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FOURTEEN YEARS OF ARID ZONE RESEARCH (1959 – 1973)

CENTRAL ARID ZONE RESEARCH INSTITUTE
JODHPUR

PREFACE

Abstract

Established in October 1959, Central Arid Zone Research Institute, Jodhpur, has completed 14 years of Scientific research in agriculture and allied fields including Aronomy, Agrostology, Agricultural Economics, Agricultural Engineering, Aggricultural Chemistry, Animal Ecology, Animal Physiology, Cartography, Climatology, Dry Farming, Geomorphology, Geology, Horticulture, Hydrology, Plant Breeding, Plant Ecology, Plant Physiology, Physics (Solar Radiation), Range Management, Sociology, Soil Science, Silviculture, Soil Conservation, Statistics, Systematic Botany, Toxicology and Plant protection. Results of research conducted have been published in National and International Scientific Journals, besides the Annual Reports of the Institute. Popular Semi-technical articles on selected subjects have been published. In order to meet the ever increasing demand from various agencies, the research results achieved and a resume of the important activities of the Institute are presented. Comments and suggestions are invited for improving the subsequent issues.

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Jodhpur.

Recent Advances in Arid Zone Research

The Indian desert occupies over 3.2 lakh square kilometres of hot desert located in Rajasthan, Haryana and Gujarat, besides small pockets in peninsular India. An area of about 70,000 sq. kilometres of cold desert in Ladakh in Jammu and Kashmir, presents desertic conditions entirely different from the hot desert.

The area under the desert in India is about three and a-half times the combined area of the States of Punjab and Haryana. About 20 million persons live in the Indian desert which is about twice the populatian of Haryana. Besides the numan population, the cattle population is quite large (23 million). The problem of desert control becomes quite complex and challenging because the technology evolved has to be introduced and implemented effectively in a manner that it not only sustains but improves large human and cattle population. Besides its economic and social importance, the desert has direct and indirect influences on the entire country. Agricultural production and living standards in the rural areas located in the more favourable conditions of the country are increasing and have caused regional disparities and imbalances.

Problems

The general problem of arid and semi-arid areas with large populations is essentially one of human ecology. In the absence of adequate scientific, technological, social and financial assistance, local population has been over exploiting the natural resources resulting in ecological imbalance. Where large

scale water resources from outside the arid regions cannot be tapped, the inherently meagre water resources within the region set the ultimate limits of production of plant material on which both human and animal populations are dependent. Erratic rainfall results in widely fluctuating production, and this, in turn, leads to frequent recurrence of famines. As populations increase, the stress becomes greater. Eventually, there is an increasing rate of imbalance between the human and animal populations on the one hand, and plant, water and land resources on the other. As the demand by the first is persisting and increasing, the resources tend to become depleted. Thus, there is set into operation a process of progressive degradation of resources, which is accelerated during every famine period. If continued unchecked, it leads to permanent damage to plant species through excessive grazing, or cutting for fuel, to their replacement by bare land, or, at best, less useful plant communities, to the loss of surface soil by water or wind erosion-to lower soil fertility and ultimately to the production of large areas of waste land cut by deep erosion channels, or of barren sand dunes which are not only unproductive but may involve considerable expenditure of public money where they encroach on community services.

As a result of cumulative effects of all these processes, changes are brought about in both the hydrology of the region and its micro-climate, tending towards the production of a more-arid and less-productive environment.

Historical background

Realising the seriousness of the problems, the Government of India established a Desert Afforestation Research Station at Jodhpur in 1952 to carry out afforestation research work and forestry extension including the erection of shelter belts and afforestation of sand dunes and denuded areas unfit for cultivation of crops. In 1957, the scope of the station was enlarged by inclusion of soil conservation programmes, and was named as the Desert Afforestation and Soil Conservation Station for tackling the serious problems of wind erosion and consequent increase in desertic conditions by conducting basic and applied researches in major aspects of land use relating to forestry, crop husbandry and grass-land development.

Subsequently it was felt necessary to establish an active research Centre at Jodhpur to develop the agricultural potentialities of the Rajasthan desert. On the recommendations of Mr. C. S. Christian, CSIRO, Australia, the station was reorganised in 1959 as the Central Arid Zone Research Institute. From April, 1966 the administrative and technical control of the Institute was transferred from Ministry of Food and Agriculture to the Indian Council of Agricultural Research.

The Scientific work of the Institute has been reviewed by two Achievement Audit Committees, first in 1966 and for the second time in 1973.

The Central Arid Zone Research Institute is one of the 23 Research Institutes of the Indian Council of Agricultural Research. The scientific work of the Institute is being conducted on inter disciplinary basis. The Institute consists of the following main Divisions :

Division I	:	Basic Resources Survey
Division II	:	Plant Studies
Division III	:	Animal Studies
Division IV	:	Wind Power & Solar Energy Utilization
Division V	:	Soil-Water-Plant Relationship
Division VI	:	Economics & Sociology
Division VII	:	Extension & Training

The Institute is collaborating with the following All India Co-ordinated Research Projects of the I. C. A. R. :

1. All-India Co-ordinated Research Project on Dry-land Agriculture.
2. Co-ordinated Project on New Cropping Patterns and Water Use in selected command areas.
3. All-India co-ordinated Research Project for the Improvement of Pulses.
4. All India Co-ordinated Research Project for Improvement of Millet.
5. All India Co-ordinated Model Agronomic Experiments Seheme.
6. Co-ordinated Project on Fodders and Forages.
7. All India-Co-ordinated Project for Blood Group and Bio-chemical Polymorphism in Indian Farm Animals.

Besides the above schemes, a sub-station of the Plant Introduction Division of Indian Agricultrual Research Institute, New Delhi is located at this Institute.

Significant Results

The important results obtained from the research projects, having direct application for the agaricultural development in the arid region are summarised.

Rational Utilization of Basic Resources

Inherent in, the desert problems is the necessity to recognise that the arid areas are supporting a substantial population and the methods of reclamation or utilization must be applied while the population continues to subsist on land. Arid and semi-arid regions have definite limitations imposed on their potential productivity. In certain areas the existing population has already exceeded the level of permanent supporting capacity. One of the objects of arid zone research, thorefore, is to assess the eventual resource potential of different areas. For the purpose of obtaining comprehensive knowledge and understanding of resources, integrated surveys have been completed in 45,267 sq. km. in the state of Rajasthan, Haryana Gujarat and Mysore. In addition, semi-detailed integrated surveys have been conducted at Development Block level in 34,000 sq. km mostly in Western Rajasthan. Besides. the detailed surveys at village level have also been done in 10,421 ha. of land. These surveys provide comprehensive imformation with regard to (a) Land use capability classes based on land use data, erosion hazards, both wind and water, type and intensity of dunes. soils; (b) pasture types; (c) tree vegetation; (d) water resources both surface and ground-water, water quality, water potential zone and their capabilities to supply ground water and village tanks and their water potentials; (e) Socio-economic conditions of the people including population characteristics, social and economic correlations of various caste groups, household structure, rural working force, class of farmers and holding size, animal vegetation-human relationships, form of settlement etc. Methods to utilise these resources rationally to up grade production have been indicated in these reports.

In the State of Rajasthan, 19 p.c. of the arid land comprising of Central Luni basin and Bikaner district has been surveyed at reconnaissance level. 17.3 p.c. of the area comprising of Siwana, Saila, Ahore, Jalore, Luni and Chohtan *Panchayat Samitis* and Jodhpur have been surveyed in a *semi-detailed* level. In Haryana State 23 p.c. of the arid area in the Mahendragarh district; in Gujarat State 2.2 p.c. of arid areas in Santalpur block; and in Mysore state 24 percent of arid areas in Challakere taluk have been surveyed at reconnaissance level. Amelioration measures have been suggested to make these areas more productive. Possibilities of exploitation of surface water and ground water in each block have been indicated. The quality of water in each block has also been assessed and recommendations made regarding its suitability for irrigation.

Biophysical mapping of each surveyed area giving an integrated picture of land forms, soils, vegetation, water resources and landuse has been done.

Assessment of basic resources of each biophysical unit to upgrade production and suggest rational approach to its development of resource has been given in the report. For example Bikaner district has been divided into 12 biophysical land types for purpose of assessment and development of resources. Flat aggraded alluvial plain and flat interdunal plain with moderately deep to very deep fine sand to loamy sand soil, kharif cropped land with 40-80 p.c. intensity of cropping form the principal biophysical units of the district which need immediate attention to introduce modern techniques of dry farming practices to increase production. Recent alluvial plain with deep stratified fine loam to silty clay soils in the north west is a biophysical unit, which needs special attention under irrigation, which is proposed in the area under the Rajasthan canal scheme. Salinity occurring in the soils at lower depth needs special attention for amelioration, if good yields are to be expected under irrigation. Large areas of active sand dune in the district without vegetation form focii of sand movement creating hazard for surrounding cultivated area, village sites, railway embankments and roads. These need immediate attention for stabilisation. With favourable moisture status in these unstabilized dunes at a depth of one metre and over, it should not be difficult to establish tree vegetation on these dunes in the first instance.

Lining of water channels

Lining of Janta emulsion at 2.5 litres with 2.5 litres of kerosene oil per 100 sq. ft. of wetted surface has been found to decrease deep seepage losses in flowing channels in loamy sandy soils of Jodhpur from 40 p.c. without lining to 3.2 p.c. with lining. Mixing of Janta emulsion with soil and plastering the same on the channel surface upto about 5 mm. depth has been found to be more effective and durable.

Rajasthan Atlas

An Agricultural atlas of Rajasthan consisting of 34 Plates of 1.2 scale has been published depicting physical, agricultural and socio-economic conditions of different regions of the State. These maps also show problem areas where immediate attention is needed to draw up reclamation and development programmes.

Aridity Explained

In view of strong monsoon circulation peculiar to Indian subcontinent, the weather conditions during monsoon in the Indian arid zone are different

from those of other deserts. Though actual rainfall is low the humidity of air is high and is almost similar to other places with higher rainfall in semi-arid and sub-humid zones as can be seen from the following table.

Table :— Mean vapour pressure, relative humidity and rainfall at selected stations in India (1931-1960)

		Barmer (Arid)	Jodhpur (Arid)	Kota semi arid)	Indore (Sub-humid)	Bhopal (Sub-humid)
Mean vapour pressure (mb)	July	28.7	27.9	28.7	26.6	27.1
	Aug.	28.1	28.0	28.7	25.9	27.0
Mean relative humidity (p.c.)	July	65	65	69	80	79
	Aug.	70	71	75	83	82
Mean annual rainfall [mm]		310	380	841	1053	1209

In the upper atmospheric levels also humidity is high. For instance, mean precipitable water vapour during July over Jodhpur is 5.6 gm/cm^2 while the corresponding values for Delhi, Nagpur, Bombay and Trivandrum are 6.1, 5.5, 6 2 and 4.6 gm/cm^2 respectively. Inspite of these comparable humidity conditions, the clouds coming in the arid region do not grow in vertical extent and tend to dissipate due to divergence in the atmosphere and associated descending of air at higher levels. During those years when no monsoon depressions move across Rsjasthan or they recurve in Madhya Pradesh, desert regions get a drought year as it happened in 1968 and 1969 in Jaisalmer, Barmer and Bikaner districts.

Preliminary scientific evidence is suggestive that the presence of atmospheric dust due to wind erosion may be one of the important causes for the divergence in the upper levels of atmosphere for absence of rain in the arid region. Provision of vegetative improvement of rangelands cover including improved rangelands and pastures, controlled grazing, afforestation, establishment of shelter belts and wind breaks, and stabilisation of shifting sand dunes would considerably reduce the dust. Techniques for these practices have been evolved. Further research on these aspects is in progress. These measures, if taken up on a larger scale over the arid region, would help in bringing more condensation of dew and more rainfall over the region besides enhanced productivity of the region.

Delineation of Arid and Semi-Arid Zones and Soil climatic Zones of India

Available climatic data have been analysed and the following results of agricultural importance obtained : [1] The boundaries of arid and semi-arid zones have been demarcated. On the basis of this classification the total areas of arid and semi-arid zones work out to be 3, 17, 000 sq. km and 9,57,000 sq. km respectively excluding the cold desert of Ladakh in Jammu and Kashmir which has about 70,000 sq. km of arid and 14,000 sq. km of semi-arid zones. Rajasthan contains 61 per cent of arid zone while Gujarat State has 20 per cent of the same. About 10 per cent of arid areas is in the peninsular India, which, however, has nearly 59 per cent of the total semi-arid zones in the country, with coverage under Maharashtra, Andhra Pradesh, Mysore and Tamil Nadu being 19, 15, 15 and 10 per cent respectively. Semi arid zone in north India is in the form of a strip to the east of the arid zone. (2) Detailed climatological analysis of Maharashtra, Gujarat, Rajasthan, Tamil Nadu, Mysore and Andhra Pradesh States has been completed. (3) The country has been divided into 64 homogeneous soil climatic zones on the basis of moisture regime index, thermal index and important soil types. Explanation of the general cropping patterns of the country in terms of these soil climatic zones has been completed and a few maladjustments pointed out. The variations in the moisture deficiencies in Kharif and Rabi seasons have also been studied. This information is important for scientific planning of the cropping pattern for these regions. (4) Maps showing the average dates of commencement and cessation and mean duration of crop growing season in India with little or without any soil moisture stress under rainfed farming have been prepared. Similar maps of India showing commencement and cessation of moderate and severe drought periods have also been prepared.

Analysis of rainfall pattern and distribution.

