1983 indicated that the average maximum air dry forage production was in the treatment maintained at utilization level of 60 percent (478 kg/ha/year) followed by 50 percent (419 kg/ha/year) and 70 percent levels (415 kg/ha/year).

To study the effect of tree overstorey on forage production an experiment was conducted on four range sites; the treatments included open, 25, 50 and 75 percent overstorey cover. Data about the total percentage of ground cover were collected for 3 years. The results are given in Table 24.

Table 24. Total ground cover in open, 25, 50, and 75 percent tree cover during 1981-83 recorded at Lohi Bher Range.

Year	OVERSTOREY COVER											
	Open			25%			50%			75%		
	D	I	U	D	I	U	D	I	U	D	I	U
1981	44	34	23	24	29	47	34	37	29	35	42	23
1982	25	55	20	32	46	22	58	22	20	28	50	22
1983	36	33	30	33	37	30	33	51	16	42	51	7

Source: Mohammad et al. (1987).

There was a gradual increase in the ground cover of desirable and intermediate species in all the treatments at the expense of ground cover of undesirable species. In the area lacking vegetation cover, the ground cover of desirable species exceeded that of the intermediate and undesirable species, while in all other treatments, the ground cover of intermediate species exceeded that of desirable species. As overstorey cover increases, the ground cover of desirable forage species decreases, probably because shade-loving annual and perennial forbs became established under tree/overstorey cover.

The frequency of desirable and intermediate species in the area without an overstorey cover exceeded that of the undesirable species (Table 25). In other treatments(i.e., 25, 50 and 75 percent overstorey cover), the percentage of undesirable and intermediate species was higher than that of desirable species due to an increasing number of shade-loving intermediate and undesirable annual and perennial forbs.

Table 25. Percent frequency of desirable, intermediate and undesireable species in open, 25, 50 and 75 percent tree cover during 1981-83 at Lohi Bher Range.

Year	OVERSTOREY COVER											
	Open			25%			50%			75		
	D	I	U	D	I	U	D	I	U	D	I	U
1981	45	67	56	27	60	90	47	86	100	43	88	89
1982	45	79	34	38	49	100	58	22	20	28	50	22
1983	55	63	61	48	58	62	58	72	69	59	70	88

Source: Mohammad et al (1987)

Overstorey cover decreases forage production of ground strata (Table 26). The average maximum air dry forage production was recorded in open area lacking an overstorey cover(i.e., 2772 kg/ha). The average maximum air dry forage production in areas with overstorey cover of 25, 50 and 75 percent was 1922, 1585 and 1276 kg/ha, respectively.

Table 26. Total production (Kg/ha) of desirable, intermediate and undesirable forage species in open, 25, 50 and 75 percent overstorey over during 1981-83 at Lohi Bher Range

Year	OVERSTOREY COVER											
	Open			25%			50%			75%		
	D	I	U	D	I	U	D	I	U	D	I	U
1981	1425	723	1415	232	633	1857	60	454	757	74	505	798
1982	1048	587	1237	139	782	956	181	503	895	595	774	452
1983	369	346	1167	67	561	540	31	1288	588	17	805	302

Source: Mohammad et al (1987)

Controlled Burning: An experiment was conducted in three LEUs: *Cynodon Eleusine* dissected subrecent loamy outwash plains; *Desmostachya-Chrysopogon*, subrecent sandy channel infills; and *Acacia-Desmostachya* loamy outwash plains. Controlled burning was carried out in January, 1984, and the data were collected for 2 years in spring and summer seasons for vegetation cover, density and palatability. Total ground cover of vegetation was reduced after burning but new leaves and shoots quickly sprouted and the palatability of forage increased (Table 27). Plants like *Desmostachya* and *Heteropogon*, which are considered as weeds and are undesirable for livestock, were grazed by livestock as plants emerged after burning. Nutritive value of the grasses also improved after burning as the old and stemmy parts of the plants died and new sprouting/growth took place. Annual forbs became well- established after burning due to an increase in space, moisture and nutrient availability. A number of important forbs appeared in the spring (*Desmodium triflorum, Launea nudicaulis, Oxalis corniculatus* and *Dicliptera roxburghiana*) which are very palatable and nutritious. Cover and yield of *Chrysopogon aucheri*, which is one of the dominant native grasses of Pothwar rangelands, also increased on burnt sites. Generally the cover of deep rooted plants increased after burning.

The results clearly indicated that forage production significantly in-

Table 27. Forage production in control and burnt area in three landscape ecological units of Lohi Bher Range.

LEU	Spring			Summer		
	Control	Burnt	Increase	Control	Burnt	Increase
			1984			
Cynodon–Eleusine dis. Sub. f/loamy outwash plains	450	659	209	1256	1681	425
Desmostachya–Chryso-pogon Sub. sandy channel infills	445	642	197	1721	2061	340
Acacia–Desmostachya Sub c/loamy outwash plains.	370	447	77	969	1155	186
			1985			
Cynodon–Eleusine dis.Sub.f/loamy outwash plains	372	499	127	1728	2046	318
Desmostachya-Chrysopogon Sub. sandy channel infills	447	615	168	1912	2073	161
Acacia–Desmostachya Sub c/loamy outwash plains.	316	413	97	1377	1732	355

Source: Mohammad et al.(1987)

creased in all burnt sites due to quick regrowth and reduced forage competition with weeds. The control plots produced less than burnt areas due to limited forage regrowth from old bunches, less space and more competition with weeds. Forage production was maximum in spring and summer 1984, but yields decreased by 25 percent in the next summer as the burning effect was reduced.

Forage Quality: Most of the ranges in Pothwar tract are depleted and the palatable species have decreased due to heavy grazing. A study was conducted to evaluate the nutritional changes in the grasses and shrubs at different stages of growth to determine the best grazing time for these species.

The crude protein content of five grasses at different growth stages (vegetative (pre- bloom), vegetative (flowering) and mature) was deter-

mined. The quality of range plants decreased with maturity. Plants contained the most protein in the vegetative state (pre- bloom). Protein content decreased by about 15 percent at the flowering stage and about 40 percent at maturity (Figure 6).

	A VEGETATIVE	B FLOWERING	C MATURE
BUFFEL GRASS	50	70	30
BLUE PANIC	55	75	20
PANGOLA GRASS	70	50	30
SABA GRASS	45	80	25

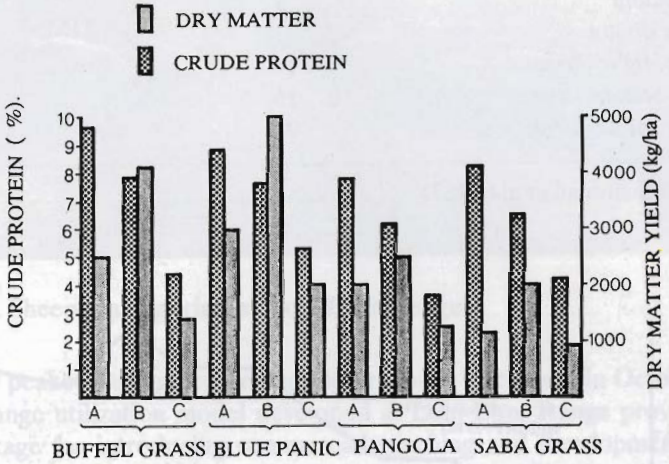

Figure 6. Forage yield (kg/ha) and crude protein (%) at different growth stages of grasses in Lohi Bher range.

Fodder trees/shrubs selected after intensive trials were analysed for their crude protein content to determine their forage value in the semi-arid sub-humid Pothwar zone. The crude protein contents of *Acacia modesta, A. cynophyla, Olea ferruginea, Ceratonia siliqua, Robinia pseudoacacia* and *Leucaena leucocephala* were 13.1, 11.3, 10.5, 9.6, 10.1 and 18.3 percent, respectively.

Animal Preference: Browse species in the Lohi Bher project area were identified and their preference value was recorded by observing sheep and goats browsing in the range area. The results are given in Table 28.

Sheep Weight Gain: A study started in the Lohi Bher project in August, 1985, concerned to find out the optimum increase in live weight during the summer grazing season. The highest weekly weight gain in sheep during the 3 month study period was recorded in the youngest age group followed by medium and old group (Figure 7). Weekly weight gain gradually increased from August to September. From the first week of October, weekly weight gain bagan to decline, which indicated that forage quality and

Table 28. Total preference percent of goats and sheep for different shrubs at Lohi Bher Range

Fodder Trees/shrubs	Preference percent	
	Goat	Sheep
Acacia modesta	22	25
Acacia cynophylla	6	6
Zizyphus nummularia	18	18
Olea cuspidata	9	10
Ceratonia siliqua	7	12
Gymnosporia royleana	16	3
Segeretia brandrethiana	15	18
Leucaena leucocephala	96	8

Source: Mohammad et al.(1987)

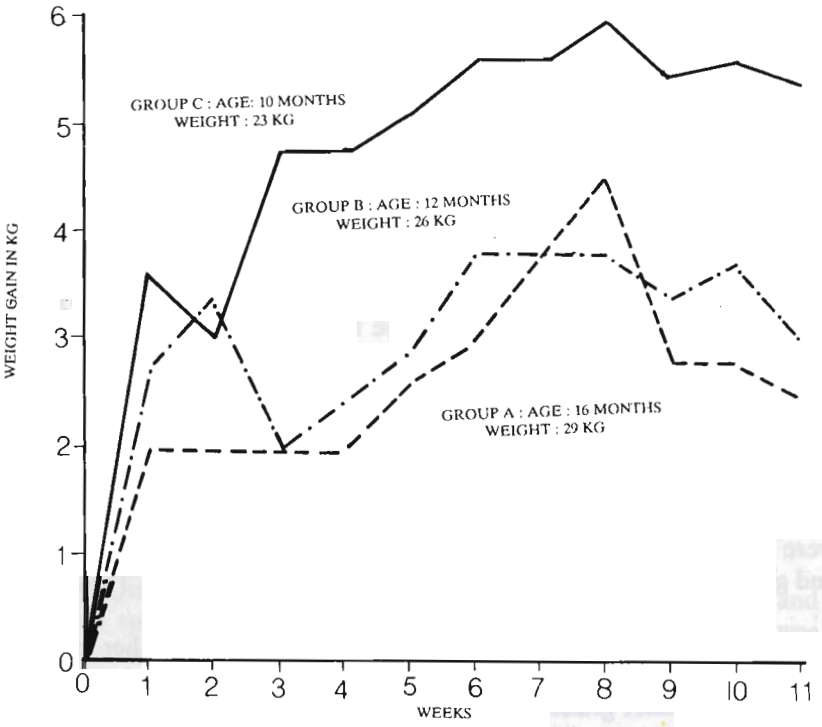

Figure 7. Cumulative weight gain (kg) in different age groups of sheep at Lohi Bher.

Plate 21. Sheep grazing trials at Lohi Bher Range.

quantity peaked during September and gradually decreased in October.

Range utilization model developed at Lohi Bher Range provides useful package for introducing commercial ranching and development private livestock farms in the Pothwar Plateau. Such range utilization models need to be developed for each range ecological region in the country.

Chapter 6.

Range Livestock Production

Livestock play an important role in the economy of Pakistan. The livestock industry contributes about 9 percent to the Gross National Product. The total livestock population has doubled during the past two decades and now totals 93.5 million head (Table 29).

Livestock provide high quality food, such as meat, milk, eggs, and raw products for industries, such as wool, skins, hides, etc. They also provide energy for various agricultural operations and manure to maintain soil fertility. Various livestock products are given in Table 30.

GRAZING PATTERNS AND PRACTICES

Livestock grazing is quite common throughout Pakistan. In irrigated areas, milking buffaloes and cows are stall fed with fodder crops and feed concentrates but dry and draught animals graze aftermath. Over a long period several traditional livestock grazing patterns have evolved as a result of biophysical, environmental, economic conditions and social customs of pastoral communities in different parts of the country.

Grazing Systems in the Northern Mountains: In the northern mountains of Pakistan, three major traditional systems of livestock grazing are practised that are not consistent with the modern scientific concept of use i.e. according to the potential of range. Nomadic grazing of livestock is dictated by seasonal climatic conditions and seasonal forage availability. Migration of livestock occurs between alpine pastures and the Pothwar Plateau, in the foothills of the Himalayas. Herds of sheep and goats start ascending

Table 29. Livestock population in Pakistan

(million head)

Year	Buffaloes	Cattle	Goats	Sheep	Camels	Donkeys	Horses	Mules	Total
1971-72	9.8	14.6	15.5	13.7	0.7	1.9	0.3	0.05	56.55
1972-73	10.0	14.7	16.9	14.8	0.7	1.9	0.3	0.05	59.35
1973-74	10.2	14.7	18.4	16.1	0.7	2.0	0.3	0.05	62.45
1974-75	10.4	14.8	20.0	17.4	0.8	0.2	0.4	0.06	64.06
1975-76	11.6	14.9	21.7	18.9	0.8	2.1	0.4	0.06	70.46
1976-77	10.9	15.0	22.4	19.5	0.8	2.2	0.4	0.06	71.26
1977-78	11.1	15.2	23.2	20.1	0.8	2.2	0.4	0.06	73.06
1978-79	11.3	15.4	24.0	20.7	0.8	2.3	0.4	0.06	74.96
1979-80	11.6	15.6	24.9	21.4	0.8	2.4	0.4	0.06	77.16
1980-81	11.9	15.8	25.8	22.1	0.9	2.4	0.4	0.06	79.06
1981-82	12.1	15.9	26.7	22.8	0.9	2.5	0.4	0.06	81.36
1982-83	12.4	16.1	27.7	23.5	0.9	2.6	0.4	0.06	83.66
1983-84	12.7	16.3	28.7	24.2	0.9	2.7	0.4	0.06	85.96
1984-85	13.1	16.5	29.7	25.0	0.9	2.8	0.5	0.06	88.56
1985-86	13.4	16.7	30.8	25.8	0.9	2.9	0.5	0.07	**91.07**

Source: Ministry of Food and Agriculture, Livestock Division, (1988).

