VISION - 2020

CAZRI
PERSPECTIVE PLAN

1947-1996

COUNCIL OF AGRICULTURAL RESEARCH

Published by :

Director
Central Arid Zone Research Institute
Jodhpur - 342 003

April, 1997

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FOREWORD

Over the years, the Indian Agricultural Research System under the aegis of the Indian Council of Agricultural Research has served a very useful purpose. Nevertheless, in the fast changing global context, managing the change on a time scale, by converting weaknesses, if any, into opportunities to become internationally competitive is considered important. We need to be forward looking and visible with appropriate agricultural research policies in place supported by the cutting edge technologies in order to attain and sustain global advantages. It is in this background that the formulation of a perspective plan with a visionary approach for the next 25 years, is quite necessary. The clearly spelt out options and likely changes would enable the system to capitalize on our strength so that the threats, if any, are converted into opportunities.

Indian arid zone covers about 12% geographical area of the country. Though a fragile ecosystem, arid zone is unique repository of natural resources. The farmers of this area are perpetually under compulsions to cultivate marginal lands and sand dunes to meet their ever increasing demands of food and fodder. Simultaneously ecological considerations also require an immediate check on the over exploitation of resources.

The typical resource set up of arid zone needs economically viable but eco-friendly technologies with social acçeptability. We have to thoroughly assess indigenous traditional knowledge, make the most judicious allocation of resource base, identify research requirements and priorities and generate appropriate technologies. The Perspective Plan of CAZRI is step forward in this direction.

In perspective plan formulation there was an overwhelming response to Council's initiative. The staff of the Policy and Planning Cell of the council deserves all appreciation for undertaking this onerous task right from designing of the necessary format and taking the plan formulation process to its logical conclusion.The various divisional heads at the ICAR Headquarters, Peer Review and RAC members made valuable contributions to the process of plan formulation. The Director and scientist of the Institute have put in their collective wisdom in bringing out the document in its present form. It is hoped that the framework prepared would continues to be reviewed to accommodate changes in future so that the perceived vision continues to be close to the expected target. In the years to come, based on the long term perspective, it would be relevant to put implementable plan to action on five yearly basis to match with the on going planning system of the country.

March 5, 1997

(R.S. PARODA)
Secretary, DARE and
Director General, ICAR

PREFACE

Central Arid Zone Research Institute (CAZRI) has been engaged in the task of arid zone research and development for about four decades, making notable contributions. It is time to critically review the achievements with a view to identify the gaps in knowledge and the areas that need greater focus in future research and development strategies. The present document is an effort in this direction and a part of a nation wide exercise undertaken by all ICAR Institutes for preparation of Perspective Plan upto 2020 AD.

Following the guidelines received from ICAR, a core group of 20 Scientists with Dr H.P. Singh, Principal Scientist, as convener, was assigned the task of preparing a base draft on the present state of knowledge, constraints and future strategies by redefining the goals and priorities. This was followed by a series of discussion involving all scientists, that culminated in finalization of 14 multidisciplinary research programmes for this document. The draft was discussed and improved in the Research Advisory Committee meeting held on June 6-7, 1995 under the Chairmanship of Dr Ranbir Singh. Besides the RAC Members, Heads of Divisions, Principal Scientists of the Institute, eminent scientists like Drs R.P. Singh, R.P. Dhir and S.D. Singh were also involved in the discussion.

A Peer Review Team constituted by ICAR, comprising Drs. J.S. Kanwar (Chairman), K.V. Raman and I.C. Mahapatra (Members) and M. Velayutham, DDG I/C (SA&AF). Directors of various Institutes and ADG (SA&AF) reviewed the draft document during ICAR Directors' meet (July 10-14, 1995) at New Delhi. Based on suggestions during review, the draft was modified and submitted to ICAR.

Subsequently, valuable suggestions were made by the distinguished members of the Peer Review Team, Dr. G.B. Singh, Dy. Director General (SA&AF), Dr. M. Velayutham, other senior officers in the Divisions and Dr. Ranbir Singh, Chairman of the RAC. To consider the suggestions so received a meeting of the RAC was convened under the Chairmanship of Dr. Ranbir Singh on March 12-14, 1996. Additional Director (Research) Rajasthan Agricultural University, Bikaner and Joint Director (Agri.), Government. of Rajasthan, Jodhpur also participated in the meeting as special invitees. Based on the decisions taken in the meeting the draft was revised. The document has been further refined to the present form based on the suggestions made during the Third Inter-divisional Peer Review Meeting in the Council held under the Chairmanship of the Director General, Indian Council of Agricultural Research, New Delhi on July 26, 1996.

The Institute records its great faith in the dynamic leadership of Dr. R.S. Paroda, Secretary DARE and Director General, ICAR, who pioneered many policy reforms including the vision for perspective planning for the Agricultural Research System of the Country. The final editing done by Dr R.P. Singh is duly acknowledged.

(A. S. FARODA)
Director

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EXECUTIVE SUMMARY

Indian arid zone, covering 12% of the country's geographical area, is characterized by low and erratic rainfall, frequent droughts, high summer temperatures and high wind velocity resulting in high evapotranspiration. Besides poor soils, undulating topography, limited availability of good quality ground water and increasing biotic pressure have further aggravated the magnitude of the problems faced by the desert dwellers. Although from ancient times animal rearing has been the main occupation of the people but arable farming has also been in vogue for fulfilment of ever increasing food requirement.

As a step forward, Indira Gandhi Nehar Pariyojana (IGNP), an ambitious irrigation power project was launched in 50's to bring Himalayan water to Thar desert through a 649 km long network of Canal System. This project started to pay dividends in late 80's onwards. Notwithstanding the intensive agriculture that began in part of this desert early in the 20th century, the fact remains that more than 80 % of the region will continue to remain under rainfed farming and pastoralism.

The systematic and exhaustive research and development efforts carried out after independence not only reversed the process of desertification but have also contributed significantly to the improvement of resource base for sustained productivity. However, such positive effects can get leveled off due to enhanced demand and aspirations leading to over-exploitation and mismanagement of natural resources on one hand, and deterioration of social values, on the other. Hence there is no room for complacency. Concerted and dedicated efforts at CAZRI during the last four decades have enhanced the understanding of natural resources, climatic changes and social fabric immensely. At present Thar desert is scientifically the best understood desert. The research gains, however, have not percolated to the end users to the desired extent.

Keeping this in view, CAZRI reorients its research strategies to develop high quality need based programmes in a mission mode. This **Perspective Plan** is an humble effort in this crusade. The plan particularly focuses on farming systems approach and on-farm research. In order to convert constraints into advantages and opportunities the plan envisages concerted research efforts centered around 14 major programmes listed below.

- Integrated basic and human resources survey, desertification monitoring and modelling.
- Survey, monitoring and conservation of biodiversity.
- Arid land farming system research.
- Rehabilitation and management of degraded lands emphasizing alternate land use systems.
- Modelling surface and ground water resources for efficient utilization.
- Improvement of annual and perennial crops including forage crops.
- Improvement in animal production and management.
- Natural products and agro-techniques of unexploited and underutilized arid zone plants.

- Agro products processing and value addition.
- Integrated pest management.
- Non-conventional energy systems, farm machinery and power.
- On farm research in a farming systems perspective.
- Socio-economic investigations and evaluation.
- Training, communication and feed back analysis.

The execution of these programmes necessitates increased emphasis on multidisciplinary and holistic approach including balanced and strong linkages with government and voluntary organizations. To achieve these time bound targets, it will be appropriate to prioritize various programmes and activities. The thrust areas are :

- On-station and on-farm research on development of sustainable farming systems models (Crops + horticultural crops + trees + shrubs + grasses + livestock) based on socio-economic aspects and land use planning – assessment and fine tuning for different agro-ecological sub regions.
- Integrated watershed management and rehabilitation of degraded lands.
- Biotechnological improvement of indigenous trees/shrubs/grasses/crops.
- Biodiversity, medicinal plants - identification, agro- techniques and process development.
- Post harvest technology and value addition.
- Desertification monitoring/mapping and description of desertification parameters.
- Energy management (wind and solar).
- Empowerment of farm women.
- Technology transfer including training.