A study on the mathematical distribution of the accumulated rainfall during the main agricultural season (Kharif) indicated that there is a difference between arid and semi-arid zones not only in the actual rainfall amounts but also in their frequency distribution.

Using these theoretical distributions rainfall probability charts have been prepared. These charts can be made use of for finding the probabilities of droughts within the growing season and also for planning cropping patterns

Evapotranspiration and soil moisture regime

Water being the main factor limiting agricultural production in arid zone, the knowledge on how the limited rainfall gets dispersed is important.

The surface run off in the sandy plains of Jodhpur is low and constitutes, on the average, only 5 per cent of the total rainfall, though it can be higher in those years receiving high rainfall intensities. Recharge to ground water takes place only during years having good rainfall intensities. Soil moisture reserves get exhausted earlier in the native vegetation site than in the cropped land.

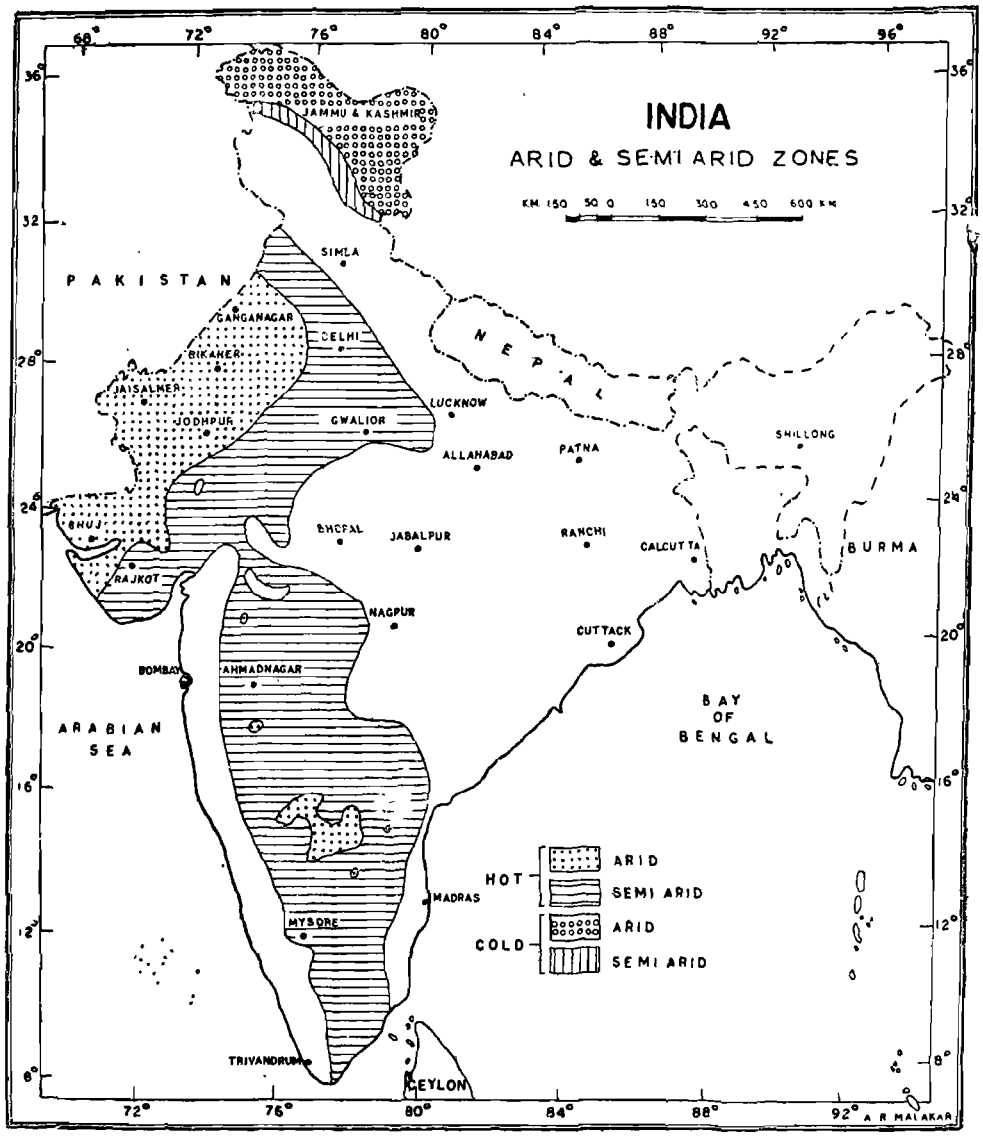
Methods have been evolved for predicting fairly accurately the soil moisture under the native grasses from climatalogical parameters by means of evapotranspiration models. Efforts are being made to develop such models for cropped areas. A rapid field method for determination in situ of hydraulic conductivity of sandy soils which determines the rate at whieh the water would penetrate into soil has been evolved.

Studies on soil thermal regime and heat fluxes

For the sandy to loamy sandy soil of Jodhpur, there are two types of soil thermal regimes (1) summer pattern when soil temperature decreases from 1 cm to 120 cm depth during maximum temperature epoch and increases from 1 cm to 30 cm depth and decreases thereafter for minimum temperature epoch, (2) winter pattern when soil temperature during maximum temperature epoch decreases upto 30 cm with an increase thereafter and during minimum tamperature epoch increases continuously from 1 cm to 120 cm depth. The former pattern lasts from mid March to mid October with a few breaks during active monsoon period when the winter pattern is brought in temporarily.

Conditions are favourable for upward movement of moisture in vapour phase during the morning hours and for the downward flow during the afternoon hours throughout the year. From April to end of October, the gradients are stronger. However, during monsoon, downward vapour pressure gradients in afternoon are much less than those in other months thereby indicating that the general upward movement of water vapour in crop growing season exist during monsoon period.

Though many workers have reported that the annual soil temperature cycle is well represented by the first harmonic alone, it has been found that under Jodhpur conditions, the first harmonic explains only 69 to 85 per cent. The change in soil temperature pattern during monsoon is well reflected only if the third harmonic is superposed over the sum of the first two harmonics. The amplitudes at various depths vary between 4.8 to 9.10 °C for first harmonic and decrease sharply with higher order harmonics. The finding of this harmonic analysis enables us to predict the soil temperature pattern at any time during crop season.



	Indian arid zone	per cent	Indian semi-arid zone	per cent	India
Area (000 Sq kms)	388	12.13	969	30.28	3200
Population (millions 1971)	20	3.65	170	31.07	547
Livestock population (millions 1966)	23	6.68	122	35.46	344

A study of weekly mean soil heat fluxes at Jodhpur indicates larger oscillations of fluxes in monsoon than in other seasons. The weeks of rainfall have large negative fluxes while the intervening dry spells have large positive fluxes. These are noticed in each individual layer upto depth of 120 c.m.

These results indicate existence of flow of appreciable heat due to mass movement of water and also flow of water in vapour phase in arid zone soil during monsoon. The above features are considered important by agro-climatologists in moisture movement problems and estimation of crop water use.

Solar energy utilisation potential in India

Average useful solar energies available for utilisation in respect of flat-plate collectors kept at optimum tilts in respect of ten stations in India, viz, Ahmedabad, Bhavnagar, Calcutta, Delhi, Jodhpur, Kodiakanal, Madras, Nagpur, Poona and Port Blair were worked out for typical winter and summer months.

During January the total solar radiation on horizontal surface varies from 341 Cal/cm^2 day in respect of Dilhi in north to 508 Cal/cm^2 day in respect of kodaikanal in the South. However, by proper orientation and optimum tilts it is possible to collect on the flat plate collectors considerably more energy comparable to summer values at most of the stations. The values exceed 600 Cal/cm^2 day in respect of Jodhpur and Poona in January.

Based on these data, generalised design curves for water heating by flat-plate collectors giving the ratio of useful energy collected by the flat-plate collector to the heat removal efficiency factor in terms of inlet temperature rise over ambient temperature have been prepared.

Because of the intermittent nature of the radiation and its high day to day variation due to cloudiness, such design curves based on the solar radiation values which are exceeded on 10 per cent, 50 per cent and 90 per cent occasions have also been prepared for Jodhpur and New Delhi in addition to those using average volues.

For instance the collector area (m^2) required for heating 140 litres of water upto 55°C in the winter after-noons for various exceedance values have been worked out in case of Delhi and Jodhpur and the same are shown in table given below :-

Table. Collector area (m^2) required for various exceedance values of total solar radiation.

	Delhi	Jodhpur
10 per cent	1.88	1.42
50 per cent	2.27	1.62
90 per cent	2.87	1.97

It has been estimated that 2 sq. metres of collector area at Jodhpur and 3 sq. metres at Delhi would be adequate.

Solar water heating

An improved type of built-in storage solar water heater has been designed, fabricated and a prototype installed at the Central Arid Zone Research Institute, Jodhpur. Its main design features are as follows :—

The heater consists of a galvanised iron (20 gauge thick) rectangular tank of dimension 112 x 80 x 10 cm. with a capacity of about 90 litres of water. This tank is placed in a rectangular mild steel sheet tray with ordinary window glass on front side and 5 cm. thick layer of glass wool insulation on the back as well as on sides. Bulging of tank under water pressure is reduced by using angle iron flats which are bolted on the sides of the tray. The front face of the tank is blackened by lamp black paint after treatment with a suitable primer. The hot water is taken out from the heater's out-let pipe at the top by opening the gate valve from the inlet pipe side of the heater fixed at the bottom. A vent pipe is also provided at the out-let pipe of the heater for safety purposes. A big funnel of the size of the bucket was fixed at the the top of the heater and then connected to the in-let tube so that this built-in storage type solar water heater can be used in rural areas where there is no regular mains water supply.

This heater should be oriented due south at an optimum tilt of latitude of the place plus 15 degrees in winter with the help of adjustable angle iron stand. The test carried out indicate good performance of this heater with the efficiency factor, ratio of total heat collected by the heater to the amount of radiation incident on it reaching upto 70 per cent. On winter days, when

mean maximum and minimum temperatures are 25° and 10°C respectively, storage water temperature rises to 55°C in the after-noon. In summer days, even at the same tilts, storage water temperatures upto 80°C have been observed.

The cost of this heater is around Rs. 300/-. Assuming its life to be about 10 years and the annual interest and maintenance cost as 12 per cent of the capital cost, the cost of the energy developed by the heater comes to 7 paise per kilowatt/hour which is cheaper than conventional rates of electricity.

Solar distillation

The studies has been made to find out optimum orientation of the conventional double sloped solar stills in respect of low latitude and high latitude stations of India namely, Madras and Jodhpur, respectively. The results show that in case of Jodhpur, the orientation of the still with their major axes facing east-west receives more radiation than the south-north orientation. There is not much difference between these orientations in respect of Madras. However, a single sloped solar still receives more radiation as compared to the double sloped solar still of equal area in case of both these stations.

The experiments carried out on a single sloped solar still facing south at Jodhpur shows that the amount of distillate increased from 1.5 litres/day per sq. metre at the radiation intensity of 300 Cal/cm^2 day to 2.75 litres/day per square metre at the radiation intensity of 600 Cal/cm^2 day, the bulk of the variations in the distillate collected in the still viz. 83 per cent of the same is explained by differences in solar radiation received on individual days.

The energy balance studies of the solar still based on experimentally measured values of temperature, radiation, wind speed and humidity etc. indicate that the efficiency of the still is only 33 per cent. This can be improved upon by controlling the major heat losses occurring through the base (26 per-cent) and those due to absorption by glass and imperfect blackening of the tray (20 per cent).

Investigations on the water resources

As a result of surveys it is now possibible to locate areas where new Nadis or reservoirs could be constructed for storage of run-off from rain water. In absence of suitable groundwater aquifer, this is the only source of water for drinking, stock use and for other domestic purpose. In many areas in Western Rajasthan since the infiltration rate is very high in sandy tracts, the run-off is hardly 5 per cent of the rainfall. Detailed work on suitable

treatments and preventation of loss of water through evaporation and seepage is in progress.

Since surface water is quite limited in arid regions, the alternative sources for water is underground. The Institute has modern geophysical equipments (Seismic refraction and resistivity equipments) with the help of which detailed survey for underground water in different areas is being carried out.

The survey can predict the depth at which the aquifer is located, the water cushion, the approximate rate of discharge, source and rate of recharge and also the quality of water.

About 85 per cent well waters of Barmer, Jalore and Jodhpur districts are distributed in classes, C_3, C_4, and C_5 which is normally used for irrigation of salt tolerant varieties of crops. About 10 per cent waters having T. S. S. over 10,000 ppm. are unsuitable for any use. Only 5 per cent waters are fresh waters. Boron content in ground water goes upto 7.5 ppm but majority of samples have values of 2.5 ppm or less and are suitable for irrigation.

Recent surveys conducted in Jodhpur district have shown number of favourable sites for surface water storage It has been estimated that there is a possiblity of further storage capacity of 27 million cubic metre of water in addition to present storage capacity of 156 million cubic metre of water. Jodhpur district has been seen to have a potential of nearly 40,000 million cubic metre of ground waters of salinity upto 2000 umhos EC. The occurrence of these waters is well distributed in various tehisls of the district. Surface water potential of the district has been estimated to be 689 million cubic metres, a large portion of which gets lost by evaporation from soil surface. Efforts are needed at certain locations to take the water down below and increase recharge of ground water so that the ground water potential of good quality water can be enhanced.

The Institute has developed a technique by which it is possible to locate the sites of shallow under ground water source from the interpretation of the aerial photographs of buried dead drainage system.