Table 30. Livestock products in Pakistan

(000, tonnes)

Year	Milk	Beef	Mutton	Poultry Meat	Eggs (million Nos.)	Hides (million Nos.)	Skins (million Nos.)	Wool	Hair	Bones	Fat	Blood
1971-72	7800	346	208	14	583	4.3	16.4	22.1	2.9	152	45.8	14.2
1972-73	7899	349	224	19	695	4.3	17.5	24.3	3.1	157	47.2	15.0
1973-74	8044	354	245	24	811	4.4	19.4	26.1	3.4	161	49.9	16.0
1974-75	8193	357	265	27	907	4.5	21.0	28.3	3.7	166	52.2	16.0
1975-76	8348	362	288	34	1159	4.5	22.8	30.7	4.1	173	54.7	17.1
1976-77	8524	375	303	37	1443	4.6	23.6	32.2	4.3	177	57.2	17.9
1977-78	8704	389	319	41	1557	4.7	24.4	33.7	4.5	181	59.8	18.8
1978-79	8888	404	335	44	1805	4.8	25.2	35.4	4.8	185	62.5	19.6
1979-80	9075	418	352	49	2094	4.9	26.1	37.1	5.0	189	65.3	20.5
1980-81	9267	434	370	52	2319	4.9	26.9	38.9	5.3	194	68.3	21.5
1981-82	9462	448	389	57	2664	5.0	27.9	40.7	5.5	199	71.4	22.5
1982-83	9662	464	408	75	3200	5.2	28.8	42.7	5.8	203	74.7	23.9
1983-84	10242	488	436	86	3619	5.3	29.8	45.1	6.2	208	79.3	25.5
1984-85	10856	513	467	99	4093	5.4	30.8	47.7	6.6	213	84.1	27.2
1985-86	11500	539	500	114	4630	5.5	31.8	50.3	7.0	218	89.0	29.0
1986-87	12198	567	534	122	4954	5.5	32.9	53.2	7.4	223	94.7	31.0
1987-88	12900	595	570	134	4140	5.7	34.02	55.0	7.8	229	101.0	33.0

Source: Livestock Division (1988)

during March along metalled roads in the Kaghan, Indus Kohistan and Neelam valleys. Livestock spend April in sub-tropical and temperate forest grazing areas, below 2000 m. Regrowth in alpine pastures occurs in May, immediately after the snowmelt. The livestock herders move up in the alpine scrub forests where sufficient browse from shrubs is available. The alpine vegetation growth in June can support livestock. Livestock remain in the alpine areas until early October when low temperatures retard plant growth. By this time, most of the forage has been consumed by livestock and herders descend towards plains or low valleys. October and part of November is spent in the forest areas between 2000 and 3000 m. During winter, livestock remain in Pothwar scrub ranges, on 'shamlats', abandoned cultivated lands or in the valleys along water channels, roads and grazing grounds between agricultural fields.

Gujars, Dogars, Kohistani and Gilgiti tribes are herders. They pay a nominal grazing fee to the Syed families of Kaghan or the Khans of Indus Kohistan who control the use of alpine pastures. The Provincial Forest Departments also require a minimum fee for livestock grazing in the forest areas. However, overstocking has seriously reduced grazing capacity.

Semi-nomadic grazing: This involves the movement of livestock from settlements within the conifer forests to the alpine pastures. For example, livestock from the Gujal Villages in upper Hunza migrate to the Khunjerab alpine pasture. This type of grazing is common in the Northern Areas and in Chitral alpine pastures. Women look after the herds and spend the summer in the alpine areas. Men maintain food supplies by travelling back and forth. Winter season is spent around permanent settlements

Local grazing: In this case, livestock graze between cultivated lands or in adjoining forests throughout the year. 'Shamlats' or communal ownership areas are heavily over-grazed.

Grazing Patterns in the Desert Ranges: Livestock grazing practices in Thal, Cholistan, Kohistan and Tharparkar desert areas are quite similar. Private livestock is allowed to graze state-owned rangelands after paying nominal grazing fees. Grazing permits for different categories of livestock are issued at the following rates:

Camel	Rs. 2.0 per head per annum
Cattle	Rs. 5
Sheep	Rs. 1
Goat	Rs. 5
Buffaloes	Rs. 10

Obviously, such grazing fees encourage overgrazing resulting in the deterioration of the range. A lack of adequate stock water means, livestock concentrate around rainfed water ponds and further discourages uniform utilization of ranges. There is no alternate source of feed for livestock. During the winter or droughts, the livestock move to irrigated areas but

these areas also lack adequate feed. Most of the camel population stays in the desert and obtain water by feeding on succulent salty shrubs. Greater Cholistan has better grazing grounds but a lack of watering points and inadequate communication, results in improper utilization.

Plate 22. Sheep grazing patterns in the Thal Desert.

The Tharparkar and Kohistan ranges are grazed by cattle, sheep, goats and camels. Most of the population is migratory. In the early winter, people leave their villages in search of better grazing and migrate into irrigated areas. In the early monsoon season when forage is abundant, they return to their villages and leave their animals to graze during July - November.

Grazing Systems in Baluchistan and Sulaiman Mountain Ranges: Livestock grazing patterns in Baluchistan have been studied by Baig (1977) and FAO (1983). The south western desert ranges are grazed by local livestock and livestock move within the valleys. Due to low productivity of the area, Afghan 'pawindas' do not go there. The central and northern parts of Baluchistan have a centuries-old system of nomadic grazing and the following three patterns:

- Spring summer nomadic transhumance,
- Winter nomadic transhumance and
- Year-round sedentary nomadic grazing.

A brief description of each system, studied by Baig (1977), is given

below:

Spring-summer nomadic transhumance: In this pattern, 56 percent of the sheep, 63 percent of the goat, 70 percent of the total camel population, a few cattle and 70 percent of total households migrate between the highlands and the lowlands (Sibi and Kacchi plains - the winter grazing ground). In winter, the livestock moves to the irrigated Sibi and Kacchi plains where they stay for about 4-6 months, depending upon the rainfall in the highland region, which governs their return. Sorghum is the main crop grown in the Sibi and Kacchi plains.

Most of the grain, the stem and stubble are used to feed the migrant livestock. The stock owners rent land under this crop.

With the beginning of the spring (in March), the livestock return to the highland areas where they move about for 6-8 months (March- October) on rangelands. Livestock are moved by trucks or on hoof through Bolan Pass.

Winter nomadic transhumance: In this pattern, 20 percent of the sheep, 10 percent of the goats and a few camels of the 'pawindas' come in the area from Afghanistan during the start of winter in October. The number of animals, however, fluctuates every year, depending on the rainfall. In good years, they bring more animals and the number is considerably reduced during drought. Scarcity of forage during winter coupled with extremely low temperatures force them to leave their country in search of forage. They stay in the area for about 4 months and return to the area on the onset of spring in March. During their stay in the area, they mainly depend on tree leaves, stubbles, roughages from fruits and vegetables, and partly on the forage from the ranges.

The 'pawindas' enter the area through different routes and return generally by the same route. They stop only where there is a spring or water. Men, women and children walk along the routes, while the livestock are separately driven by shepherds.

Sedentary nomadic: In this pattern, 24 percent of the sheep and 27 percent of the goats remain all year in the area. They depend either on forage from the ranges or from the cropland. In winter, they receive silage made from wheat, barley, lucerne and *Alhagi camelorum*.

With the Russian invasion of Afghanistan, the Afghan 'pawindas' do not go back to Afghanistan, thus increasing the grazing pressure on summer highland ranges and causing rangeland to deteriorate. Several protected forests in Baluchistan have disappeared due to the illegal cutting of trees and shrubs and grazing by Afghan refugees and 'pawindas'. The grazing patterns in Sulaiman mountains are similar to those in Baluchistan ranges.

RANGE ANIMALS

Sheep (Ovine Sp.): *General features:* Most of the sheep breeds have traces of mediterranean as well as Asian wild sheep. The Pakistani breeds most probably descended from urial (*Ovis vignei*), the wild sheep of

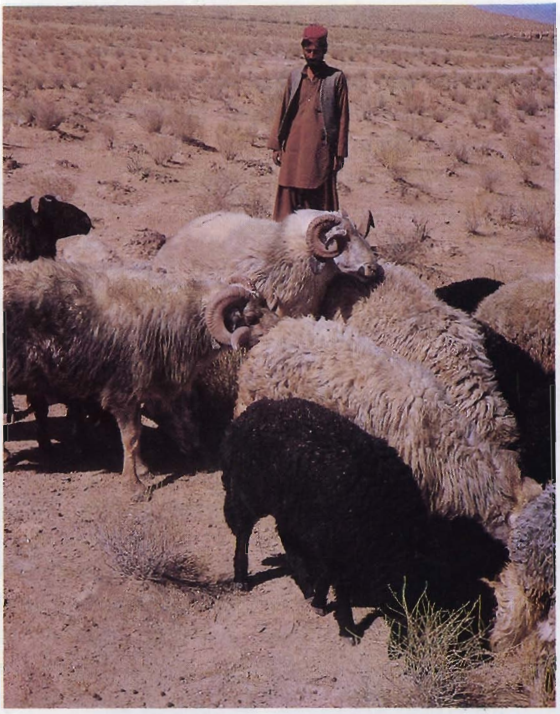

Plate 23. Sheep grazing in Baluchistan.

Baluchistan, Afghanistan, a Soviet Central Republics and from Argali (*Ovis ammon*), the morcopolo sheep of China (Husnain, 1985).

Sheep is the most important range animal. It is kept for wool, mutton and milk, although skins, guts, blood and droppings are also useful products. Pakistani wool, which is primarily a coarse type, is an ideal carpet wool. The estimated wool production during 1984- 85 was about 47,000 t. Sheep produced 42 percent of the mutton and 20 percent of the total meat production in 1984-85. (Government of Pakistan, 1986).

Different breeds of sheep are scattered all over the country in small flocks in irrigated and non-irrigated areas, but are largely maintained under transhumant system in arid and semi-arid grazing lands of the country.

Breeds and breeding: There are 28 defined breeds of sheep. Almost half of them are thin-tailed and half are fat-tailed (Naqvi, 1986). A few exotic breeds like Karakul', Hissardale' and Rambuillet' have also been introduced in Pakistan and are being crossbred with local breeds. Distribution, live weight and breed characteristics of some of the breeds are described in Table 31.

Sheep are usually shorn twice a year; February to April and in October to November. The exceptions are Quetta Region in Baluchistan and some mountainous regions in the north where they are shorn once a year. Pakistani wool is generally classed as carpet wool, and its suitability for this purpose is well-recognised at home and abroad. The wool characteristics

Table 31. General characteristics of sheep breeds of Pakistan

Breed	Distribution	Av. Birth wt. (kg)		Av. Adult wt. (kg)	
		Male	Female	Male	Female
Cholistani	Cholistan	3.5	3.0	38	30
Damani	D.I. Khan	3.0	2.8	33	26
Kachhi	Tharparkar	3.2	2.8	42	32
Kajli	Irrigated Plains	4.0	3.5	68	50
Kooka	Tharparkar	2.7	2.3	39	30
Lohi	Tharparkar	4.0	3.8	65	45
Thalli	Thal	2.5	2.3	34	27
Balkhi	NWFP Tribal Sulaiman Ranges	3.5	3.0	70	50
Bibrik	Loralai and Sibi	2.8	2.4	38	30
Harnai	Loralai, Quetta and Sibi	3.0	2.8	39	31
Hasht nagri	Peshawar	3.0	2.8	40	32
Salt Range	Salt Range, Pothwar	3.0	2.7	42	32
Waziri	Sulaiman Mountain	3.0	2.8	45	30
Hissardale (Cross between Merino and Bikaneri)	Sahiwal	–	–	60	50
Baghdale (Three way cross between Damani, Hissardale and Rambouillet)	Mianwali	–	–	63	55

Source: Khan et al. (1982).

of various sheep breeds of Pakistan are given in Table 32

Sheep are seasonal breeders and the breeding season varies from one area to another. By and large, there are two distinct peaks of breeding activities; September - October, and in spring, March - April. However, most of the animals breed in autumn. Sheep have a more defined breeding season than goats. Once a year lambing system is common in our rural areas, but twice a year lambing has also been successful. Twice a year lambing can produce 12.7 kg more live weight and additional income of Rs. 104 per year per ewe in Lohi sheep (Salim and Shah, 1983).

The gestation period in sheep ranges from 140 to 159 days, with an average of 148 days. Oestrous cycle varies from 14 to 19 days, with an average of 16 days.

Grazing habits: Sheep are rarely stall fed. They subsist on extensive grazing in rangelands. In irrigated areas, they are fed crop residues and by-products. The desert rangelands of Thal, Cholistan, D.G. Khan, Thar-

Table 32. Wool characteristics of sheep breeds in Pakistan

Name of breed	Fleece weight (kg/yr)	Fibre dia (micron)	Spinning counts	Staple length (cm)	Clean wool content (%)	Vegetable matter (%)	Colour of wool (%)
Balkhi	1.28	45.1	36	8.3	78	2.5	Black 100
Baluchi	2.25	37.0	50	7.3	50	1.7	White yellow
Bibrik	1.55	43.5	36	5.2	63	1.4	White 100
Harnai	1.37	31.3	50	7.0	67	1.1	White 94
Hashtnagri	1.43	35.0	44	6.4	75	1.4	White 87
Afridi	1.29	34.5	44	6.1	60	1.8	Grey 99
Salt Range	1.90	35.3	44	8.4	91	1.4	White 99
Michni	1.27	30.7	50	5.4	70	2.7	White 97
Waziri	1.38	35.0	44	6.5	64	1.6	White 91
Dumbi	1.38	38.5	40	6.0	70	1.3	White 99
Rakhshani	0.93	31.0	50	4.8	75	0.9	White 97
Lohi	1.86	40.2	36	5.2	59	0.7	White 98
Thalli	1.45	37.7	40	5.3	64	1.6	White 90
Buchi	3.12	36.3	44	5.9	--	1.8	White 99
Kajli	2.50	37.1	40	5.2	51	1.2	White 100
Kooka	2.13	44.1	36	5.0	47	1.2	White 94
Damani	1.15	43.3	36	5.0	70	0.9	White 97
Kaghani	1.24	32.5	50	4.2	--	0.9	White 96
Kail	2.00	33.7	46	5.0	90	1.6	White 88
Cholistani	3.20	46.6	36	7.0	47	1.0	White 95

Source: PARC (1982).

Plate 24. A traditional way of sheep sheering in Baluchistan.

parkar and arid mountainous ranges of Baluchistan are main areas for sheep production.

A sheep has a cleft in her upper lip which, though not used in prehension, permits very close grazing. The lips, lower incisor teeth, and the dental pad are the principal prehensile structures; the tongue does not protrude during grazing as in cattle. Since there are no upper incisors, leaves and stems have to be pressed by the lower incisors against the dental pad as the animal jerks its head slightly forward and upward. In sheep, the jaws work very close to the ground and provide an opening of some 3 cm in diameter. For mechanical reasons, easily torn grasses are selected more often. The time spent on grazing and the amount eaten are summarized in Table 33.

Large flocks do not graze together but split into sub-groups, which occupy separate areas. It is not known whether the sub-groups are based on families in the flock. Different breeds vary in their tendency to move and flock together. Some breeds tend to stay within a part of the available grazing areas; others split into small groups, occupying the area around a patch of good grazing. Gregarious breeds are not adapted to pastures in which patches of herbage are widely scattered; these breeds may be well suited to uniform and abundant pastures (Hunter, 1960).

The location of grazing may vary according to the forage available. The other factors that affect grazing may be climate, nutritional requirement and presence of lambs. Sheep not receiving any supplementary feed spent more time grazing than those that were supplemented (Tribe, 1950).

