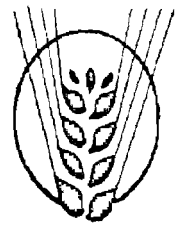

Management of Indian Arid Rangelands

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CONTENTS

FOREWORD

The Indian desert is unique in the sense that it sustains the highest population density per unit of land. Escalation of human and livestock population, besides the climatic and geomorphological factors, has been the major cause of desertification. Obviously, in order to combat the process of desertification, what is required is to have the rational utilization of available soil, water, plant and animal resources in rangelands. In this context, adoption of proper land use pattern is necessary so as not to disturb the ecological balance.

In the arid zone of Rajasthan alone, the livestock population has increased from 9.4 million in 1951 to 15.5 million in 1972, of which goat and sheep population account for almost 60 per cent, indicating animal husbandry as an important occupation of the region. Contrary to this, marginal as well as grazing lands are being brought under cultivation mainly due to pressure on land in spite of the fact that crop cultivation in these areas, receiving invariably less than 300 mm rainfall, is indeed a risky proposition. Therefore, it is utmost relevant to work out a policy whether, as already recommended by the National Commission on Agriculture, the arid lands should be put under plough or used as rangelands for the livestock. Arguments on the issue go mostly in favour of the latter since Indian arid rangelands are bestowed with several useful and productive species of grasses, trees and livestock compared with those in other parts of the world. What is needed most is to have rational utilization of available resources so as to ensure long-term socio-economic benefits in these rangelands.

Over the last two decades, considerable work has been carried out on rangeland management at the Central Arid Zone Research Institute, Jodhpur and vast scientific data have accumulated both on the primary and secondary productivity.

Results have revealed beyond doubt the utility of scientific management of Indian arid rangelands for increased grass (primary) and animal (secondary) productivity. These results have given basic information, based on which ambitious pasture development programmes have already been launched in the arid regions of India under D. P. A. P. (Drought Prone Area Programme). Improved strains of grasses, with scientific management, could yield as high as 40 to 50 q/ha of dry forage with a stocking rate of almost 1.25 ha/heifer under deferred rotational grazing system. *Sewan*, essentially a grass of sandy arid tract, has been found to be yielding high total digestible nutrients (TDN) as well as high animal body weight gains under properly managed rangelands. Grass and animal productivity could, therefore, be increased substantially in these areas.

It was a long-felt need that all available information on different aspects related to management on arid rangelands of India should be available in a compiled form. I am extremely happy to see that Dr. H. S. Mann, Director, CAZRI and his colleagues Dr. R. S. Paroda, Head, Division of Plant Studies and Late Dr. C. M. Verma, Junior Pasture Utilization Officer, have compiled very useful information on the subject of scientific management of Indian arid rangelands in the form of this Technical Bulletin which, I am sure, will be of much use to the scientists, planners and the extension workers. I hope that the information in this bulletin will find wider acceptance not only from the point of view of scientific management for improved primary and secondary productivity but also from the point of view of eventual check of desertification process in these arid rangelands.

Sd/-
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Dated : January 18, 1980
NEW DELHI.

MANAGEMENT OF INDIAN ARID RANGELANDS

1. INTRODUCTION :

In India, about 3.2 million sq.km area is under arid zone of the hot Thar desert covering mostly the states of Rajasthan, Gujarat and Haryana. Most of it is covered under sandy plains, hummocks and sand dunes (Fig. 1). Indian desert is one of the most thickly populated deserts of the world having a population of over 19 million people with an average density of 61 persons (1971) per sq.km as against 3 persons per sq.km in other deserts (Mann et al., 1977). The population of the livestock is about 23 million and it is steadily increasing (Figs. 2a, b, c). In the arid zone of Rajasthan alone, the livestock population has increased from 10.27 million in 1951 to 16.44 million in 1972. This is an obvious indication of increased pressure on land. Moreover, area under forage crops is very limited mainly because farmers invariably put their cultivable land only under cereals and legumes during the rainy season.

In view of their low carrying capacity, the increased pressure of livestock on the natural grazing lands results in over-exploitation of resources leading to depletion of natural vegetation. It is in this context that need for rational utilization of available resources like land, vegetation, water etc. in the rangelands of arid and semi-arid regions becomes evident. In order to evolve scientific technology for speedy regeneration of the grazing lands, their improvement and rational utilization of available resources, studies were initiated in 52 Range Management and Soil Conservation areas (each about 80 ha) in 1959. These were located in the eleven districts of western Rajasthan. Later, the number of these areas was confined to twelve covering seven districts. Salient research findings in the field of Rangeland Management technology, evolved over the last 20 years by the scientists of the Central Arid Zone Research Institute, Jodhpur are being presented in this publication.

Fig. 1 : Rangeland with sandy hummocks and sand dunes (Jaisalmer)

Fig. 2 : Pressure of livestock on the desert rangelands
(a) Cattle grazing on agricultural wastes

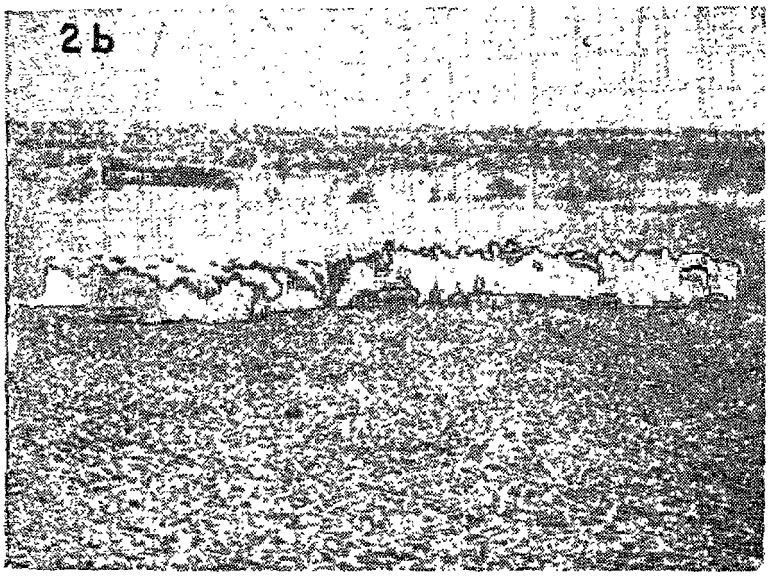

Fig. 2 (b) : Sheep and goats raised on *denuded grassland*

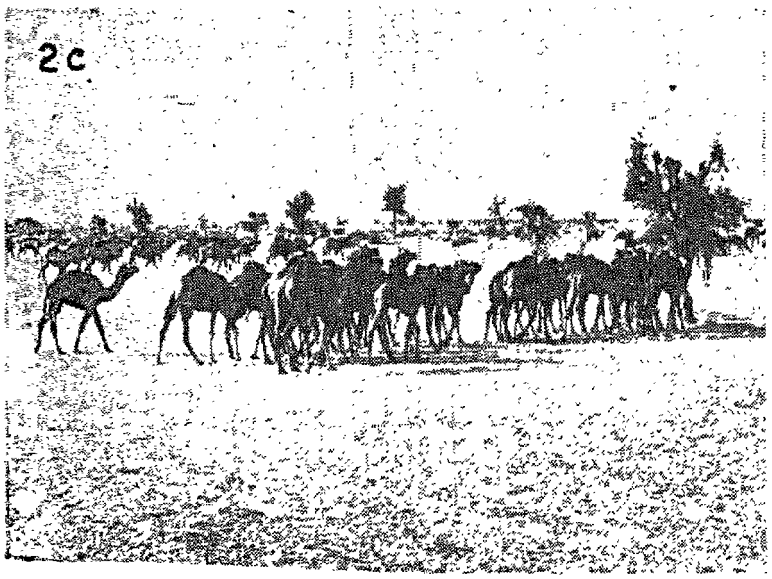

Fig. 2 (c) : Camel in search of fodder

2. ENVIRONMENTAL CONDITIONS :

2.1. Climate :

The climate of the Indian Arid Zone is of the dry tropical type. The mean annual rainfall varies from 100 mm in the north-western sector of the Jaisalmer to 450 mm in the eastern boundary of the arid zone in Rajasthan (Fig. 3). Rains occur from mid-June to mid-September with virtually dry season from mid-September to mid-June. Rainfall years of large deficit are more frequent in the border districts of western part. The peak of the rainy season invariably occurs in August. Winter rainfall is hardly 3-6 per cent of the total precipitation; and frost frequently occurs between mid-December to the end of January.

The mean maximum temperature during summer goes to 40°C. The highest temperature in the region ranges between 48 to 50°C (Krishnan, 1977). During May and June, dry and hot dust

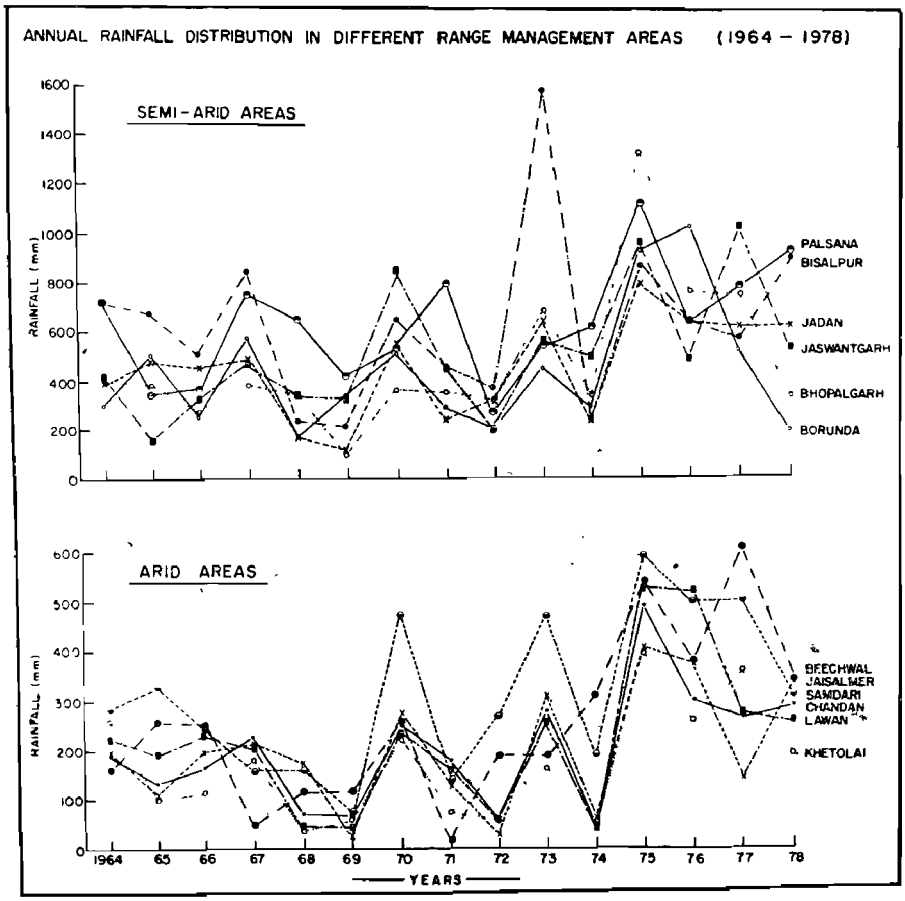

Fig. 3 : Annual rainfall distribution in arid and semi-arid rangeland of western Rajasthan

raising winds and dust storms occur. Temperature drops to 14-16°C in December-January with absolute minimum rarely less than 4°C.