Ecology and Grass species

Autecological studies of important grasses like *Lasiurus sindicus*, *Cenchrus ciliaris* and *C. setigerus* showed that the productivity in these grasses is directly related to the soil moisture conditions. Considering growth and germination crude protein content *Cenchrus ciliaris* is a better species than

C. setigerus. Dry matter production in *C. ciliaris* under competition with the surrounding herbage is reduced by about 52 per cent as compared to production without competition during the growth period. Above ground productivity studies in the natural pastures on the older alluvial soils at Jodhpur under different intensities of grazing viz.. protected, partially utilised, and overgrazed under natural conditions of grazing showed that dry matter production (above ground biomass) is 0.264, 0.174 and 0.067 g/day/m^2 in 1968-69 against 0.26, 0.144 and 0 13 g/day/m^2 in 1969-70, respectively.

Afforestation

Of the different exotic tree species that were tried *Acacia tortilis, Acacia aneura, Acacia raddiana, Acacia victoria, Acacia seyal, Var. seyel, Eucalyptus Camaldulensis BE. melanopholia E. terminalis, E. tessellaris, E. codabah, E. oleosa, Cassia Phyllodenea, Grevilla pterosperma, Pittosporum phillaraeoides, Schinus molle, At-riplex, nummularia* and *Colophospermum mopane* have been found very promising for planting in arid zone areas. Of these *E. Camaldulensis* and *Acacia tortilis* have profuse flowers and bear fruit.

Species performance trials in four distinct habitats revealed that *Prosopis juliflora* and *Acacia senegal* are suitable species for afforestating largely frost free refractory habitats viz., rocky and semi-rocky sites.

Species best suited for shallow soils over lying hard calcareous pan in 300-400 mm isoheyet are, *Acacia nilotica, syn arabica ssp. Indica Albizzia lebbek* and *Azadirachta indica.*

Prosopis cineraria exhibited comparatively higher establishment and growth when planted in the first half of August as compared to other dates of planting.

Six month and nine month old tree seedling *(Albizzia lebbek* and *Acacia senegal)* have been found to establish better than seedlings of higher age groups i. e. one year and two year old.

Two weedings a year for the first three growing seasons and 5 x 5 m spacing are the ideal treatments for raising tree plantations in this tract.

Raising of nursey stock in galvanised iron tubes kept in partially shaded cemented sunken beds with watering @ 2 gallons/set of 50 tubes at a time has been found to be the most suitable and economic technique.

1295.5 kg seeds and 27,600 seedlings of *Acacia tortilis* and 65.8 kg seeds and 25,700 seedlings of *E. camaldulensis* have been distributed to the State Development agencies and other progressive farmers for trial in their regions besides supply of seeds.

Stabilisation of shifting sand dunes

Dune morphology has been studied. Dunes of western Rajasthan have been classified as old and new dune systems. Distribution, occurrence, and orientation of different types of dunes in two systems have been mapped in various areas. Largest occurrence of dunes is that of parabolic dunes followed by longitudinal, transverse and barchan dunes. The dunes of the old system are by and large stabilised, while the dunes of new system are shifting dunes, which prove hazard to surrounding areas during high wind velocities in the month of March to June. The shifting dunes of new system are by and large barchan and shrub coppice dunes. These dunes need stabilisation on priority basis to remove hazard of sand blowing in the area. The dunes of old system which are by and large stabilised need management system to keep them largely free from intense biotic activity.

Techniques have been evolved for stabilization of shifting sand dunes by fixing barries and growing suitable plants and grasses, taking advantage of the moisture sand mulch (sub surfaces).

The sand dune stabilization techniques comprises of three distinct processess (1) Protection against biotic influences, through fencing preferably with angle iron posts and barbed wire which costs Rs 6/— per running metre. (2) Treatment on shifting sands and dunes by mulching which involves fixing of barriers from crest down heel of the dune. This is done by collecting locally available brushwood and burrying it vertically crown downwards in lines to 2 to 5 metres apart, across the wind direction. These mulches reduce the wind velocity at the dunes surfaced by creating obstructions. Mulching should be completed before the onset of monsoon. The cost works out to Rs. 100/— per hectare. (3) Establishment of vegetation, to stablise the sand in the interspace between mulch barriers, it is essential to vegetate them properly. This comprises of establishment of tree and grass cover. For successful plantation of tree species on the dune "Brick planting" technique has been evolved. By using the seedling raised on 'Bricks' prepared from mixture of clay, sand and manure and then

sundried, the plantation does not need any watering. For successful planting in the sand dunes well developed seedlings of 0.8 to 1.2 m high should be planted 50-80 cm deep and about 0.40 m above the ground so that the root zone comes in direct contact with the moist sand in cost of plantation is about Rs. 300/— per hectare. Trees species adaptable to different agroclimatic regions for stabilisation of dunes have been selected namely *Acacia tortilis*, *Prosopis juliflora* and *Caligonius Polygonoides*. It is essential to grow drought hardy and quick growing grass species in the interspace between the tree rows. *Sccharam munja* a deep rooted grass is a good soil binder. Cost of planting *Saccharum munja* and grass seeds is about Rs. 150/— per hectare.

Sowing seeds of drought hardy grass species like *Panicum turgidum*, *Panicum antidotale* and *Cenchrus ciliaris* have given good performance. Castor which is fact growing tall plant and acts as a wind break has proved successful and the seeds should be sown along the mulches.

Management of dunes

Sand dunes when establishment is to be done and planting as stated above, should be closed to grazing, cropping and other biotic influences for at least 15 years. Grasses during first 2 years should not be harvested. From tenth year onwards the trees should be lopped for top feeds and felling rotation may be carried out on from 10th year onwards. Approximate cost of managment of such dunes involved a watch and ward replacement of casualities, general up keep of areas is about to Rs. 80/- to 100/— per hectare based on a block of 200 hectares.

The Central Arid Zone Research Institute has demonstrated sand dune stabilization over 1000 hectares of shifting sand which were threatening towns of Bikaner, Jhunjhunu, Sardar shahar, Sikar, Barmer etc. have been stabilized and their movement arrested.

A preliminary study on the dynamics of soil moisture in sand dunes at Osian 72 km. WNW of Jodhpur indicated high moisture contents exceeding field capacity throughout the year below 1.5 meter depth in the shifting sand dunes. The moisture content in the stabilised sand dunes were very low upto 7 metres. This evidently indicates better afforestations possibilities on the shifting dunes.

Shelterbelts

As a result of experimental work extended about 207 km roadsides,

species have been selected and techniques developed for raising avenue planting along high ways in arid regions of Rajasthan.

The technique of establishing shelter belts with a number of species were developed after raising 103 km long shelter belts at the Central Mechanised Farm, Suratgarh. Following this technique raising of further shelter belts in the Central Mechanised Farm is in progress.

Tepping gum arabic

Gum arabic is being imported in the country. A technique for exploitation of indigenous *Acacia senegal* trees for tapping gum arabic has been developed, thereby making it possible to exploit the indigenous resource of *Acacia senegal* trees for producing gum arabic.

Acacia senegal trees growing in sandy and semi-rocky land types only are to be tapped for gum arabic. Tapping of branches is only recommended and it may be restricted to May and June, Blazes be treated with 50 per cent sulphuric acid.

Strains of grass spacies

The cultivars/strains of different desert grass species viz. 357 and 358 in *Cenchrus cilliaris*, 175 and 176 in *C. setigerus*, 333 and 297 in *Panicum antidotale*, 490 and 491 in *Dichanthium annulatum* and 318 and 319 in *Lasiurus sindicus* have been selected for arid and semi arid tracts on the basis of their height, number of tillers, basal and crown cover, greater leaf area forage yield and higher nutritive value. About 1000 kg., of nucleus seeds of the promising desert grasses i. e. *Lasiurus sindicus*, *Cenchrus ciliaris*, *Cenchrus setigerus*, *Panicum antidotale* and *Dichanthium annulatum* collected from the seed multiplication blocks of the section have been distributed to various agencies in and out-side Rajasthan for pasture development and soil conservation work. The demand for grass seeds is on the increase.

High yielding selected strains of the above grasses have been multiplied and they are being supplied to the different Research stations of India for trial under different edaphic and climatic conditions.

Pasture establishment techniques

Techniques for pasture establishment which involves complete soil working, grubbing out the entire vegetation and interculture with optimum seed rates and line sowing etc., have been worked out.

Introduction of legumes

Two promising perennial legumes i e. *Dolicos lab-lab var. lignesus* and *Atylosiia scaraboides* were found suitable for arid zone pastures. There is a great demand for seeds of these legumes.

Inter cropping grass *(Lasiurus sindicus, Cenchrus ciliaris, C setigerus* and *Dichanthium annulatum)* with most common legumes (*Phaseolus aconitifolius* and *P. radiatus)* resulted in 20–30 per cent increased forage yield as compared to pure culture of grass. In addition to this it also gives some relief to the farmer when agriculture crop fails during the drought period.

Pasture Reseeding

The grasslands of the arid zone are at a very low level of their productivity because of the inadequacy of soil moisture, low fertility level of soil and absence of high-yielding perennial grasses. The urgent need for improving the forage supply makes it imperative to develop the available resources of grasslands, through adoption of proper system of management on the basis of research studies. Fortunately there is good nucleus of high-yielding and palatable perennial grasses such as *Cenchrus ciliaris, C. setigerus*, and *Lasiurus sindicus* in the north western region and *Dichanthium annulatum, Sehima nervosum* and *Chrysopogon fulvus* in the southern region which provides good potential for grassland development.

Establishment of improved pastures from recommended species can be done by direct sowing and transplanting of seedlings. Complete soil working and grubbing out of shrubby weed and seeding of perennial grasses in lines 50–75 cm apart at a depth of 1–2 cm indicated satisfactory establishment. Planting of 2 to 3 seedling per hill followed by one weeding gives about 60 per cent establishment in a pasture.

It has been observed that complete soil working and removal of all kinds of bushes and other vegetation from the area followed by reseeding with the perennial grass species mentioned above resuted in 67 per cent increase in forage production. The average seed rate recommended is 2 kg per hectare for *Dichanthium annnlatum* and *Panicum antidotale*, 2 to 3 kg per hectare for *Cenchrus ciliaris* and *C. setigerus* and 5 kg per hectare for *Lasiurus sindicus* grass. Seeding during the monsoon season (July-August) resulted in maximum germination of seeds in the field as compared to the results for the pre-or post monsoon sowings. It is not depth of seed placement but that of soil cover on the seed which is improtant. Studies

carried out at Jodhpur indicated that the seeds should be covered with soil to a depth of 1 to 2 cm only. The grass seeds may be sown by drills or by bullock driven implements. In order to make the seed heavy some quantity of soil may be mixed. The line sowing has the advantage over broadcast seeding as it is easy to operate the tractor or bullock-driven implements in between the lines for the purpose of interculture, fertilization, and harvesting of forage and seeds by machines. The recommended spacing between the lines is 50 cm for grass and 100 cm for grass legume mixture where an annual legume crop may be grown in between the grass rows for combined forage and grain production.

The perennial grasses mentioned will remain productive for a very considerable period extending over 10 years or more under proper care and management. Hence these grasses should not be utilised in the year of its reseeding in order that they may establish well and develop proper root system for the optimum production and growth.

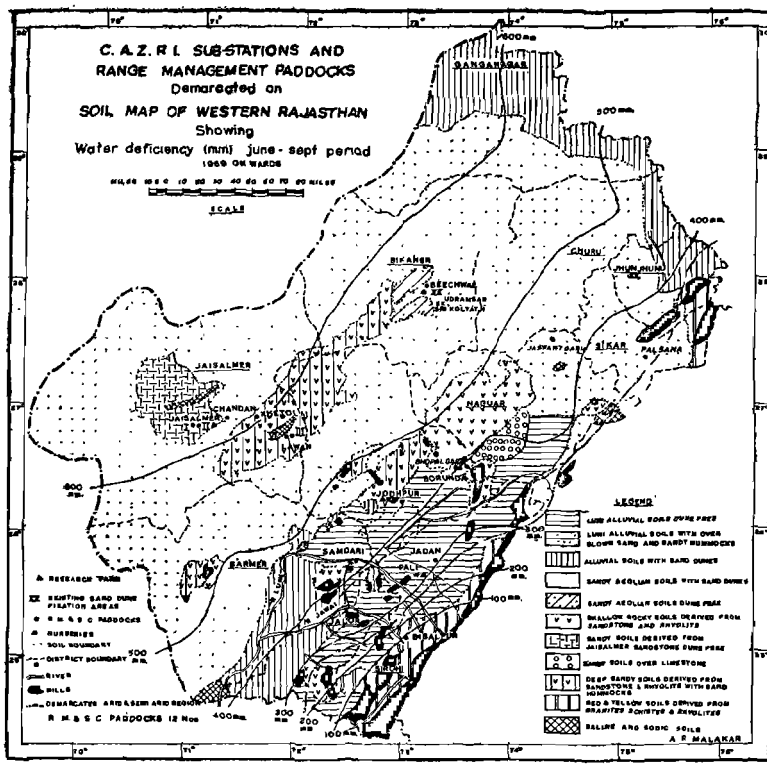
Range Management and Soil Conservation

With a view to find out scientific methods of upgrading and utilisation of existing denuded rangelands in arid and semi-arid regions of western Rajasthan studies were commenced on 52 Range Management and Soil Conservation areas (each of about 80 Hactares) located in different rainfall and Soil conditions (land forms) in eleven Districts from 1959 onwards. With a view of intensify the research, there peddocks were further reduced to 28 and 12 in number during 1965 and 1969 respectively.