Table 33. Daily ingestive and eliminative behaviour in sheep

	Pattern	Average values per day
Grazing and Feeding	Number of grazing period	4–7
	Total grazing time (hrs)	9–11
	Consumption of fresh herbage (Lambs)	1,700–1,900
	On permanent pasture (g) (Adults)	1,300–5,000
	Dry matter consumption on (Lambs)	480–830
	Permanent pasture (g) (Adults)	530–1,300
Rumination	No. rumination periods	15
	Total rumination time (hrs)	9–10
	No. of chews/rumination	39,000
	Rate of chews/min	91
	Duration of a rumination period (min)	1–20
	No. of boli regurgitated	500
	No. of chews/bolus	78
Drinking Water (lb)	On range or dry pasture	5–13
	On hay and concentrates	3.0–6.0
Ranging	Distance travelled (miles)	3–8
Elemination	No. of urinations	9–13
	No. of defaecations	6–8

Source: Hafez and Scott (1962)

Sheep prefer certain species of herbage, stages of growth in a given species, and specific parts of individual plants. Several psychological, physiological and mechanical factors are potentially involved in selective grazing. This of type grazing was studied by comparing the chemical composition of forage samples (Wier and Torrel, 1959). The sheep consistently selected forage higher in protein and lower in crude fibre. In general, selectivity is directly proportional to the amount of herbage available; thus the less feed is available, the less sheep discriminate among plants. Sheep ordinarily reject plant, contaminated with the odour of sheep urine and faeces. However, in a pasture widely contaminated with excreta, they adapt to the odour of faeces and may eat the contaminated herbage (Tribe, 1949, 1955). This behaviour contributes to overgrazing.

Sheep graze on young and tender grasses. When grasses are not available sheep browse on bushes and shrubs. Sheep graze relatively few flora (Anon, 1970). Wahid (1984) found that sheep in Thal preferred grasses,

e.g., *Cynodon dactylon, Aristida plumosa,* **and grazed browse only, when young and succulent grasses were not available. The species thus browsed were** *Salvadora oleoides* **(green and dry leaves) and** *Calligonum polygonoides.*

Areas for future research: Breeding for improved mutton and milk production.

- Digestive efficiency of sheep.
- Grazing behaviour of sheep, alone versus mixed grazing with goat cattle, etc.
- Grazing systems for better production in rangelands.
- Reproductive performance (fertility, multiple births, age at first lambing, lambing interval, lambing twice a year, etc.).
- Housing and management for economical production.
- Ecto-parasites and diseases.
- Role of sheep in the livestock farming system in Pakistan.

Goat (Capra Sp): *General features:* The goat is an important range animal. It is believed to have descended from two living races of wild goats namely, the Bazoar or Pasang (*Capra hircus aegagrus*) breed of the high mountains of Asia Minor and the wild goats of Sind (*Capra hircus blythi*). The latter is replaced by Markhor (*Capra falconieri*) in Baluchistan and Afghanistan and Caucasian Tur (*Capra caucasica*) in the Soviet Central Republics. Toys from Harappa and seals from Moenjodaro show that goats greatly resemble the ancestral wild goats (Husnain, 1985).

The goat is known as the poor man's cow. It provides meat, mohair, skins, blood, etc. Small ruminants have a high potential as a source of meat in Pakistan. Goat meat is preferred and is priced much higher than beef. During 1984-85, goat meat was 28 percent of total meat production and 58 percent of total mutton production; they produced 0.2 million tons of meat and 57 percent of the skins (17.62 million). They also provided about 4 percent of the total milk production in the country. (Government of Pakistan, 1986).

In Pakistan, goats are distributed in tropical sub-tropical, arid and semi-arid rangelands, extending from coastal region to sub- mountain areas in the north . The uncultivated area and goat population has a positive correlation. The highest percentage of goats is in the Hyderabad Division (20 percent) followed by Multan (12 percent), Quetta (11 percent) and Sargodha (10 percent).

Breeds and breeding: Twenty-five breeds of goats have been recognized in Pakistan; they can be categorised as hairy or smooth coated. They can also be classified as dairy or meat types (Husnain, 1985). 'Beetal' and 'Dira Din Panah' are milk breeds, whereas 'Barbari','Chappar' and 'Teddy' are reared for meat production. 'Bekanari', Kaghani 'Kharasani' and 'Angora' are well known for mohairs and Nachi, Beetal and 'Dira Din Panah' are known for their skin (Ishaque, 1987). In India the 'Jamnapari' and 'Dera', which closely resemble the, Nubian, is known for its milk production

(Ishaque, 1984). Live weights of Pakistan breeds are given in Table 34.

Breeding season under wild conditions is in autumn and/or spring when grazing is good and the flocks gain weight. The breeding season is also adjusted so enough of mother's milk is available, followed by good grazing. Domestication and regular availability of feed has altered the breeding behaviour of some species.

Table 34. Average birth weight, weight at six months and adult weight of different breeds of goats in Pakistan

(kg)

Breed	Birth Weight		Six month weight		Adult weight	
	M	F	M	F	M	F
Barbari	2.05	1.82	10.45	10.00	21.36	20.00
Beetal	2.50	2.27	15.91	13.64	36.36	29.55
Beiari (Camber)	1.80	1.50	13.00	10.00	25.00	20.00
Buchi	2.00	1.08	14.00	11.00	30.00	22.00
Chapper	2.27	2.05	13.64	11.36	26.36	22.73
Damani	2.27	2.05	12.27	10.00	22.73	20.45
Dera Din Panah	2.73	2.50	25.00	21.82	45.45	40.91
Desi (Jattal)	1.05	1.02	12.00	9.05	23.00	19.00
Gaddi	2.82	2.59	23.64	21.36	50.00	46.91
Kaghani	2.05	2.02	20.04	17.20	36.03	31.08
Kajli	2.45	2.32	15.91	13.64	29.55	25.00
Kamori	2.70	2.50	29.50	25.00	59.00	50.00
Kharasani	2.27	1.82	12.05	10.23	29.55	25.00
Kooti	1.02	1.00	10.00	8.00	20.00	15.00
Lehri	2.73	2.50	15.45	13.64	32.95	30.68
Nachi	2.00	1.08	14.00	11.00	28.00	22.00
Pothowari	2.00	1.08	12.70	10.00	25.00	20.04
Shurri	2.03	2.01	18.00	14.00	38.00	30.00
Sind Desi	2.73	2.50	29.55	25.00	59.09	50.00
Teddy	1.60	1.40	16.00	13.60	33.90	23.20

Source: Naqvi (1986)

In goat, heat lasts from 1 to 2 days at 21-day intervals. According to MacKenzie (1980), the gestation period ranges from 143 to 157 days with an average of 150 days. The average of gestation period in tropics is 146 days which ranges from 145 to 148 days (Ishaque, 1984). In 'Teddy' goats, the average kidding interval is 205 days and that service period (how soon a doe conceives after kidding) is 61 days (Ishaque, 1983). Breeding behaviour and mutton production potential of different Pakistani goat breeds are given in Table 35 (Naqvi, 1986).

Grazing habits: Goats have special feeding habits. They always prefer

Table 35. Breeding behaviour and mutton production of different goat breeds

Traits	Teddy	Beetal	Nachi	Dera Din Panah
Average weaning age (days)	120	90	90	90
Average weaning weight in males (kg)	11.6	9.7	14.3	11.5
Average weaning weight in females (kg)	11.4	9.6	11.3	11.4
Average service period (days)	60	202	146	162
Average kidding interval (days)	206	352	296	312
Average gestation period (days)	146	150	150	150
Average twinning rate (%)	56.4	26.5	27.5	22.5

Source: Naqvi (1986).

to browse. They would, however, graze if there is little or no browse available. The feed includes herbs, forbs, shrubs, tree leaves, twigs, bark, clothes and even papers (Wahid, 1975). Goats' diet consists more than 50 percent browse during all seasons of the year. Forbs constitute less than 15 percent of the total diet. Grasses are utilized only in spring when they are young and succulent (McMahan, 1964).

Hanjra (1984), studied the grazing behaviour of 'Teddy' goats and sheep and observed that most of the prevalent species of grasses, shrubs and trees such as *Cenchrus ciliaris, Lasiurus sindicus, Pennisetum dichotomum, Cymbopogon jwarancusa, Aristida adscenciosis, Eleusine flagellifera, Cynodon dactylon, Calligonum polygonoides Zizyphus nummularia, Z. mauritiana, Salvadora oleoides, Calotropis procera, Prosopis cineraria* etc., were grazed and browsed by goats in the Thal range area. Goats travelled more than sheep in search of feed, and unlike sheep did not show any noticeable loss in body weight when fodder was scarce. The female goats matured at 180 days and kidded at 330 days. The ewes matured at 365 days and lambed at 515 days. The goats were more fertile, had better carcasses and produced more meat.

Grazing capacity of the goat varies from 25 to 40 percent normally and can be as high as 50 or 55 percent of body weight (Ishaque, 1984). In temperate pastures, goats use 15 percent more of the available varieties of plants.

Goats eat many varieties of roughages with low nutritional value. They eat leaves, small branches, weeds, herbs, grasses, hays, silage, roots and concentrate feeds. High intakes of grasses are normal in paddocks but while browsing, over 80 percent of their feed consists of leaves and young shoots of shrubs and bushes while browsing.

Feeding habits of goats vary. Consumption of grass varies from 75 to 85 percent daily to practically nil in arid areas. Season and ecological factors affect these variations. Goats are selective when feed is abundant but

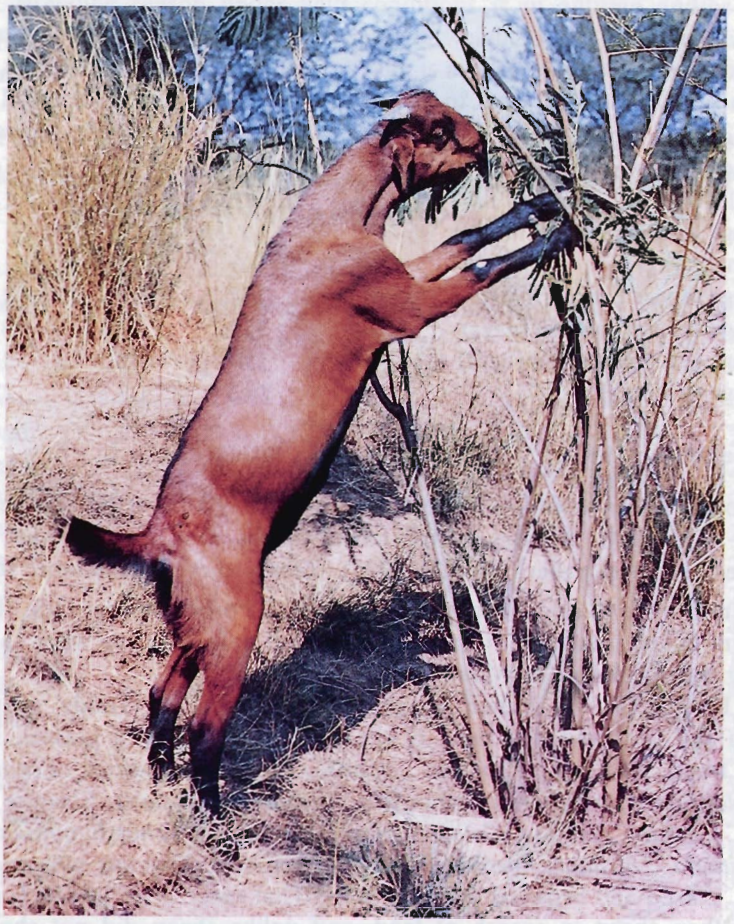

Plate 25. Beetal goat – an important milch and mutton breed of the Punjab.

less so when it is deficient. The senses of touch, smell and taste are constantly used while grazing or browsing. One sense important in determining the preference to one plant specie may be of little value in deciding the acceptability of another plant. Goats can distinguish between bitter, salt, sweet and sour, which enables them to choose from a wider range plant species than cattle and sheep. This is why they can survive in areas where cattle and sheep cannot. Goats also eat certain plants at a definite stage of maturity and not at any or all stages of growth.

Goats do not graze uniformly. They normally pick more palatable grasses and leave a feeding site long before all the available feed is consumed. The time spent on grazing depends on the quality and quantity of forages

and the nutrients, consumed from concentrated feeds. Normally, 8 hours of grazing a day during spring and monsoon, when plenty of forage is available, are sufficient; grazing may be extended to 13 hours during the dry season. Usually goats are put in the pens by evening but when allowed to graze during the evening about 20 percent of the total daily intake was consumed during the night (French, 1970). Kurrar and Midgal (1978) suggested that browsing goats need considerably higher intake than penned goats.

Areas for future research: Breeding goats for better meat, milk and hair production.

- Digestive efficiency of goats for various forages.
- The nutritional requirements for maintenance and production (meat and milk).
- Stocking capacity of various grazing areas.
- Sole grazing of goats vs mixed herds, and grazing systems in various rangelands.
- Mortality due to various diseases and other causes at different ages and in different seasons.
- Feeding habits and grazing behaviour under climatic stress and thermo regulation.
- Water conservation mechanisms.

Camel (Camelus Dromedarius): *General features:* There are only two living species of camel, the dromedary (one-humped, or Arabian (*Camelus dromedarius*) and the bactrian (two-humped of the Asia C. *bactrianus*). The first is not wild, but the second species is found wild in the Gobi Desert (Burton, 1972). The bactrian camel has long, dark hair, shorter legs and a more massive body, which are features useful in adaptation to the cold. The dromedary is slightly larger than the bactrian camel. Its coat is also woolly but shorter than that of the bactrian and its coat colour is usually fawn. In general, bacterian camels are found in mountainous rocky regions while dromedaries are restricted to dry, arid climates and on flat terrian. Bactrian camels are not found in Pakistan. The Arabian or single-humped animal is the only camel found in Pakistan in the arid, and semi-arid areas of Thal, Thar, Cholistan and arid mountainous areas of NWFP and Baluchistan. The estimated population in Pakistan is 0.9 million head. In addition to the production of meat, milk, bones, fibre, and hides, it is used as a draught animal for agriculture and to pull carts. It is the cheapest means of transport in desert and is a beast of burden. It is popularly known as the ship of the desert.

Breeds and breeding: Fifteen breeds have been differentiated in Pakistan which may be classified into two general types; the riding camel and the loading camel. (Ansari and Shah, 1983). The distribution and breed characteristics of some of the camel breeds are given in Table 36.