The mean value of vapour presure in winter is less than 10 mb. The relative humidity, however, is high especially in the mornings owing to very low temperature. The values of vapour pressure during monsoon exceed 25 mb and relative humidity ranges from 75 to 80 per cent in the mornings and 50 to 60 per cent in the afternoons.

Potential evapo-transpiration during summer varies from 7 to 9 mm per day, whereas in monsoon it varies from 5.2 to 7 mm per day.

2.2. Soils :

Soils are pale brown to light yellowish and greenish brown in colour, sandy to sandy loam in texture, loose and structureless. Major soil distribution is depicted in Fig. 4. The dune sand is generally constituting of 63.7-87.3 per cent fine and 11.3 to 30.3 per cent coarse sand with 1.8 to 4.5 per cent clay and 0.4-3.1 per cent silt (Dhir, 1977).

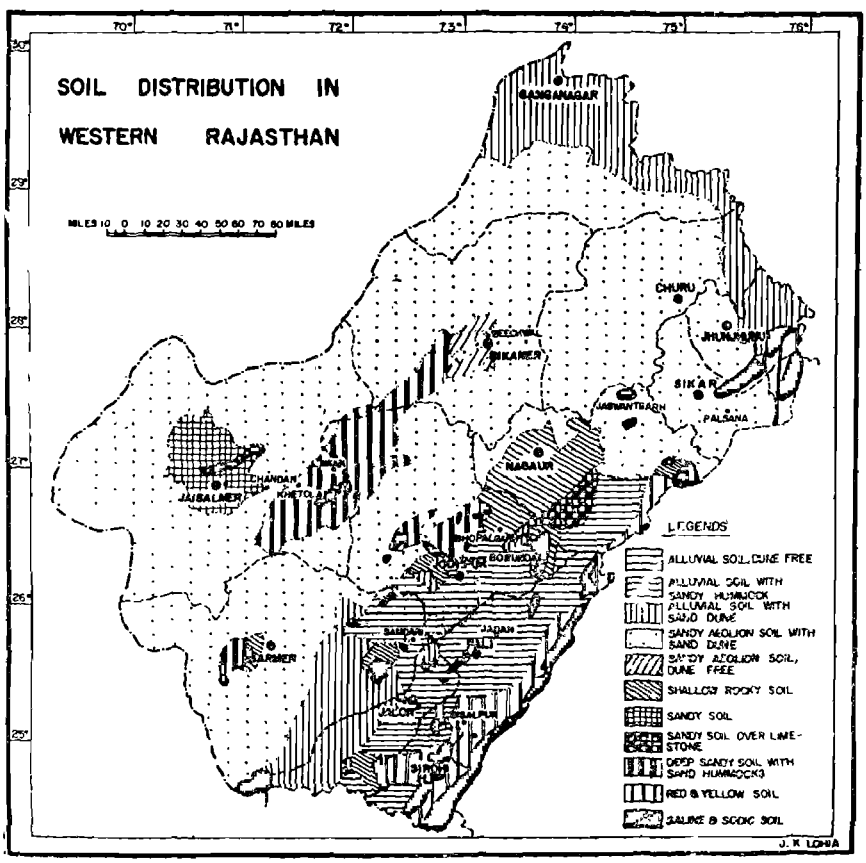

Fig. 4: Soil map of western Rajasthan

The soils are generally calcarious having a sub-soil concretionary layer of lime and are very poor in organic matter (0.02-0.2 per cent). They are generally very deficient in plant nutrients except potash (806 mg/10gm) and have pH of about 8.5. The light textured soils have 285 ppm of total phosphorus, compared to 327 to 450 ppm in the soils of semi-arid zones of Rajasthan. The organic carbon ranges from 0.50-0.75 per cent and above in low medium and heavy textured soils.

3. RANGE MANAGEMENT AREAS :

In order to evolve scientific technology for upgrading and rational utilization of the rangelands in arid and semi-arid regions of western Rajasthan, studies are under progress in twelve areas. Details of land type, location, rainfall, soil and vegetation cover in these different areas are given in Table 1. Locatoin of these areas is also shown in Fig. 5, which reveals that six areas namely,

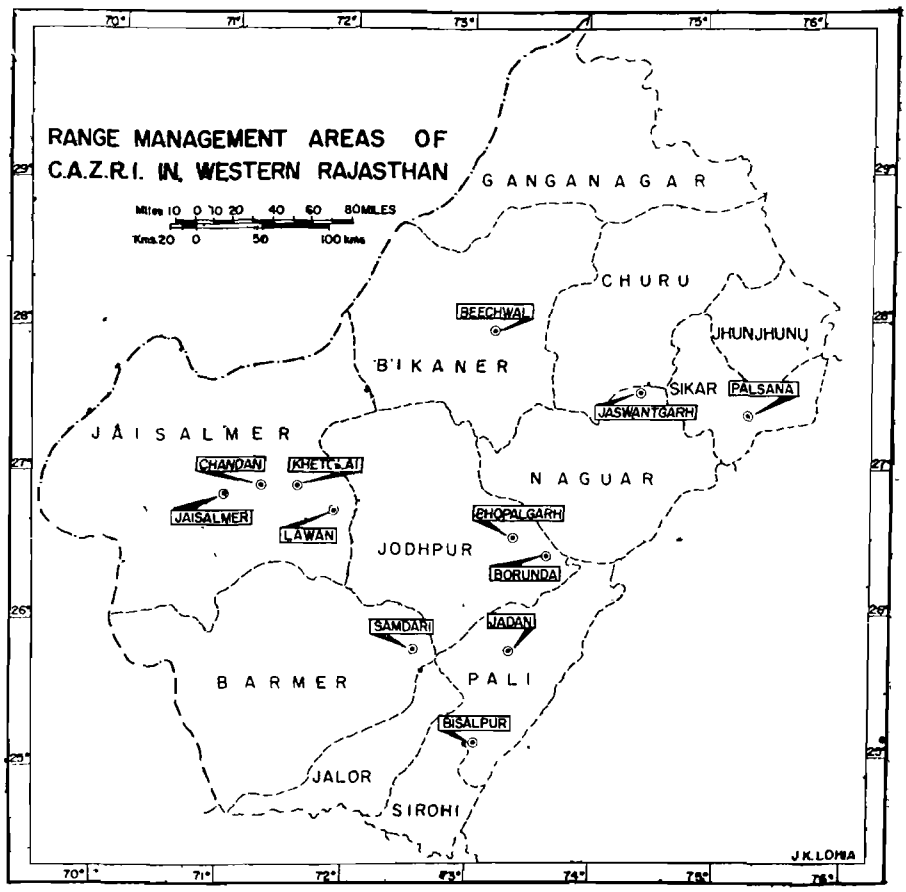

Fig. 5 : Range management areas of CAZRI in western Rajasthan

TABLE 1

Details of land type, location, rainfall, soil and vegetation cover in range management areas

Range management area	District	Annual rainfall (mm) Av. of 19 years	Area (ha)	Land capability classification	Soil type	Vegetation cover
ARID ZONE						
Lawan	Jaisalmer	210	168.34	VI	Sandy to sandy loam	*Lasiurus–Eleusine*
Khetolai	,,	180	70.90	VI	Sandy to sandy loam	*Lasiurus-Eleusine*
Chandan	,,	189	95.10	VI	Sandy	*Lasiurus–Sindicus*
Jaisalmer	,,	207	133 90	IV & VI	Sandy	*Lasiurus–Cymbopogon*
Samdari	Barmer	357	81.12	VI	Sandy to sandy loam	*Cenchrus–Eleusine Aristida*
Beechwal	Bikaner	237	71.22	III & IV	Sandy	*Lasiurus–Eleusine Aristida*
SEMI-ARID ZONE						
Bhopalgarh	Jodhpur	434	54.10	VI	Sandy loam	*Cenchrus–Aristida*
Borunda	,,	433	67.60	IV & VI	Sandy loam	*Cenchrus–Eleusine–Aristida*
Jadan	Pali	409	76.89	IV & VI	Sandy loam to loamy sand	*Cenchrus–Aristida Sporobolus*
Bisalpur	Pali	612	63.13	IV & VI	Sandy clay loam	*Dichanthium–Aristida*
Jaswantgarh	Nagaur	455	76 50	III & V	Heavy clay loam	*Sporobolus–Desmostachiya–Cyperus*
Palsana	Sikar	586	78.65	IV & VI	Sandy	*Cenchrus–Eleusine Aristida*

Lawan, Khetolai, Chandan, Jaisalmer, Samdari and Beechwal represent arid conditions, whereas rest of the six areas namely, Bhopalgarh, Borunda, Jadan, Bisalpur, Jaswantgarh and Palsana represent semi-arid conditions having more than 40 mm rainfall annually.

Studies initiated at these locations cover aspects like reseeding and management of high yielding perennial grasses, soil conservation measures, introduction of leguminous shrubs and trees, and grazing management involving different animal species of Indian arid zone. Technology evolved and results obtained on primary and secondary productivity from these areas are discussed separately.

4. PLANT-ENVIRONMENT RELATIONSHIPS :

4.1. Grass cover and ecological distribution :

The grassland cover of Indian arid zone with particular reference to western part of Rajasthan is of **Dichanthium-Cenchrus-Lasiurus** type (Dabadghao, 1960). Under this cover, several potential grassland types exist in different eco-systems. Based on the edaphic factors, the vegetation cover may conveniently be treated under the following heads :

1. Sand dunes and sandy plains.
2. Well drained sandy alluvial soils.
3. Sandy clay loam to clay soils (old and young alluvium type).
4. Hilly and piedmont regions.
5. Low lying heavy saline soils.