1. With adequate protection and grazing, rangelands on carrying capacity basis, forage yield on these range lands could be practically doubled in 3 to 5 years time. Fertilization with 22.5 Kg N/hactare further increases the forage yeild by 15 to 69 per cent.

2. Among different types of fencings tried, the one having angle iron posts with barbed wire is most effective and economical in the long run. Its present cost works out to Rs. 6.00 per running metre.

3. Reseeding rangelands with appropriate high perennial grass species suiting the agroclimatic conditions has given encouraging forage yields. In well established strips of high perennial grass species maximum air dried forage yield of 8.8, 3.4 and 3.0 m. tonnes per hectare have been obtained from areas under *Dichanthium annulatum*, *Cenchrus* species, and *Lasiurus sindicus* respectively.


C. A. Z. R. I. SUB-STATIONS AND
RANGE MANAGEMENT PADDOCKS
Demarcated on
SOIL MAP OF WESTERN RAJASTHAN
Showing
Water deficiency (mm) June - sept period
1969 ONWARDS
SCALE
GANGANAGAR
BIKANER
CHURU
SRIDESHWAL
UDRAMSAR
JAISALMER
JAISALMER
CHANDAN
NAGAUR
SIKAR
PALSANA
JODHPUR
SOJAT
SAMDARI
JADAN
BARMER
LEGEND
RESEARCH FARM
EXISTING SAND DUNE FIXATION AREAS
R. M. & S. C. PADDOCKS
BUNDARIES
SOIL BOUNDARY
DISTRICT BOUNDARY
RIVER
HILLS
DEMARCATED ARID & SEMI ARID REGION
R. M. & S. C. PADDOCKS 12 Nos
LOAMY ALLUVIAL SOILS DUNE FREE
LOAMY ALLUVIAL SOILS WITH OVER BLOWN SAND AND SANDY HUMMOCKS
ALLUVIAL SOILS WITH SAND DUNES
SANDY AEOLIAN SOILS WITH SAND DUNES
SANDY AEOLIAN SOILS DUNE FREE
SHALLOW ROCKY SOILS DERIVED FROM SANDSTONE AND RHYOLITE
SANDY SOILS DERIVED FROM JAISALMER SANDSTONE DUNE FREE
STONY SOILS OVER LIMESTONE
DEEP SANDY SOILS DERIVED FROM SANDSTONE & RHYOLITE WITH SAND HUMMOCKS
RED & YELLOW SOILS DERIVED FROM GRANITES SCHISTS & RHYOLITES
SALINE AND SODIC SOILS
A. P. MALAKAR

4. Forage yield on rangelands specially in desertic areas was affected by different intensities of grazing viz. light medium and heavy (average of 5 years). Light intensity of grazing (grazing based on carrying capacity) proved to be superior.

5. Soil and water conservation measures like contour furrows, trenches and bunds on rangelands with shallow soils and rolling topography increase the forage yeild by 95.7 per cent (from 683 kg to 1337 kg/ha) within a year.

6. Among the different soil and water conservation measures on range lands with shallow soils and rolling topography, contour furrows with 929 sq. cm cross with section, 61 cm width, and 22.6 cm depth space 8-10 metres apart, proved superior to contour bunds and trenches. Increased forage yield was of the order of 638 percent over control (average of 10 years).

7. Body weight gains of yearling heifers in 'Good', 'Fair' and 'Poor' condition class of rangeland has been 1964, 1625 and 92 kg, respectively per year on a unit area of 100 hactares of rangeland. The gains in sheep (ram lambs) in 'Poor' and 'Fair' conditions class rangelands were 554 and 889 kg respectively per year. Continuous controlled grazing gave highest livestock production, while deferment to the pasture from grazing for 16 weeks from 1st July gave live gains by 50 per cent.

8. Growth of yearling heifers was highest on treatment based on carrying capacity basis as compared to that of medium and heavy intensity of grazing. Feeding concentrates from January-July, to meet with digestible crude protein (D.C.P.) and Total Digestible Nutrients (T.D.N.) requirements, practically doubled the growth rate in comparision to grazing based on carrying capacity for early maturity also.

9. Under the mixed grazing with cattle and sheep, growth of heifers was higher than lambs on a unit area of rangeland.

10. Regression equations to estimate body weight of different class of cattle, with the help of girth measurement have been evolved to assist in estimation of feed requirement of cattle.

11. Drinking water requirments of different classes of farm animals on the range has been found out.

12. In desertic areas with scarcity of pottable water, an under ground reservoir locally called 'Tanka' has proved useful and economical for meeting the needs of drinking water for stock and human beings.

13. From 1961-72, total of 42.0 tonnes of seeds of perennial grass species have been distributed to different development department for reseeding the rangelands.

Horticulture

Climatic conditions, in arid regions are excellent for the cultivation of some of the horticultural plants like ber *(Zizyphus mauritiana)*. A number of varieties have been tried and are doing well. Under irrigated conditions grape and pomegranate orchards are quite popular. A number of problems such as cracking, of fruits of pomegranate, poor yield of grapes after a couple of years of good crop are faced by the orchadists. With the introduction of the Rajasthan Canal, date palm production appears promising.

Work on salinity tolerance and saline water use in grape, citrus, *ber* and tomatoes is in progress Work on dryland horticulture by run-off concentration and storage of moisture is being initiated. Most of the plant material required for these projects and for performance trial of the cultivars of improtant fruit crops has been introduced.

Agronomy

About 40 per cent of the total area in western Rajasthan is under crops. Most of this is under dry farming conditions. Agronomical practices have been evolved that give yields and stabilise agriculture.

Strip cropping

Winds cause considerable damage to crops in the area. A system of strip cropping consiting of permanent grass strip of crop to grass strip in 6: 1 ratio was studied. Strip cropping reduced wind erosion, increased crop yield by 6-17 per cent, giving an average return of Rs. 285/ha. The corresponding return from green gram *(Moong)* was Rs. 168/ha.

Crop residue management

Another practice for the control of wind erosion is the residue management known popularly as stubble mulch farming. Stubble mulching was found to eleiminate 5 to 99 percent of wind action on soil surface, minimise soil loss by 8 to 52 times, allow adequate incorporation of decayable residues and aid subsequently in the moisture abosorption and retention by the soil and increase the yield of subsequent crop of pearl-millet *(bajra)* over non stubble plot, by 11 per cent.

Cropping in runoff concentration system

Advantage of run off farming with different catchment widths was compared with conventional cultivation of crops. A 3 years study revealed that in low rainfall years production by cropping two-thirds of the area was double than that obtained by cropping all the area. Similar trend was obtained even in wet season of 1973. Production obtained by cropping two-thirds of the area and by cropping all the area did not differ. The production in quintal per ha. by cropping two-thirds of the land area in runoff concentration system was 23.52 of pearl-millet (Bajra HB 3), 31.49 of sorghum 'CSH$_1$', 11.75 of cowpeaC152, 9.85 of green gram 'RS 4', 9.11 of seasmum 'Pratap', and 7 82 of sunflower 'EC 68414'. The corresponding productions of these crops by cropping all the area, without runoff benefit, were 29.13, 36.44, 12.35, 10.73. 6.97 and 7.42 q/ha. This technique, was found to avert crop failures and ensured economy in seeds, fertilizers etc. to a tune of Rs. 150 to Rs. 227/ha. where two-thirds and half of the land area are cropped, respectively.

Use of bentonite, farmyard manure and organic mulches

In-corporation of bentonite at 75 cm and farmyard manure 60 cm in pits increased the yield of round gourd, cucumber, and watermelon *(Citrullus lanatus)* grown under rainfed conditions by 49, 51 and + 138 per cent, over the control, respectively. Surface application of amendments, farmyard manure and *Calotropis* increased the yield of pearl-millet variety 'HB 3' by 30 per cent over the control. When the amendments were incorporated 15-20 cm deep, the increase in yield was 53 and 58 per cent from placement of farmyard manure and *Calotropis*, respetively. The yield increase over the control, of green gram 'S 12' was around 20 per cent in the case of sub-surface application of these amendment.

Bajra husk used as mulch gave 26 per cent higher yield than the control, under late sown conditions. This was found as affective as polyethelene mulch in preventing moisture losses due to evaporation from the soil surface. In years of high and well distributed rainfall, use of mulches did not confer any advantage.

Cultural Practices, Minimum tillage

Studies on minimum tillage revealed that 'plough planting' with a 6-row Trader seed drill without any prior seed-bed preparation gave the yield of pearl-millet (bajra) about the same obtained from the crop after 2 preparatory tillage, and saved about Rs. 39 to 83/ha.

Choice of Crops, Varieties and Cropping Pattern

(I) Varieties

The varieties of crops so far found adapted to arid zone are 'HB 3' of pearl-millet, 'Palsana' and 2470-12 of cluster bean (Guar) 'Aruna' and 'Gujarat Hyb, 3' of castor bean, 'Sojat Bavani' of forage sorghum, 'AK12-24' of groundnut and 'RS 4' of green gram.

Green gram (moong) varieties 'G-1', 'G-2', 'T 44' and 'B 10-5', besides being early, exhibited excellent yield potential during '*Kharif*' 1973. Four high yielding and drought tolerant mutants developed from green gram 'RS 4' ('M 16' 'M 10', 'M 8' and 'M 15') have shown further promise for western Rajasthan by revealing higher yield potential than 'S 8' and 'RS 4',

A variety of setaria, '184-4/2, maturing in 60 days with an yield potential of 27 q/ha has been identified. This has opened up possiblities of taking two crops (example : setaria-sunflower) in the same croping season.

Groundnut varieties 'Exotic' 'SB 1', and 'RG 61-240' have given better performance than 'AK 12-24' in favourable rainfall years. Among sunflower varieties, 'EC 68414' and Bulgarian' have been found promising for normal sown condition.

Under late sown conditions, sunflower, castor bean, green gram and moth bean have given better performance than pearl-millet. Varieties 'S 8', 'S 9' and 'KS 4' of green gram, 'Bulgarian' and 'EC 68414 of sunflower, 'Aruna' 'Gujarat Hybrid 3' and '1-32' of castorbean, and 'K 11' of cowpea have also been found promising for sowing as late as the second week of August, provided the rainfall distribution is favourable.

For irrigated sandy plains and mild winter conditions of Jodhpur, wheat 'S 307' and 'Kalyan Sona' have done well. Recently, comparisons of 3-gene dwarf 'Kalyan Sona' with 3-gene dwarf wheat varieties 'HD 1941', 'HD 1949' and 'HD 1925' revealed no significant difference in yields of these wheats. 'Kalyan Sona' (also 'S 307'), therefore, is a promising variety for irrigated pockets of this region.

Studies on bases for variation in yield of dwarf and tall varieties of wheat over two years have shown that dwarf variety, apart from possessing superior morphological architecture, has better metabolic capability, and utilizes to its best advantage the conditions provided which was manifested in greater germination potential

chlorophyll, soluble carbohydrate, starches, organic Phosphorus, nitrogen and protein percentages over tall variety.

Mixed cropping

The practice of mixed cropping is very common on drylands of this region. Most of the cultivated lands in western Rajasthan fall under the category of class IV and V, according to the Land Capability classification of the FAO. It is, therefore, necessary to work out suitable grass legume mixtures for such lands. Experiments carried out have shown that growing of grain legumes (green gram, moth bean, cowpeas) in-between two rows of forage grasses (*Cenchrus* species) did not have any adverse effect on the yield of the principal crop. Similarly, crop mixture sown in the ratio of 3 lines of pearl-millet to 2 of green gram has shown promise with net return of Rs. 234.43/ha. Green gram variety '288–8' and 'RS 4' and cowpea variety 'K 11' possess favourable combinations of characters to be grown as companion crops with forage grasses (*Cenchrus* species). The incidence of yellow mosaic virus in mixed stands of green gram was strikingly lower than that of the pure crop.

Sunflower is a new introductiou in this region. Possibilities of taking grain legumes as companion crops with sunflower have been explored. Intercropping of cowpea variety 'FS 68'and green gram variety'S 8'with sunflower 'EC 68414'. resulted in additional gross returns of Rs. 1294 and Rs. 1153/ha over the pure sunflower crop, the corresponding efficiency of the intercropping systems being 45 and 40 per cent. Groundnut variety 'KG 61-240' and moth bean local could be grown as companion crops with sunflower, with an inter-cropping efficiency of 19 to 20 per cent. Growing of cluster bean variety 'FS 277' had an adverse effect on the yield of the principal crop (sunflower).

Crop rotation

A 10-year rotation experiment has shown that pearl-millet greengram is the right type of cropping in this desert with economic return of Rs. 377.67/ha/year. The efficiency of this rotation (expressed in terms of per cent increase/decrease in pearl millet yield over continuous cropping system) is equivalent to 15 per cent increase in yield of pearl-millet rotated with green gram, over that of pearl-millet grown under continuous cropping system.

Judicious Use of Fertilisers

The rate, source, time, mode and method of fertilizer application was investigated. Fertilizer N has been found more efficient than organic manure as equal nutrient basis source. Under rainfed conditions optimum level in Kg/ha of N is 17.5 for RS Bajra and for H B, 3, 53.7 for forage sorghum. For irrigated crop it is 147 for 'S 307' and 145 for 'Kalyan Sona' wheat, and 159 for hybrid sorghum variety 'CSH 1' N applied in two equal splits-one-half at sowing and one half top-dressed is better than all applied at planting. Urea spray improves the yield of pearl-millet variety ' HB 3 ' by 18 Percent in wet to 74 Percent in dry season.