Besides, it has been proposed to strengthen the research and training activities of the existing centres. Establishment of the following new units is also envisaged :-

1. Regional Research Station for Cold Desert.
2. National Centre on Desert Technology.
3. Trainers Training Centre.
4. Farmers Service Centre.

ABBREVIATIONS

ACSAD	Arab Centre for Studies of Arid Zones and Dry Lands
ACU	Adult Cattle Units
AICRP	All India Coordinated Research Project
BAIF	Bharat Agro Industries Foundation
BSI	Botanical Survey of India
CABI	Commonwealth Agricultural Bureaux International
CARI	Central Avian Research Institute (Izatnagar)
CAZRI	Central Arid Zone Research Institute
CCSHAU	Chaudhary Charan Singh Haryana Agricultural University
CDRI	Central Drug Research Institute
CFTRI	Central Food Technological Research Institute
CGIAR	Consultative Group on International Agricultural Research
CGWB	Central Ground Water Board
CIAE	Central Institute of Agricultural Engineering
CIDA	Canada International Development Agency
CIFE	Central Institute of Fisheries Education
CIFRI	Central Inland Fisheries Research Institute
CIMAP	Central Institute on Medicinal and Aromatic Plants
CIPHET	Central Institute of Post Harvest Engineering and Technology
CIRG	Central Institute for Research on Goat
CISH	Central Institute of Sub-tropical Horticulture
CMFRI	Central Marine Fisheries Research Institute
CPR	Common Property Resources
CRIDA	Central Research Institute for Dryland Agriculture
CSIRO	Commonwealth Scientific and Industrial Research Organization
CSSRI	Central Soil Salinity Research Institute
CSWRI	Central Sheep and Wool Research Institute
DANIDA	Danish International Development Agency

DDP	Desert Development Programme
DESCONAP	Desertification Control in Asia and the Pacific
DNES	Department of Non-conventional Energy Sources
DPAP	Drought Prone Area Programme
DRDA	District Rural Development Agency
DST	Department of Science and Technology
EIA	Environment Impact Analysis
FAO	Food and Agriculture Organization of the United Nations
FYM	Farm Yard Manure
GATT	General Agreement on Tariffs and Trade
GIS	Geographic Information System
GWD	Ground Water Department
HP	Himachal Pradesh
HRD	Human Resource Development
IAHS	International Association for Hydrological Sciences
IBGP	International Bio Geosphere Programme
ICARDA	International Center for Agricultural Research in Dry Areas
ICAR	Indian Council of Agricultural Research
ICASALS	International Center for Arid and Semiarid Land Studies
ICFRE	Indian Council of Forestry Research and Education
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute for Semi Arid Tropics
IGFRI	Indian Grassland and Fodder Research Institute
IGNP	Indira Gandhi Nahar Pariyojana
IIM	Indian Institute of Management
IITA	International Institute of Tropical Agriculture
IIT	Indian Institute of Technology
IMT	Institute of Microbial Technology
IPALAC	International Programme for Arid Land Crops
IPE	Indian Institute of Petroleum
IPGRI	International Plant Genetic Resources Institute

IPM	Integrated Pest Management
ITC	International Institute for Aerospace Survey and Earth Sciences
ITK	Indigenous Traditional Knowledge
IUCN	International Union on Conservation of Nature
IVRI	Indian Veterinary Research Institute
JIRCAS	Japan International Research Centre on Advancement of Sciences
J&K	Jammu & Kashmir
KVK	Krishi Vigyan Kendra
MLRU	Major Land Resources Unit
MPa	Megapascals
NABARD	National Bank for Agricultural and Rural Development
NARP	National Agricultural Research Project
NATP	National Agricultural Technology Programme
NBPGR	National Bureau of Plant Genetic Resources
NBSS&LUP	National Bureau of Soil Survey and Land Use Planning
NCIPM	National Centre for Integrated Pest Management
NRCM	National Research Centre for Mushroom
NDRI	National Dairy Research Institute
NIH	National Institute of Hydrology
NIN	National Institute of Nutrition
NPAC	Newcastle Photovoltaics Applications Centre
NRCAH	National Research Centre on Arid Horticulture
NRCC	National Research Centre on Camel
NRDC	National Research Development Corporation
NRSA	National Remote Sensing Agency
NWDB	National Wasteland Development Board
OFI	Oxford Forestry Institute
ONGC	Oil and Natural Gas Commission
PRA	Participatory Resource Appraisal
RAC	Research Advisory Committee
RAU	Rajasthan Agricultural University

REDA	Rajasthan Energy Development Agency
RMDC	Rajasthan Mines Development Cooperation
RRS	Regional Research Station
RSC	Residual Sodium Carbonate
RSEB	Rajasthan State Electricity Board
SAU	State Agricultural University
SCOPE	Scientific Council on Problems of the Environment
SWH	Solar Water Heater
TERI	Tata Energy Research Institute
TIM	Transparent Insulation Material
TOT	Transfer of Technology
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Scientific and Cultural Organization
UN	United Nations
VO	Voluntry Organization
WTC	Water Technology Centre
WTO	World Trade Organization
WWF	World Wide Fund for Nature
YSPUH&F	Dr. Y.S. Parmar University of Horticulture and Forestry
ZSI	Zoological Survey of India

1. PREAMBLE

Arid zone research and development has been a national priority during the last few decades. The post green revolution era demanded a greater focus on conservation of resources and optimizing production on a sustainable basis in arid and semi-arid regions. This is a prerequisite for social equity on one hand and meeting the targets set for food production on the other. This task becomes formidable in view of fragility of arid ecosystem and poor resource base.

The Indian hot arid zone covers about 10 per cent (31.7 million ha) of the country's geographical area. The production and life support systems in this region are constrained by environmental limitations such as low precipitation (100-420 mm/year), high temperature (45-50°C), high wind speed (30-40 km/hr), high evapotranspiration (1500-2000 mm/year), and sandy soils having poor fertility and low water retention. These low yielding systems are perpetually under stress due to ever increasing population of both human and livestock. Even though local inhabitants have evolved suitable landuse and management systems of farming, pastoralism and animal husbandry; of late, these local survival systems have become inadequate to fulfill the ever increasing needs. This has resulted in overexploitation of resources causing rapid and widespread land degradation and decline in productivity. While the need for reversing such a trend is widely recognized, the scanty and sporadic knowledge to achieve this goal was a limitation. Hence, Desert Afforestation Station was established in 1952 at Jodhpur, which was later expanded into Desert Afforestation and Soil Conservation Station in 1957, and finally upgraded to Central Arid Zone Research Institute in 1959. Systematic research efforts by the Institute during the last four decades have produced a large number of need based, viable and cost effective technologies. Many of these technologies were transferred to the field through various developmental programmes including Drought Prone Area Programme (DPAP) and Desert Development Programme (DDP) of Government of India initiated in 1972 and 1978, respectively. The research efforts to combat desertification have since been continuing, primarily in hot deserts. In contrast scientific interventions in the cold desert, comprising an areas of 7 million ha, have been inadequate.

As we grew we realized our lacunae and tried to fill them up by altering mandates wherever necessary so as to improve productivity and *inter alia* quality of life of people.

Considering the enormity and complexity of problems and issues in the arid ecosystem, CAZRI re-dedicates itself to the following guiding principles in the pursuit of its mandate during the coming 25 years.

- Adoption of mission mode programme in replacement of some sectoral approach adopted in the past.
- Consultation and sharing of information through well set out linkages, focussing on-divisional and inter-institutional cooperation.
- Adoption of participatory approach i.e., close involvement of clients (farmers) in programme planning, implementation and monitoring.
- Development of models of integrated technology packages, based on resource conditions and farmers' priorities/aspirations that can be replicated by the Development Agencies, including VOs over the entire region.