4.1.1. Sand dunes and sandy plains :

Major portion of the western Rajasthan lies under sand dunes and sandy plains having very low precipitation (100-250 mm). The common perennial grasses under existence are **Lasiurus sindicus, Panicum turgidum, Panicum antidotale, Cymbopogon jwarancusa, C. scheonanthus, C. parkerii, Eleusine compressa, Dactyloctenium sindicum, D. aegypticum** and **Cenchrus ciliaris.** Annual grasses frequently found are **Aristida adscensionis; Cenchrus biflorus, Eragrostis tremula, E. tenella** and **Tragus biflorus.** The common legumes found are **Indigofera cordifolia, I. linifolia, Tephrosia pur-**

purea. Some of the weeds and shrubs are **Tribulus terrestris. T. alatus, Farsetia hamiltonii, Pulicaria wightiana, Citrullus colocynthis, Heliotropium strigosum, Sericostoma pauciflorum, Haloxylon salicornicum, Aerva javanica, Calotropis procera, Crotalaria burhia, Leptadenia barbarum, Capparis decidua** and **Zizyphus nummularia.**

4.1.2. Well drained sandy alluvial soils :

Cenchrus ciliaris and **C. setigerus** predominate on these types of soils. The other grasses, herbs and shrubs associated are : **Aristida funiculata, Eragrostis ciliaris, Cenchrus biflorus, C. prieurii, Eleusine compressa, Dactyloctenium sindicum, Urochloa panicoides, Tragus biflorus, Convolvulus microphyllus, Heliotropium subulatum, H. strigosum** and **Boerhavia diffusa.** The common legumes are **Indigofera cordifolia I. linifolia, Tephrosia purpurea, Phaseolus trilobus** and **Rhyncosia minima.**

4.1.3. Sandy clay loam to clay soils :

Dichanthium annulatum predominates on such types of soils in high rainfall zones (350 mm and above). Associated grasses with **Dichanthium** are **Heteropogon contortus, Tetrapogon tenellus, Echnichloa colonum, Eremopogon foveolatus, Aristida funiculata** and **Bracharia ramosa.** Among the leguminous species, **Cassia mimosaides, Alycicarpus vaginalis, Haylandia latebrose, Tephrosia purpurea, T. petrosa** and **Indigofera cordifolia** are common.

4.1.4. Hilly and piedmont regions :

Sehima nervosum associated with **Dichanthium annulatum, Eremopogon foveolatus, Heteropogon contortus, Oropetium thomaeum, Aristida funiculata, Tragus biflorus** and **Bracharia ramosa** are commonly found in these types of habitats. The most common shrubs are **Acacia senegal, Capparis decidua** and **Commiphora weightii.**

4.1.5. Low lying heavy saline soils :

The salinity in Rajasthan is also well spread. The notable grass species found in these habitats are **Sporobolus marginatus, S. coromandelianus, Chloris virgata, Echinocloa colonum, Eremopogon foveolatus** and **Eragrostis ciliaris** etc. **Halophytic succulents** like **Suaeda fruiticosa, Salsola baryosma** and **Haloxylon salicornicum** and sedges like **Cyperus arenarius** and **C. rotundus** contribute to a large part of the ground cover.

4.2. Ecological succession in protected areas :

The rangelands in western Rajasthan are very heterogeneous in nature occuring on vast sandy areas, rocky stretches, saline and other areas with climax vegetation where there is practically no grazing of animals due to water scarcity. Measurement of rangeland vegetation by different methods namely 'Parker's Loop' and 'Pace Transects' etc. did not give tangible results to get a valid estimate of plant succession, in rangelands (Prakash and Ahuja, 1966). Studies on ecological succession were, therefore, initiated and are presently in progress in different rangeland management centres. Stockmaps (Fig. 6) of these areas are drawn each year in

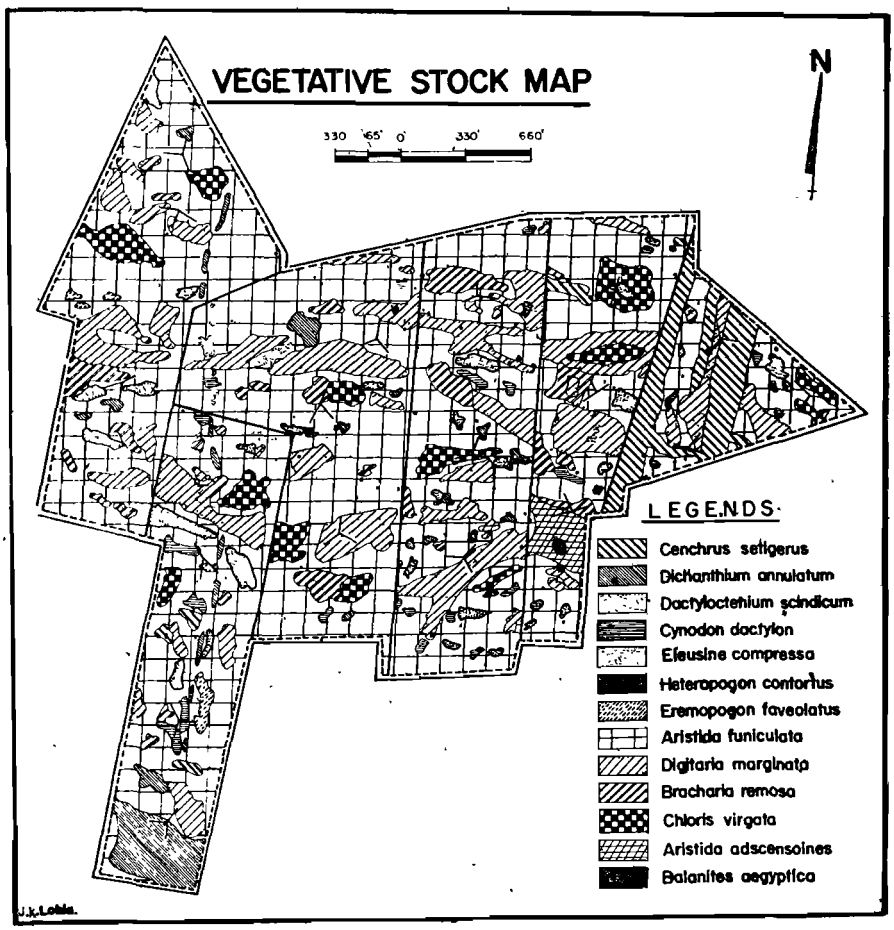

Fig. 6 : Vegetative stock map of a rangeland in semi-arid region

order to get a proper estimate of area covered and subsequent spread by different plant species.

4.3. Management for yield improvement :

Success of a program is largely dependent on the soundness of research technology advanced. This is all the more of vital importance in rangeland management where limitations are of good land, adequate rainfall, favourable climatic conditions etc. Research work done earlier at this Institute has revealed that adoption of suitable range management technology can go a long way in improving land and vegetation types in both arid and semi-arid areas of western Rajasthan. In brief, the technology is defined here.

4.3.1. Fencing :

For protection against biotic factors, angle iron posts ($6' \times 1\frac{1}{2}'' \times 1\frac{1}{4}''$) with barbed wire (four to five strands) fencing has proved to be most durable and economical in the long run although the initial cost is high (Rs. 7/- per running metre). The fact to be reckoned with is that fencing is a must before any management program is launched at least in arid regions of western Rajasthan where pressure on land is maximum both from human and animal as compared to elsewhere in the desert areas of the world. Moreover, larger the area, cheaper it is to go for fencing and as such, initial coverage of area between 100 to 1000 ha is desirable for range management program. Fencing cost works out to be approximately Rs. 125 and Rs. 300 per ha based on blocks of 1000 and 100 ha, respectively. In this case, depreciation is also much less. Recurring cost for maintenance of barbed wire fencing works out to be 0.15 paise/running metre/year, whereas maintenance is invariably high on other types of fencing although they are relatively cheaper to start with (Table 2). Obviously, cost and area involvement makes it more of a community program. Based on this principle as well as based on our research findings, pasture development programs have been taken up in various drought prone districts in the State of Rajasthan and results so far are quite encouraging.

It was interesting to note (Fig. 7a, b) that the forage yield on rangelands, after two years of protection, increased by 148, 92 and 116 per cent in 'Poor', 'Fair', and 'Good' rangelands, respectively.

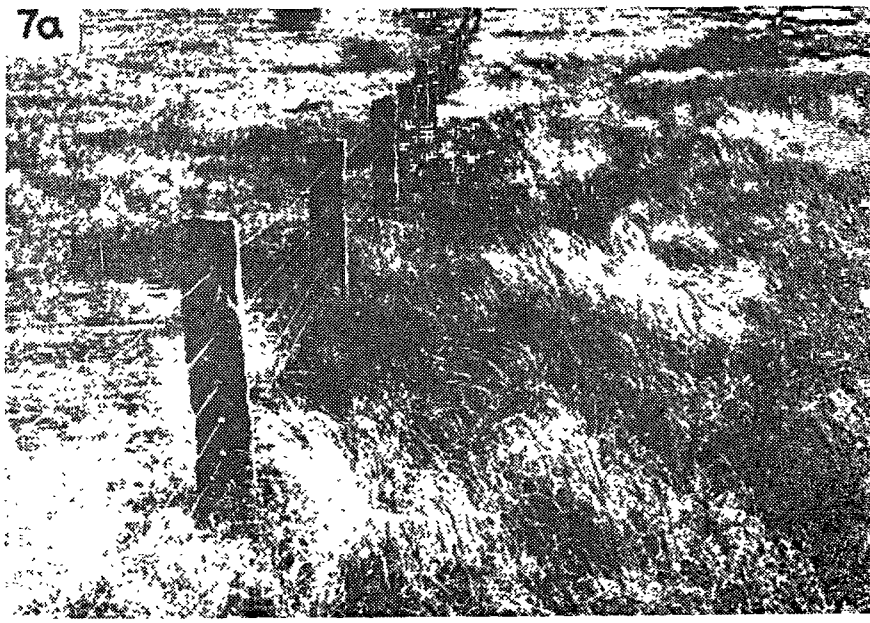

Fig. 7 (a) : Stone post and barbed wire fencing at range-management area—Borunda

Fig. 7 (b) : Angle iron posts and barbed wire fencing at range-management area—Khetolai

TABLE 2

Initial and maintenance cost of different fencing

Type of fencing	Cost per running metre (Rs.)	
	Initial	Recurring per year
Angle iron post and barbed wire	7.00	0.15
Angle iron post and woven wire	10.62	0.19
Stone post and barbed wire	10.81	0.24
Wooden post and barbed wire	8.28	0 29
Ditch and core wall fencing	4.87	1.17
Core wall fencing	2.83	0 73
Stone wall fencing	4.43	2.40
Cactus fencing	4.97	0.78