Fertiliser use in cereals particularly hybrid sorghum variety ' CSH 1 ' was remunerative in the years of normal and well distributed rainfall. However, in a year of high and well distributed rainfall (like 1973), all the millets gave high response to fertilizer use. Irrespective of quantum and distribution of rainfall, it was profitable to apply fertilisers to fodder and forage crops. Application of fertilisers to grain legumes and oilseeds like groundnut and sesamum in the years of low and erratic rainfall distribution was unremunerative.

Sunflower has shown very favourable response to fertilizer application, Application of 90 kg N/ha gave 98 Perecnt higher yield over the control (5.5q/ha) in 1973, the response being 6 kg seeds/kg of nitrogen applied. Under favourable conditions of rainfall distribution (1973) sesamum responded well to fertiliser application (191 Perecnt over unfertilized crop) giving higher moisture use efficiency (3.55) than sunflower (2.73). However, under conditions of uneven distribution of rainfall (1952), though the response of sesamum to fertiliser application was higher its yield as well as moisture use efficiency were poorer than sunflower. Returns per rupee invested in fertiliser use were higher in case of forage grasses followed by cereals and fodder crops. Returns to fertilizer use, in general, were much lower in case of grain legumes and oilseed crops.

Plant-water relationship

Investigations on the adaptabilities of grasses like *Lasiurus sindicus*, *Cenchrus ciliaris* and *C. setigerus* indicated that the fast rate of water up take by their seeds helps in their germination and quick establishment in the arid areas. The glumes enclosing the seeds contain inhibiting compounds which keep the seeds dorment and with adequate showers in the next rainy season these inhibitors are washed out and the seeds sprout within the enveloping glumes having high water absorbing capacity which varies from 60 to 100 per cent of

their dry weight depending on the species. Thus these grasses are about to establish themselves in desert where surface soils mostly remain dry. The desertic trees again display a peculiar adaptability of restricting the surface area of their leaves to minimise water loss by transpiration when soil moisture conditions are adverse. Tree seedlings are only exposed to such conditions but established trees with their deep and extensive root system tap water from great depths and are hardly ever subjected to moisture shortage. They generally use up large quantities of water and in case of *Prosopis cineraria* the annual loss was estimated to be roughly 222 mm per hectare of land consisting of forty trees.

In crops like bajra where root system is rather limited, problems of drought and water shortage attain a very significant dimension. The yield of this crop may decrease by 50 percent when drought is experienced at 2 to 3 weeks of sowing and at advanced stages like earing drought may reduce the production by 80 to 90 percent. Although such drought conditions reduce the dry matter production and the yield but the shoot tissue and grains become very much enriched in nitrogen and proteins. Detailed studies on the drought problems, however, have indicated certain measures for avoiding this hazard. It has been found that legumes like guar use about half the water during its growing period as that of bajra. Hence when the rains are delayed and expected to be low, legume cultivation is advantageous. It has further been observed that adequate soil fertility conductive for optimum plant vigour induces better metabolic adjustments to endure environmental stresses like sporadic drought and hyperthermia. Under high fertility condition, drought even at the critical stage entails only 30 to 40 per cent yield loss which may be otherwise manifold more. Easy penetration of ions through bajra leaves and two definite peak periods of nitrogen uptake at tillering and earing stages suggested that foliar application of nitrogenous fertilizer at these stages may bring about desirable effects when meagre rainfall at sowing precludes the prospects of soil fertilizer application. This has been found to be true. There are again varietial differences in drought resistance. For instance, var. RSK displays more dry matter production under water shortage but hybrid 3 yields more under such conditions. Experiments conducted with wheat indicated that water for irrigation can be minimised without substantial decrease in production when adequate conditions of nutrition are provided. Under controlled watering condition var. RS 31-1 yielded about 21q/ha with 80Kg/ha each of N and P_2O_5 where water used was only about 26 cm. In the absence of adequate nutrition yield dropped to only 6q/ha although water was not limiting during the growing period. Detailed studies have shown that intake and utilisation of nutrients become enhanced, despite general water shortage, when their level in the growing medium remain high. Investigations have shown

that the application of certain chemicals like CCC offered a better condition for grain formation under water shortage.

Rainfall supplement for efficient water use

Crop failure or low economic yield is a recurring feature of desert agriculture. This usually happens when one or two periodic droughts set in during the growth cycle of crops. Protective irrigations, where ever available during such cycles would turn the crop failure into a pleasant success. Evidence is the production of 103.32 q of pearl-millet variety 'HB 3' and 68.85 q of grain sorghum variety 'CSH 1' obtained from spreading by sprinkler 25 cm of water over 4 ha of pearl-millet and 27.5 om of water over 2.5 ha of sorghum. Where such supplement to rain was not made, these crops failed altogether.

Squeezing the best out of available water

About 5 percent of the area in Western Rajasthan is under irrigation. The main source is tube wells, open wells etc. It is important to study the water use efficiency under different irrigation techniques.

Planting of cotton on edges of 40 cm wide furrow alternated with 80 cm spacing gave the same yield as from planting on ridges in normal 60 cm row spacing and doubles the water use efficiency. Under unirrigated conditions planting pearl-millet variety 'HB 3' in double rows 40 cm apart alternated with 80 cm spacing and of sorghum in double-rows, triple-rows, 25 cm apart, alternated respectively with 75 and 100 cm increased the yield of pearl-millet by 93.8 and of grain sorghum by 98.6 and 194.3 per cent over regular 50 cm row planting. Planting of sunflower in the paired row system did not confer any advantage over the uniform system of planting in wet year (1973).

Use of efficient irrigation method

Wheat variety 'Kalyan Sona' irrigated by sprinkler, check basin, and border strip when 50 per cent of the available water remained in the top 30 cm soil depth and on equal water basis gave yield of 43.01 q/ha under sprinkler. This yield was 36.5 and 33 per cent higher than that under border strip and check basin respectively. In porous soils and duny area of western Rajasthan, use of sprinkler thus ensures conservation of limited water and increases water use efficiency.

Even better than sprinkler in this area is the pioneering introduction of *trickle* irrigation which saves water and gives significant increase in yield of high-value widely spaced vegetable crops. In a field trial, production in tonnes/ha by tirckle irrigation were 55.79 in bottle gourd, 12.03 in ridge groud, 33.38 in potato, 82.33 in watermelon and 40.61 in round gourd. Percentages increase in yield of these crops, over sprinkler and furrow methods of irrigation, varied from the lowest of 32 in round gourd to the highest of 65.4 in potato. In potato, irrigation by trickle saved 50 per cent of the water and gave the same yield as obtained by irrigation in furrows. On equal water basis, application of saline water of 3000 micromhos in potato crop gave 37 per cent more yield than irrigation with nonsaline water in furrows. It thus marks a new frontier in the use of saline warer largely found in the area. The yield advantages and extra returns will pay the initial investment on trickle in one season.

Quantification of soil-water-plant relationship for efficient water use

For efficient use of limited water resource of the arid zone, crop yield-stored moisture-rainfall irrigation water relationships have been quantified in wheat, mustard, sunflower, safflower, pearl-millet and sorghum. Quantification has enabled the farmers (1) to know probable reduction in yield of one of these crops corresponding to given reduction in water, (2) to decide how much area of what crops may be optimal to plant with given supplies of water, (3) to choose the most suitable crops less subject to loss in yield by reduced water supply (4) to determine what area of the farm should be left unirrigated in given season, and (5) to predict the expected physical increments in production and economic return for selected crops, which are essential both for evaluating the potential of irrigation development in the area and forecasting return or capacity to repay costs of such development.

Another way of using limited water efficiently is to apply small quantity over large area rather than large quantity over small. This is illustrated by the fact that yields from 33, 20 and 10 inches of water applied respectively over 1 hectare of wheat ('Kalyan Sona' sunflower 'EC 68414' and mustard 'Haryana No. 1 are 54.58, 16.07 and 11.02 quintals. The corresponding production from the same quantities of water given over 3, 2 and 1.5 hectares of these crops are 91. 04, 27.12 and 19.35 quintals. Use of water in this way decreases the return per unit of land, but increases it per unit of water. The latter aspect serves the agriculture of the region the best.

Sociology

The crucial problem of Rajasthan desert is one of human ecology since over exploitation by man of water, plant and soil resources has disturbed the ecological balance and has led to progeressive degradation of resources. Recognising this, investigations were conducted among different nomadic groups to assess their role in the economy of the region and to suggest welfare measures. Socio-economic surveys of the sedentary population inhabiting the arid zone of Rajasthan were also taken up to make available the socio-economic data which could form the base for drawing up developmental plans for raising the standard of living of people.

Socio-economic surveys

Nomads: An important problem of the arid regions is of the nomads. Histrorical, political and cultural factors combined with climatic and geographical factors give rise to this way of life. Nomadism is an adaptation to the environment.

The nomadic groups of arid zone may be broadly grouped in four categories viz (a) the pastoral nomads (Raikas, Sindhis, Parihars, Billochs etc.), (b) the trading nomads (Banjaras, Ghatti-wala Jogis and Gowarias), (c) artisan nomads (the Gadoliya Lohars, Sansis and Sattias) and (d) miscellaneous type of nomads (Nats, Kalbeliya Jogis).

The nomads performed an important complementary function in the economy of the region but in recent years, however, due to change in the political, social and economic set up the source of livelihood of nomads has received a set back.

Each type of nomad is associated with some kind of live-stock which make indiscriminate use of the meagre available water and grazing resources and destroy the local soil conservation measures. The nomads in the present day thus prove a menace for the whole society and their sedentarization is inescapable. The opning up of means of communication has reduced the importance of distribution activities of the trading nomads. Shrinkage of grazing lands in sown area due to extension of cultivation has created difficulties for the cattle breeder nomads. Villagers are no longer dependent upon the nomads who rendered specialised services. Our studies have shown that the sedentary population, in general, do not welcome the nomads for various reasons.

This rupture of relationship of mutual dependence between the nomads and the sedentary population points to the need of a policy for the welfare of nomads.

POPULATION IN ARID AND SEMI-ARID ZONE OF INDIA

	Population (1971) in lakhs			*Density of population per sq. km.*		
	State	Aridzone	Semi-arid zone	State	Arid zone	Semi-arid zone
Rajasthan	257	86	150	75	44	120
Gujarat	267	30	162	136	45	174
Punjab	135	27	86	268	189	300
Haryana	100	20	67	255	152	255
Maharashtra	417	2	267	164	158	142
Andhra Pradesh	434	22	182	157	108	147
Karnataka	293	9	222	153	112	159
Jammu and Kashmir	46	0.7	0.2	*	**	–
Uttar Pradesh	884	–	250	300	–	391
Madhya Pradesh	417	–	62	94	–	105
Tamil Nadu	411	–	249	316	–	292
Total	3661	196	1697	162+ +	61+	182

*Includes area under illegal occupetion of Pakistan and China.

**Could not be worked out because no census was possible, in the areas which continue to be under illegal occupation of Pakistan and China.

+(1; Excludes are of Nefa (2) Total may not tally because of rounding.

++Excluding Jammu and Kashmir and North-East Frontier Agency.

	per cent area under		*per cent Population under*	
	Arid zone	Semi Arid zone	Arid zone	Semi-Arid zone
Rajasthan	57.42	36.67	33.47	58.37
Gujarat	33.72	47.50	11.18	60.56
Punjab	28.60	57.40	20.11	64.02
Haryana	29.32	59.77	19.70	67.36
Maharashtra	0.42	61.17	0.49	64.69
Andhra Pradesh	7.18	44.66	4.99	41.89
Karnataka	4.27	72.60	3.14	75.72
Jammu and Kashmir	31.13*	6.22	1.64	0.33
Uttar Pradesh	–	21.73	–	28.26
Madhya Pradesh	–	13.38	–	14.19
Tamil Nadu	–	65.54	–	60.48
TOTAL	12.13	29.17	3.6	31.00

Detailed rehabilitation schemes have been prepared which provide leads for the Banjaras (the trading nomads), the Gadoliya Lohars (the artisan nomads) and for the nomadic cattle breeders of Anupgarh-Pugal region of western Rajasthan keeping in view their present cultural values, kinship structure and other important social and economic factors.

The studies have shown that the Gadoliya Lohars desire sedentarization in small agnatic groups within their own *chokla* and such a process will ensure stable sedentarisation since the symbiotic relationship with the sedentary population can be continued through marketing facilities for the fabricated articles. The settlement in scattered fashion in small groups will make it easier for the Government to allot lands for cultivation to *Gadoliya Lohars*. Moreover such sedentarisation should rule out any chances of fued amongst the households of different clans which are likely to occure when households of dfferent clans are settled at one place. It was, therefore, recommended that the Gadoliya Lohars be settled in bands of small kinship groups within their own *chokla* or their present area of movement.

The nomadic Banjaras be sedentarised *tandawise* i. e. in small kinship groups. The economy of the settled Banjaras be built upon agriculture, animal husbandry, trading in cattle and salt. The resettlement schemes should be under the *Panchayat samities*. The *tanda* should be treated as the unit for settlement purposes. Approach to Banjaras should be through *Mukhias* who are their best spokesmen and the best media for communicating with them.