The breeding season lasts from February to April in the mountains and from November to January in the plains. Oestrus duration is 3-4 days

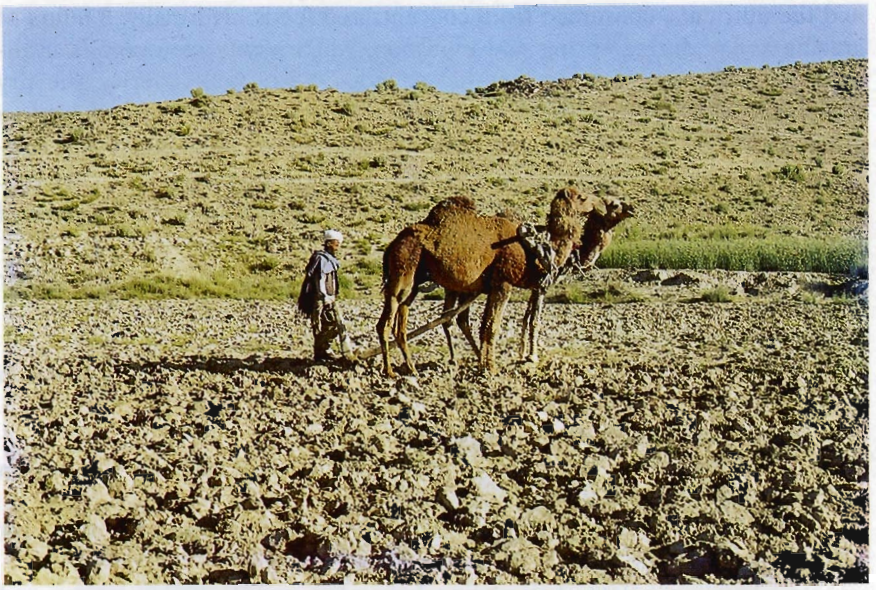

Plate 26. Camels used for draught power in Baluchistan

Table 36. Characteristics of camel in Pakistan

Breed	Distribution	Characteristics
Marecha/Mahra or Bekanari	Cholistan in Pakistan and Rajputana in India	The most excellent riding and racing animal small size head, pointed muzzle, slim body long legs.
Bagri or Booja	Cholistan and Thal	Excelling riding and racing animal, small head, blunt muzzle.
Brela	Reverian tract of Punjab and Sind	Milch type, yields 10–14 litres per day. Lactation 9–18 months, beast of burdon, and can carry upto 1000 kg of load.
Sindi	Sind Province	Heavy size animals used for loading.
Mountaineous breeds such as Kachhi, Mekrani, Brohi, Pashin.	Arid areas of NWFP and Baluchistan	Short statured animal with compact body, used for loading.

Source: Qureshi (1986).

and the oestrus cycle is 23 days (Qureshi, 1986). Gestation is 12 to 13 months, and lactation lasts 1 to 2 years. The mares foal every second year. The foal can run after 2-3 hours (Burton, 1972).

Grazing habits: The camels only browse on local vegetation, and rarely receive any supplementary feed. However, in drought and when working extra barley, oats, date stones or maize is sometimes fed. Unlike slow moving cattle and intensively grazing goats, camels are economical feeders that never overgraze. They keep on moving while feeding. On a good pasture, for example, they may cover 5 kilometers in 2.5 hours while grazing. No matter how rich or how poor the vegetation, the camels take only a few bites from any one plant before moving to another (Pilters and Dagg, 1981). Despite low food intake compared with body weight (300-500 kilograms) desert camels can tolerate hard work and a shortage of food and water than the camels that graze on richer pastures in less arid regions. Indeed, low food intake may increase tolerance to heat (Schmidt-Nielsen, 1964).

Camels thrive on hard dry thorny plants. They have often been observed browsing on spiny plants and ignore leaves that appear to be more palatable. (Pilters and Dagg, 1981).

Camels usually take a variety of food that presumably provides optimal nutrition. The plants commonly utilized by camels belong to genera *Acacia, Salsola, Suaeda, Calligonum, Atriplex, Zizyphus, Tamarix, Aristida, Helianthimum, Capparis, Gymnocarpos, Albizia, Parkinsonia, Prosopis, Haloxylon, Salvadora* and *Tecoma.*

Camels consume 10 - 20 kg of green feed each day, depending on the plants available, which corresponds to 5 to 10 kg of dry matter. Unlike sheep, which graze for longer periods when vegetation is poor or when the water/dry matter ratio is so high that they must eat a large quantity of food to get enough nutritious material (Arnold 1964), camels graze 8 - 12 hours a day, irrespective of the quality of ranges.

The flexible long neck and legs enable them to browse on tall trees and shrubs. The upper lip is cut in the middle and the flaps of the upper lip not only help catch twigs but also enable the nostrils to close during dust storm to keep sand and dust away. They can smell the water from a long distance.

In conclusion, the camel is the most economical and efficient animal in the arid and semi-arid rangelands of tropical and sub-tropical areas of Pakistan.

Yak (Bos Grunnieus): *General features:* The Yak is an important animal of alpine pastures and the Trans-Himalayan grazinglands. It is unsurpassed among the bovines for its capacity to survive under these harsh environments. Perhaps no mammal can thrive at the altitudes of the Himalayas as well as the yak.

Domesticated yaks are about the size of ordinary cattle and rarely exceed 1.3 m at the shoulder. Their live weight is generally between 250 to 550 kg for the male and 180 to 350 kg for the female. The wild yak bull is

twice large as a domesticated bull. The wild yak is one of the largest members of the ox family. Bulls can be more than 2 m high at the withers.

In the Himalayas, the domestic yaks are found almost above an elevation of 2000 m. Most are found in the mountains and plateaus of Tibet and western China. However, they occur from north Afghanistan, the Northern Areas of Pakistan, Nepal, India, Bhutan to Mongolia and the Soviet Union (Annon, (1983).

Domestic yaks are pack animals and are especially useful for riding. They can carry up to 150 kg and at an altitude up to 6000 m. They may carry a pack or persons at a steady pace for day and still remain in good condition. They are also used for ploughing and threshing grain. In some regions, they are the only feasible pack animals. Yak's milk is golden coloured, aromatic and much richer than cow's milk. Milk production varies according to management and nutrition and averages 600 to 1000 kg per lactation period. Yak's hair is used to make ropes, saddles and blankets. Because they are often found above the timber line, their dung is an important fuel at very high altitudes.

Grazing habits: Yaks eat grasses and herbs and also browse, nibbling the leaves of small shrubs. (Annon, 1981). Often, they graze just below the snowline, but use their hooves to uncover patches of grass. They can eat snow when water is scarce. While grazing, they remain widely spaced up to 20 to 50 m apart, and gather for wallowing at mid-day. They eat all types of grasses and small shrubs and may eat encrusted earth to supplement their mineral requirements (Shrestha, 1981). In early summer, yaks graze on lush green grass but subsist on dry, coarse mountain grasses, shrub twigs and leaves during much of the year.

Areas for future research:

- Identification of different yak breeds.
- The genetic potential of the yak for meat, milk and crossing with various cattle breeds adapted to high altitudes.
- Breeding strategies, and herd management systems for domestic yaks.
- Feeding behaviour and nutritional requirement for better production.
- Herd hygiene and diseases.

Buffalo (Bos Bubalis) *General features*: The buffaloes are normally stall fed but dry animals usually graze. Buffaloes were first domesticated in Mesopotamia about 2500 B.C, but the homeland of water buffalo (milk buffalo) is reportedly the Pakistan - India sub-continent. Discovery of seals with drawing of buffalo bulls from Moenjodaro revealed that buffaloes were also reared in this area (Cockrill, 1974). Pakistan's Nili-Rivi is the finest milk breed in the world (Saleem, 1986). Besides several dairy products, it also provides meat, manure and draught power. About 75 percent of the milk supply comes from buffaloes. The average milk yield of Nili-Ravi, is 1800 litres in 305 days; of 5733 litres in 305 days has also been observed.

Ahmed (1983), compared the performance of Nili-Ravi buffaloes and Sahiwal cows; better buffalo calves and heifers gained more weight and utilized nutrients more efficiently than cow calves and heifers. Lactating buffaloes were also superior to cows with respect to the digestibility of various nutrients and in milk production. The dressing percentage of calves varies from 42 to 49 percent and the carcass quality of calves is generally good and meat is consumed in rural as well as in urban areas.

Pakistan has 9.8 percent of the buffaloes of the world which produce about 23 percent (6.525 million t) of the world's buffalo milk (Chaudhry, 1987).

On the basis of the "buffalo human ratio," Pakistan ranks number one in the world (1:7). It also has about 13.6 million head of the best milk breeds (Nili-Ravi and Kundi). Nili-Ravi is found mainly on banks and areas between the Ravi and Sutlej rivers. Though it is concentrated in the central and southern areas of Punjab, it can be seen also in other areas. Kundi is found in Nawabshah, Hyderabad, Larkana and the Mirpur districts of Sind province. The buffalo population in Pakistan by province is 79.19 percent in Punjab, 15.20 percent in Sind. 0.21 percent in Baluchistan and 0.04 percent in the Northern Areas. Buffaloes are mainly concentrated in the province of Punjab, where a large number of animals are reared in and around the cities for milk production.

Breeds and breeding: The buffaloes are divided into 19 distinct breeds (Saleem, 1986) but the major breeds in Pakistan are Nili-Ravi and Kundi, which are described below:

NILI-RAVI: The skin and hair are usually black but brown skin is not uncommon 10 - 15 percent, forehead, face, muzzle, legs, and tail swirl

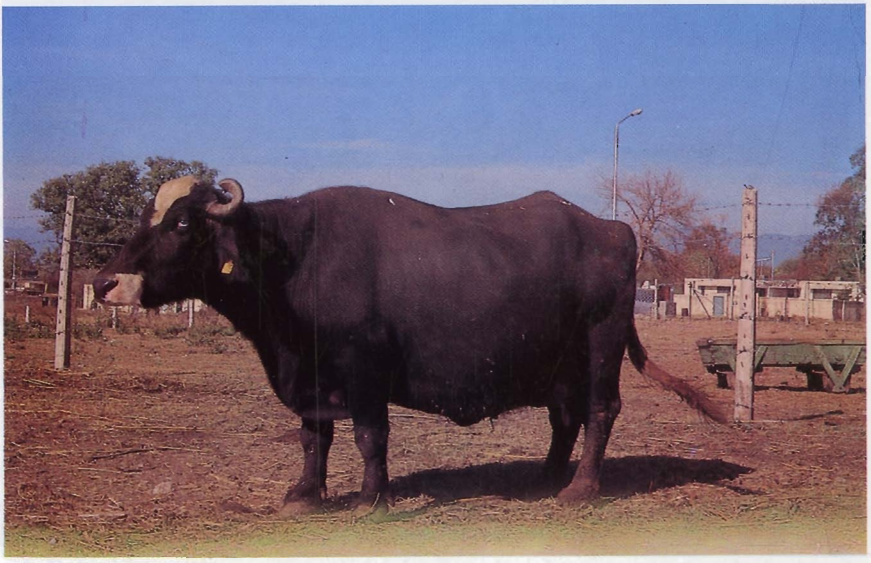

Plate 27. Nili-Ravi buffalo known for high milk yield.

desired, pink markings on the udder are also occasionally present. Horns are short, broad at the base and closely curled back behind the base, teats are long and uniformly placed.

KUNDI: The name 'Kundi' reflects the shape of horns (Kundi means fish-hook); the horns are small and spirally twisted, The skin is jet black but may be light brown. It has a small head and forehead, the tail is thin and flexible. Teats are smaller than Nili-Ravis. Average annual milk yield is 320-450 kg.

Females mature in 959 days, which could be reduced to 585 days if fed a balanced ration. Average age at first calving is 1222 days. Average calving interval is 512 days. Lactation lasts 300 to 326 days and the dry period varies from 65 to 145 days (Saleem, 1986). Gestation period averages 317 days.

Feeding habits: Buffaloes are normally stall-fed. The dry animals are allowed to graze in the areas where cereals have been harvested. Fodder crops such as oats, lucerne, sorghum, maize and cowpeas are the main source of feed. Wheat straw in combination with grains is also liberally given to lactating animals. Buffaloes are often allowed to graze along the river and canal banks. Wallowing in rivers and cannals is also a common feature.

Dry animals are usually fed wheat and paddy straw when fodder is not available. Treating paddy and wheat straw with alkali compound markedly improved the palatability and digestibility of these major roughages. Alkali treated straws had a satisfactory mineral balance (Fahimuddin, 1975).

Plate 28. A herd of Nili-Ravi buffaloes in NARC pasture.

Mudgal (1966) found that buffalo can utilize protein, ether extract, crude fiber, calcium and phosphorus.

Areas for future research:

Future research should address nutrient digestation, rumen microbiology and digestive efficiency, etc.

- Female reproductive problems and artificial insemination.
- Fattening of male calves for beef production by economical balanced rations.
- Production traits, especially to reduce the age at maturity, age at first calving, calving interval, service period, etc., to increase production per animal.

Cattle (Bos Indicus) *General features:* Cattle are very important range animals. In addition to providing milk, meat, hides, and manure, they are also the source of motive power for various agricultural operations such as ploughing, threshing, working wells and mills. They also pull carts in towns and villages and are used as pack animals in some places. Zebu cattle of Pakistan and India are famous for their heat and drought tolerance and are crossbred with Western breeds to upgrade their tolerance for heat.

The cattle provide 23 percent of the total meat and 48 percent of the beef. They provide 2.5 million t of milk annually, 24 percent of total milk production.

The estimated population of cattle during 1987 was 16.9 million head. The percentage of total cattle population in the provinces is as follows:

Punjab	55 %
Sind	19 %
NWFP	20 %
Baluchistan	6 %

Breeds and breeding: According to Joshi and Phillip (1953), there are 28 breeds and types of Zebu cattle in Pakistan and India. The distribution, average weight and milk yield of some of the Pakistani breeds are given in Table 37.

In general, there is no specific breeding season. The cows breed throughout the year; their fertility is higher than buffaloes; the gestation period is 270-299 days, with an average of 280 days (Husnain and Shah, 1985). The age at maturity, age at first calving, calving interval, and lactation period of some of cattle breeds are given in Table 38.

Feeding habits: Feeding pattern varies tremendously according to the purpose, breed and the zone. The milk breeds are usually stall-fed and allowed to graze wherever possible. The river banks provide some pasture after the monsoon in Punjab and Sind. The cattle breeds of Thar, Cholistan and Baluchistan, however, subsist on grazing in extensive and depleted desert rangelands and are rarely stall-fed. In marginal lands, however, bajri

Table 37. Characteristics of cattle breeds of Pakistan

Breed	Distribution	Average weight (kg)				Average milk yield (305 days)
		At birth		At maturity		
		Male	Female	Male	Female	
Red Sindhi	North and north western part of Karachi and Hyderabad popularly known as "Kohistan area" in Sind Province and Lasbela district in Baluchistan Province.	26	24	410	320	2050 litres with 4.2% butter fat
Sahiwal	District Sahiwal and parts of districts Multan and Faisalabad in Punjab Province.	28	26	430	350	3000 litres with 4.5% butter fat
Bhagnari	Bhag territory in north of district Jacobabad in Baluchistan Province.	33	32	600	480	900 litres
Dajal	Dajal area in district Dera Ghazi Khan in Punjab Province	32	30	500	390	900 litres
Dhanni	Attock, Rawalpindi and Jhelum districts in Punjab Province	24	22	400	300	800 litres
Lohani	Loralai district in Baluchistan Province and Dera Ismail Khan in NWFP Province	22	20	300	235	Very low

(continued)

Table 37 continued

Rojhan	Sulaiman Range of Mountains in Southern part of D.G. Khan district (Rojhan, Kachagaddi, Umarkot and Somemiani Villages) in Punjab Province and parts of Dera Ismail Khan, Kohat and Bannu districts in NWFP Province.	23	21	350	250	Very low
Tharparkar Thari	Tharparkar District and Surrounding areas in Sind Province	30	28	480	380	1900 litres

Source: Khan et al., (1982).