4.3.2. Adoption of soil and water conservation measures :

Rangeland management areas generally comprise of land falling in class IV to class VIII which are mostly highly eroded thereby exposing rocky surface, stones and boulders. As such, soil conservation measures specially on land forms with shallow soils and rolling topography are essential. Contour furrows (60.96 cm wide and 22.86 cm deep) with a cross section of 929 sq.cm at a distance of 8-10 metres across the slope (Fig. 8a, 8b) have invariably

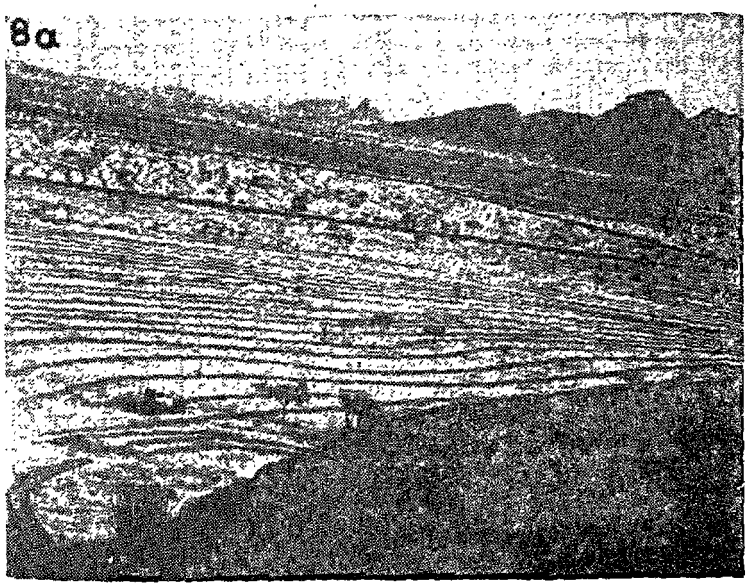

Fig. 8 (a): Contour furrows on semi-arid rangeland at Bisalpur

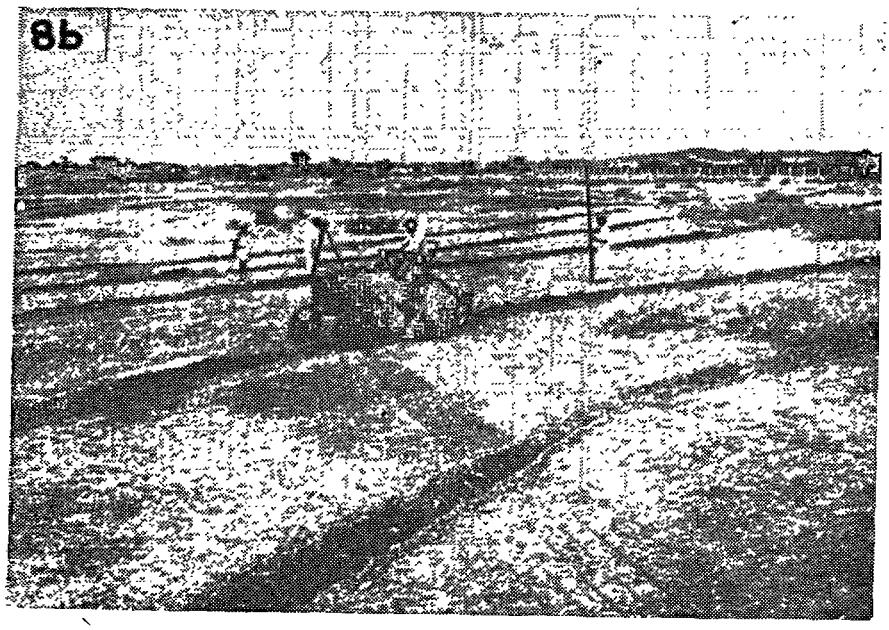

Fig. 8 (b): Making of contour furrows

Fig. 8 (c): Effect of contour furrows on the productivity of rangeland

proved to be more effective than any other soil conservation measures, viz. contour bunds and staggered contour trenches. Moreover, contour furrows are cheapest to maintain in the long run. Cost of such works is Rs. 150-200 per hectare depending upon the terrain. Contour furrows help in increasing the forage production from, on an average, 4 q/ha to 15-20 q/ha in a period of 10-15 years (Fig. 8 c).

4.3.3. Reseeding in rangelands :

Natural succession of the high yielding perennial grasses in the arid regions is rather a time consuming process. Reseeding of suitable perennial grasses adopted to the specific agroclimatic conditions is the best recourse for increasing the forage as well as animal productivity.

Lasiurus sindicus gives high yield (25-36 q/ha) on sandy soils with low precipitation (200-250 mm and below). **Cenchrus ciliaris** and **C. setigerus** produce high forage yield (20-30 q/ha) on well drained soil under 300-400 mm and above rainfall zones, and **Dichanthium annulatum** gives high yield (50-60 q/ha) in heavy soils with annual precipitation of 400-500 mm and above.

Removal of unwanted bushes (**Mimosa hamata, Balanitis aegyptica, Gymnosporia montana, Lycium barbatum, Acacia leucophiloa** and **Sueda fruiticosa** in saline soils) is the pre-requisite for taking up the reseeding program. Complete soil working, involving ploughing and disc harrowing once, is essential for better establishment of perennial grasses (Chakravarty and Verma, 1970). Sowing of grass in rows 50-75 cm apart is advantageous. Seed rate of 4-5 kg/ha for **Cenchrus ciliaris** and **C. setigerus**, 5-7.5 kg/ha for **Lasiurus sindicus**, whereas 2-3 kg/ha for **Dichanthium annulatum** is most appropriate. Higher seed rate may be required to achieve better establishment when grass sowings are undertaken by broadcasting the seed in dry soil just before the onset of monsoon.

For large scale development program, placement of seeds on the top (not below 1-2 cm) of the mound (Fig. 9), prepared through tractor mounted disc plough, and also broadcasting just before or at the onset of first effective showers proved to be most effective (Verma **et al.**, 1977). Pelleting of seed with lime, clay and farm yard manure has so far not proved to be of any specific advantage. Thus, direct seeding preferably by mixing the seed in moist sand is advocated for achieving better establishment. Since some toxic inhibitors are reported to be present in the seed fuzz, it is generally recommended to soak the seed in water for about 8-12 hrs just

before sowing. Results have shown that reseeding with local seed of 'Climax species' increased the forage productivity to about 20 q/ha.

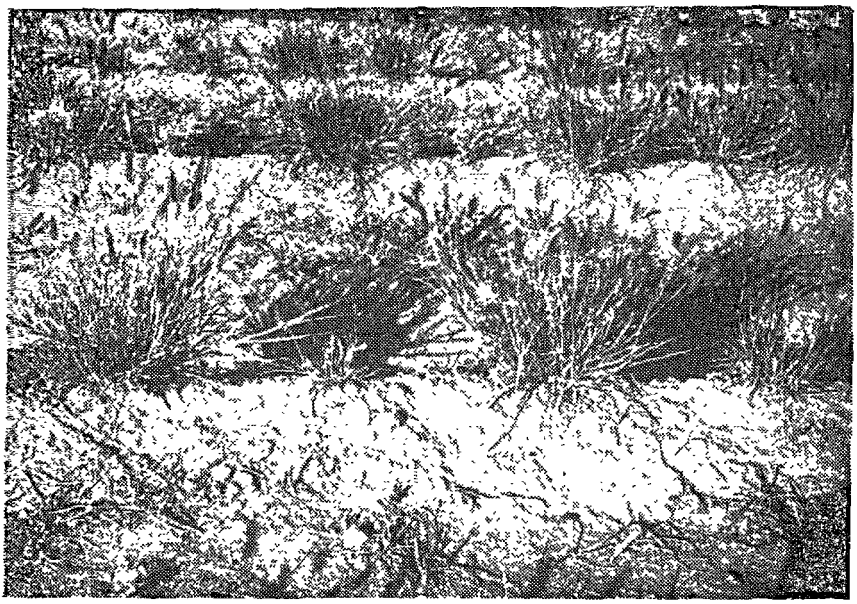

Fig. 9 : Cenchrus ciliaris established on the top of the mound

Pitting discer (Fig. 10) helps in forage production by retaining moisture in about 63,000 staggered micro-pits per ha (Das and Yadav, 1977 and recent results (Table 3) have indicated that yield increase is substantial in case of natural pasture (80-115%) as against reseeded pasture (50-70%).

TABLE 3

Forage yield (q/ha) as influenced by the use of 'Pitting Discer'

Treatment	1976*		1977+	
	Natural	Reseeded	Natural	Reseeded
Control	13.64	14.25	12.03	11.00
Pitting	29.30	24.28	22.02	16.82
% increase	114.80	70.40	83.04	52.90

* *Pooled yield of two cuttings*

+Forage yield from one cutting

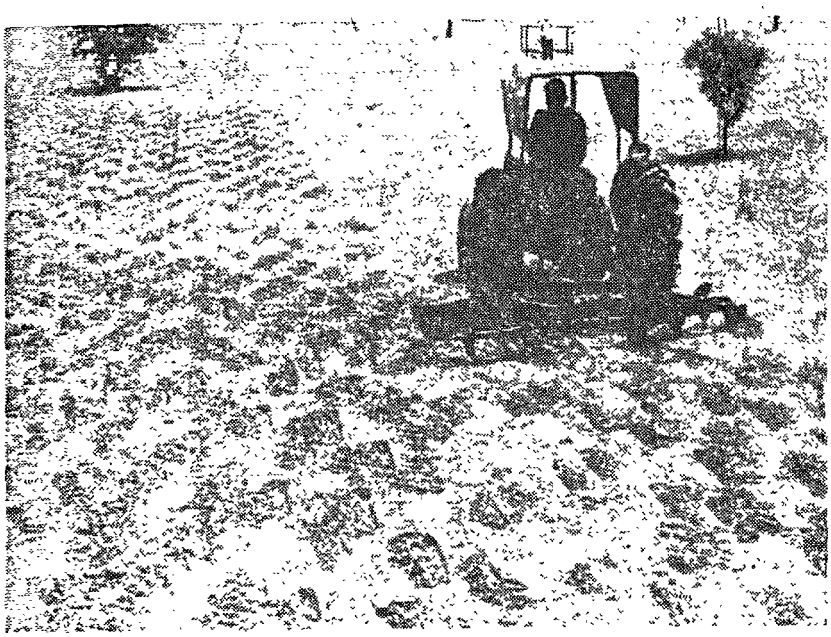

Fig. 10 : Staggered micro-pits made from Pitting Discer

4.3.4. Genetically improved strains of grasses :

Improved strains of grasses have the genetic production potential of even higher than 40 q/ha and, therefore, should be used for reseeding program. Extensive research in Agrostology at CAZRI has shown that some of the improved strains (Fig. 11a, 11b,