For the area (Anupgarh-Pugal region) coming under canal Irrigation, it is recommended that each household may be alloted one square (6.3. ha) of land and partial mechanisation of cultivation may be resorted to. Dairying industry may be introduced on scientific lines. Sheep raising is the chief subsidiary occupation in the region. At present the sheep owners have to travel long distances and their nomadism can be arrested by upgrading the short grass rangelands by reseeding these pastures by *Anjan* and *Dhaman* grasses. Introduction of mutton industry, setting up of wool grading and shearing centres shall further save a lot of their energy and fetch the breeders much higher income than they earn at present.

Settled population

The Socio-economic surveys conducted in 18 community Development Blocks in the arid zone of Rajasthan have provided a sociological map of the region. The demographic features revealed that the spurt to

population growth has been comparatively higher in the arid zone and the potentialities for the future growth rate of population are also higher as compared with the other regions.

The growth rate of population in the arid zone of Rajasthan during the decade 1961-71 comes to 27.22 per cent as against 24.66 per cent for the country during the decade. There has been 158 per cent increase of population between 1901-1971 in the arid zone of Rajasthan as against 150 per cent increase in the whole state of Rajasthan and 132 per cent increase in the country. This, thus reveals that the growth rate of population in the arid areas had so far been higher.

Within the arid zone the percentage increase of population is higher in the areas receiving comperatively lesser rainfall. The percentage increase in population between the period 1931-1971 had been 144,132 and 107 in the regions receiving annual rainfall of less than 12", 12" - 16" and 16" and above respectively. Thus 144 per cent increase of population during 1931-71 in the areas receiving less than 12" rainfall as compared to only 119.0 per cent increase for the entire Rajasthan State sets up an alarming situation specifically when viewed in the context of extremely limited potentialities for agricultural and industrial development in the arid regions.

Density of population has increased from 36 in 1961 to 45 persons per sq. km. in 1971. The traditional large size joint households are disintegrating to small nuclear households. Caste is still the pivotal institution in the region and governs most of the social and economic relations. The general standard and level of literacy in the region is poor It is much lower 22.7 per cent as compared to 29.3 per cent for the entire country) and there is a greater concentration of workers on the occupation of cultivation (72.14 percent in Indian arid zone as compared to 68.63 per cent in the country as a whole.)

Inspite of the low soil fertility and the scanty and erratic rainfall, cultivation and not animal husbandry forms the major occupation of the people in the region. According to 1971 census, the percentage of workers enumerated as cultivators and agricultural labourers in the rural areas of the arid zone of Rajasthan was 72.6 and 9.8 respectively. The distribution of size of land holdings is uneven and there are marginal, small, middle and upper class farmers. The concentration of land holdings reveal that 49.3 per cent of the land holders in the Luni basin had 16.2 per cent of the total cultivated land and 82.2 per cent of the holders had 51.5 per cent of the cultivated land only. The adoption of improved agricultural practices has made only a small leewey in the region. All

measures to increase production should be widely distributed geographically and embrace all the groups scattered in *dhanis* which at present receive lesser attention . The quality of livestock in the region is poor and the animal husbandry management practices also largely traditional. The income from other sources of livelihood is meagre. Indebtedness is widespread and Mahajan the traditional money lender still remains to be the chief source of credit. The co-operative societies need strengthening and the foresight of the people for advantages of controlled credit has to be induced through persuation and extension methods.

Keeping in view the socio-economic aspects and integrating these data with the data of Basic Resources Surveys, land transformation plans for various community development blocks have been prepared.

Socio-economic survey of Challakeri Taluka of Karnataka State has been completed. During the year 1964-65t here was deficit of 5,275 tonnes of food grains in the Taluka and if the production remains the same there is deficit of 39.57 per cent in the year 1971 and 52.68 per cent will be in the year 1976 at the same rate of growth of population. Living accomedation is scarce. More than three-fourths of the popuation is illiterate. There is a scope for increasing the production by bringing more lands under cultivation and by putting more and more area to double cropping through intensive cultivation methods. Extension work has to be taken up more vigorously. Garden crops like beatle leaves, areknuts, Coconuts are good cash crops and cultivation of these crops should be encouraged through provision of loans for installing electric pump sets. Household and cottage industries should be developed on more scientific lines. The present livestock in the Taluka are of poor breed which needs improvement. The density of livestock specifically on the permanent pastures and grazing lands is veryhigh. The pastures available in the Taluka are poor and need development through introduction of drought resistant varieties of grasses recommended by the Central Arid Zone Research Institute, Jodhpur. Shortage of fuel wood is experienced and large number of households burn dung cakes. Fuel wood lots with fast growing tree species need to be established so as to reduce pressure on reserve forests.

Impact of irrigation

The introduction of irrigation in Rajasthan Canal Project Tehsil Gharsana, District Ganganagar, has brought changes in land use, size of holding, cropping pattern, irrigation potential. area sown, expenses on agricultural inputs and occupations followed. The area under irrigation has increased from 0.45 per cent in 1967-68 to 12.32 per cent 1969-70. There is an over-all increase of 5.64 per cent in the net area sown within the period of three years.

The cropping pattern is gradually changing from subsistance farming to commercial farming. The various kharif crops introduced are *maize*, *jowar*, *rice*, *urad*, and *arhar* in the Tehsil. Even after irrigation *Bajra* and *Moong* remained the chief cereal and pulse crops. The chief rabi crops introduced in the region are wheat (among-cereals) *Massoor* (Pulse) *Sarson* and *Tarameera* (oil seeds) and *Barseem* (Fodder crops). The multiple crops grown and introduced have made an intensive use of land thus increasing the intensity of land in the region.

Economics : For the study in Inter-district variations and factors affecting crop output growth rates of principal crops in Arid Zone of Rajasthan, data on area, production and productivity were compiled for a period of nineteen years (1951-52 to 1969-70) for principal crops like Bajra, Kharif Pulses, Sesamum, Jowar, Gram, Barley, and Wheat. Linear time trends for all 12 arid districts were computed. From these, growth rates of area, production and productivity of principal crops were worked out. Growth coeffecients thus computed were ranked on the basis of absolute magnitudes, so as to identify their tendencies in different districts. On the basis of this procedure, it can be said that Jowar, Bajra and Kharif pulses are predominantly area-Intensive crops. Gram, Barley and Wheat are, on the other hand, predominantly yield-intensive crops.

For study on Economics of Bullock and tractor power use the data on 40 bullock farmers and equal no. of tractor farmers were collected on comparative time usage economic indicators and technological process. On the basis of time effeciency, after accounting for crop, non crop and domestic operations, small and medium farm families who owned tractors were about 2.1 and 2.5 times more effecient in getting their jobs done. Data however did not allow any further comparison because every farmer above 60 ha. possessed tractor only.

For studies on economic evaluation of sand dune stabilization technology after employing alternative concepts of ammortization and absolute magnitudes cost–benefit ratios were compared the results revealed that a minimum of 10 years is necessary for economic appreciation of such project. This could be proved out by data that where. gestation period of 10 years, was completed, like in Jhunjhunu and Udramsar, the technology could prove its economic soundness.

Breeding sheep for finer and heavier wool

The desert is the home of some of the hardiest breeds of sheep in the country, but the quality and the quantity of wool yielded by these

animals are generally too poor to ensure any worthwhile income to the stock-owners. Attempts have been made here to develop a biochemical approach to sheep production to obviate the delay inherent in the time-consuming conventional method of selection based on performance tests. Three biochemical polymorphic traits have been intensively investigated in the blood of six breeds of sheep. These are (i) blood potassium type (high, HK or low, LK), (ii) haemoglobin type (Hb A, Hb B or Hb AB), (iii) erythrocyte reduced glutathion type (high GSH_H or low, GSH_h).

The LK type sheep has been found to yield finer wool than the HK type. The Hb A and GSH^h type animals have been found to produce comparatively more wool than others. Further, GSH^h type animals also yield finer wool than others. Since all these biochemical polymorphic traits are genetic characters of established modes of inheritance, it would seem well worth the trial to have a breeding programme aimed at evolving a strain within each indigenous breed of sheep having the following combination of genetic traits: LK GSH_h-HbA for the purpose of improving wool production, both in quality and in quantity.

Physiological investigation on heat and water stress in sheep

Availability of drinking water being the most critical limiting factor for survival in the desert, a detailed comparative study of the physiological response of different sheep breeds to imposed heat and water stress has been made. These studies have pointed to the unusual ability of several breeds (e.g. Marwari, Jaisalmeri, Pugal etc.) to maintain circulation even when faced with considerable haemo-concentration. When water intake was reduced below 75 per cent of the normal daily requirement, there was a steady decline in the body's water stores. On an average, there was an 18 per cent loss in body weight in all breeds after remaining without water for 3 days during winter and 25 per cent during summer. No ill effects are observed if sheep are watered every third day or if the quantity of drinking water is not reduced below 75 per cent of the normal intake. Interestingly, the digestibility of crude fibres has been found to be increased in water-restricted sheep while nitrogen balance does not seem to be affected due to water strees. The rate of passage of feed is slow in water restricted sheep in comparison to normally hydrated animals.

A study on the relative thermolytic efficiency of normally-watered and 72 hour water deprived sheep of 3 breeds, viz., Marwari, Jaisalmeri and Chokla, when exposed to the sun for the whole day in early summer, has pointed to the

Chokla animals as more resistant to body weight loss (or body water loss) than either the Marwari or the Jaisalmeri.

The effectiveness of the wool of different sheep breeds as a barrier against entry of environmental heat into the body has been investigated.

Salinity tolerance in sheep

Studies made on the Marwari breed of sheep have indicated that a salinity level of one per cent in the drinking water may be taken as a safe upper limit for this breed. Since the plasma chloride level of the saline drinking animals of this breed remain unaffected over a long period, it is evident that these animals have a very efficient renal excretory mechanism.

An improved nutritional technique for increasing wool production

A simple chemical treatment, involving dilute formaldehyde solution, of a high-protein roughage, e. g. *pala (Z. nummularia leaves)* has proved to be very effective in inducing increased wool growth when the treated leaves are fed to the animals in small quantities daily. This chemical protection of feed proteins from ruminal degradation and the subsequent more efficient utilization has considerable possibilities in the field of animal production.

Performance of cross-bred sheep

The Institute's flock of F_1 cross-bred sheep (Russian Merino sire X Marwari dam) has done exceedingly well so far as adaptation to the desertic conditions and wool production characteristics are concerned. These animals yield significantly heavier and finer wool than any of the indigenous breeds. Their superior wool producing efficiency is not, however, associated with higher dry-matter intake or digestibility.

The physiological responses of white and black wool cross-bred sheep to grazing stress in early summer have been studied. Both groups tended to maintain rectal temperature within a narrow limit during the observation period. Respiratory rate was consistently and significantly lower and water intake similarly higher in the white animals in comparison to the black ones. Also, in the black group, water intake was significantly correlated with both rectal temperature and respiratory rate, while no such significant correlation was observed in the white group. It appears that the white animals may be at a disadvantage, in comparison with the black, in adapting to desertic conditions.

Physiological studies on desert rodents

Detailed physiological investigations have been carried out on several species of desert rodents e. g. *Meriones hurrianae*, *Tatera indica* and *Gerbillus gleadonei*. The structural peculiarities of the desert rodents kidney and its metabolic characteristics of depositing increased quantities of body fat, along with its behavioural adaptive mechanisms, allow these animals to survive in the desert. The desert rodents can live without water for as long as 18 months. Its kidneys produce highly concentrated urine, thus conserving body water. The rodents are usually highly salt tolerant. The patterns of their oestrous cycles resemble that of other rodents. The adrenals of these animals exhibit clear density dependent changes with increased concentration of cholesterol as the population density increases.

Animal Ecology

Certain rodent pest species exhibit a habitat-specificity such as *Gerbillus n. indus* exclusively inhabits the sandy habitat. *Rattus c. cutchicus* and *Mus cervicolor phillipsi* are found in the rocky habitat, *Rattus rattus* and *Mus musculus* the urban and village complex, and *R. melada pallidior*, *Golnda ellioti Nesokia in indica* and *Mus booduga* in the agricultural crops. Other species of rodents inhabit a variety of habitats representing various vegetation types. Data on the relative abundance of rodent pests in all the desert districts of Rajasthan have indicated that *Meriones hurrianae* and *Tatera indica* are the most abundants pecies followed by *Gerbillus gleadowi*, *Rattus meltada* and *Rattus cutchicus*.

The ecological studies on rodent pests have yielded information regarding the optimum season for control operation (based on population fluctuations and breeding cycles), effective ways of bait placement (on the basis of habitat preference) and optimum distances between bait stations (on the basis of home range data). The ecological evaluation of rodent control is very helpful in organising the rodent control compaign in a more effective manner.

Control of desert rodents

Rodents are responsible for serious damages to foodgrain, grasses and pastures, stored material, orchards, natural vegetation and tree plantations.

On the basis of studies conducted at the institute on bait preferences, seed consumption, and lethal dosages of various toxic chemicals, two methods for the control of field rodents have been recommended.

The first method is an improvement of the old one in vogue. Experiments at the institute revealed that mixing of 1.5 to 2 per cent zinc phosphide in carrier, was sufficient for rodent control, as against 5 per cent practised in the past. The decrease in the poison concentration not only increases the palatability of the poison-baits but also reduces the chances of secondary hazards and pollution of environment. The other improvement made is replacement of gur (jaggery) by 3 to 5 per cent with groundnut oil. The third change found advantageous is poison-baiting after three days of pre-baiting which brings about significantly higher mortality of field rodents. The fourth improvement is poison baiting on only one day. If it is continued for more than a day, not only the consumption of the poison-bait is so low as to be wasteful of labour and material but the rodents develop bait shyness.