Table 38. Production traits of cattle breeds of Pakistan

Breed	Age at maturity (days)	Age at first calving (days)	Calving interval (days)	Lactation period (days)	Dry period (days)
Sahiwal	808	1149	412	269	143
Bhagnari	830	1263	545	312	223
Lohani	912	1275	390	192	198
Thari	916	1336	571	353	218
Dhanni	869	1210	459	224	235

Source: Lala and Saleem (1984), Wahid (1975).

Plate 29. Cross breeding of Sahiwal and Australian cattle for high milk yielding hybrid.

(*Pennisetum typhoidies*) and guar (*Cymopsis psoyaloides*) are grown, if monsoon rainfall is adequate. Famine in the desert areas usually occurs every third or fourth year. The intensity is inversely proportional to the amount of rainfall received during monsoon. Cattle normally graze on grasses and legumes, but can also browse various fodder trees and shrubs when forage

is scarce. When little or no grazing land is available, the cattle are fed wheat straw, dry stalks of jowar, bajri and rice paddy. The milk cows often receive concentrates. The by-products of farm crops and industry including, oil cakes, crushed grains and pulses, pulse husks, wheat bran and rice polishings are fed as concentrates to milking animals. In irrigated areas, the maize, sorghum, cowpeas, oats, brassica, lucerne and barseem are grown for fodder and fed either as green fodder or as hay.

Cattle have no upper incisors and, therefore, use their highly mobile tongue as prehensile organs. The tongue encircles a small stand of grass, and is drawn into the mouth. The structure of the lower jaw makes it impossible for cattle to graze closer than 1 cm from the soil while sheep can graze at soil level (Hafez and Scott, 1962).

Cattle cover about 4 km per day during grazing. It increases in warm, wet, windy weather and when forage is scarce. Cattle prefer to consume herbage just under the muzzles. Intake of fresh herbage is about one-tenth of body weight. Time of grazing varies from 4 to 9 hours a day.

Areas for future research:

- Beef breeds of cattle suited for extensive/semi-extensive farming system in various ecological zones.
- Efficiency of feed utilization, for beef production, milk production, etc.
- Economical and available rations to fatten beef calves.
- Reproduction performance, e.g., reduction of calving interval and age at first calving, fertility.
- Crossing with exotic breeds for beef and milk production.
- Grazing behaviour and grazing systems suited to various ecological zones.

RANGE ANIMAL FEEDS AND NUTRITION

Livestock are fed on different sources of feed from season to season as well as from one ecological zone to the other. At present, about 2.71 m ha are devoted to fodder crops, which produce about 17.44 million t of dry fodder.

Cereal crop residues are fed to animals in combination with concentrates. About 35.8 million t of crop residues are produced from wheat, rice, barley, oats, maize, sorghum, millet and rice hulls; production is 21.7, 8.7, 0.4, 1.3, 1.5, 0.5, 0.5 and 1.2 million t, respectively (Ali, 1986). Production of oilseed cakes/meals from cotton seed, brassica seed and other oilseed is about 1.8 million t. Rangelands provide about 15.30 million t forage. It is estimated that shamlats, belas and irrigated plantations provide about 2 million t of dry forage. Total forage yield and TDN and DP yield are given in Table 39.

To feed 93.5 million livestock, about 43.8 million.t of TDN and 4.8 million.t of DP are required. The TDN shortage is about 21 percent and the DP shortage is about 35 percent. Due to heavy competition with grain

Table 39. Livestock feed resources in Pakistan

Feedstuff	DM (m.t)	TDN (%)	DP (%)	TDN	DP
				(million tons)	
Fodder crops	17.50	60	10.0	10.57	1.75
Cereal crop residues, straw, etc	35.85	30	2.0	10.76	0.70
Crop by-products, etc	3.00	30	2.0	0.90	0.06
Rangelands at 60% utilization of available forage	15.30	50	4.5	7.65	0.69
Oilseed cakes and other protein concentrates	1.80	70	18.0	1.26	0.31
Cereals, legume seeds and their by-products	4.60	70	7.0	3.22	0.31
Total:	78.05	–	–	34.36	3.82

Source: Mohammad (1987)

crops, there is a limited ability to expand the production of fodder crops on cultivated areas. However, rangelands, which constitute over 60 percent area of Pakistan, have the potential to feed the increasing livestock population. The current annual forage production from rangelands is about 25 million t of dry matter which could be increased three times.

Very limited research has been concerned with the digestibility of grasses, legumes and fodder trees and shrubs. Even the nutritional values of most of the range forages are not known. Estimated analysis of a few promising grasses was obtained from University of Agriculture, Faisalabad, (Table 40). Gohl (1981) reviewed the nutritional contents of tropical feeds. Sheikh (1966) reported the nutritional composition of a few plants of desert lands. Pathak and Jakhmola (1984) provided the estimated composition of common forages, many of which are found in Pakistan. Research concerning forage quality, particularly of fodder trees and shrubs, must be emphasized.

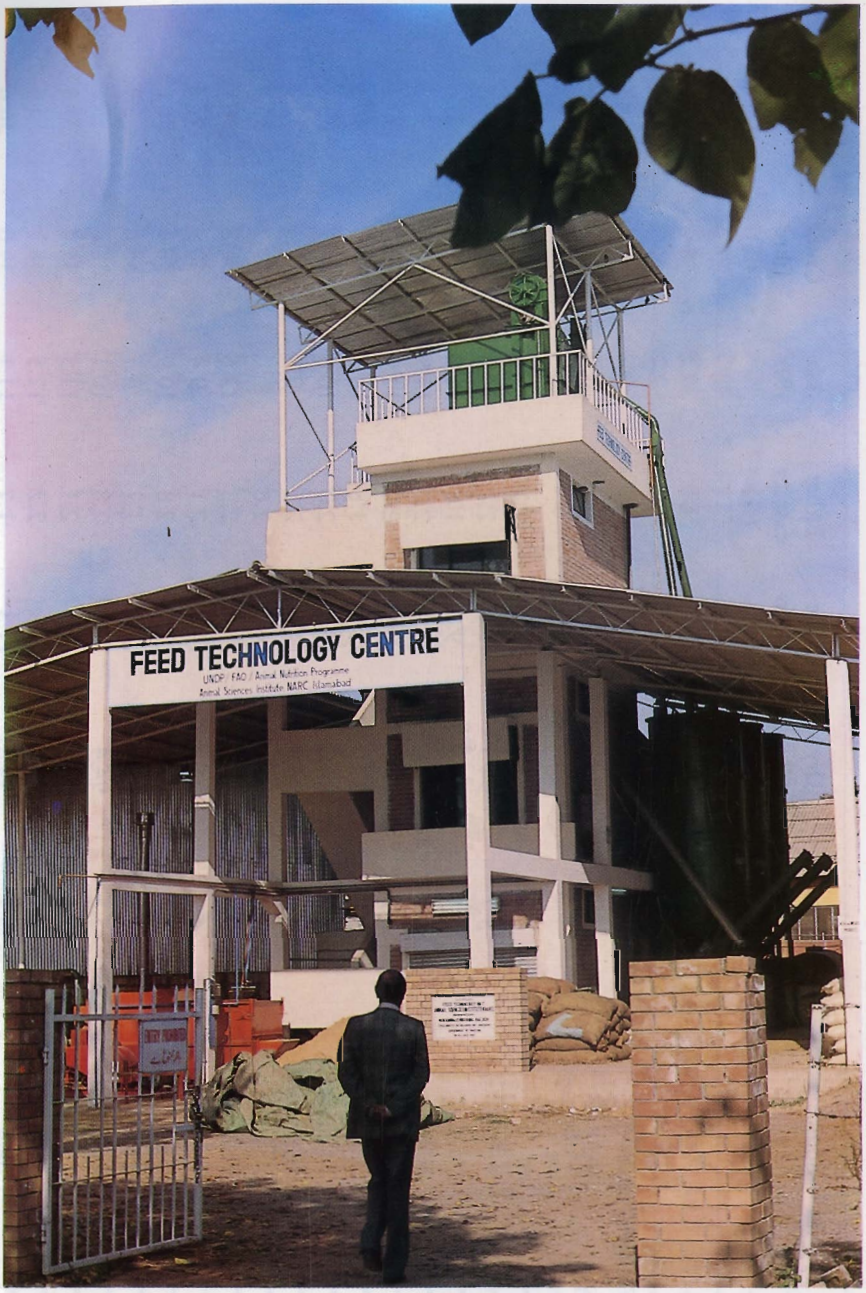

Plate 30. Feed Technology Unit at National Agricultural Research Centre, Islamabad.

Table 40. Proximate analysis of range plants in Pakistan

Forage Species	Source	Moisture (%)	Dry matter (%)	Crude protein (%)	Either extract (%)	Ash (%)	Crude fibre (%)	NFE (%)
1	2	3	4	5	6	7	8	9
A. Forage Grasses								
Cenchrus ciliaris	PFI	5.4	94.5	10.7	1.8	10.0	37.6	39.7
"	"	5.2	94.7	11.8	2.3	11.6	38.2	35.8
"	"	5.7	94.3	9.6	2.1	14.0	36.7	37.5
"	"	5.1	94.8	9.8	1.8	11.2	36.3	40.6
"	Islamabad	5.1	94.8	10.0	2.0	11.9	37.8	38.2
"	"	3.2	96.7	9.6	2.0	12.9	36.2	39.1
"	Sind	5.9	94.0	11.8	1.8	12.2	37.6	36.5
"	Peshawar	5.9	94.0	13.1	2.0	10.8	40.1	33.8
"	Islamabad	4.9	95.8	14.0	2.2	9.3	41.4	32.9
"	Australia	4.7	95.2	14.0	2.6	8.3	41.2	33.7
"	Peshawar	3.9	95.0	11.8	2.3	12.6	36.8	36.4
	"	4.7	95.2	14.2	2.1	9.4	40.9	33.2
"	USA (Taxas)	5.1	94.8	11.9	2.8	10.9	38.3	36.8
"	Thal	4.9	95.0	12.1	1.7	9.7	38.6	37.7
"	Peshawar	5.5	94.4	13.1	2.8	10.1	38.3	35.5
"	"	5.5	94.4	11.3	2.1	11.5	37.4	37.5
"	"	5.7	94.2	10.9	2.2	12.5	38.1	36.0
"	Sind	5.1	94.8	11.3	1.7	11.1	39.0	36.6

(continued)

Table 40 continued

"	Tunis	5.2	94.7	12.5	2.1	10.9	39.4	34.9
"	"	4.0	95.9	10.3	2.5	9.9	37.3	39.8
"	Peshawar	6.0	93.9	9.6	2.0	13.4	36.6	38.2
"	Australia	5.8	94.1	14.4	2.8	9.7	40.1	32.9
"	"	7.0	92.9	14.5	1.8	9.2	40.1	34.2
"	Peshawar	5.4	94.5	11.8	1.7	10.4	37.5	39.4
"	India	6.0	93.9	12.6	2.1	10.8	35.2	39.1
"	"	6.9	93.1	12.2	2.7	11.1	35.1	38.8
"	USA	6.1	93.8	14.4	2.3	8.7	39.7	34.7
"	Peshawar	7.3	92.6	13.3	2.6	9.1	39.8	34.9
"	"	7.3	92.6	13.3	2.6	9.1	39.8	34.9
"	"	5.9	94.0	11.3	2.1	11.8	37.5	37.6
"	"	6.2	93.7	13.1	2.0	10.3	36.2	38.2
"	USA	6.1	93.8	11.8	2.1	12.3	38.4	35.3
"	"	6.0	93.9	12.6	2.1	10.9	30.7	35.5
"	Cholistan	6.3	93.6	11.8	2.4	10.1	39.1	36.4
"	Peshawar	6.2	93.7	10.0	1.9	11.5	39.5	36.9
"	Local	4.0	95.3	13.2	2.2	9.6	40.1	34.6
"	USA	6.2	93.7	13.1	2.3	9.5	40.2	34.7
"	Karachi	5.3	94.6	9.7	2.0	12.8	36.5	38.7
"	Thal	5.3	94.6	12.6	2.8	10.1	38.2	36.8
"	Peshawar	6.2	93.7	12.2	2.2	10.4	38.4	36.5
Chrysopogon	"	5.6	94.3	9.2	1.4	10.5	26.3	52.2

(continued)

Table 40 continued

montanus								
Chrysopogon aucheri	"	6.1	93.8	9.6	1.5	9.6	28.5	50.6
Cymbopogon *jawarancusa*	"	4.8	95.1	8.7	4.2	11.1	26.7	49.0
Eragrostis cuperba	USA	4.7	95.3	10.5	1.1	12.1	33.5	42.4
Lasiurus sindicus	Sind	4.4	95.6	8.9	1.5	8.1	40.3	40.9
Panicum	"	6.1	93.8	16.1	3.2	13.1	29.3	38.1
Panicum antidotale	Peshawar	6.3	93.6	16.4	3.2	9.7	28.1	42.3
"	"	4.8	95.1	15.3	2.8	10.6	29.7	41.6
"	Islamabad	5.3	94.6	15.3	3.4	10.2	29.3	41.6
"	Peshawar	5.1	94.8	16.7	2.7	10.3	28.6	41.5
"	Sind	4.9	95.0	14.8	3.2	8.7	30.1	42.9
"	"	6.1	93.8	14.4	3.4	8.8	29.6	43.6
"	Peshawar	5.3	94.6	16.6	3.0	10.2	29.5	40.5
"	"	5.7	94.2	17.5	3.4	10.3	28.9	39.7
"	Sind	5.5	94.4	15.7	3.6	9.3	29.6	40.6
"	"	6.5	93.4	15.3	3.5	9.4	30.5	41.1
"	USA	5.9	94.0	15.7	3.8	10.1	30.0	40.7
"	Sind	6.7	93.2	14.1	3.1	9.6	30.1	42.5
"	"	6.1	93.8	16.6	3.4	9.4	29.2	41.3
"	"	7.1	92.8	16.4	3.5	9.5	29.2	41.1

(continued)