Fig. 11 : Collection and evaluation of desert grass strains at CAZRI
(a) Lasiurus sindicus strains (Sewan)

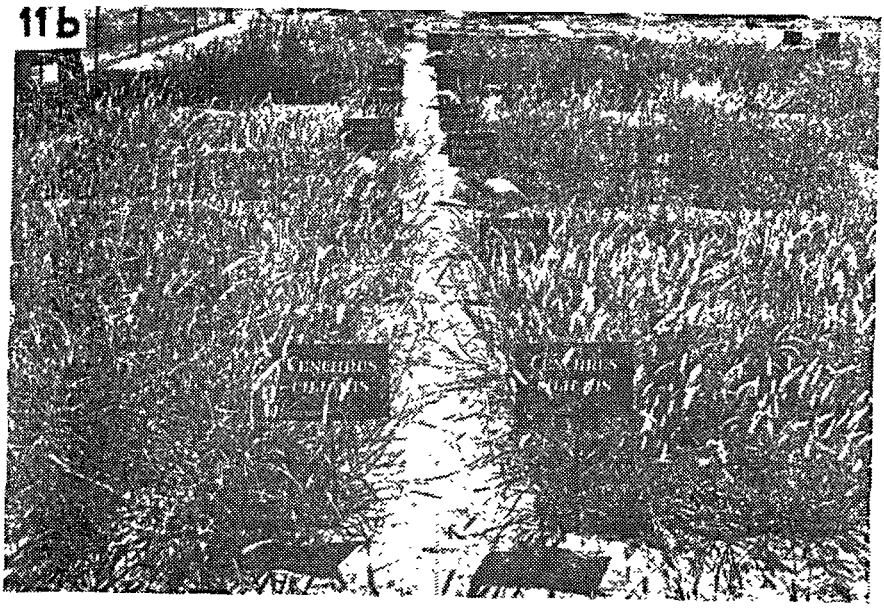

Fig. 11 (b) : **Cenchrus ciliaris** strains (Dhaman)

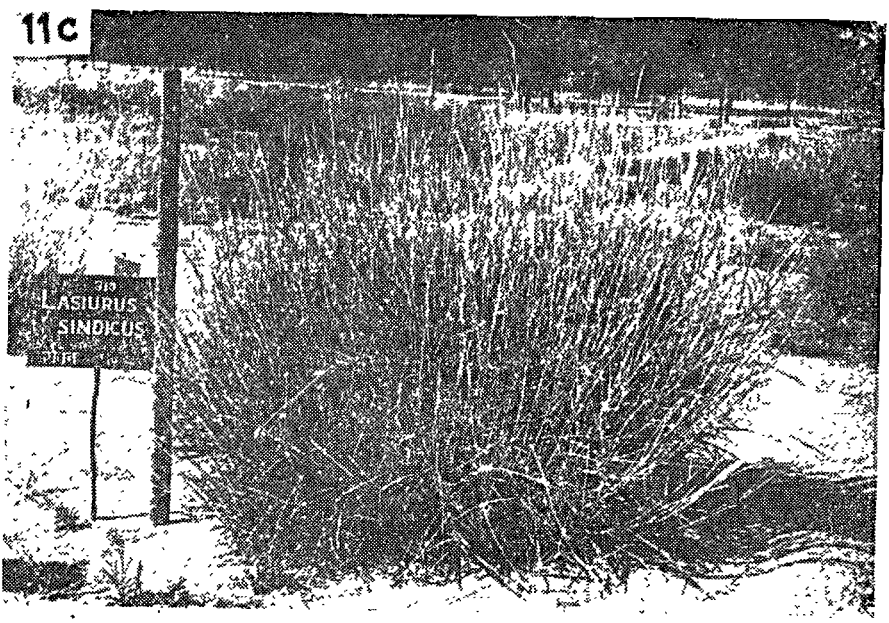

Fig. 11 (c) : Selected strain of **Lasiurus sindicus** (Sewan)

11 c) are CAZRI Nos. 357, 358, 303, 214, IGFRI 3108 and Molapo (from Australia) of **Cenchrus ciliaris,** CAZRI Nos. 175, 296 and 416 of **Cenchrus setigerus,** CAZRI Nos. 318, 319 and 565 of **Lasiurus sindicus** and CAZRI Nos. 491 and 495 of **Dichanthium annulatum.** These strains have shown both stability for production as well as better persistence over years at some of the testing locations representing zones suitable for different grass species.

4.3.5. Fertilization :

The nutrient content and production potential of forage species on the rangelands in western Rajasthan is quite low and, therefore, for optimum production, it is essential to provide adequate nutrients to the soils as these are often subjected to erosion hazards and are highly depleted. Placement of nitrogenous and phosphatic fertilizers @ 40 kg N/ha+20 kg P_2O_5/ha revealed that forage production increased in the semi-arid regions receiving relatively more than 300 mm rainfall (Table 4), whereas the response to 20 kg N/ha appeared to be favourable in arid regions getting less than 300 mm rainfall. It has also been reported that the fertilizer application increased the yield of crude protein in **C. setigerus, L. sindicus, C. ciliaris** and **P. antidotale** by 108, 82, 58, and 26 per cent, respectively (Das **et al.,** 1969).

TABLE 4

Effect of fertilisers on forage production (kg/ha) in different rangelands

Range management area	Vegetation cover	Control		20kgN/ha		20kgN + 20kgP/ha		40kgN + 20kgp/ha		F test		SEm ±		C.D. at 5%	
		1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978
ARID AREAS															
Lawan	*Lasiurus-Eleusine*	1269	1249	1384	1120	1649	1138	1706	1178	NS	NS	200	102		
Chandan	*Lasiurus-sindicus*	2100	2008	2530	2600	2550	2786	3050	2991	**	*	168	210	537	673
Jaisalmer	*Lasiurus-Cymbopogon*	2160	1497	2230	2354	1965	2106	1715	2185	NS	**		123	—	395
Beechwal	*Lasiurus-Eleusine-Aristida*	4580	138	5615	129	6012	133	6847	192	*	*	336	155	1074	429
Samdari	*Cenchrus-Eleusine-Aristida*	1719	993	1669	1516	2106	1224	1515	1395	NS	NS	224	209	—	—
SEMI-ARID AREA															
Bhopalgarh	*Cenchrus-Aristida*	2423	1662	2402	1153	3152	1518	2743	1944	NS	*	246	159	—	508
Borunda	*Cenchrus-Eleusine-Aristida*	1447	1424	1742	1877	2450	1837	2554	2511	**	*	173	230	553	736
Bisalpur	*Dichanthium-Aristida*	3340	3156	5648	4001	5558	4382	6035	4846	*	**	322	182	1029	292
Jadan	*Cenchrus-Aristida-Sporobolus*	1613	2119	1897	3902	2452	3479	2737	3721	NS	**	438	272	—	815
Palsana	*Cenchrus-Eleusine-Aristida*	1103	2056	1252	2523	1436	2476	1291	3150	NS	**	143	332	—	1062

4.3.6. Role of legumes :

The key role of legumes in soil enrichment in the absence of manuring needs no emphasis. However, their importance is two fold; firstly, they constitute a high protein component in Indian dietary and secondly, they provide nutritious forage for livestock. Further, legumes constitute the cheapest way of providing nitrogen to the animals and associated grasses. Owing to comparatively high costs of nitrogenous fertilizers the possible supply of nitrogen by legumes attains a place of great importance in overall rangeland technology. Studies on the introduction of legumes like **Dolichos lablab** (Fig. 12 a), **Atylosia scarboeoides** (Fig. 12 b), **Clitoria ternatea** (Fig. 12 c), **Macroptilium atropurpureum, Stylosanthes** species etc. in the grasslands, under different agroclimatic regions, are in progress. Performance of **Clitoria ternatea** appeared to be better as, when established in the pasture by providing about one metre space between grass rows, it gives productivity for two to three years. **Dolichos lablab** also performs better but being annual it requires reseeding every year.

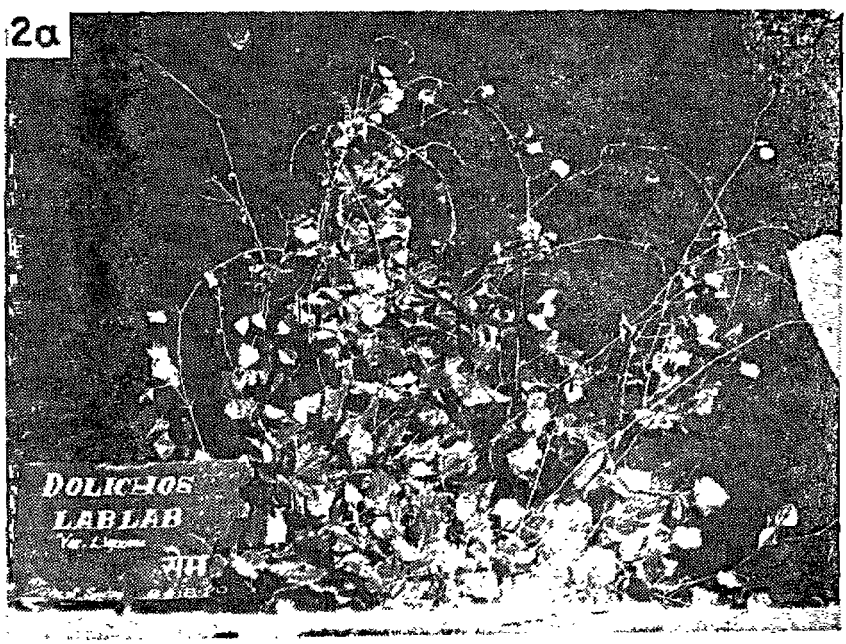

Fig. 12 : Adaptable legumes of Indian arid zone
(a) **Dolichos lablab**

Fig. 12 (b) : **Atylosia scaraboeoides**

Fig. 12 (c) : **Clitoria ternatea**

4.3.7. Forage Conservation and Preservation :

Recurring droughts are common features in the arid regions which often result in shortage of forage. To overcome this difficulty, conservation of fodder is most essential. Moreover, it has also been experienced that the livestock generally start loosing weight from November onwards which obviously is a reflection of decline in the quality of growing forage. Timely harvesting and the preservation of forage will ensure both the quality and regular supply of forage.