The modified method is to prebait the active burrow openings in field for 6 gm per rodent per day. Pre-baiting is to be done with :

Bajra flour	97 parts
Groundnut oil	3 ,,

On the fourth day the burrow openings should be poison baited at the same rate with :

Bajra flour	95 parts
Groundnut oil	3 parts
Zinc phosphide	2 parts

The second method is based on three principles. The food grains should be saved for human consumption instead of using them for baiting rodents, the prebaiting and poison baiting should be done together and thirdly, the method should be fairly cheap. Having studied the food habits of desert rodents, it was found that ber (*Jhadberi*, dried berries of *Zizyphus nummularia)* is preferred by them over seeds of most of the desert vegetation. These are usually collected by farmers when they prune the bushes for 'Pala' (leaves of ber, an excellent concentrate for goats, and the thorn are used for fencing). Ber grows in the desert in abundance. Even if bought, the dried berries are cheap, 0.50 paise per kg. In addition to high palatability, the air-dried berries passes sufficient soaking capacity. This 'non-food-grain' material is, therefore, used as carrier of poison for rodent control. The air-dried berries are soaked in a solution of compound 1080 (Sodium monofluoroacetate) heaving a dosage of 3 mg/kg. After soaking for 24 hours each berry is impregnated with a lethal dose for rodents weighing upto 100 gm. One lethal ber and four ordinary ones are pushed inside burrow openings. This one-shot baiting technique is fairly economical. Including the cost of labour,

ber and poison, a farmer will spend 30 to 45 paise per hectare for effective rodent control. If, however, he collects ber from wild and does the job himself, the method will cost him 0.5 to 1 paisa per hectare as compared to Rs. 3 to 15 per hectare by conventional methods.

Summer is the most appropriate season when large scale rodent control should be taken up effectively.

If rodents are controlled on a district level, i. e. in a large area, the reinfestation will be slow but if it is carried out only in one hectare or so, naturally the immigration of rodents from the surrounding areas will make reinfestation quick.

Bird pests and their control

Damages caused by bird pests to the standing crops amounts to about 10 per cent of the total production. Food habits and breeding cycles of a large number of bird pests have been studied with a view to evaluate efficient methods for their control.

Occurrence, relative frequency and seasonal fluctuations of insect pests

Studies have revealed that insect population tends to be high during monsoon although lepidopterans were found in sufficient numbers during peak winter also. Coleopterans were more abundant than other orders. The order Coleoptera had maximum representation of families, Scarabaeidae and Meloidae. Association between insect abundance and climatic components have been investigated.

Lindane or Solvirex granules @ 1 kg (a. i.) per ha as presowing treatment against white grubs in bajra resulted in 30-32 per cent additional net profit over control.

Handbook of vertebrate pest control

The Handbook, published by the ICAR, is primarily meant for plant protection staff entrusted with the task of controlling bird and mammal pests in the field. In addition to being a handy practical guide to such workers the hand-book

contains latest information on the ecology and life history of the important vertebrate pests. The handbook is profusely illustrated with useful line-drawings, has useful list of suggested further readings and contains the relevant chemical and pharmacological information regarding most of the poisons discussed.

Extension

Apart from providing technical know-how to the farmers of surrounding areas, who often visit our farms, this Institute has adopted one village namely-Daijar, Panchayat Samiti, Mandore for demonstrating various recommendations of the Institute at the farmer's fields.

The extension programme, undertaken so far include (i) introduction and demostration cum field trials of different crops like Bajra HB 3, and wheat Kalyan Sona, (ii) use of fertiliser which had never been made earlier for kharif crops; (iii) introduction of improved varieties of vegetables like chillies NP 46 A and tomatoes Pusa Ruby; (iv) stabilization of sand dune by planting trees and shelter belts, viz. *Acacia tortilis*, *Albizia lebbek* and (v) introduction of grasses like Sewan *(Lasiurus Sindicus)* and Dhaman *(Cenchrus ciliaris L.)* grasses Rodent control and plant protection measures viz. dusting of B.H.C. powder on bajra plots as a measure against blister beetle and use of Malathion on brinjals and tomatoes as protective measure against aphids, (vi) extension activities like organizing Silver Jubilee of India's Independence, Farmer's Fair, Garibi Hatao Day, Field day etc. in the Institute and village Daijar.

Crop demonstrations : A number of result and method demonstartions are conducted on cultivators' field in Kharif and Rabi season to convince the farmers about the suitability, superiority and introduction of various recommended practices and innovations over the local ones.

During Kharif 1973 three Bajra demonstrations were taken up in village Daijar. It was found that an overall net benefit of Rs. 446/—, Rs 873/— and Rs. 100/—, was obtained in each of these three plots over the local plots of the same size within the same locations. Thus on an average an extra benefit of about Rs. 470/— was obtained by using the improved variety of seeds and fertilizers in the package of practices for this crop.

During Kharif 1972, when the rains had almost failed, under a very limited supply of irrigation hybrid bajra (HB-3) and castor aruna demonstrations were found to be successful. Inspite of all the unfavourable conditions the yields obtained from hybrid HB-3 and castor aruna were quite encouraging for the farmers whereas not even a single plot of local or hybrid bajra was found in the surrounding area in the village. The yieldes of bajra varied from 16 to 20 q/ha and castor aruna yielded 12 q/ha. The average net return came out to be Rs. 2,226 per hectare in case of 'Aruna' as compared to the approximate Rs. 1500/- per ha. in the case of local variety. Local variety is not only uneconomical in terms of yield but it also takes more time for its maturity, viz. 250-300 days as compared to 120-150 days in case of castor 'Aruna',

Sand dune stabilization

A medium sized sand dune at village Daijar was taken up for stabilization. The total area of the said sand dune comes to about two hectares. The length of the sand dune is about 300 meters and its width ranging from 60 and 90 meters. This was mainly formed by the transported fine particles of sand and gradually got deposited on the rocky surface. For the purpose of stabilization of the sand dune in all 440 trees of various species i. e. *Acacia tortilis, Prosopis juliflora. Tamarix articulata, Salvadora oleoides, Acacia senegal* were planted at spacing of 5 m x 5 m and keeping 50 m apart from the grass planting. In all the plantation of trees, grasses were in 4 strips. The work is under progress.

Extension activities

Farmer's Day: The Division of Economics and Extension, organizers Farmer's Days at the Central Farm of the Research Institute, Jodhpur. Farmer's of surrounding villages participated in this fair. The high-lights exhibited include nursery techniques for the arid zone, use of fertilizers, demonstrations of important desert grasses, cafetaria for dry farming crops, fodder legumes, pest control etc. Besides, stalls for exhibiting different improved agricultural implements, sale of seeds, improved varieties of crops and for demonstrating pestisides etc. are also organized.

Question-answer part relating to the various problems faced by the farmers in cultivation of crops, grasses, trees, utilisation of water, problems of salinity, application of fertilizers, rodent control and pesticides are solved by the Scientist of the Institute. Small hand outs in Hindi providing informations on different dryland agricultural techniques, forestry and sand dune stabilization etc. are distributed to the farmers.

BIBLIOGRAPHY

Research publications of the Institute covering various disciplines have been enlisted in the publication entitled, "Bibliography of C. A. Z. R. I. Publications, 1959-69". This is available from the C. A. Z. R. I. Library at the cost of Rs. 10-00, U.S $ 2.50 and £ 1.25 only.

ROLE DURING THE SEVENTIES

There are six divisions, and the role of each during the seventies is projected below.

I. DIVISION OF BASIC RESOURCES SURVEY

1. Creating new knowledge for harnessing arid lands

(i) Intensification of work on (a) dune morphology and dune dynamics, analysis and structure of different type of dunes to develop methods for dune rehabilitation, (b) location, and mapping of dead stream channels for identifying areas of ground-water availability, (c) quantitative geomorphology of drainage basins to predict water yield for different type of catchments.

(ii) Study of the dynamics of salt movement in soils irrigated with saline waters.

(iii) Analysis and structure of run-off *(khadin)* cultivation to suggest methods of amelioration to reclaim abandoned *Khadin* and preserve and improve the production in rest of the *khadins*.

(iv) Characterization of soil condition of waste and barren lands in the arid region to facilitate their rehabilitation for crops, pastures and forestry.

(v) Intensification of work on inter-relation of biotic effect on changes in density, cover and frequency of occurrence of plant species under different edaphic, climatic and hydrological conditions in different land types of arid zone.

(vi) Intensification of work on ecological studies of different communities and pasture types in relation to site for upgrading plant production in different land types.

(vii) Study and location of large sources of natural plant communities useful (a) in small-scale industries (like gum industry, paper industry, pulp industry, fibre industry), (b) as medicinal and aromatic plants, and (c) for use as edible and non-edible oils.

(viii) Intensification of work on hydrological investigation in (a) water-sheds, (b) stream flows, and (c) village ponds, for assessment and

augmentation of surface water and for control of evaporation and seepage losses from village ponds.

(ix) Development of regional formulae for detecting optimum size of small and medium-sized reservoirs as a function of climatic and catchment characteristics.

(x) Development of cheap irrigation water conveyance and distributional aids with minimum seepage losses.

(xi) Intensification of work on ground-water exploration and location of potential ground-water points, with seismic refraction and resistivity surveys.

(xii) Studies on recharging of aquifers from run-off water injection wells and other methods.

(xiii) Studies on deep seepage to subsurface formation from canal irrigation to predict waterlogging and land subsistence under irrigation.

(xiv) Studies on movement of ground-water bodies in arid zone to help plan their long-term utilization.

(xv) Studies on geomorphology of piedmont zones under the arid environment for assessment of potentiality of ground water resources.

(xvi) Studies on weathering complex and impact of climatic teomorphology on the formation of water resources of various desertic features.

2. Developing new techniques in the service of land utilization in the arid environment.

(i) Application of infra-red remote sensing technique in locating and mapping of fluvial bodies and burried channels.

(ii) Improvement in photo-interpretation for basic-resource surveys.

(iii) Development of soil vegetation relationship for aerial photo interpretation and land-capability interpretation.

(iv) Development and application of different geophysical methods like seismic refractor and resistivity methods for predicting ground water resources.

(v) Establishment of gauge stations on important streams, ground water regions and water-sheds, collection of data on fluctuating water regime for hydrological investigation and water-yield planning.

(vi) Establishment of instrumented water-sheds for development of relationships between water-shed and yield.

(vii) Compilation of (a) agro-ecological maps, (b) agro-climatological zonation maps, and (c) composite resources maps.

3. Serving all-India co-ordinated research projects and universities

Survey of lands for co-ordinated dry-land research project at the Central Arid Zone Research Institute, Jodhpur, is being done.

Studies relating to co-ordinating scheme for research on use of saline water in agriculture will be undertaken.

4. Education and training

(i) Training of post-graduate students of geography of different universities in aerial photo-interpretation and photo-grammetry for applied geomorphology and land use planning will be continued.

(ii) Training will be given to soil conservation officers.

(iii) Training programme of agricultural graduates in relation to scheme on rural engineering surveys on agricultural aspects in villages will be undertaken.

5, Transfer of information to agents of change and farmers

Integrated survey reports of blocks and districts will be collected and a transformation plan will be drawn up to upgrade agriculture, pasture and fuel production in the area. The plan will be projected for the next decades taking into consideration the growth rate in population, livestock and agricultural production, and will be brought out in the form of a pamphlet for use by extension agencies.

II. DIVISION OF PLANT STUDIES

1. Creating new knowledge

(i) Physiological potentials of grass, tree, horticultural and vegetable species suited for different regions of arid zone.

(ii) Ecological inter-relationships of species in grassland communities to know the functions of the species and their reaction to various stresses of climate, management, and influence of various habitats.

(iii) Adaptability of different strains of grasses, legumes, and tree species in over-grazed and mismanaged rangelands and their compatability for better production.

(iv) Evolving species of grasses, legumes and trees and shrubs suitable for saline areas in arid regions.

(v) Different repellants absorbable by roots and leaves (specially of tree species) against vertebrate pests.

(vi) Site preparation and agronomic techniques for planting of trees, grasses, legumes and vegetable crops under different regions.

2. Extending frontiers of production technology

(i) Multiplication of seeds of high-forage producing strains of desert grasses like *Cenchrus ciliaris*, *Cenchrus setigerus*, *Lasiurus sindicus*, *Dichanthium annulatum* as well as legumes under different regions, for distribution to revegetate the desert.

(ii) Production of seeds and raising seedlings of forest and horticulture species.

3. Newer techniques

(i) Reseeding rangelands, formulating afforestation techniques, and raising of horticultural and vegetable crops in different land forms of various arid regions.

(ii) Treatment of seeds of different species for better keeping quality and viability.

4. Fighting instability of production

Integrated approach on range management, raising cultivated and irrigated fodder crops with water from tube-wells in arid regions and creation of fodder banks.

5. Serving all-India co-ordinated project

Studies on different grass and forage species are in progress under the all-India project for research on forage crops.

6. Education and training

Short-term training on pasture production, range management, and forestry, is being imparted to officers of different states.

7. Transfer of information to the agents of change and farmers

This will be done through bulletins, advise to the development and extension agencies, radio-talks, demonstratrations of results on farmer's day, and participation in seminars and symposia.

III. DIVISION OF ANIMAL STUDIES

1. Creating new knowledge

(i) Assessment of the relative physiological desert-worthiness of different indigenous sheeps breeds in relation to production capacities.

(ii) Establishment of some physiological correlates of high wool production in desert breeds of sheep.