2. MANDATE

1959 to 1973

- To undertake studies on land, soil, water, vegetation (pasture and trees) resources of arid and semi-arid regions for their conservation, and efficient and sustained utilization.

- To obtain an understanding of the amount and fate of water received through rainfall, condensation and surface and sub-surface flow by undertaking :

  - Studies of the soil-plant-water-energy relationship of major plant communities in different parts of the region.

  - An inventory of runoff, recharge to, and losses from underground reservoir to evaluate the regional water balance.

- To understand the regional dynamics of the landscape, its tendency to change due to various climatic conditions and through use by man and animals, and its susceptibility to interference and control.

- To identify the natural plant communities of the major environments in the area in terms of relative densities of adaptive and useful trees, shrubs and ground flora under different conditions of utilization.

  - To ascertain the best use of water and land in relation to :

    Optimum balance between forests and pastures as well as cultivated crops and animal production.

    Specific practices applied to each of the above.

    Optimum level of soil fertility which can be achieved and maintained under various environments.

    Specific type and quality of products ultimately useful and favourable for the human community, and

    Assessment of the best grouping of sources of income and occupations.

1973 to 1990

1973 onwards greater emphasis was envisaged towards dissemination of knowledge and human resource development. The scope of mandate was therefore, enlarged with an objective.

- To expose the rural population to recent technologies and their economic benefits, to monitor gains of the newly evolved plant and animal husbandry techniques through extension programmes, to impart short term training for quicker impact on the management of desertic areas and to identify constraints in the transfer of technology.

1990 to 1994

Changing priorities with time required greater attention to specific areas on research for sustainable production in the Indian arid zone. On the recommendation of 4th Quinquennial Review Team, some strategic changes were made and the mandate comprised of the following objectives :

- Undertake resource inventory studies on soil-land-water, plant-animal continuum, with a view to their optimum utilization for sustained productivity in the Indian Arid Zone.
- Evolve technology for desertification control involving people's perception of environment and develop efficient methods of production systems involving different alternative land use systems.
- Evolve strategy for drought management by developing forecast models for adjusting risk uncertainties over time and space in arid agriculture.
- Develop technology for optimizing energy use in arid agriculture through renewable sources of energy and animal draft power such as bullock, camel and donkey considering their draft capabilities.
- Study socio-economic impact of drought and desertification, migration and pastoralism, dynamics of animal and plant ecology in desert ecosystem and provide training in technologies developed for improvement of arid zone agriculture and desertification control.

Since 1994

Owing to rapidly changing international scenario and need for well concerted efforts on the development of sustainable farming systm, mandate was drafted as follows :

- To undertake basic and applied researches that will contribute to the development of sustainable farming systems in the arid ecosystems.
- To act as repository of information on the state of natural resources and desertification processes and their control.
- To provide scientific leadership and collaboration with relevant national and international institutions, including State Agricultural Universities for generating location specific technologies for achieving the above objectives.
- To act as a centre for training in research methodologies in relevant scientific areas.

Globalization leading to changes in life styles and consumptive patterns is likely to create a diversity of demand of products and facilities. This will entail changed production systems. Hence, with these changing priorities and recommendations emerging from Quinquennial Reviews, some minor modifications may be required in the mandate in the coming decades.

3. Growth

3.1 Infrastructure

Research and Development efforts for management of arid areas began in 1952 with the establishment of Desert Afforestation Station at Jodhpur. This station was redesignated as Desert Afforestation and Soil Conservation Station in 1957 and upgraded as Central Arid Zone Research Institute, Jodhpur in 1959. It was transferred from the Government of India to ICAR in 1968. The institute is now organized in the following eight divisions.

1. Resources Survey & Monitoring
2. Resource Management
3. Arable Cropping System
4. Perennial Cropping System
5. Animal Science and Rodent Control
6. Energy Management, Engineering and Product Processing
7. Social and Information Sciences
8. Out-reach Programme

Divisional setting may undergo change over time depending on priorities and requirements.

There are four regional stations (Fig. 1) at Jaisalmer, Bikaner and Pali in Rajasthan and Bhuj in Gujarat to carry out location specific research. Besides, there are four experimental field areas located in different agroecological subregions.

3.1.1 Laboratories

Over the years the Institute has developed well equipped and spacious laboratory facilities catering to the needs of advanced research in wide ranging disciplines viz., resource ecology, biotechnology, plant physiology hydrology, genetics, agroforestry, silviculture, animal nutrition and physiology,soil fertility, organic chemistry, climatology, solar energy and product processing, etc.

3.1.2 Library

With a modest collection of 400 books in 1952, the Institute library has gradually acquired nearly 11,000 books and is now subscribing to 228 national and international journals. It has developed facilities of microfilm reader, computerization and reprography. It also serves as a centre for dissemination of information. Scientists also have access to their colleagues in India and abroad through E-mail and Internet services. Nearly 11,000 copies of reprints and reports published by the Institute have so far been supplied by the library.

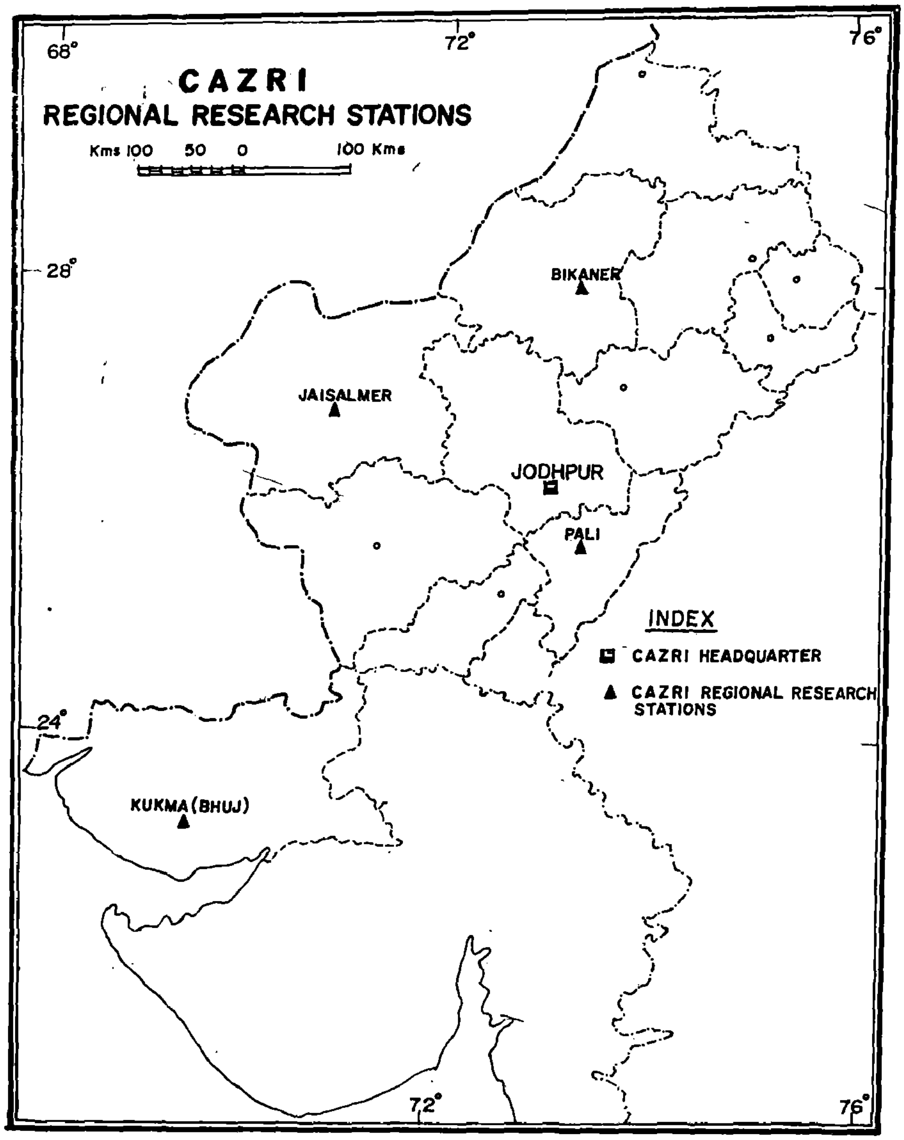


Fig. 1. Regional Research Stations of Central Arid Zone Research Institute.