All the four methods of hay making i.e. (i) Ground method, (ii) Tripod method, (iii) Farm fences, and (iv) Use of thatched huts open on all sides, with racks having open bottoms and length across the wind direction, are suitable for arid grasses like **Cenchrus, Dichanthium, Lasiurus** and **Panicum**. For better results, plants should be harvested at pre-flowering stage in the morning hours and kept on ground/tripod/farm fence etc. for sun drying. Freshly cut grass contains approximately 75 per cent water, whereas a good hay should contain only 10 per cent moisture. When kept dry in stacks (Fig. 13), hay will invariably store well for long, without any further decline in quality. To reduce the chances of any possible spoilage, stacked hay could be covered by a canvas tarpaulin.

Fig. 13 : Stacked hay of ***Lasiurus sindicus*** *(Sewan) at Jaisalmer*

4.4 Silvi- pastoral management :

Since livestock husbandry occupies the most important place in the economy of the arid region and that frequent droughts result in loss of livestock owing to the shortage of fodder resources, it is necessary that range improvement program is also complemented by raising fodder tree and shrub species. Introduction of suitable tree species will not only provide nutritionally better quality fodder during the lean period, but will also be useful in nitrogen build up in the soil and serve as shade tree for grazing animals. In addition, fodder trees and shrubs will ameliorate the micro-climatic conditions and thereby improve conditions for better regeneration of grasses.

Studies conducted on the contribution of the understory in afforested areas with **Prosopis cineraria, Albizzia lebbek, Tecomella undulata** and **Acacia senegal** have revealed that the production of forage under first three species did not differ significantly (15.46, 14.06, 14.78 q/ha, respectively) but the yield under **Acacia senegal** was significantly lower (6.91 q/ha) than the other three species (Ahuja **et al.,** 1978).

Silvi-pastoral studies (Fig. 14) conducted with **Acacia tortilis, Azadirachta indica, Albizzia lebbek,** and **Holoptelia integrifolia** and

Fig. 14 : Silvi-pastoral management : **Cenchrus ciliaris** with **Acacia tortilis**

four grasses namely **Cenchrus ciliaris, Cenchrus setigerus, Dichanthium annulatum** and **Panicum antidotale** revealed non-significant differences in the dry matter production under different tree species. The mean dry forage yield of 29.0, 25.1 and 21.6 q/ha was recorded in case of **Dichanthium annulatum, Cenchrus ciliaris** and **Panicum antidotale,** respectively (Muthana and Shankarnarayan, 1978). Yield levels are quite comparable with those when grasses are raised without tree species. Introduction of indigenous and exotic tree and shrub species in the rangelands viz., **Acacia tortilis, A. aneura, Colophospermum mopane, Leucaena leucocephala** and **Dichrostachys nutans** are under progress.

4.5. Grass seed production and distribution :

Seed production of high yielding perennial grasses viz., **Cenchrus ciliaris, C. setigerus, Lasiurus sindicus, Dichanthium annulatum** and **Panicum antidotale** is a major limitation due to uneven distribution of rainfall in the arid condition. Since seed is the most important input for any grassland development program, concerted efforts in this direction are required. CAZRI has an excellent record of producing a total of 694 q of grass seed (Table 5) and so far distribution of 642 q to the various development agencies. About 50 q seed of the above mentioned grass is being collected and distributed annually. Efforts in producing genetically improved seeds of grasses and legumes are also in progress.

Seeds of different grass and legume species (Appendix III) can be obtained by sending indents well in advance to the Director or to the Head of Division, Plant Studies, Central Arid Zone Research Institute, Jodhpur. Supply is generally made against cash/ advance payment in favour of the Director, Central Arid Zone Research Institute, Jodhpur.

TABLE 5

Grass seed production and distribution 1963–77

Grass species	Production (q)		Distribution (q)		Average price per q (Rs.)	Income (Rs)	
	Total	Average per year	Total	Average per year		Total	Average
Cenchrus ciliaris	211.3	14.1	211.3	14.1	238.79	50456	3364
Cenchrus setigerus	243.0	16.2	237.1	15.8	238.79	56617	3774
Cenchrus species	123.0	8.2	79.1	5.3	238.79	18889	1259
Lasiurus sindicus	87.9	5.6	85.5	5.6	238 79	20416	1361
Dichanthium annulatum	27.4	1.8	27.4	1.8	238.79	6543	436
Panicum antidotale	1.5	0.1	1.5	0.1	238.79	358	24
Total	694.1	46.0	641.9	42.7	238.79	153279	10218

5. ANIMAL-ENVIRONMENT RELATIONSHIP :

5.1. Stocking rate in areas :

Rangelands are essentially to be used for optimised livestock production. As such, a proper balance between the number of livestock and productivity of the range need to be maintained by continuous and careful observation on the morphological and physiological characters of plants growing on the range. Proper stocking rate on the range is the first range conservation practice which should be adopted.

'Excellent', 'Good', 'Fair', 'Poor' and 'Very poor' condition rangeland (having approximate productivity of 20, 15, 10, 7.5 and 5.0 q/ha, respectively) can safely provide year long grazing to 25-30, 20, 17, 13 and 1-6 adult cattle units per 100 hectare blocks, respectively during the normal years (Bhimaya and Ahuja, 1969). Under abnormal years, grazing stress has to be increased or decreased depending on the availability of forage on the rangelands.

Experimental results have revealed that stocking rate of 2.4 ha/heifer was capable of giving 230-270 gm/day/heifer body weight gain in case of **Cenchrus** and **Lasiurus** rangelands in the arid zone having less than 300 mm rainfall. In areas getting higher rainfall (between 300-600 mm), stocking rate of 1.3 ha/heifer was capable of providing almost similar animal body weight gains as reported in arid areas.

Similar stocking rate of ramlambs per hectare are capable of giving 30-40 gm/day/ramlamb body weight gain on well managed rangelands in arid zone of western Rajasthan (Paroda, 1978).

Studies conducted on different stocking rates without supplemental feeding on different types of rangelands revealed that growth rate per animal remains highest when the animals grazed on the carrying capacity basis (2.40 ha/heifer). Although by increasing the stocking rate viz., 1.20 and 0.60 ha/heifer the total livestock production goes considerably high but the grass component, particularly the annual species, got eliminated through effective utilization. As a result of which, it was considered essential to provide concentrates to the animals during lean periods (December-June) so as to meet out their digestible crude protein (DCP) and total digestible nutrients (TDN) requirements.

5.2. Grazing management :

Sustained primary and secondary productivity of the rangelands is only possible when the ranges are to be managed scientifical-

ly. Results of studies conducted by the Range Management Section of this Institute on different systems of grazing management in the rangelands representing varying agroclimatic conditions of western Rajasthan are briefly summarised in this portion.

5.2.1. Continuous v/s deferred grazing :

In arid regions, deferred grazing frequently means keeping the livestock away from the range until major grasses have produced the seed. Under different systems of deferment, maximum gain in body weight of adult cows (Av. body wt. 270 kg) was observed in continuous controlled grazing (based on carrying capacity) system on year long basis irrespective of different types of rangelands. However, adult cow exhibited gains in body weight by 25.8, 35.8 and 56.0 kg on an average in 'Poor', 'Fair' and 'Good' condition rangelands, respectively. Deferment to grazing for eight fortnights from growing period of vegetation resulted in decrease in body weight by about 30 kg per cow. Similarly, adult sheep exhibited body weight gain of the order 9.2 and 7.1 kg/sheep in 'Good' and 'Fair' class rangelands, respectively under continuous controlled grazing system. Deferment to grazing on rangelands for 16 weeks from July gave less animal gain.

5.2.2. Continuous v/s rotational grazing :

Rotational grazing means grazing of two or more range paddocks in sequence for the purpose of permitting the forage to recover between use. Growth of yearling heifers under system of monthly rotational grazing (Fig. 15) based on carrying capacity on an average, gave monthly growth of 7.4 kg/heifer in **C. setigerus** cover, 6.6 kg/heifer in **Cenchrus-Sporobolus** cover, 7.9 kg/heifer in **Cenchrus ciliaris** cover, and 4.5 kg/heifer in **Lasiurus sindicus** cover. From July to October, growth rate of animals remained highest on the range and it was of the order of 11.2 to 13.7 kg/heifer without detrimental effect on the existing range conditions.

Similarly, continuous and rotational grazing at fortnightly intervals with ramlambs of Marwari breed on **Cenchrus-Eleusine-Aristida** cover (Fig. 16) exhibited no significant variation between the two different systems of grazing management. However, a satisfactory gain of 12-16 kg/lamb/year was observed irrespective of different systems of grazing treatments.

5.2.3. Continuous v/s deferred rotational grazing :

Continuous controlled grazing versus deferred rotational grazing at 2 to 4 months interval revealed that different systems of