Table 40 continued

B. Fodder crops:

Berseem *(Trifolium alexandrium)*

F.S.D. Late	83.1	16.9	16.7	2.1	12.9	18.6	49.3
Khundrani	83.0	16.9	19.3	2.1	13.5	17.7	47.3
I.–64 + 13	83.7	16.3	17.5	2.1	13.6	18.2	54.4
Multifliate	84.6	15.3	19.1	2.2	14.2	17.7	86.5
Muscavi	85.6	14.3	19.4	2.2	13.8	17.3	47.4
P–31	83.6	16.3	17.4	2.2	13.0	18.3	48.9
P–37	85.2	14.7	17.4	2.3	12.1	16.2	52.0
P–57	82.6	14.7	17.4	2.2	13.6	18.4	50.5
P–157	82.6	17.5	18.5	2.1	13.2	18.2	47.6
Sadi	85.5	14.4	18.3	1.9	13.6	18.6	48.2
Synthetic 1/79	83.4	16.5	17.8	2.1	14.3	17.7	47.9
3/73	82.7	17.2	16.9	2.2	13.9	18.1	48.3
4/11	84.5	14.5	17.9	1.9	14.4	17.9	48.5
P-139	83.6	16.3	17.4	1.9	13.4	17.8	49.5
P-143	83.6	16.3	16.5	2.2	12.9	17.7	50.4
P-155	83.6	16.3	16.6	2.0	12.9	16.5	51.9
Synthetic II	84.0	15.9	16.8	2.1	12.4	18.2	50.2
Synthetic III	83.0	17.1	17.3	2.1	12.5	17.2	50.7
B-18	83.1	16.8	19.6	2.1	14.3	17.2	46.5
B-32	83.4	16.5	17.1	1.9	12.3	17.7	50.5

(continued)

Table 40 continued

L-67	83.4	16.5	16.5	2.4	13.8	18.3	48.9
L-94	82.9	17.0	17.1	2.2	13.5	18.4	48.9
L-117	83.1	16.8	19.1	2.2	12.5	17.5	48.5
P-22	83.9	16.0	18.3	2.1	13.4	17.8	47.9
P-178	85.4	14.4	17.7	2.1	13.7	18.4	47.1
P-185	83.5	16.6	17.3	2.1	12.8	17.7	49.9
Sadabahar *(Sorghum sudanensis)*							
J-S 263	75.0	24.9	6.4	1.5	8.3	32.7	50.8
RLA x SG 523	77.1	22.8	5.8	1.5	8.5	32.2	51.9
RLA x SG 555	76.8	23.1	6.2	1.3	9.3	32.0	50.9
RLA x SG 556	77.7	22.2	7.0	1.7	9.2	32.2	49.6
RLA x SG 565	77.1	22.8	6.6	1.8	8.4	32.4	50.4
RLA x SG 605	74.0	25.9	7.2	1.6	10.1	32.1	48.8
RLA x SG 1252	77.5	22.3	6.2	1.5	8.2	32.1	51.3
RLA x SG 1253	76.0	23.9	7.2	1.7	8.7	32.8	49.2
RLA x SG 4158	76.5	23.4	7.0	1.5	8.4	32.0	50.8
RLA x SG 8823	78.5	21.4	6.3	1.7	9.5	32.6	49.7
RLA x SG Piper	77.2	22.7	6.3	1.7	9.8	32.5	49.5
RLA x SG Sweet I	76.4	23.5	5.9	1.8	9.8	32.4	49.8
RLA x SG Sweet II	77.1	22.8	6.4	1.5	9.3	32.4	50.1
RLA x Sg Sweet III	76.9	22.9	6.7	1.5	9.8	32.0	48.7

(continued)

Table 40 continued

Sorghum	65.8	34.6	4.9	0.8	6.7	30.8	56.6
Oats *(Avena sativa)*							
Avon	67.1	32.3	5.8	2.0	10.5	26.9	54.4
Kent	70.8	29.1	6.3	2.1	10.5	26.9	53.9
No. 11	70.2	30.0	5.7	2.2	10.5	27.1	54.2
Pd2 Lv65	72.3	27.6	6.4	2.1	10.5	25.6	54.9
Swan	69.3	30.6	5.4	2.1	10.8	26.9	54.6
Sargodha 81	70.0	28.9	6.2	2.1	10.8	26.6	54.1
Algerian	70.2	29.4	6.6	2.1	10.7	26.8	53.6
Cowpeas *(Vigna sinensis)*							
Australian	82.1	17.8	14.6	2.7	13.4	24.0	45.1
Mississipi	82.4	17.5	14.7	2.6	12.7	24.3	45.3
No. 1	81.5	18.4	14.0	2.8	11.7	24.7	46.9
P-76	81.8	18.1	14.1	2.4	13.6	24.8	44.8
P-251	82.3	17.6	14.2	2.6	13.3	23.8	46.3
P-259	83.0	17.0	13.8	2.6	11.3	24.2	47.8
P-518	82.6	17.3	13.8	2.6	13.5	24.5	45.3
411	81.5	18.4	13.4	2.8	13.2	24.8	45.6

Source: Forage and Fodder Research Unit, University of Agriculture, Faisalabad, 1987.

Chapter 7

Range Management Strategy

RANGE POLICY

The need for a national policy concerning the scientific management of rangelands has been recognized since independence in 1947. The CENTO range teams in 1964 and 1971 recommended the formulation of a national range policy. The Pakistan Range Management Conference held in 1966 recognized the importance of involving livestock producers in major decisions regarding range policy, and recommended the creation of grazing advisory committees (including the representatives of public) at provincial, divisional and district levels to outline range policy and programme and to implement these decisions, (PFI, 1966). The Working Group on Range Management (1970) also stressed the urgency of the developing rangeland management policies.

The National Range Management Committee (1973) outlined the following policy guidelines which should be implemented immediately.

- All rangelands will be developed/managed primarily for livestock production consistent with the concept of multiple land use.
- Indiscriminate and unscientific practice of shifting cultivation and breaking rangelands for agriculture has proved unrewarding and harmed the land by reducing their productivity to support livestock. Shifting cultivation should be stopped in arid/semi-arid zones and on steep slopes. Regulated, scientific methods should be adopted and fodder crops could be cultivated to support the maximum number of livestock compatible with correct land use to increase economic returns.

- Legislation is needed to support range management agencies and their programmes.
- To develop and manage vast rangeland resources, independent and effective organizations will be created at provincial as well as federal levels. These organizations will be exclusively responsible for planning, developing and implementing range management schemes.
- To ensure co-operation, support and participation, producers will be involved at all levels of project formulation and execution. Suitable technical as well as economic incentives will be provided to seek producers cooperation and encourage their participation in range management programmes.
- To optimize economic returns from rangelands, efforts will be made to ensure proper feeding, management, marketing and upgrading of livestock through selection and breeding. Preparation of livestock feeds from agro-industrial wastes and by-products will be encouraged. In order to eliminate or minimize overgrazing, surplus livestock off take facilities should be created to make maximum use of excess livestock. This would require streamlining of management, marketing, processing, packing and even export of livestock/livestock products. Feed lots will be organized.
- A balanced integration of rangelands, croplands and forestlands is imperative to ensure year-long optimum provision of forage and fodder to livestock.
- Scientific range management will improve the economic well being of stockmen. The range development programme will no longer be primarily concerned with the direct financial return to state.

The national range policy should include the recommendations of various committees. Management of rangelands must be phased over next 15 years. During the seventh five-year plan period, development of technical manpower, establishment of research facilities and creation of scientific awareness among the pastoralists may receive priority. Range management plans based on proper resource evaluation may also be prepared during this period. Range areas located in different ecological zones may be selected for demonstration projects concerning the scientific management of rangelands. Range research should be made an important component of each project. The eighth five-year plan may primarily focus on large scale adaptation of the practices demonstrated in pilot projects.

RANGE AGENCIES AND ORGANIZATIONS

At present no independent agency deals with the management of rangelands in Pakistan. The public rangelands are under the control of the Provincial Forest Departments. In Punjab and Sind provinces, Conservator of Range Management positions have been created to look after range development projects. It has been difficult to attract and retain highly qualified range managers partly because range management is viewed as

being outside the mainstream of Forest Departments. The posts are more isolated, offer few amenities and personnel receive no extra compensation. In Baluchistan, a few range areas are under the control of Provincial Forest Department. Cholistan Development Authority in Punjab and Arid Zone Development Authority in Sind are also working in desert range areas. However, they have not yet initiated any project dealing with the management of rangelands. At the federal level, the Inspector General of Forests in the Ministry of Food, Agriculture and Cooperatives looks after the affairs of range management sector.

The need for an independent agency dealing with planning, development and management of rangelands in Pakistan has been emphasized time and again. The First Range Management Conference (1966) and Working Group for Range Management in 1970 recommended the creation of a separate rangeland agency. The National Range Management Committee in 1973 recommended a comprehensive organization structure for the federal government and the provinces. In 1983, a Subcommittee of Range Management outlined an institutional strategy for the development of range resources (Government of Pakistan, 1983); this involved creation of a post of Rangeland Development Commissioner under the Ministry of Food, Agriculture and Cooperatives.

Scientific management of livestock as well as the development of forage resources needs equal attention. Range management experience during the past 40 years indicates that foresters have successfully improved several rangelands by reseeding of grasses, planting trees and shrubs and developing water ponds. However, most of the projects where livestock were introduced had little tangible impact. On the other hand, range management projects run by livestock specialists concentrated on the veterinary aspects and paid little attention to ensure sustained forage production from rangelands. It is, therefore, imperative that range managers, who have been trained both in the management of range vegetation and livestock production, be assigned the responsibility of rangeland management. The need for the creation of a cadre of range professionals in Pakistan was emphasized by Johnston (1962). A prerequisite to the development of such a cadre is to ensure that working conditions and other amenities of range management positions are comparable to those enjoyed by individuals in related endeavours. At present, they are not. A transfer to a range management posting is viewed by most forest officers as a retrogressive step in their career. This attitude must be changed to attract adequate technical ability to rangeland problems. The payment of Unattractive Area Allowance for range management personnel may be an added incentive.

Those already trained in range management should be mobilized to work in the field. Unfortunately, few are interested in the discipline because of the reasons outlined above. Transfers at less frequent intervals or transfers limited to the range management field would greatly enhance the development of a group with a comprehensive knowledge of their discipline.

The National Commission on Agriculture (1988) has recommended

the creation of a Watershed and Aridland Development Authority (WALDA) under the Ministry of Food and Agriculture with the following functions:

- To evolve a long range policy for conserving the country's land, water and forest resources.
- To undertake or promote appropriate research activities in cooperation with the federal and provincial agencies in the field of watershed management, range development and development of arid areas.
- To coordinate and financially support, to the extent possible, the activities of all federal and provincial agencies dealing with the subjects entrusted to the Authority.

The proposed "Authority will perform a policy coordinating, funding and training role for the provincial agencies, which will be charged with the main responsibility for the execution of policies and programmes. The Authority should cover all the natural resources - water, land and forest - in the areas covered by its activities and can commence its operations with a nucleus organisation created by the merger of the present Watershed Management Wing of WAPDA and the office of the Inspector General of Forests in the Ministry of Agriculture. The main task of the new organisation will be to develop a resource development and management plan and to coordinate and support the work of existing organizations, such as the Federal Arid Zone Research Institute, the Pakistan Desertification Monitoring Project, the Cholistan Institute of Desert Studies, the Cholistan Development Authority and the Sind Arid Zone Development Authority, (SAZDA) and the Agency for Barani Area Development (ABAD) in the Punjab. Some of the organisations will have to be strengthened or new ones may be created to deal with tasks which are not now being addressed. Detailed plans for this purpose can be formulated after the master plans for watershed management, range development and the development of barani and arid areas have been prepared".

The current drought prevailing in the country is directly threatening the very existence and survival of human beings, livestock and wildlife in the deserts of Cholistan, Tharparkar and Kohistan. Therefore, recommendations of the Commission must be implemented immediately so this vast natural resource can be protected.

Given the limited technical manpower available in the range management sector, the Authority may help provincial agencies to prepare management plans of rangelands, organize short term training courses for provincial range managers and provide liaison with international agencies to keep abreast with the latest technology. For this purpose a Directorate of Rangeland Management with a core staff of the following professionals is needed in the Authority:

i. Range Management Specialist
ii. Range Improvement Specialist
iii. Range Livestock Management Specialist

iv. Range Sociologist cum Economist
v. Range Evaluation cum Planning Specialist

The provincial agencies like SAZDA, Cholistan Development Authority etc. may recruit range management professionals to undertake range improvement/development projects.

RANGE RESEARCH NEEDS

The scientific management of rangelands in Pakistan was initiated at the Maslakh Range Project in 1954. A Range Management Research Branch was created at the Pakistan Forest Institute (PFI), Peshawar, during 1964. Since then, Provincial Forest Departments have developed several range education, demonstration and research projects in various areas. A major advance was the establishment of a Directorate of Range Management and Forestry in the Pakistan Agricultural Research Council (PARC) in 1974. In 1975, PARC developed a National Forage and Fodder Research Programme to achieve the following objectives:

i. To develop an integrated National Forage and Fodder Research Programme whereby each research institution would be a vital component of the system; National Agricultural Research Centre at Islamabad would be a nucleus institute of this programme.
ii. To select and breed superior forage and fodder varieties.
iii. To evaluate varieties, fertilizers and other agronomic practices to maximise the forage and fodder production per unit area of important forage crops.
iv. To evaluate forage and fodder quality through biochemical analysis as well as feeding trials with livestock; and
v. To introduce, test and select grasses, legumes, shrubs and important forage trees in various range ecological zones of Pakistan.

Range Research Activities: The organization of the forage and pasture research network in Pakistan is given in Figure 8.

Current research activities at different collaborating institutions/stations under the National Forage and Pasture Programme are listed in Table 41. Progress and plan of work of the cooperating units is reviewed periodically and priorities of research are determined according to the socio-economic needs and ecological conditions of the area.

Range research activities in Pakistan also involve germplasm evaluation, pasture evaluation trials, pasture management studies and economic evaluation (Figure 9).

Range Research Thrusts: So far, very little information is available for the scientific management of range resources. There is an urgent need for the development of a comprehensive National Range Research Plan, which can be prepared by appointing a range research group under the supervision of WALDA. All range development projects must have a strong research component. Research in various range ecological zones may be

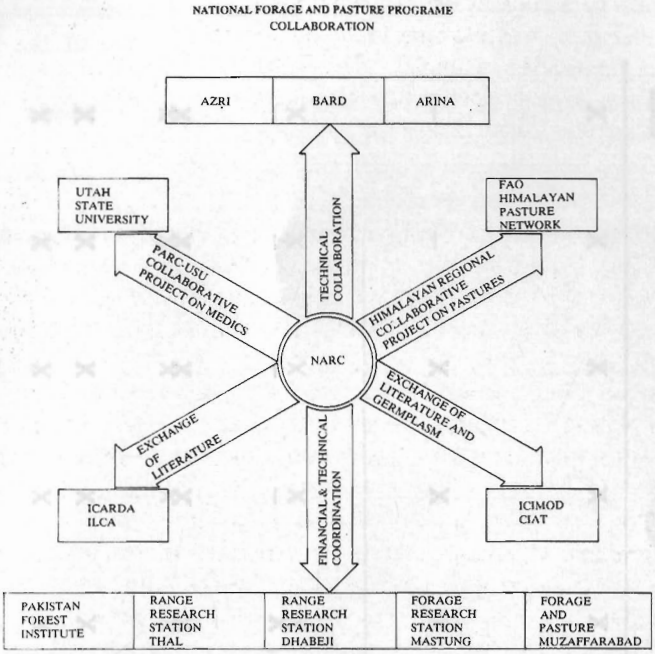

Figure 8. Forage and pasture research institutions network in Pakistan.