3.1.3 Research Farms

The Institute has adequate research farm facilities (Fig. 1) — 283.48 ha at Jodhpur, 380.4 ha at Pali, 263.22 ha at Bikaner, 133.94 ha at Jaisalmer, and 58.53 ha at Bhuj. Besides, there are experimental field areas located at Bhopalgarh (51.39 ha), Jadan (76.89 ha), Kailana (311.85 ha), Chandan (95.1 ha) and Beriganga (262.68 ha). Research farms located in such diverse edaphoclimatic situations offer an unique opportunity for multi-location testing of technologies as well as location specific problem solving research.

Other relevant particulars regarding water resources, soil types, rainfall patterns and scientific activities of each of the Regional Research Stations and Experimental Areas are given as follow :-

Regional Research Stations

Regional Research Station	Water resources of the region	Soil type & Topography	Rainfall (mm)	Activity
Pali Estd : 1953* Area : 380.4 ha	Groundwater (80% saline), Surface water resources like Jawai dam, Hemavas dam	Shallow sandy loam Transitional plain of Luni Basin	400	Management of saline/sodic water; R & D for location specific farming systems; and Seed production of grasses and trees
Bikaner Estd : 1958* Area : 263.22 ha	Canal irrigation (IGNP)	Loamy sand, dune and inter-dune arid western plains	250	Integrated farming system research with focus on silvipasture and livestock management
Jaisalmer Estd : 1959* Area : 133.94 ha	Lathi aquifers, IGNP, Surface water resources (*Nadis*, *Khadins*, etc.)	Loamy sand, dunes, interdunes and rocky-semi rocky area	150	*Lasiurus sindicus* (Sewan grass) based silvipastoral system; Research on *khadin* water harvesting system; Water management (groundwater and canal); EIA and biodiversity conservation; and Seed production of trees and grasses
Bhuj Estd : 1987 Area : 58.53 ha	Groundwater saline-brackish	Saline/Sodic, sandy loam and silty clay loam (Banni area)	275	Assessment, fine tuning and demonstration of technology; Evaluation of suitable farming system for saline/sodic soils; and Seed production of trees and grasses

* Established as experimental areas, upgraded as RRS in 1987.

Experimental Area

Area	Soil type	Area (ha)	Status	Activity
Kailana	Rocky, Sandy loam	311.85	Research Farm of CAZRI, Jodhpur	*Acacia senegal* based silvipastoral system; and tree seed/gum production
Beriganga	Rocky, sandy loam	262.68	Research Farm of CAZRI, Jodhpur	*A. senegal* silvipastoral systems research; and Biodiversity conservation
Bhopalgarh	Rocky, semi-rocky	51.39	Research Farm of CAZRI, Jodhpur	Range management and silvipastoral system
Jadan	Shallow sandy loam, saline/sodic	76.89	Experimental area of RRS Pali	Integrated watershed management; Seed Production of grasses; and Studies on medicinal and high value plants
Chandan	Sandy	95.10	Experimental area of RRS Jaisalmer	Integrated farming system research on effective use of ground water

3.1.4 Buildings

Beginning with a modest building in 1964 housing the office of Director, Library, Administration and Laboratories, more buildings were added from1975 onwards for administration and Divisions of Resource Management, Arable Cropping System, Extension, Economics, and Wind Power and Solar Energy. A separate and spacious library building came up in 1987, followed by a KVK building in 1988 and a farm management block in 1989. At regional stations, office and laboratory buildings were constructed at Pali and Bikaner in the year 1980, and at Jaisalmer and Bhuj in 1995. Building facilities have also been provided to NBPGR research station and to the Zonal Coordinator (TOT) located at the campus.

Institute has a museum displaying achievements of research in various fields. An auditorium and a conference hall meet the requirements of trainings, seminars, symposia, etc. A hostel accommodates trainees, research students, etc., while a guest house with modern amenities exists for visiting scientists and other visitors.

3.1.5 Others

The Institute houses one of the oldest ecological herbarium having 6000 specimens from desert area. The Botanical garden with its roses and Bougainvilleas and foliage plants has created a craving for these plants in the hearts of local people. In-house facilities of photo laboratory, instrument repair cell and automobile workshop provide support to the research programmes.

3.2. Budget (Rs. in lacs)

Plan Period	Plan	Non-plan	Others	Total
II	56.19	26.51	-	82.70
III	55.44	-	0.06	55.50
IV	107.45	15.54	7.43	130.42
V	207.21	185.56	16.41	309.18
VI	551.92	285.18	-	837.10
VII	245.40	1249.60	53.23	1548.23
VIII	750.00	2793.18	271.73	3814.91

3.3 Manpower

Plan	Scientific	Technical	Administrative	Auxiliary/ Supporting
V	174	225	100	-
VI	196	235	90	-
VII	191	283	123	50
VIII	150 (130)*	290 (253)*	130 (120)*	52 (43)*

* Actual in position

4. SALIENT RESEARCH ACHIEVEMENTS

RESOURCE ECOLOGY

- Information on natural resources has been integrated into a conceptual framework of Major Land Resources Units for devising developmental plans. Such an appraisal completed for 43919 sq. km at reconnaissance level, 17190 sq. km at semi- detailed level and 827.36 sq. km at detailed level. Landuse/Land cover mapping was standardized and completed for 79581 sq. km and wasteland mapping for 75474 sq. km area.
- Methodology of mapping desertification was standardized and desertification map (Fig. 2) of western Rajasthan prepared. Wastelands in five districts were mapped and their management suggested.
- Concept for fine tuning land capability classification on the basis of soil moisture balance characteristics was developed. This helped in determining broad and specific land uses, choice of crops and cropping patterns under rainfed conditions.