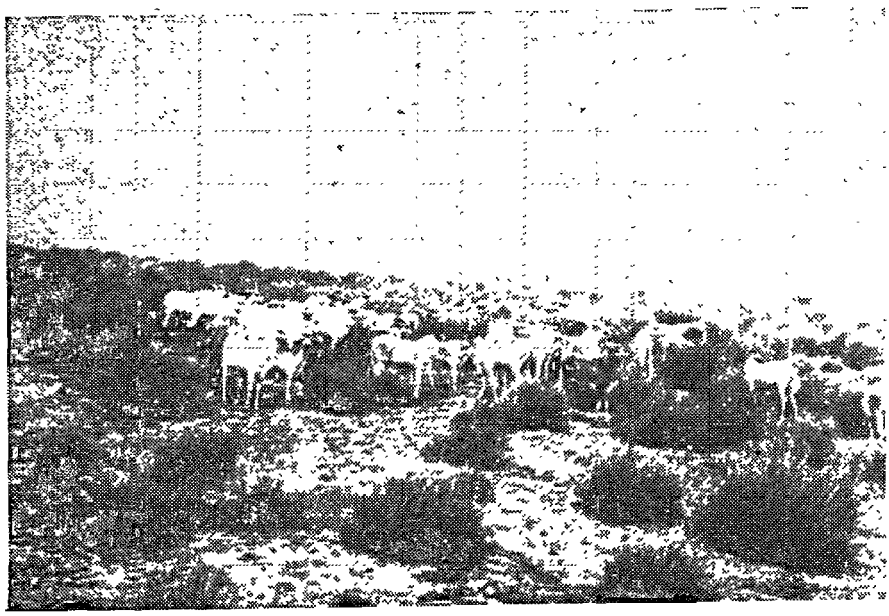

Fig. 15 : Heifers grazing on **Lasiurus sindicus** rangeland

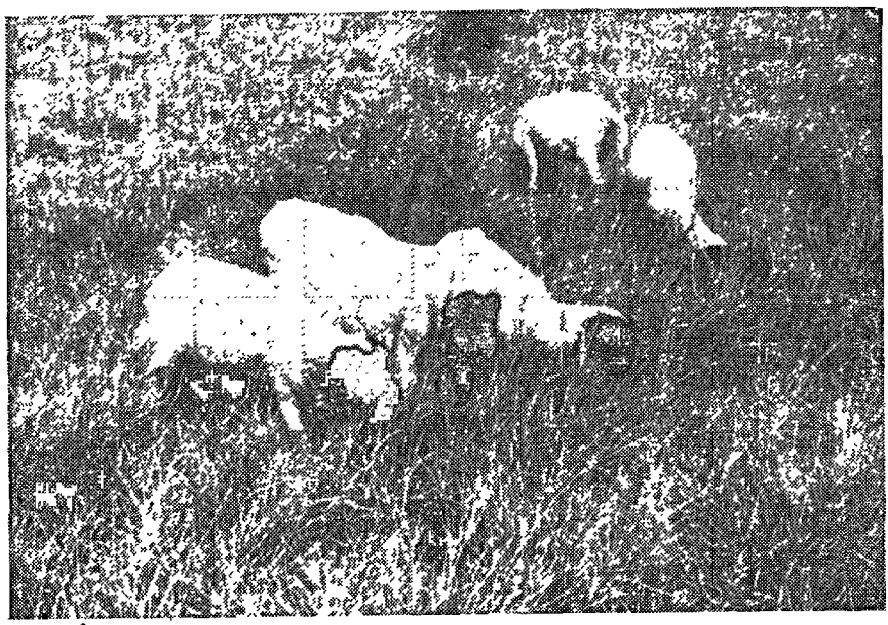

Fig. 16 : Sheep grazing on **Cenchrus setigerus** dominated rangeland

grazing management did not influence growth rate of animals (yearling heifers) on any type of rangelands studied. However, the growth rate varied from year to year. During the year of sub-normal and above normal rainfall, growth rate of yearling heifers on **Lasiurus-Eleusine-Aristida** cover varied from 45.0 to 58.0 kg/ animal/year, it ranged from 66.2 to 73.3 kg/animal/year on **Sporobolus-Desmostachiya-Cyperus** cover and 54.8 to 87.3 kg/animal/year on **Dichanthium-Aristida** cover (Verma and Ahuja, 1979).

Similarly, growth of yearling ramlambs under deferred rotational grazing and continuous controlled systems was not significantly different. However, differences did exist in respect of different breeds. On an average, 18.8, 25.8 and 25.9 kg/animal/annum growth was observed in ramlambs of Chokla, Marwari and Jaisalmeri breeds, respectively. Growth rate remained highest during July-December. In areas where **Cenchrus biflorus** and **Aristida** dominated, the growth declined mainly during September-October as a result of discomfort due to piercing of awns and burs in the body and mouth parts of grazing animals.

Considering different systems of grazing of both the heifers and sheep, it appeared that the continuous controlled grazing, based on carrying capacity, was equally effective in the rangelands when compared with deferred rotational grazing. However, it has been observed that in dry land ranges, due to continuous grazing for number of years, high yielding and palatable species showed a declining trend. Hence, distinct advantage of deferred rotational grazing for better establishment of perennial grasses through natural self seeding is obvious, especially in areas where reseeding has not been practised.

5.2.4. Mixed grazing :

Studies on mixed grazing with cattle and sheep on **Lasiurus-Cymbopogon-Aristida** rangeland in rainfall zone below 250 mm was conducted wherein heifers and lambs grazed separately and when both the animals grazed together. Results revealed that the growth of animals per unit area remained to be the highest when heifers grazed alone followed by mixed grazing with heifer and sheep and the least when sheep grazed alone.

5.2.5. Seasonal grazing :

Seasonal grazing with yearling heifers on rangelands with annual rainfall below 250 mm revealed that growth per animals during monsoon (August-October), winter (November-January),

spring (February-April) and summer (May-July) was 27.6, 14.0, 10.1 and 4.3 kg/animal, respectively giving a total growth of 47.4 kg/animal. Losses in body weight of animals during summer was due to quality of the forage, high temperature and hot wind velocity etc.

5.2.6. Goats v/s sheep grazing :

Studies on the comparative performance of goats and sheep on sown pasture of **Cenchrus** species infested with **Zizyphus nummularia** and **Mimosa hamata** bushes (Fig. 17) revealed 292 per cent increase in the body weight gains in buck (male goat) as compared to ramlamb (male sheep) within a period of one year under light intensities of grazing (3 animals/ha). The increase in gain of buck over ramlamb was 178 and 75 per cent under medium (4 animals/ha) and heavy (6 animals/ha) intensities of grazing, respectively (Annon., 1978).

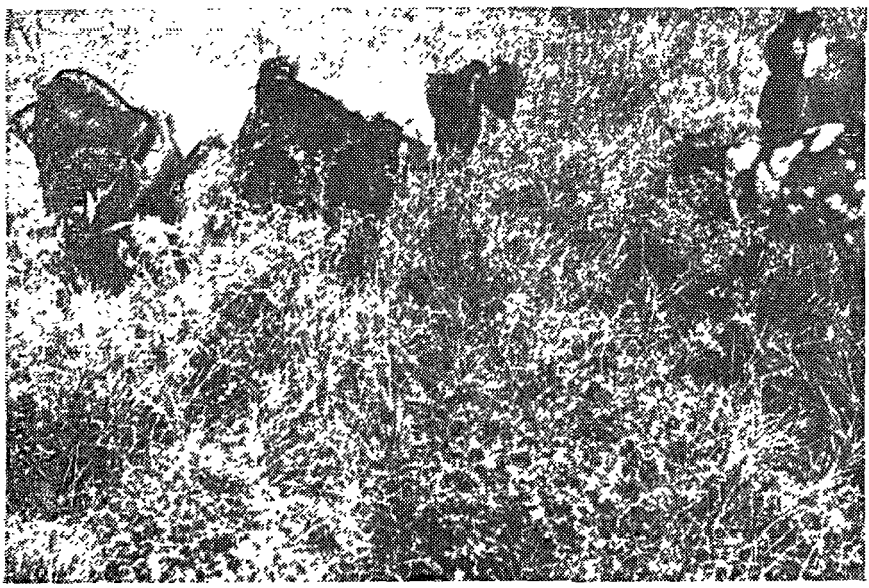

Fig. 17 : Goats grazing on **Cenchrus setigerus** rangeland associated with ***Zizyphus nummularia*** bushes

6. PRODUCTION FROM RANGELAND MANAGEMENT :

6.1 Primary production :

Studies on primary production in all the 12 rangeland management areas, over a period of last 10-15 years, have provided very

useful information. Results on different aspects of rangeland management for increased primary productivity are given in brief:

Forage production in these rangelands, which are not suitable for cultivation to start with, could be increased by almost 100-150 per cent in 2-3 years provided proper protection and controlled grazing practices for effective utilization are adopted. Later, productivity to an extent of 15 to 30 q/ha/annum could be achieved from these areas.

Soil and water conservation measures like contour furrows, trenches and bunds on rangelands with shallow soils and rolling topography increased the forage yield by 95.7 per cent (from 6.8 to 13.4 q/ha) within a year. Similarly, contour furrows of 929 sq.cm cross section, 61 cm width and 22.6 cm depth and spaced 8-10 m apart have proved superior to contour bunds and trenches. The increase in forage yield has been of the order of 638 per cent over control during the period of 10 years.

Reseeding rangelands with appropriate high yielding perennial grass species suiting the agroclimatic conditions has given encouraging forage yields. In well established strips of high perennial grass species, the maximum air dried forage yields of 58.34, and 30 q/ha have been obtained from areas under **Dichanthium annulatum, Cenchrus** species and **Lasiurus sindicus,** respectively. In saline soils, where reseeding has not succeeded, salt-tolerant grass like **Sporobolus** species have given forage yield of 20 q/ha.

Results on reseeding of local seed of climax species have so far revealed that average productivity can be increased from 5-7 q/ha to about 20 q/ha. Improved strains of grasses have the genetic production potential of even higher than 40 q/ha and, therefore, should be adopted. However, their seed availability is a major limitation and efforts in this direction are urgently needed although CAZRI has an excellent record of producing about 50 q of grass seed annually for the last 15 years.

Some of the improved strains are CAZRI 357, CAZRI 358, IGFRI 3108 and Molapo (from Australia) of **Cenchrus ciliaris.** CAZRI 76, CAZRI 175 and CAZRI 416 of **Cenchrus setigerus.** CAZRI 318, CAZRI 319 and CAZRI 575 of **Lasiurus sindicus** and CAZRI 491 of **Dichanthium annulatum.** These have shown stability for production alongwith better persistence over years at some of the important locations representing zones suitable for different species (**Lasiurus sindicus:** 200 mm and sandy soils; **Cenchrus** spp.: 300 mm and above, well drained soils; **Dichanthium annulatum:** 400 mm and above, heavy soils).

Studies on response to fertilization @ 40 kg N+20 kg P_2O_5/ ha in dry land ranges revealed that forage production increased in the semi-arid regions receiving relatively more rainfall, whereas the response to 20 kg N/ha was evident in arid regions getting less than 300 mm rainfall.

In reseeded rangelands, dominated by **Cenchrus ciliaris,** forage yield increased by 17.2 and 50.0 per cent when soil working followed by application of 20 kg N/ha and 40 kg N/ha, respectively was adopted.

Studies on the contribution of the understorey (grass component) in areas afforested with **Prosopis cineraria, Albizzia lebbek, Tecomella undulata** and **Acacia senegal** have revealed that the production of forage under different tree species vary with rainfall in different years (Ahuja **et al.,** 1978). The overall production was observed to be the least under **Acacia senegal** and the differences in the forage yield under the rest of the species were non-significant.

Studies on introduction of legumes in rangelands have revealed that none of the legumes tried is so far more suitable for the purpose. However, performance of **Clitoria ternatea** appeared to be better as once established in the pastures, by providing reasonable space (about 1 m) between grass rows, it could give productivity for two to three years. **Dolichos lablab** also performed better but being annual it requires reseeding every year.

6.2. Secondary production :

Grazing, based on carrying capacity, appeared to be most advantageous both in terms of primary and secondary production as compared to medium or high intensity of grazing.

Results have revealed that stocking rate of 2.4 ha/heifer was capable of giving 230-270 gm/day/heifer body weight gain especially in **Cenchrus** and **Lasiurus** pastures in arid zone having less than 300 mm rainfall. In areas getting higher rainfall (between 300-600 mm), especially in semi-arid zone, stocking rate of 1.3 ha/heifer was capable for providing almost similar body weight gains as in arid zone (Paroda, 1978).

The forage yield on rangelands especially in desertic areas was found to be affected by different intensities of grazing viz., light (2.4 ha/heifer), medium (1.20 ha/heifer) and heavy (0.60 ha/heifer). Light intensity of grazing (grazing based on carrying capacity) proved to be superior.

