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

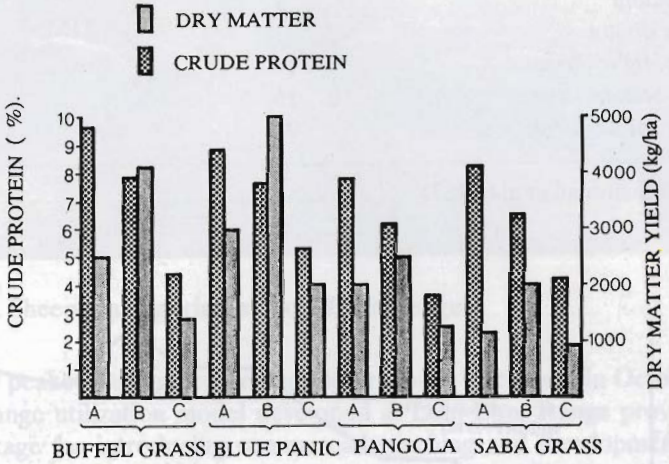

Figure 6. Forage yield (kg/ha) and crude protein (%) at different growth stages of grasses in Lohi Bher range.

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)

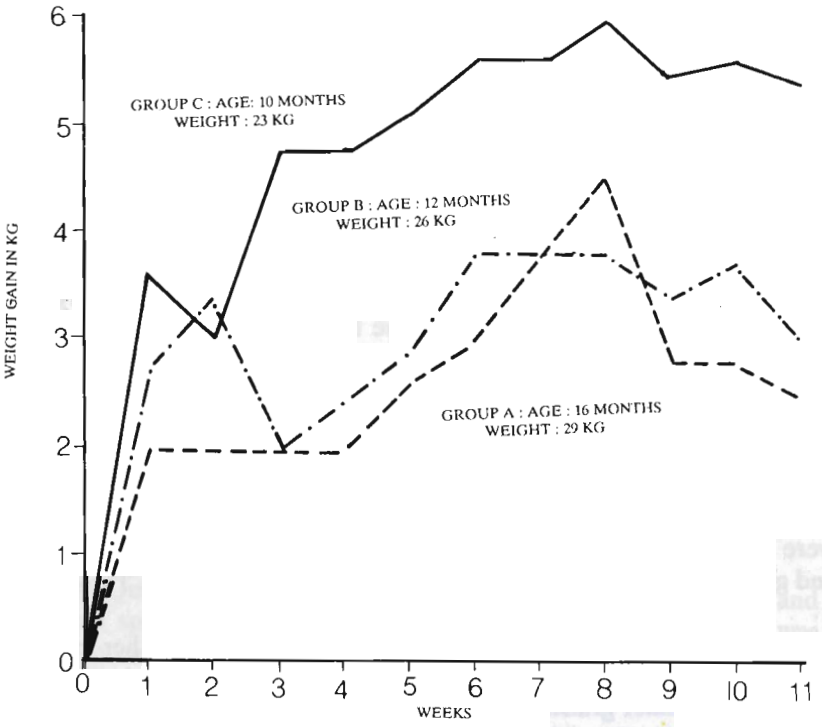

Figure 7. Cumulative weight gain (kg) in different age groups of sheep at Lohi Bher.

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.