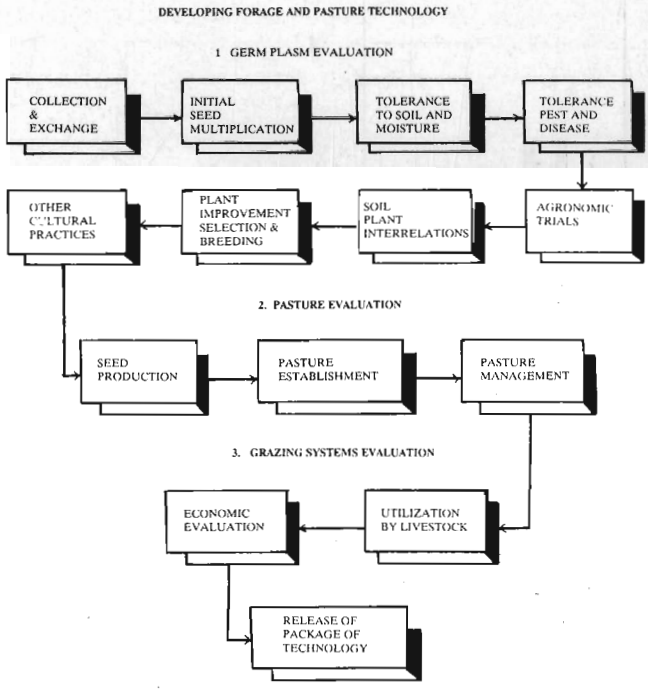

Figure 9. Range and posture research methodology adapted in Pakistan.

Table 41. Research activities under way at different Range Forage Research Stations/Institutions

Research activities	NARC	PFI	Thal	Dhabeji	Mastung	Muzaffar-abad
Collection and introduction of superior exotic and indigenous forage species/ecotypes and preliminary screening and selection under different ecological conditions.	X	X	X	X	X	X
Uniform agronomic trials on the improved varieties of *Cenchrus ciliaris, Panicum antidotale, Pennisetum purpureum* and *Chloris gayana.*	X	X	X	X	–	–
Ecophysiological studies on plant, soil and water relationship	X	X	–	–	–	–
Test adaptation trials of shrubs and trees for fodder, fuel and soil improvements.	X	X	X	X	X	X
Application of suitable improvement practices for pasture development.	X	X	X	X	X	X
Evaluation of nutritional value of forage grasses, legumes, shrubs and tree species/ ecotypes.	X	X	X	X	X	X

(continued)

Table 41 continued

Establishment of ecological exclosures	–	–	X	X	X	X
Seeding of pasture lands to test, demonstrate and evaluate package of technology.	X	X	X	X	X	X
Establishment of pastures of selected grasses and legumes for simulated and/or animal grazing trials.	X	X	X	X	X	X
Seed multiplication of promising forages and their distribution	X	X	X	X	X	X

strengthened by adequate funding and provision of qualified range scientists and research facilities at various coordinating units of the National Forage and Pasture Programme.

Research must be initiated or strengthened in the following areas:

i. Forage germplasm evaluation.
ii. Range improvement studies such as reseeding, range fertilization, water harvesting and spreading.
iii. Range resource inventory, evaluation and utilization modelling.
iv. Range plant-soil-water relationships.
v. Forage quality and range animal nutrition.
vi. Development of supplemental feeds such as silage, urea molasses, etc.
vii. Testing of grazing systems.
viii. Selection of forages for winter feeding.
ix. Selection of drought and salt tolerant plants.
x. Economic evaluation of livestock ranching.
xi. Determination of the social customs and patterns of range use and learning which approaches/incentives will facilitate social changes or adaptation of new practices.

Research on Fodder Crops: Research on fodder crops is being conducted at the following institutions:

i. National Agricultural Research Centre (NARC), Islamabad.
ii. Fodder Research Institute (FRI), Sargodha.
iii. Livestock Production Research Institute (LPRI), Bahadurnagar, Okara.
iv. University of Agriculture, Faisalabad (UAF).
v. Agricultural Research Institute (ARI), Tandojam.
vi. Agricultural Research Institute (ARI), Tarnab, Peshawar.
vii. Agricultural Research Institute (ARI), Sariab, Quetta.

The research activities at the above institutions are given in Table 42

Some of the main constraints and problems in increasing fodder production are as follows:

- Paucity of technical manpower, specialized in fodder crops.
- Shortage of short-term training of in-service personnel.
- Lack of good quality seed of high yielding fodder varieties.
- Failure of private/public agencies to produce seed of fodder crops.
- Inadequate use of fertilizer in fodder crops by farmers.
- Lack of large-scale dissemination of improved fodder production technology.
- Lack of coordination/linkage with international institutions dealing with fodder crops.
- Lack of provincial institutions to deal with fodder research in various agro-ecological regions.
- Insufficient financial resources for fodder crop research.

Research priorities: The following areas of research are recommended

Table 42. Fodder crops research activities under way at various agricultural institutions

Research activities	NARC Islam-abad	UAE Faisal-abad	FRI Sargodha	ARI Tando-jam	ARI Sariab	ARI Tarnab
Collectin & introduction of superior exotic & indigenous fodder crop species/ varieties and their screening and selection	X	X	X	X	X	X
National uniform performance trials on sorghum, millet, cowpeas, berseem, lucerne, oats and barley varieties	X	X	X	X	X	X
Agronomic and other cultural practices for evaluation of high fodder yielding, multicut nutritious and disease and insect resistant varieties of different fodder crops	X	X	X	X	X	X
Bio-chemical analysis and digestibility trials	X	X	X	X	X	X
Breeding and hybridization of fodder crops to produce nutritive and high yielding varieties	X	X	X	X	X	X
Demonstration of improved fodder varieties on farmer's fields	X	X	X	X	X	X
Seed multiplication of selected, improved fodder crop varieties and their distribution	X	X	X	X	X	X

for increasing fodder production in cultivated lands:

- Breeding better varieties of fodder crops.
- Demonstration of improved production practices for fodder crops like berseem, lucerne, oats, sorghum, maize, millets, barley, cowpeas and guara.
- Development and multiplication of seed of improved varieties.
- Evaluation of the nutritive value of grasses, legumes, cereal, and other fodder species/varieties through biochemical analysis, feeding and digestion trials.
- Studies of crop rotation and intercropping to integrate livestock and crop production.
- Collection and introduction of germplasm of superior exotic and local fodder species/varieties and evaluation under different ecological conditions.
- Determination of the irrigation requirements for different fodder crops.
- Improved methods of preserving fodder.
- Development of fodder varieties suitable for saline and waterlogged soils and drylands.

Actionable Programmes: The following programmes are suggested:

- Introduction trials at various Fodder Research Institutes.
- Uniform national yield trials to test and select varieties at various institutes under irrigated and barani conditions.
- Uniform national yield trials to test and select varieties at various institutes under irrigated and barani conditions.
- Plan outreach programmes for farm demonstrations.
- Crop rotation trials to determine how the fodder crops and varieties fit into the cropping patterns of different ecological zones.
- Plan studies on hay and silage making and preservation of fodder.
- Determine the water requirements of fodder crops.
- Evaluate the nutritive value of grasses, legumes, cereals and other fodder species/varieties through biochemical analysis.
- Implement a hybridization programme to produce a S.S. Hybrid and a B.N. Hybrid.
- Acquire and maintain parent lines of existing high yielding hybrid crops like 'Sadabahar'.
- Produce seed of improved and tested varieties of fodder crops at research institutions/stations and multiply this seed at Provincial Seed Corporations.
- Develop fodder varieties for saline, waterlogged and dry lands.
- Establishment of a national fodder research institute with subcentres in every province.

RANGE EDUCATION

There is an acute shortage of those with technical training in range management. In early 1960s, a few foresters received their degrees in range

management from the United States. During past 10 years, PARC sponsored five Ph.D and eight M.S. students and several short term courses in range management. More than 100 professionals enrolled in training courses organized by National Forage and Pasture Programme during 1982-87 at NARC. So far, there has been no concerted effort to training of pastoralists or livestock farmers.

Graduate Course Work at PFI: At present, range management is taught at PFI, Peshawar, and the University of Agriculture, Faisalabad. The Baluchistan Agriculture College, Quetta and Barani Agriculture College, Rawalpindi are introducing B.Sc. in Range Management Programmes. At PFI, only one graduate course in range management is offered as a part of M.Sc. Forestry Programme. The course contents are as follows:

i. *Introduction:* Definition of rangeland and range management, importance of range management as a science, its contribution to the national economy, components of land resource (i.e., water, soil, forage, timber, wildlife, people and aesthetic values and their relationship with forage production), integrated management of land resources as contributed by watershed management, forest management, wildlife management and range management and benefits of an integrated approach.

ii. *Development of range management:* Grazing as a natural result of interaction between man and game, development of pattern of use in nomadic life, semi-nomadic and sedentary life (agriculture and industrialization), brief development history of range management in the United States, South America, Australia, Europe, Asia, Africa and Pakistan.

iii. The range resources of Pakistan.

iv. *Basic principles of range management:* Plant morphology and range management, classification of plants into grasses and grass-like, forbs, shrubs and trees; comparison, morphology, importance of plant morphology in range management and morphological responses of plants to grazing and browsing.

v. *Plant physiology and range management:* Physiological activities of plants as affected by range management, absorption of minerals and water, translocation modes, photosynthesis, metabolism, storage of food material and growth, range management and ecology, principles of plant succession and development of rangelands, conception of climax vegetation and seral stages and stabilization of seral stages.

The principles of plant competition and the stability of rangelands: Interaction between environmental factors and organism, effect of grazing on selection and stability of plant species, removal of plant tissue, mechanical decrease in canopy coverage, diminution of litter cover and its effects, compaction of soil, autecological condition, phenology and range management, responses to environmental factors i.e. climatic, edaphic and biotic.

vi. *Concepts in range management:* The animal unit (A.U.M.), carrying capacity, utilization in relation to carrying capacity, intensity and frequency of use, preference value, productivity, key species, key area; indicator species and range readiness.

vii. Range suitability classification.

viii. Grazing systems.

ix. *Range management techniques:* Range sampling methods, range analysis, range condition and trends, range mapping, determination of utilization, water development, salting, fencing and herding.

x. *Range improvement:* Protection, rehabilitation by natural and artificial means, control of water and prevention of erosion.

xi. *Range nutrition:* Seasonal fluctuation in the nutritional status of plant tissues, effect of season and intensity of use on the nutritional status of plant tissue, relationship between range condition and range livestock production, requirements for supplemental feed, maintenance ration and production rations for breeding and lactating animals, poisonous and undesirable plants on rangelands and their control.

xii. *Range policy:* National policy with regard to ownership.

xiii. *Range livestock husbandry:* Kinds of range livestock, important breeds of sheep, goats, and cattle, importance of foraging habits of range livestock animals (goats, cows and camels), preference for forage, methods of taking forage, grazing patterns, response to terrain, daily requirements for food and water, range management and livestock production.

The education offered is probably too short to produce qualified range managers who can run the range project independently. The need for a full-fledged M.Sc. degree programme in range management at PFI was stressed by Goodwin (1966). ABAD (1987) stated that curricula in PFI cannot meet the academic needs of range management. Without trained personnel, the range management programmes cannot operate effectively. It is also very difficult to attract students into range management when the career possibilities are minimal. Development of special courses for a M.Sc. in Forestry with specialization in Range Management is underway at PFI. On the request of the Director of Forest Education, PFI, the author developed the following four special courses in range management.

i. Range resources of Pakistan.

ii. Range development and improvements.

iii. Range livestock production.

iv. Range evaluation and utilization modelling.

M.Sc. Course Work at UAF: The University of Agriculture, Faisalabad, is the only institution which awards a multi- disciplinary M.Sc. degree in forestry, range management and wildlife. However, provincial forest departments do not recognize graduates from this institution equivalent to those who earn a M.Sc. degree in forestry from PFI, even for

range management jobs.

The following courses are taught for B.Sc. degree in forestry, range management and wildlife (UAF, 1982).

- Farm forestry.
- Range management for animal husbandry.
- Introductory range and watershed management.
- Principles of range management.
- Rangelands of Pakistan.
- Principles of forestry.
- Forestlands of Pakistan.
- Principles of watershed management.
- Watersheds of Pakistan.
- Principles of wildlife management.
- Wildlife management in Pakistan.
- Range physiology and ecology.
- Climate and vegetation.
- Range forage.
- Range field problems.
- Range improvement and utilization.
- Range management planning.
- Range research methods.

The contents of the advanced courses in range management taught for a M.Sc. degree in forestry, range management and wildlife at the University of Agriculture, Faisalabad are outlined below:

Range Improvement: Importance of range improvement, detailed discussion of various range operations pertaining to range vegetation as well as range livestock such as artificial reseeding, water spreading, fertilization, controlled burning, water development, soil conservation, development of alternative feeds, range livestock improvement, introduction of exotic plant species and development of communication, and other facilities etc.

Range physiology: Generalized life-cycle of a range plant and review of major physiological processes with reference to grazing. Study of root system and shoot system, i.e., stem foliage and seed (production, viability, dispersal, germination, etc.). Root-shoot ratio, foliage-stem ratio, shoot- seed ratio and leaf area index.

Range ecology: Influence of climatic, biotic, edaphic and pyric factors on range flora and fauna; range population, their growth, dispersal, survival and competition; range communities, their structure, development or retogression; range ecosystem, its analysis, stability and productivity; application of ecological concepts for various range problems.

Advanced range management: Range ecosystem, multiple land use, site classification, range condition and trend, range utilization, intensive range feed lots, fattening yards, prospects of private ranching.

Visit to livestock farms: Field practices in site and vegetation surveys and forage sampling.

Advances in range forage: Forages in a changing world, grassland

agriculture, botany of grasses and legumes, legume and grass seed production, evaluation of forage production, establishment of new seedlings, mixed cropping and weed control, soil fertility and fertilization of forages, role of nitrogen in forage production, physiological considerations in forage management, dehydration of forage crops; grass legumes silage and high energy silage, range pastures and their improvement, forage animal stresses, forage testing and its applications, utilization of forages by range livestock, forage land use efficiencies with commercial cattle, sheep/goat efficient users of forage tropical and sub tropical forages.