WATER RESOURCES

(A) Prospecting

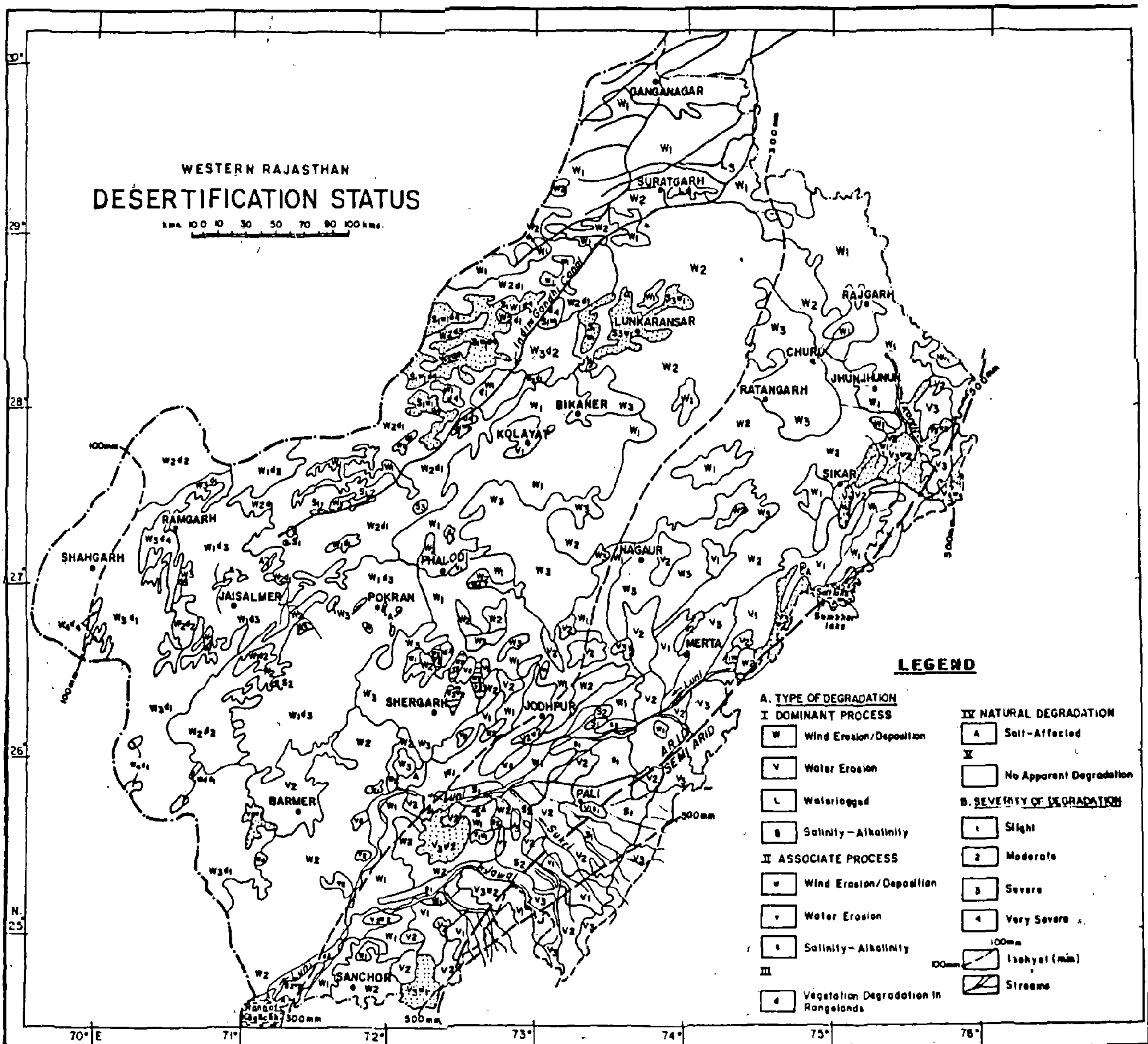
- Buried former streams were identified as potential source of subterraneous water in the desert.
- Index catchment technique was standardized to assess surface water over duny landscape.

(B) Harvesting

- Improved *Tanka* (underground cistern that stores harvested rainwater) to meet drinking water demand in less than 200 mm rainfall zone was designed. A *tanka* of 21 m^3 capacity can meet yearly drinking water demand of a six member family.
- Techniques for sealing of catchment with plastic, pond silt for run off generation and cropped area were developed.
- Circular catchment of 1-2 m diameter around tree saplings was found to be effective in increasing water availability. On slopy lands half moon terraces proved appropriate.
- Designs of environmentally safe *Nadi* and *Khadin* were standardized.

(C) Optimizing water use

- Drip irrigation in crops like maize, tomato, long gourd and watermelon proved cost effective in increasing yield per unit of water (Fig. 3). Double row planting with lateral in the centre reduced capital cost and water use by 50%.
- Sprinkler irrigation schedules for different crops were standardized.


WESTERN RAJASTHAN
DESERTIFICATION STATUS
LEGEND
A. TYPE OF DEGRADATION
I DOMINANT PROCESS
Wind Erosion/Deposition
Water Erosion
Waterlogged
Salinity–Alkalinity
II ASSOCIATE PROCESS
Wind Erosion/Deposition
Water Erosion
Salinity–Alkalinity
III
Vegetation Degradation in Rangelands
IV NATURAL DEGRADATION
Salt-Affected
V
No Apparent Degradation
B. SEVERITY OF DEGRADATION
Slight
Moderate
Severe
Very Severe
Isohyet (mm)
Streams
GANGANAGAR
SURATGARH
RAJGARH
LUNKARANSAR
CHURU
JHUNJHUNUN
RATANGARH
BIKANER
KOLAYAT
SIKAR
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75°
76°

Fig. 2

- *Jal Tripti*, a device having a double walled earthen-pot was developed. It can save water (80-90%) in raising tree saplings.
- Double row plant geometry and improved management practices maximized production per unit of *in situ* harvested water.

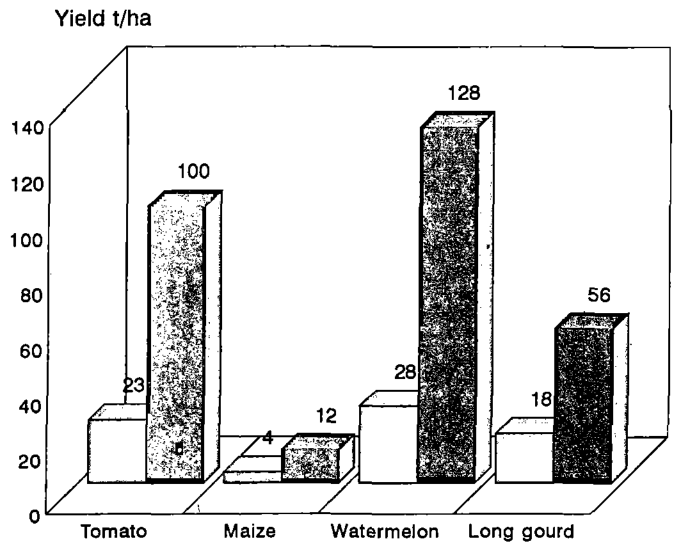

Fig. 3. Increase in production of different crops irrigated with drip system.

- Use of discarded plastic infusion sets filled with water and nutrient with its nozzle at root base was found effective for saving water in raising tree saplings.
- Lining of irrigation channels with a mixture of *Janta* emulsion and soil at 2.5 l/100 sq. ft. reduced seepage losses (70%) of water.
- Consumptive use of water by various crops (clusterbean, mung bean, sorghum, wheat, mustard and pearl millet) grown under optimal conditions was quantified.

(D) Conservation of water

- Computation of water balance of entire western Rajasthan revealed a deficit of 2500 MCM by 2000 AD which can be met by following suitable technological interventions.
- Subsurface barriers of bentonite clay, field bunding and mulching (for tree crops) proved effective in conservation of rainwater.
- Use of Fly ash (15%) in sandy soil increased water retention by 35% and 46% at 0.1 and 0.3 MPa, respectively.
- Vegetative barriers across the slope of cultivated fields increased crop yields by conserving soil moisture. *Cymbopogon jawarancusa, Cenchrus ciliaris* and *Leptadenia pyrotechnica* proved effective as barriers.
- Application of fertilizers in various crops enhanced vigour to evade moisture stress.

WIND EROSION

- Based on the types of sand dunes, their specific vegetation and erosivity of sand grains sizes, stabilization measures were standardized.
- Besides conventional afforestation methods, aerial seeding proved effective for stabilizing most erosive crests and leeward slopes of dune systems.
- For controlling wind erosion from croplands, following techniques were found effective :

  (i) Microwind breaks of castor and *L. sindicus;*

  (ii) Strip cropping of grass with crop (6:1 ratio of crop: grass strip);

  (iii) Leaving stubbles of pearl millet after harvesting;

  (iv) Ridge furrow cultivation system; and

  (v) Shelterbelts of *Cassia siamea* and *Acacia tortilis.*

SALINITY MANAGEMENT

- Management technology for use of high RSC water was standardized.
- Technique for use of industrial effluent water for raising trees was developed.

PRODUCTION SYSTEMS

A. Crops

A1. New varieties and Agrotechniques

- Improved varieties of *Moth* (Maru Moth), *Guar* (Maru Guar) and *Kulthi* (Maru Kulthi) were released and agro-techniques standardized.
- Agro-techniques for pearl millet, sesame and mung bean were developed.
- One supplemental life saving irrigation can increase pearl millet yield upto 60%.

A2. Integrated Nutrient Management

- Intercropping systems of pearl millet with mung bean/moth bean/clusterbean/cowpea were developed.
- Application of FYM (4 t ha^{-1}) on seed furrows of pearl millet reduced surface crusting.
- Urea mixed with elemental sulphur reduced the losses of N in volatilization.