The growth rate of heifers observed to be the highest in the treatment where animals grazed on the basis of carrying capacity (light intensity) of the rangeland as compared to medium and heavy intensities of grazing. Feeding of concentrates from January-July, to meet the digestible crude protein (DCP) and the total digestible nutrients (TDN) practically doubled the growth rate in comparison to grazing based on carrying capacity.

Forage production appeared to be high in areas having **Lasiurus** as climax species and also the animal production was fairly comparable with that of other grasses reflecting thereby its superiority over other grasses especially when its suitability in low rainfall zone is of distinct advantage. Results have revealed that sheep productivity increased considerably in pastures having **Lasiurus** as one of the climax species (Das and Paroda, 1978). Also quality data have revealed another interesting feature that protein level in **Lasiurus** remains much at higher level (4-6%) at later stages (80-120 days) of plant growth as compared to other grasses like **Cenchrus ciliaris** and **Cenchrus setigerus** (having less than 4% protein) and thus, makes **Lasiurus** more suitable for efficient utilization in the animal system. As such, wherever possible, **Lasiurus** should form an important component of reseeded pastures.

Considering different systems of grazing both heifers as well as sheep, continuous controlled grazing proved to be equally effective in rangelands when compared to deferred rotational grazing which has shown its superiority mostly in pasture management system. This obviously is the reflection of low proportion of climax species and high proportion of annuals in these rangelands, whereas in reseeded pastures, deferred rotational grazing proved to be more effective mainly due to better establishment of perennial species as against annuals which was reflected by an increase of dry matter production. However, distinct advantage of deferred rotational grazing for better establishment of perennial grasses through natural self seeding is obvious especially in areas where reseeding has not been practised.

Studies on the seasonal grazing of rangelands have revealed that the growth of animals was highest during the period August-October, followed by November-January. The least gains were obtained during the period May-July. The availability of fodder to the animals during this period is about 33 per cent of the estimated production value.

On an average, body weight gain of yearling heifers was 5-7 kg/month on rangelands. Per day production of 230-270 gm/day/

heifer and 35-40 gm/day/ramlamb can thus be achieved on well managed rangelands in arid zone of western Rajasthan. In a recent study, it has been seen that animals (heifers) of same age are capable of producing 50-300 per cent more body weight on rangelands during July-December as compared to animals of same age maintained by the local villagers. It has also been found that in range management areas heifers take only $2\frac{1}{2}$ years for the first calving as against normally $3\frac{1}{2}$-4 years with the cattle owners.

Comparative growth of heifers and lambs (sheep) under mixed grazing was studied in rangeland of **Lasiurus-Cymbopogon-Aristida** cover which revealed that the growth of heifers per unit area was highest when cattle grazed alone, followed by alternate grazing at six month interval by cattle followed by sheep and the least gain was recorded when sheep grazed alone.

Drinking water requirement of different species of animals was studied on these rangelands. The requirement in adult cows increased from 19.3 litres in January to 41.1 litres in June and from 2.1 litres in January to 4.5 litres per day in June in case of adult sheep. In case of young stock (heifers), the water consumption in December was 9.0 litres and it increased to 17.0 litres in June. In case of ramlambs, 1.6 and 4.0 litres of water per lamb per day was required in December and June, respectively.

7. FUTURE RESEARCH NEEDS :

Research achievements in the field of plant studies especially in relation to rational utilization of plant resources are indeed quite encouraging especially when we consider above mentioned research findings in the field of rangeland management. Also, they have much relevance as far as checking of the process of desertification is concerned. However, as is obvious, there is an urgent need to take up intensive research on some relatively important aspects needing immediate attention like :

1. Productivity of fodder tree species, exotic or indigenous, need to be assessed now in relation to grass production and thus, research on silvi-pastoral system should find priority. There is also an urgent need to introduce suitable fodder trees in range management areas. Not only that these will provide nutritionally better quality fodder, they will be useful through nitrogen build up in the soil and serve as shade trees for grazing animals. Fodder tree species which can immediately be considered at present are **Prosopis cineraria, Leucaena leucocephala, Acacia aneura, Dichrostachys nutans, Brasilettia mollis** and **Colophospermum mopane.**

2. Long-term grazing studies on rangelands are required so that economics of primary productivity could be associated with that of secondary productivity like milk production per hectare. Also long term studies will generate useful data with regard to maturity, body weight gains, lactation period, and both meat and wool production etc. Data on these aspects are, therefore, required so that the recommendations are more meaningful, economically sound, and viable.

3. Role of legumes in rangelands as well as established pastures need to be examined in detail. For this, it will be necessary to take up intensive studies on aspects like their introduction, establishment and cultivation. Similarly, application of fertilizers in rangelands and its economics in relation to productivity requires specific attention. Also the role of grass seed pelleting for better establishment needs to be examined critically.

4. To examine utility of forage conservation measures in enhancing the productivity of animals in range areas especially after October-November months when yield increases invariably reach a plateau, mainly due to the deterioration in forage quality. Specific role of hay and silage making and even fortification of nitrogen, either through incorporation of legumes or urea, needs to be examined in detail particularly in relation to livestock needing production ratio. Suitable harvesting devices, if developed, will accelerate the process of grass harvesting in these areas at right stage for their conservation.

5. Although contribution of genetically superior strains of grasses and legumes in increasing the level of production is well established, breeding efforts are now obviously required. Some studies of immediate relevance are already under way to improve both quantity and quality in arid zone grasses and legumes.

8. CONCLUSIONS :

Whereas some of the research aspects need immediate attention of the scientists, research findings as well as technology advanced in the field of rangeland management offer great promise and should, therefore, find wider acceptance in arid zone of western Rajasthan in order to ensure rational utilization of resources for both primary and secondary productivity and eventual check of desertification process. Evident as it is from the foregoing discussion, application of technologies in the field of rangeland management will certainly pave way to improve both the primary and secondary productivity. For effective and viable management, their adoption will require a community approach as areas involved will be large enough and the financial involvement will also be beyond the reach of a common farmer. Considering immediate as well as long term benefits of these programs, integrated involvement of both the Public Sector and Village Panchayats will accelerate the process for adoption of rangeland management technology.

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APPENDIX I

LIST OF COMMON PLANTS IN RANGELANDS

Species (Botanical name)	Common name
A. HIGH YIELDING PERENNIAL GRASSES	
Cenchrus ciliaris	Dhaman
Cenchrus setigerus	Anjan
Dichanthium annulatum	Karad
Heteropogon contortus	Kala lamp
Lasiurus sindicus	Sewan
Panicum antidotale	Gramna
Panicum turgidum	Murat
Sehima nervosum	Rudia
B. LOW YIELDING PERENNIAL GRASSES	
Cymbopogon jwarancusa	Boor
Cymbopogon parkerii	Boor
Cymbopogon scheonanthus	Sugani
Dactyloctenium sindicum	Ganthiya
Dactyloctenium aegypticum	Makra
Desmostachya bipinnata	Dhab
Eremopogon foveolatus	Jhunjali
Eleusine compressa	Tantiya
Oropetium thomaeum	Khargose chunti
Sporobolus marginatus	Kharada
Sporobolus helvolus	Kharada
C. ANNUAL GRASSES	
Aristida funiculata	Lampra
Aristida adscensionis	Lampra
Bracheria ramosa	Kuri
Cenchrus biflorus	Bhurat
Cenchrus prieurii	Lamb Bhurat
Chloris virgata	Chinki
Digitaria marginata	Jherania
Echniocloa colonum	Jirio
Eragrostis tremula	Chirighas
Eragrostis ciliaris	Under-puncho
Tetrapogon tenellus	Kagio
Tragus biflorus	Charchara

D. LEGUMES

Cassia auriculata	Anwal
Indigofera cordifolia	Bakeria
Indigofera linifolia	Bakeria
Tephrosia purpurea	Dhamasa
Tephrosia petrosa	Dhamasa
Phaseolus trilobus	Chiri moth
Rhyncosia minima	Tapni-bel

E. EDIBLES, HERBS AND SHRUBS

Boerhavia diffusa	Santa
Citrullus colocynthis	Tumba
Convolvulus microphyllus	Dholi-phooli
Crotolaria medicagenia	Oonth Kantala
Cyperus arenarius	Motha
Cyperus rotundus	Nagar Motha
Heliotropium subulatum	Kali-bui
Heliotropium strigosum	Kali-bui
Fagonia cretica	Dhamaso
Farsetia hamiltonii	Kag-pilang
Pulicaria wightiana	Sonela
Salsola baryosma	Lani
Suaeda fruticosa	Lunaki
Tribulus terrestris	Kantee
Zizyphus nummularia	Bordi

APPENDIX II

LIST OF COMMON FODDER TREES

Species (Botanical name)	Common name	Palatability rating
Acacia tortilis	Israeli babool	Good
Acacia nilotica	Babool	Good
Acacia senegal	Kumat	Moderate
Acacia leucophloea	Arunj	Fair
Albizzia lebbek	Siris	Moderate
Ailanthus excelsa	Ardu	Good
Azadirachta indica	Neem	Good
Anogeissus pendula	Dhokra	Moderate
Capparis decidua	Kair	Fair
Cassia auriculata	Senna	Fair
Calligonum polygonoides	Phog	Moderate
Grewia tenax	Gangana	Fair
Maytenus emarginata	Kankera	Fair
Prosopis cineraria	Khejri	Good
Prosopis juliflora	Vilayathi babool	Fair
Salvadora oleoides	Pilu-jal	Good
Salvadora persica	Khara-jal	Good
Tecomella undulata	Rohida	Fair
Zizyphus nummularia	Bordi	Good

APPENDIX III

PRICE LIST OF GRASS AND LEGUME SEEDS

Name of species	Approved price* (Rs. per kg.)
GRASS SEEDS	
1. **Cenchrus ciliaris** (General)	10/-
2. **Cenchrus setigerus** "	10/-
3. **Lasiurus sindicus** "	10/-
4. **Panicum antidotale** "	10/-
5. **Dichanthium annulatum** "	10/-
6. **Cenchrus ciliaris** (Strains)	15/-
7. **Cenchrus setigerus** "	15/-
8. **Lasiurus sindicus** "	15/-
LEGUME SEEDS	
1. **Dolichos lablab**	10/-
2. **Clitoria ternatea**	10/-
3. **Atylosia scarabaeoides**	10/-
4. **Macroptelium atropurpureum**	15/-
5. **Rhyncosia minima**	10/-
6. **Stylosanthes** strains	25/-

*Price list is effective for seeds available at CAZRI, Jodhpur w.e.f. 1-1-1979