Identification of major forage species in Pakistan, collection and mounting of forage species, study growth behaviour of at least two important forage species, visit to various fodder research stations.

Range and forest inventory: Range and forest inventory, planning principles, inventory sampling design, range vegetation survey and mapping, quantity relationship, estimating grazing capacity, range condition, classification and trend, personnel and training, logistic support, field measurement procedures, calculation and compilation, field sampling, identification and measurement of vegetation, practice in map reading, interpreting aerial photographs, recognition of physical features, types of vegetation and their boundaries, preparation of range management map and or forest stock map.

The Department of Forestry, Range Management and Wildlife at University of Agriculture needs to be strengthened. For this purpose, the following steps may be taken immediately:-

- Instead of awarding a multi-disciplinary degree, the University should concentrate on range management programme. PFI is better equipped to offer a M.Sc. degree in forestry. However, Pakistan Forest College may be affiliated with NWFP Agricultural University.
- The University may recruit highly qualified staff by providing better incentives and research facilities for career development.
- The Department needs a range research station at Thal for field studies and thesis research.
- The graduate students should be allowed to do research work at NARC where better research facilities and competent range scientists are available.
- The M.Sc. degree in range management offered by the University of Agriculture should be recognized by Provincial Forest Departments that offer jobs in Range Management Projects.

A comprehensive education plan for range management must be prepared for short as well as long-term training. In-service training courses may be regularly organized by PARC. Field training for pastoralists may be offered by provincial agencies on a relatively large scale. The programmes of PFI and the University of Agriculture should be strengthened by offering incentives to attract highly qualified personnel in range management.

Chapter 8

Summary

Rangelands are generally uncultivated areas which are mostly used for wildlife habitat and livestock grazing. Most of the countries in the Hindu Kush-Himalayan region including Pakistan are over- populated with livestock. Shortage of fuelwood and livestock feeds are the major problems in the region. During the past 40 years, significant achievements have been made in Pakistan for the improvement of feed resources from rangelands in different ecological zones of the country. The current effort is aimed to review the progress and achievements of Rangeland Management in Pakistan. The findings could equally be utilized by other countries of the region with similar ecology.

Rangelands in Pakistan extend over 60 percent area of the country. Livestock grazing is done even on crop harvested lands also. The major range areas of Pakistan in different ecological zones are as under:

Range Area	Extent (m.ha).	Distribution
Alpine pastures	1.68	Northern mountains, altitude above 3500 m.
Trans-Himalayan grazinglands	3.50	Hindu Kush region.
Himalayan forest grazinglands	0.67	Western Himalayas.

Pothwar scrub ranges	1.68	Pothwar Plateau and Salt Range
Desert rangelands	7.97	Thal, Cholistan, D.G. Khan and Tharparkar deserts.
Kohistan ranges	2.38	Kirthar range of Sind and Baluchistan.
Central Baluchistan ranges	8.00	Quetta and Kalat Divisions.
Eastern Baluchistan ranges	5.00	Loralai, Zhob, Sibi Districts.
Western Baluchistan ranges	18.50	Chagai, Makran, Coastal belt
Sulaiman mountain ranges	1.50	Western mountains along Afghanistan border.

During the past 20 years, plant introduction in various range ecological zones got high priority leading to the selection of the following promising grasses and legumes:

Main grazing areas	Recommended Species
Alpine pastures	*Phleum alpanicum, Festuca arundinacea,Elymus junceus, Medicago falcata Trifolium pratense.*
Trans-Himalayan grazinglands	*Lolium multiflorum, Dactylis glomerata, Agropyron desertorum Chrysopogon sp., Astragallus spp. Medicago sativa, Potarium sanguiserba.*
Himalayan forest grazinglands	*Lolium multiflorum, Festuca arundinacea, Agropyron cristatum, A. desertorum, Chrysopogon aucheri, Dichanthium annulatum, Bothriochloa pertusa, Trifolium pratense, T. repens, Medicago sativa.*
Pothwar scrub ranges	*Cenchrus ciliaris, Panicum antidotale, Pennisetum purpureum, Chloris gayana, Chrysopogon aucheri, Dichanthium annulatum, Digitaria decumbens,*

	Macroptilium atropurpureum, Vicia sativa, Medicago sativa, Annual medics.
Desert rangelands	*Cenchrus ciliaris, Lasiurus sindicus, Pennisetum orientale,Panicum antidotale*
Kohistan ranges	*Cenchrus ciliaris, Lasiurus sindicus, Panicum antidotale, Chrysopogon aucheri*
Central Baluchistan ranges	*Agropyron desertorum, A. elongatum, Festuca elatior, Medicago sativa, Elymus junceus.*
Sulaiman mountain ranges	*Chrysopogon aucheri, Panicum antidotale, Dichanthium annulatum.*

Fodder trees and shrubs are an important source of livestock feed in many countries of the world. Due to special morphological characteristics, shrubs are better suited to the harsh environment of the desert. Therefore, the trend of replacing shrublands by grasses and cultivated crops needs to be discouraged. Shrubs play a vital role in maintaining ecological equilibrium viz., control of soil erosion, provision of habitat for wildlife, sand dune stabilization, etc. Some of the trees and shrubs are highly drought resistant and tolerant to salinity. Through planting of trees and shrubs, coupled with adapting latest dryland afforestation technology such as drip irrigation, pitcher irrigation, earthen tubes, etc., there is ample scope to make the desert bloom.

Field adaptation trials of indigenous and exotic trees and shrubs in different ecozones may be intensified. The following selected trees and shrubs need to be planted over large areas in these zones:

Main grazing areas	Recommended species
Alpine pastures	*Artemisia maritima, Haloxylon spp., Amorpha fruticosa, Indigofera gerardiana.*
Trans-Himalayan grazinglands	*Amorpha fruticosa, Indigofera gerardiana, Prunus padus, Fraxinus excelsior, Aesculus indica, Alnus nepalensis, Quercus dilatata, Hybrid poplar, Elaeagnus* spp.
Himalayan forest grazinglands	*Quercus incana, Grewia oppositifolia, Prunus spp., Robinia pseudoacacia.*
Pothwar scrub ranges	*Acacia modesta, A. cynophylla, Ceratonia siliqua, Leucaena leucocephala, Robinia, pseudoacacia, Olea ferruginea.*

Desert rangelands	*Acacia nilotica, A. tortilis, Prosopis cineraria, Tecoma undulata, Zizyphus mauritiana, Calligonum polygonoides.*
Kohistan ranges	*Acacia nilotica, A. senegal, Leucaena leucocephala, Atriplex nummularia, A. polycarpa, spineless cactus.*
Central Baluchistan ranges	*Atriplex canescens, Caragana ambigua, Pistacia khinjuk, Fraxinus excelsior, Elaeagnus spp., Artemisia maritima.*
Sulaiman mountain ranges	*Artemisia spp., Haloxylon recurvum, Zizyphus nummularia, Acacia modesta, Olea ferruginea.*

Range reseeding had been the major component of development projects carried out in various parts of the country. Natural revegetation had been limited to high rainfall areas of northern Pakistan. Although protection of vegetation from grazing had significant effect on species composition, the process of plant recovery had been slow in desert rangelands. Artificial reseeding on the other hand, had been successful in aridlands of Thal, Kohistan, Pothwar and parts of Tharparkar. Mixed seeding of 'buffel' and 'gorkha' grasses before the onset of monsoon rainfall season proved exceptionally useful. Small scale testing of annual medics, vetches, oats and cowpeas widened the prospects of introduction of several new forage crops. The failure of range reseeding operations in the Cholistan desert points out limited scope of artificial reseeding in low and erratic rainfall areas.

There is an extreme shortage of drinking water in desert areas, for human and the livestock population. Rainfed ponds alone cannot meet the requirement of desert dwellers. The development of extra water reservoirs in the desert ranges may retrograde range trend. Development of communication systems, provision of watering points alone probably may not provide relief to the drought affected in Cholistan and Tharparkar unless concerted efforts are made to increase livestock feed resources. Several range areas in the country remain un-exploited for want of adequate water. Migratory routes of nomads in Baluchistan are dictated by the availability of water points. Therefore, provision of livestock water points at suitable distances may be given due consideration in the development of rangelands.

Northern mountains are valued for watersheds which drain into Tarbela and Mangla reservoirs. Being strongly sloping these mountains are highly erodible. Pothwar Plateau being highly fragile is subject to soil erosion. Soil and water conservation practices such as afforestation, reseeding of grasses,land preparation and construction of engineering structures (terracing, etc.) can significantly check soil erosion. Proper livestock grazing in these areas would substantially increase life span of the dams as well

as improve land productivity. In these areas proper use of the land according to the ecological principles needs due consideration. Adequate technology has been developed for an integrated land use development.

Rain harvesting and water spreading in the arid had been practised since times immemorial. Dry afforestation techniques tested in the Thal area provide a new horizon for the improvement of desert areas in Pakistan. Dryland planting techniques such as grass and plastic mulching, drip irrigation, watering through pitchers and sand filtration of saline water are worth testing on large arid tract. The successfully tested techniques of water spreading coupled with reseeding of grasses in Rakh Miran area indicate its wide application in the 'Rod-Kohi-System' of Sulaiman mountain ranges. The centuries old karez irrigation system in Baluchistan has worked well under very arid conditions. There is an enormous scope of exploiting solar and wind energies for mining underground water in the desert ranges of Sind and Baluchistan. However, there is a need for low cost technology.

Native and exotic shrubs have been identified which are highly drought tolerant and can be grown in saline water in the deserts of Thal, Cholistan, Tharparkar and Baluchistan. Mesquite regarded by foresters as a weed is highly desirable for sandy deserts and saline areas.

Some pioneering work has been done on stabilization of sand dunes in Baluchistan and Thal deserts. These biological techniques of sand dune fixation need to be expanded over large areas.

Due to over-use of the ranges, several undesirable plants have invaded range and cultivated lands. Controlled burning helps in the replacement of undesirable plants by the desirable ones and increasing the forage production as well. Potential of herbicides may be explored in various ecological zones.

Rangelands provide habitat for the conservation of wildlife and preservation of other natural resources. There is ample opportunity for the development of recreational facilities.

Comprehensive inventory and evaluation of the natural resources (grazinglands) need to be prepared to provide a framework for sound land use planning and resource management. The evaluation and utilization model of Lohi Bher Range provides a basis for such ventures. Working plans of major range areas may be prepared by using such technology.

Livestock are the major user of rangelands. About 70 percent of rural population is engaged in livestock production. Contribution of livestock to GNP is about nine percent. At present, the livestock population is about 93.5 4 million head. Total TDN requirement is about 43.8 million tonnes against the available TDN of about 34.4 million tonnes. Currently, there is shortage of about 21 percent of TDN and 35 percent of DP. Livestock population is increasing at a rate of about four percent. Therefore, concerted efforts are needed to fill the present feed gap and meet future requirements. Rangelands have the potential to produce at least double the current available yield.

Hay and silage preservation can ensure year-round supply of forage.

New innovations like urea molasses, etc., may help in meeting nutritional requirements of livestock. The performance of livestock particularly sheep, goat, cattle, camel, buffalo and yak on rangelands have not been studied. The technology from cultivated areas cannot be directly applied to range areas. Therefore, livestock production technology for rangelands may be developed so that commercial ranching can be popularized.

Very little is known about the traditional grazing patterns and practices of the pastoralists. Of special interest are the centuries-old nomadic, semi-nomadic, transhumant and sedentary systems of grazing being practised in various parts of the country. Detailed studies are needed to investigate their ecological as well as economic viabilities.

Categorizing over 60 percent area of the country as wastelands by planners is unrealistic and contrary to the fundamental philosophy that nothing has been created useless. Through consistent national range policy, with proper planning and organization and use of scientific knowledge of the resources, the so-called wastelands can be used for the betterment of human being. Ever increasing pressure of population demands formulation of a comprehensive master plan for the development of this vast natural resource. The basic steps needed in this direction are: formulation of a national policy, creation of Watershed and Arid Land Development Authority (WALDA) at federal level, development of technical manpower, preparation of technical rangeland management plans and their execution by the competent and motivated range professionals.

Coordination among various agencies such as Sind Arid Zone Development Agency (SAZDA), Cholistan Development Authority, etc. are needed for comprehensive planning and judicial use of the meagre technical as well as financial resources. Technical collaboration with international agencies may help in the development of range resources.

Range research, in Pakistan, has not been given due priority. Inadequate allocation of financial resources had always restricted initiation of a comprehensive range research programme. At present, most of the funding is provided by PARC through National Forage and Pasture Programme which had been too meagre to cover such a vast and variable natural resource. There is an immediate need for preparation of master plan for Range Research. National Forage and Pasture Programme may be strengthened to the level of National Research Institute with research stations in each major range ecological zone. Research activities may be oriented to develop package of technology for commercial ranching. Range improvement/development projects may include a research component.

There is an acute shortage of technical manpower in range management sector. Although several long and short term training facilities were provided by PARC in the recent past, the huge technical manpower requirements can be met only by offering in- country M.Sc. degree programme in range management at PFI, Peshawar, and UAF, Faisalabad. Range Management Departments at both these institutions need to be strengthened by providing more qualified staff, modern laboratory, field research facilities and adequate operational funds. The NARC, Islamabad

may offer Ph.D. research facilities in collaboration with the aforementioned institutions through extending advanced level laboratory and field research facilities. Range graduates from agriculture universities may be treated equivalent to PFI degree holders for range management jobs. The NARC may regularly hold post graduate diploma courses and short-term training for in-service professionals. The professionals may constitute a society duly affiliated with the International Society of Range Management. This may provide an intellectual forum for exchange of visits, technical materials, etc. The society may initiate publishing a scientific journal and a quarterly newsletter on the subject.

Participation of local pastoralists in the preparation and execution of range management plans has been felt at every forum. Grazier association experience in Thal may be tested in other areas. Village organization system applied in the Northern Areas by Aga Khan Rural Support Programme has produced useful methodology for involving local people in the development of grazinglands.

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Founding of ICIMOD

ICIMOD is the first International Centre in the field of mountain area development. It was founded out of widespread recognition of the alarming environmental degradation of mountain habitats, and consequent increasing impoverishment of mountain communities. A coordinated and systematic effort on an international scale was deemed essential to design and implement more effective development responses in each of the countries concerned.

The establishment of the Centre is based upon an agreement between His Majesty's Government of Nepal and the United Nations Educational, Scientific and Cultural Organization (UNESCO) signed in 1981. The Centre was inaugurated by the Prime Minister of Nepal in December 1983, and began its professional activities in September 1984.

The Centre, located in Kathmandu, the capital of the Kingdom of Nepal, enjoys the status of an autonomous international organisation.

Participating Countries of the Hindu Kush-Himalaya Region

* Nepal
* India
* Bhutan
* Bangladesh
* China
* Pakistan
* Burma
* Afghanistan

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