A-3 Integrated Pest Management

- Control measures for white grubs, termite, grass hoppers, hairy caterpillars and diseases of pearl millet and clusterbean were evolved.

- Ecological studies on rodent pest brought out the optimum season for control operation, effective ways of bait placement and optimum distances between bait stations.

B. Horticultural crops

B1 New varieties

- Improved varieties of *Ber* (*Ziziphus mauritiana* - Gola, Seb and Mundia) were identified and widely popularized.
- Improved varieties of pomegranate (Jalor seedless and Ganesh) were identified.

B2 Agrotechniques

- Propagation techniques of *Ber* (budding) and Pomegranate (cuttings) were perfected. Planting of *Ber* at spacing 6 x 6 m and Pomegranate at 5 x 5 m were recommended as optimum.
- A polypack technique of transporting grafted *Ber* was standardized.
- *Ber* - dryland legumes intercropping was found compatible and economic.
- Horti-pastoral and agro-horti systems were developed in a farming systems perspective.
- Post harvest technology for the *doka* stage of dates was standardized.
- Early fruiting in *Cordia gharaf* (Gonda) was induced by its complete defoliation in the middle of January.
- Vegetative propagation of *Capparis decidua* was standardized.

WOODY PERENNIALS

A. New introductions/varieties

- *Acacia tortilis*, a fast growing species for arid and semi-arid situations was identified, *Prosopis juliflora* and *Acacia senegal* were found suitable for rocky areas. *Prosopis cineraria* and *Hardwickia binata* were recommended for agroforestry. Other suitable species for plantation in arid areas include *Acacia salicina, Atriplex nummularia* and *Colophospermum mopane.*
- Plus trees of *Prosopis cineraria, Tecomella undulata* and *Acacia albida* were identified and multiplied.
- *Colophospermum mopane* and *Hardwickia binata* were evaluated as potential forage trees.
- Jojoba, a high quality oil yielding plant, was introduced and found suitable for arid and semi-arid conditions.
- A large number of Bougainvilleas and floricultural plants were introduced and recommended for domestic gardens.

B. Agrotechniques

- Nursery techniques for raising tree saplings were developed.

- Lopping schedule of *P. cineraria* was standardized
- Silvi-pasture systems for location specific situations were standardized.
- Techniques for rehabilitation of degraded rocky wastelands were developed.
- Mine-spoil reclamation technique was standardized for gypsum and limestone mined areas. *P. juliflora, A. tortilis, A. farnesiana, T. aphylla, Parkinsonia aculeata* did well on gypsum soils while *A. tortilis, Circidium floridum* and *A. senegal* performed well on limestone mine spoils.
- Suitable trees/shrubs for salt affected lands were identified.

C. Vegetative propagation

- *In vitro* micropropagation technique through tissue culture was developed for *P. cineraria* , Date Palm, Jojoba and *Salvadora oleoides.*
- Air layering of *P. cineraria* was found successful for its vegetative multiplication. Clonal seed orchard was established using this technique.

D. Processing

- Diosgenin (an anti-fertility agent) and vegetable oil were extracted from *Balanites* fruit and seed, respectively.
- Rotenone pesticide was extracted from *Tephrosia villosa.*
- Candelilla wax was isolated from *Euphorbia antisyphilitica.*

E. Pasture/Range Management

New varieties

- Varieties of *C. ciliaris,* (Marwar Anjan) and *C. setigerus,* (Marwar Dhaman) were released. Improved strains of *Dichanthium annulatum* (490, 491 strains) *L. sindicus* (318, 319 strains) and *Panicum antidotale* (333, 297 strains) were identified.
- Technology for bulk grass seed production and its pelleting was developed.

Agrotechniques

- Contour furrows, bunds and trenches increased the forage yield. Soil working by creating contour furrows in *L. sindicus* grasslands encouraged its regeneration.
- Pasture regeneration techniques of *L. sindicus, C. ciliaris* and *C. setigerus* were standardized.
- Optimum carrying capacity for rangelands in various rainfall zones was standardized with different types of animals and grazing schedules.

ANIMAL STUDIES

- Marwari sheep tolerates salt in drinking water. Thriving on plasma water, it can well adapt to water scarcity conditions.

- Desert sheep, owing to low intake, excellent digestibility of diverse feeds, tolerance to water stress and heat, were found more eco-friendly.
- Management techniques for Tharparkar cow were standardized.
- Technology was developed for making silage from agrowaste and selected weeds.
- Technique for removal of tannins from *P. cineraria* leaves developed.
- IBOWMIX, a balanced mineral mixture, was formulated. It increases the body weight of cattle, sheep, lambs and goat kids by 50 to 60% over a period of six to eight months and milk and wool yields by 25-30%.

AGRO-METEOROLOGICAL/SOLAR ENERGY RESEARCH

- A new drought classification system was developed.
- A solar candle maker (cost Rs. 3000-5000) was developed. It can help earn Rs. 25 to 50 per day in rural areas.
- A polyhouse was designed and tested for preliminary trial for mushroom cultivation.
- Several solar appliances viz., cookers, water heaters, driers, and water stills were developed and found widely useful.

OTHER TECHNIQUES /DEVICES DEVELOPED

- A technique to determine hydraulic conductivity of soil was evaluated and tested.
- Evapotranspiration models were evolved for predicting soil moisture storage under field conditions.
- A prediction equation for estimating the body weight of cattle from heart girth measurements was developed.
- A pitting discer to create 63,000 micropits ha^{-1} for soil and water conservation in grass lands was designed.
- A bullock drawn fertilizer-cum-seed drill with *bukhar* attachment was developed for sowing and fertilizer application.
- Camel drawn seed-cum-fertilizer drill was improved by incorporating hitching and metering devices.
- A laboratory technique for raising mono-xenic culture of root knot nematode through tissue culture standardized.
- Soil solarization technique for control of soil borne pathogens was standardized.

5. IMPACT ASSESSMENT

5.1 Growth

Afforestation and pasture development research initiated in 1952 was later enlarged in scope in 1959 to include five major areas :

i) Basic Resources Studies

ii) Resource Utilization Studies

iii) Human Factor Studies

iv) Special Animal Studies

v) External Liaison - Physical and Chemical Science.

To address complex problems of the arid zone, two new research divisions were later added viz., Division of Wind Power and Solar Energy Utilization and Division of Soil-Water-Plant Relationship in 1971 based on the recommendation of the first achievement audit committee. The Division of Extension and Training was established on the recommendations of the Second Achievement Audit Committee in 1976. Besides, AICRPs on Dryland Agriculture in 1970, water management and soil salinity in 1971, millet improvement in 1972, and rodent control in 1977 were initiated. The major reorganization in 1989 resulted in the formation of present eight divisions of research. This is the only Institute of its size in South East Asia to carry out basic and applied research on the problems of the arid regions of the country. Evidently, initial scope of research on pastures and afforestation was enlarged to include crops and related issues, physical sciences, energy, socio-economics, extension and process development.

Over the years, technology for dryland farming comprising improved varieties, primary and secondary tillage operations, *in situ* water harvesting, integrated nutrient management, integrated pest management has been developed for traditional and introduced dryland crops like pearl millet, moth bean, clusterbean, mung bean, horse gram, cowpea and sesame. Similarly in perennials, there have been a significant improvements in horticultural crops like *Ziziphus mauritiana* (*ber*), *Punica granatum* (pomegranate) and *Emblica officinalis* (aonla). Appropriate range/pasture management practices have been developed.Keeping in view the goals of drought management and sustained productivity, the Institute has embarked upon the development of various alternate and integrated land use systems.This has made tangible impact on the improvement and sustenance in the productivity of drylands. The sand dune stabilization technology developed by this Institute has found wide acceptability in the massive developmental programmes undertaken by the Government of Rajasthan. So far 96,000 ha of dunes have been stabilized. Basic information on resource inventory encompassing soil, water, vegetation type, etc., and their management is being used by the State Government and other developmental agencies.