(iii) Economics of increased livestock production through supplemental feeding of chemically protected feed proteins.

(iv) Occurrence and possible productive significance of biochemical polymorphic traits in desert dwelling sheep, goat, donkey and camel.

(v) Assessment of nutritive quality of different arid zone feeds through *in vitro* and *in vivo* metabolic trials.

(vi) Fundamental studies on red-cell metabolism in desert animals.

(vii) Assesment of lethal dosages of various toxic chemicals and bait preferences of birds and rodent pests.

(viii) Evaluation of naturally occurring phenomeonon of baits-hyness among rodents.

(ix) Use of fumigants for controlling field populations of rodents in relation to burrow-humidity.

(x) Use of chemosterilants in rodent control.

(xi) Filling up the lacunae in knowledge on fluctuations in the number of rodent and bird pests and their breeding cycles.

(xii) Augmentation of knowledge on the distribution of rodent pests in arid and semi-arid regions, with special reference to the relationship with habitat, vegetation and soil types.

(xiii) Investigations on the behavioural aspects of rodent pests of the desert region.

(xiv) Assessment of losses to various crops due to bird pests.

(xv) Determination of toxicity of various insecticides.

(xvi) Establishment of techinques for controlling major insect pests.

(xvii) Inventory of insect pests of crops, grasses and trees.

2. Extending the frontiers of production technology

(i) Conclusive evidence was obtained that sheep having low blood potassium (LK) produce wool of fine fibre. This is a clue to the rapid improvement in wool quality of indigenous, coarse-wool breeds. All that is needed now is to apply this new knowledge in the field. Controlled LK x LK matings on a large scale, followed by culling of the high-potassium (HK) progeny at each successive generation, would result in the evolution of a fine-wool producing strain within Indian Merino.

(ii) Prelminary trials made on the effect of feeding formaldhyde-treated *Zizyphus nummularia* (pala) leaves on wool growth in sheep have shown great promise. This simple and inexpensive chemical protection, aimed at maximum utilisation of feed proteins for production purposes within the ruminant's system awaits large-scale application.

(iii) Increasing the productivity of food crops, grasses and fodder through controlling destructive pests, specially rodents, birds and insects.

(iv) Enhancement of natural resources of the arid regions through wildlife conservation.

3. Newer techniques

(i) Advanced biochemical methods for determining the genetic individuality of farm animals in respect of certain polymorphic traits which may have a bearing on production.

(ii) Use of synthetic supporting media in the separation of proteins, etc., by electrophoresis and TLC.

(iii) Utilization of physical, including electronic, devices for studies on climatic physiology of animals.

(iv) *In vitro* techniques of determination of digestibility of common feeds and fodders of the desert region.

(v) Evaluation of methods for controlling rodent pests through biological methods and use of chemosterilants.

(vi) Investigating the phenomenon of bait shyness among rodents for increasing the efficacy of control operations.

(vii) Utilization of telemetric devices for ecological studies on rodents and wildlife.

(viii) Playing back distress calls and other acoustic methods for bird control.

(ix) Screening of insect-resistant lines of various crops.

4. Serving all-India co-ordinated research projects

The data obtained in the course of studies will serve several all-India co-ordinated projects on animal production and rodent control.

5. Education and training

(a) Organizing courses leading to Ph. D.

(b) Short-term training of Plant-protection assistants in rodent control.

6. Transfer of information to agents of change and farmers.

(a) Organizing farmer's fairs.

(b) Extending informations to animal husbandry, agriculture and Plant--protection assistants.

(c) Extending information to village-level workers and Plant protection assistants.

IV. DIVISION OF WIND-POWER AND SOLAR ENERGY UTILIZATION

1. Creating new knowledge

(i) Investigations on the utilization of solar energy for desalination of water and providing energy for agricultural purposes.

(ii) Basic studies on physical processes governing wind erosion and the dynamics of wind-breaks and other soil-consevation practices in wind erosion control.

(iii) Survey for wind power in arid and semi-arid zones and utilisation of wind-mills for lifting water and for operation of small electrical generators at suitable locations.

(iv) Development of suitable implements for cultural practices in the arid zone with the aim of reducing wind erosion to the minimum and facilitating optimum tillage for good agricultural production.

(v) Conducting micro-climatic and water balance studies under various conditions for prediction of the storage of soil moisture during different periods of the growing season of crops and grasses. These studies would help in relating ultimate crop yield in terms of water deficit in different stages, in preparing schedules for supplementary irrigation, indicating the possibilities of selecting the best conditions for planting of certain species of plants, and in suggesting programmes for successful agriculture.

(vi) Agro-meteorological studies at the regional centres, and forecasting of drought and frost for making suggestions for proper cropping patterns.

(vii) Experimental studies on evaporation and evapotranspiration and their association with other climatic factors in the incidence of pests and diseases.

(viii) Studies on the effect of climatic factors on the incidence of pests and diseases.

(ix) Analytical study on drought and critical periods in the growth cycles of crops in arid and semi-arid zones of India with the available data on rainfall, agricultural production, soil moisture and climate. Considerable data

are available with agricultural universities, Indian Meterological Department and the Co-ordinated projects of the ICAR.

(x) Studies on the energy balance including determination of profiles of net radiation and global radiation, soil-heat flux, albedo, and radiation intensity in the spectral ranges important for photo-synthesis. All these would be useful not only for determination of water use by crops but also for estimation of maximum potential yields of major crops at various radiation levels. With simultaneous determination of carbon dioxide concentration and aerodynamical factors, it is possible to estimate photosynthetic efficiency of crops.

(xi) Studies on soil moisture and its movement in sandy plains and in the stabilized and unstabilized sand-dunes in relation to the distribution of soil temperature.

2. Extending the frontiers of production technology

(i) Exploitation of cheap and freely available power resources such as solar energy and wind power for desalination and pumping of water.

(ii) Studies on evolving of a multi-factor growth index using the ratios of actual-to-potential evapotranspiration in different growth stages and a procedure for incorporating water stress experienced by crop during critical periods of growth. These would enable us to determine the technolngy required for maintaining optimum production.

3. New techniques

(i) Increasing the efficiency of solar distillation unit for desalination of saline waters by introducing humidification dehumidification techniques.

(ii) Study of relationship of germination and emergence of major crops with soil and air temperatures, development of a heat unit system (including in it the photo-thermal concept for predicting the various development stages of major crops), and evolving triquadric equations involving day and night temperatures and photo-period.

(iii) Evolution of mathematical models for simulation of processes in the plant community : (a) micro-climate model concerning the exehange of enery within and above plant community, calculation of vartical profiles of turbulence transfer co-efficients, and aerodynamic approach for estimating carbon-

dioxide assimilation and (b) radiation models which define photosynthetically active light regime in the canopy, direct and diffuse light, leaf-angle distribution, of light and solar elevation. All these models will be evolved in collaboration with the Division of Soil Water-Plant relationship, which would also study stomatal aperture, diffusion-pressure deficit and relative turgidity, which would all be finally incorporated in a soil-plant-atmosphere model (SPAM) for the crop concerned.

4. Serving all-India co-ordinated research projects and universities

Analytical studies proposed for evaluation of critical periods in the growth cycles of crops and incidence of droughts, its commencement period, intensity and a real extent would be carried out by processing the data on soil moisture, climatic parameters and crop growth collected at various agricultural universities and the ICAR coordinated projects.

V. DIVISION OF SOIL-WATER-PLANT RELATIONSHIP

1. Creating new knowledge

(i) Physiology of plants more suited to arid and semi-arid environment. Studies will be in the fields of plant-water-relations with special reference to water and nutrient utilization, control of growth for economic use of water, and physiological basis for improving quality and quantity of produce under arid environment.

(ii) Maintenance and build up of soil fertility.

(iii) Improvement of soil physical conditions.

(iv) Study of micro-organism population under different conditions of aridity and the changes that they undergo under various conditions of management.

(v) The most efficient method of use of water under arid conditions for producing crop economically and profitably.

(vi) Development of stable agriculture by optimization and standardization of inputs. Improvement of water-use efficiency, adjustments of crop density, nutrient and water-regimes conducive to maximum production, and modification of crop micro-climate, water harvesting and re-evaluation of fertilizer needs of high-yielding crops. Study of agronomic practices for differrent regions of arid zone depending on soil-rainfall situations and exploration of possibilities of introducing new crop species and varieties in arid areas.

2. Extending the frontiers of production technology

(i) Raising the efficiency of arid zone farming by optimization of inputs and determination of package of practices,

(ii) Optimum use of limited water resources for maximum production.

(iii) Breeding of soils through changes in their physical and hydrological proportions.

(iv) Improvement of soil fertility and soil microbial activity.

3. Newer techniques

(i) Extensive use of neutron moisture meter in soil-water studies.

(ii) Assessment of the merits of different irrigtion techniques like drip irrigation and sprinkler irrigation for stepping up production with limited water resources.

4. Fighting instability of production

(i) Development of model cropping patterns for stable agriculture in arid areas.

(ii) Study of soil characters of low-rainfall areas to devise measures for better management of such soils.

(iii) Standaridization of irrigation norms and best use of limited water resources.

5. Serving all-India co-ordinated research projects

Information derived from researches will be of great use to different schemes on dry-land farming, millets, pulses, and model agronomic rials.

6. Education and training

Short courses on soil-water-plant relationship will be arranged for officers from central and state institutes and departments. Students will be guided for Ph. D in various subjects.

7. Transfer of infromation to agents of change and farmers Organization of farmer's fairs and communication of information to farmers through village-level workers.

VI. DIVISION OF ECONONMICS AND EXTENSION

1. Creating new knowledge

(i) *Socio-economic surveys :* Socio-economic surveys proposed to be conducted on the settled, nomadic and semi-nomadic population of the arid and semi-arid regions of India shall provide new knowledge in the structure of population, economic production patterns, caste factor, household characterstics, education and social welfare, human-vegetation-lives tock relationships *etc.* The results of such a survey shall be integrated with the results of the survey on basic resources to evolve the pattern of economic production based on the improved agricltural and animal husbandry aspects so that eccnomic activities and social changes go together.

(ii) *Research in social change :* (a) New knowledge will be obtained by conducting research in rural institutions in relation to development of agriculture, animal husbandry and household industries. (b) The nature and extent of adoption of different types of agricultural innovations, channels of communication involved in the process of diffussion, techniques for the identification of key-communicators and their role in agricultaral comminication and relationship of different socio-economic and psychological factors associated with the adoption of innovations, shall provide knowledge for the formation of recommendations for the quick diffusion and stable adoption of improved agricultural practices and highyielding varieties of crops, (c) A study will be conducted on improved home-management through family budgeting, economic utilization of leisure time, change of dietary, etc. A comparative study of the traditional and improved home-management practices shall broaden the horizon of knowledge, (d) Studies in education psychology will provide a knowledge of the social values, attitudes and motivational aspects of the communities towards adoption of innovations.

(iii) *Socio-economic changes :* Study on the impact of irrigation on the socio-economic changes in irrigated areas will provide information on the nature and extent of social and economic changes which would suggest the means for bringing about planned social and economic changes in similar of arid and semi-arid zones of India.

(iv) *Research in extension :* Studies on the relative effectiveness of different extension methods and approaches will be taken up. Research in training strategy of the extension workers and farmers will be taken up for gaining knowledge on the efficiency of different training methods for extension

work. Studies will also be conducted on the role or pre-primary, primary, higher and adult education in agricultural development, to develop 'techniracy' in arid and semi-arid regions.

(v) *Agricultural economics research :* New knowledge will be obtained by evaluating improved agricultural practices, on the basis of the input-output relationships, (b) Studies will be taken up on economics of sprinkler irrgation and on scope and limitations of mechanization in desert areas in relation to size of holding, (c) Economic aspects of soil conservation, land reclamation, land consolidation, land ceiling and other land reforms will be studied. Economics of water management and optimal use of water resources would be worked out, (d) Assessment will be made of the saving potential, misutilization of credit and overdues, comparative efficiency and role of different farm finance institutions etc.

2. *Fighting instability in production*

As a result of unfavourable climate and scanty and erratic rainfall, there is a greater instability in agricultural production. To reduce the risk, studies will be conducted on the economics of different farm and livestock enterprises in the arid and semi-arid regions. Specific attention will be paid to the identification of the problems of small farmers whose agricultural production at present is unstable.

3. Developing newer techniques

It is proposed to develop newer research models and attitude scales in relation to the behaviouristic pattern of the farming communities inhabiting the arid and semi-arid regions. Research projects in statistics will help in designing newer methods and techniques for planning field experiments and sample studies on various research projects. Modern methods of tabulation and computation will be acopted.

4. Serving all-India co-ordinated research projects

The results of expe.iments conducted in the co-ordinated projects stationed at Jodhpur, will be evaluated with economic yard-sticks to suggest appropriate approaches to complicated economic problems.

5. Education and training

Most of the economic relationships among the nomadic and rural population of the arid regions of the country are embodied in their social framework,

It is, therefore, proposed to organize training courses for extension workers to provide them an adequate insight into the social and cultural aspects. Training will also be provided on the use of various extension media for transfer of information to farmers. Short training courses and field trips will be organized to enlighten farmers of the modern scientific developments in agriculture.

6. Transfer of information to agents of change and farmers

Research findings will be projected at the field level through extension methods. To begin with it is proposed to adopt one or two villages around Jodhpur where recommendations will be implemented and tested. The programme will then be extended to a community development block and the district. Audio-visual aids will be provided and farmer's fairs and exhibitions organized, for translating recommendations in the farmer's language.

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