CAZRI has also contributed in development of water resources in the region. Delineation of buried former courses of streams has led the State and Central Ground Water Departments to locate drilling sites with a reasonable success. The rainwater collection for drinking purposes is a traditional practice in the region. Based on rainfall pattern, an improved design of *Tanka* was proposed that is adequate for a family of six members all the year round. This design was adopted by the National Drinking Water Mission as a model on which about 10,000 *tankas* have been constructed in Barmer district.

The study of potential climax vegetation and successional trends on each habitat enabled outlining of recovery programmes for degraded habitats and mine spoiled areas. The integrated basic resources inventories developed, are quite in demand. Several agencies are providing funds to the Institute for such surveys. The Luni basin development plan being financed by Germany was prepared by CAZRI. Resource development plans for DRDAs, All India Radio's Buildings, Gas Authority of India's infrastructure, Gujarat Ecology Commission, Rajasthan Agricultural University and Defence Organization were developed by the Institute. Technologies developed here have since been disseminated under various Central/State Governments schemes. CAZRI has been an active agency with the state governments in the preparation of action plans and their implementation under various developmental programmes. Under DPAP an amount of Rs. 1470.92 crore has been spent under various core activities viz., land development and soil conservation (27.4 lakh ha), afforestation and pasture development (16.47 lakh ha) and water resource development (9.02 lakh ha). With the realization of the fragility of the arid land ecosystem, the DDP was initiated in 1977-78. CAZRI has played a leading role with the state government in enhancement and sustenance of productivity of arid lands through technologies developed for conservation and management of resources. An amount of Rs. 468.5 crore has been spent by 1993 under various key activities viz., afforestation and pasture development (2.34 lakh ha) land development and soil conservation (1.22 lakh ha) and water resource development (0.57 lakh ha). Technology

Physical achievements of salient technologies	
Sand dune stabilization (lakh ha)	0.96
Afforestation and pasture development (lakh ha)	16.47
Watershed development (lakh ha)	1.2
Improved tankas (no.)	10,000
Improved seed supplied (ton)	
crops	9.7
grasses	100
forest trees	66.5
Saplings of woody perennials (lakh)	10
Ber -.nurseries (no.)	50

for integrated watershed development has been employed in 85710 ha and water harvesting in 39232 ha. Strategic plantation techniques developed by the Institute have been widely used under DDP. Till 1993, the physical achievements were: fuel-wood development (24662 ha), silvipasture (23091 ha), roadside plantation (274 ha), recovery of degraded forests (28149 ha) and pasture development (24011 ha).

Besides the overall contribution of CAZRI in desertification monitoring and control, evaluation and conservation of resource base and stabilization of the productivity, some specific impact areas are as under :

- The standards of gypsum application developed by the Institute have been accepted by State Government in giving subsidies to farmers for reclamation of salt affected soils developed due to irrigation with RSC water.
- Nursery techniques developed by CAZRI have been adopted by various state nurseries. Besides sand dune stabilization, shelter belt plantation, road side plantation and afforestation of other degraded areas are being undertaken by the Government of Rajasthan. Till VII plan 4.40 lakh ha have been covered. CAZRI has provided primary inputs in terms of afforestation techniques and choice of species. Among suitable exotics identified, *Acacia tortilis* deserves a special mention.
- Contribution of CAZRI in arid horticulture has also been recognized in semi-arid regions of the country. According to an estimate, there are around 50 *Ber* nurseries around Jodhpur selling 5.7 lakh budded plants every year. Rural youth are employed for pruning and budding operations, generating additional employment. Since 1979, more than 5 million plants (turn over of Rs. 25 million) have been supplied by nurseries and 37500 man days have been generated as employment. Pomegranate cultivars developed by CAZRI are becoming popular in Gujarat, Maharashtra and Karnataka.
- Based on techniques developed by this Institute for pasture development and management, 3.5 lakh ha area in the desert has been developed as pastures with genetically improved varieties of pasture grasses.
- Pioneering work on sprinkler and drip irrigation done at the Institute has resulted in coverage of large areas under these techniques.
- The designs of solar energy gadgets developed here have been commercialized and are in wide application. Of particular interest is solar candle maker. Solar driers for drying of vegetables are also finding the clientele.
- Among the different crop varieties developed, Maru Guar and Maru Moth are the prominent ones. In the last decade, 5.4 tonnes breeder seed of Maru Guar, 2.3 tonnes seed of Maru Moth and more than 2 tonnes seed of other dryland crops was produced. Similarly 66.5 tonnes seed and 1 million saplings of forest trees and more than 100 tonnes of grass seeds have been supplied by now. Jojoba has been commercialized recently and 200 ha is already under its cultivation.

Besides the above, there are many technologies in the pipe line. Establishment of seed orchards for production of genetically superior seeds of trees, studies on water use systems, surveys using modern techniques, pest management, fisheries, mushrooms are some of these. **Diversification in research is essential for sustainable agriculture.** The increase in human population in western Rajasthan is much higher than the rest of the country. For example, increase in human population between 1971-1981 was 37.29% in arid Rajasthan as compared to 24.75% in India during the same period. **The very fact that desert has been able to sustain all these pressures and of late there is some increase in the vegetative cover, is a testimony to the contributions and impact of agricultural research and development in this region.**

Notwithstanding the scenario as outlined above, a lot more still needs to be done in terms of technology development, transfer and adoption by the clients. There are many constraints - financial, institutional as well as technological. Technology assessment and testing and fine tuning have to be carried out through on-farm research by involving farmers in programme planning and implementation.

5.2 Input/Output Assessment

Cost benefit analysis shows that various techniques like sand dune stabilization, pasture based livestock management, afforestation using fuel/fodder tree species, agro-horticulture, agri- pasture etc. have positive net present value and annuity in a comparable system prevalent in arid and semi-arid areas (Fig. 4). The internal rate of return on adopting these technologies are favourably comparable with the long term rates of return on borrowing from banks. The only constraint is the longer gestation period associated with these technologies.

In addition to the tangible monetary benefits, the input can also be evaluated in terms of a large number of intangible benefits. For illustration, **stabilization of sand dunes is a costly activity but once accomplished, it will stop sand creep on the adjoining cultivated interdune. Thus damage to crops shall stop for all times.** Same is true for shelterbelts, wind breaks and roadside plantation which, if executed according to a well-conceived plan, protect croplands and roads respectively from sand burial.

The rainwater collection is a traditional practice. Appropriate standards of water harvesting structures, however, were non-existent. These designs were standardized and 10,000 such *tankas* (underground cisterns) were constructed in Barmer district. Measuring this immense relief to rural folks in terms of money will be fallacious because the very survival of humanity and livestock depends on water. Some other forms of intangible outputs are also now visible.

Identification of *Citrullus colocynthis* seed as potential source of non-edible oil has led the villagers to collect large amount of seeds, sell the same in cities to add to their income. Identification of *Balanites* as a source of Diosgenin and oil, *Commiphora* as source of Guggul, are further going to strengthen the economy of the region. Thus, while new varieties and agrotechniques directly increase the income, other technologies ameliorate the environment and at the same time help to increase the income and reduce the hardships to life.

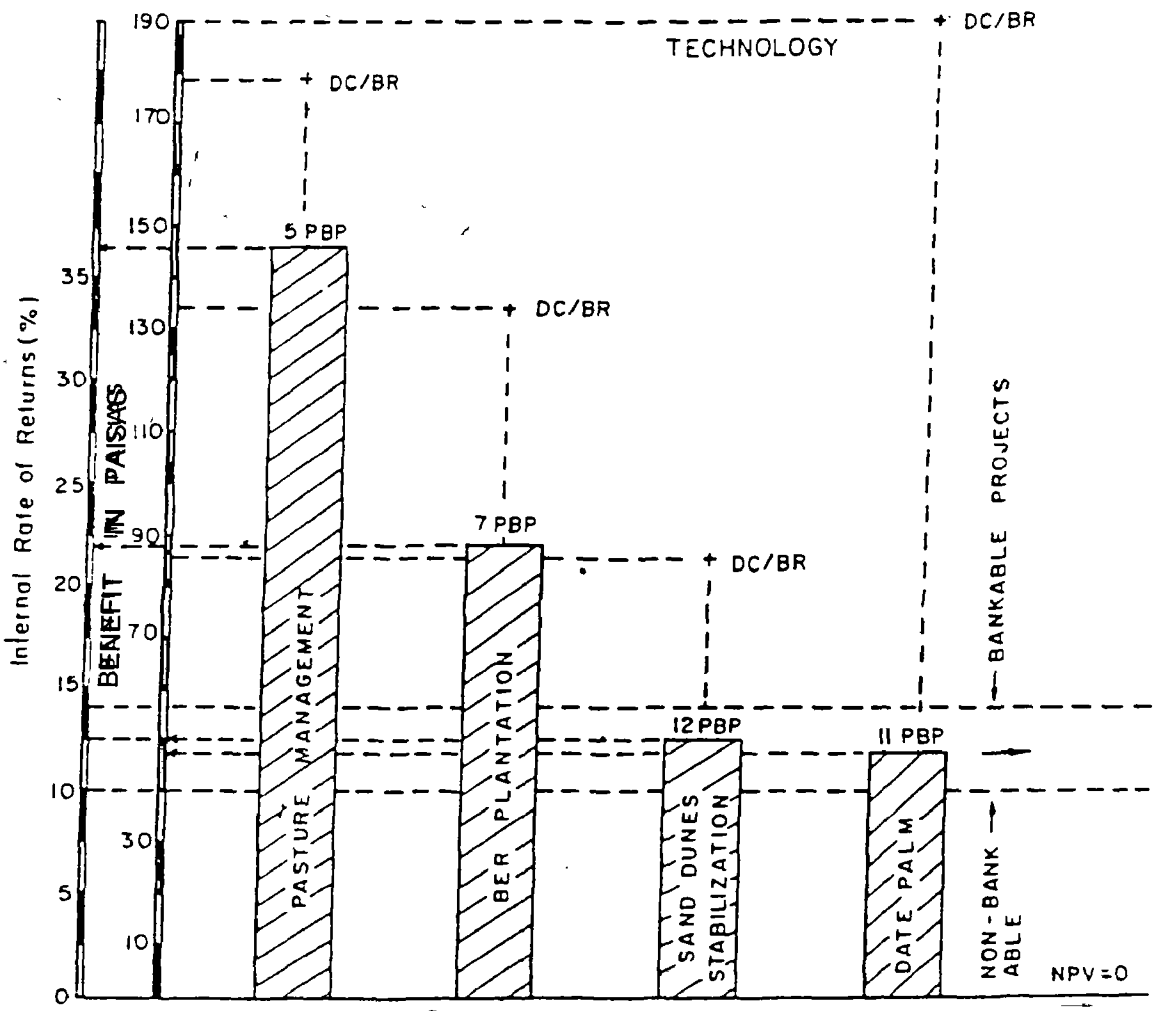

Fig. 4. Economic Evaluation of Long-term Arid Land Management

5.3 Shortcoming

5.3.1. Resource Appraisal and Monitoring

Systematic and intensive surveys could not be carried out in the entire region due to limitation of manpower and resources. Identification of specific area and parameters to monitor desertification needs priority. Similarly the efforts on monitoring and conservation of plant resources need strengthening. Owing to this limitation, though biodiversity was documented systematically it could not be monitored, collected, conserved and utilized to the desired level.

5.3.2. Resources Management

A host of technologies have been evolved. However, their assessment and testing under on-farm situations with close involvement of farmers was not quite adequate. Some of the technologies did find a place but only in the resource affluent areas. Indian desert is rich in well adapted races of flora and fauna. Their conservation and genetic improvement came to focus only in the recent past.

In arid region, there are time tested water harvesting structures like *khadins, tankas,* etc. However, this indigenous knowledge was not fully studied and properly utilized. Groundwater is limited in the region. This resource has been over exploited for short term gains. Efficient rainwater management could help in rational management of this scarce commodity. Location specific research to conserve water needs further strengthening.

The region is endowed with a rich wealth of medicinal and other economically important plants. Only a few of these were explored for products of economic importance. Biocontrol strategies using non-chemical products and indigenous methods of pest control need greater impetus from sustainability consideration.

5.3.3. Technology Assessment and Transfer

Technology dissemination has been slow especially in case of small holders. Some of the technologies could not have wide application due to inadequate assessment and testing. VO's and local bodies' involvement was not adequate. On-farm research for synthesis of research results into appropriate technological packages in a farming system perspective was not carried out systematically and adequately.

Though many technologies were cost effective yet could not become popular due to lack of community participation.

5.4 Lessons Learnt, Suggestions and Options for Future

This region has immense environmental fluctuations on one hand and a huge variety of habitats on the other hand. The technologies generated could not match up with such a diversity of situations. This enlightened us to go in for on-farm research and fine tuning of technologies at the farmers' fields. Further, many of these were community oriented or adopted by government agencies. It has now been realised that a technology, irrespective of its merits cannot be successful without active participation of the community or individual farmer.

Research has so far been concentrating on achieving academic excellence. These efforts did find utility in both understanding desertification processes and strategies for their management. However, for direct applicability of research results, people's perceptions must be given adequate emphasis. It has been learnt over time that there is need for greater emphasis towards improvement of indigenous plants and shrubs using both conventional and non-conventional approaches. The indigenous plants being well adapted to the region pose no threat to the balance of existing ecosystem and their adoption by people is also easy.

Systematic surveys have generated lot of useful information on all aspects of the region. It has been realised that little emphasis has been placed on collection and conservation of wild diversity. The immense plant and animal wealth of the region has many species of economic value that are now endangered. It has been learnt that it is important to conserve such biodiversity and there is also need for collection, cataloguing and verification of ITK existing in the area about indigenous flora and fauna.

The farming system in the Indian arid zone is largely livestock based. The research efforts were not in proportion with the significance of animals in this region. It has been a common knowledge that we have the best breeds of animals which are thoroughly adapted to this region. There has been some changes in the animal population pattern and it is likely to continue in areas where irrigation is becoming available resulting in loss of breed's purity. It is now apparent that without concerted efforts towards improvement in management, fodder production and processing, and all aspects of nutrition, the full potential of these breeds cannot be realised.

Farmers have limited period for arable farming in this region. They have spare time to be engaged in processes that may help in earning additional income. The little efforts made in this direction need to be intensified.

Desert pests including rodents have unique methods for survival. These pests proliferate rapidly during favourable conditions resulting in epidemics. Importance of their control was realised long ago, but the complexity of the region and fluctuations in disease pattern due to variations in climatic conditions have made the task difficult. Hence increased effort on integrated pest control is warranted.

Judicious use of limited water is the key to successful agriculture in this region. It has been learnt that more methods for efficient use of limited water need to be developed, as prolific use of this resource in canal areas is going to lead to environmental hazards. Further only those approaches may produce results which can be adopted by individual farmer and may give immediate benefits.

For sustainable development of the arid zone the areas not adequately explored hitherto need priority in coming decades. The areas of research requiring further in depth study are :

- On-farm development of farming systems for different Agro-ecological situations.
- Improvement of indigenous species of trees/shrubs and grasses – role of biotechnology.
- Cows/buffaloes in Farming system; their water requirement and nutrition.
- Value addition, fodder/fruits/vegetables.
- Technology for IPM.
- Indigenous agricultural tools/equipments and their improvement.
- Sprinkler irrigation technology including water requirement of different crops in sandy, duny/hummocky areas.
- Drip irrigation for vegetable/fruit production in hard pan areas of IGNP.
- Mapping of desertification parameters and identification of sustainability indicators.
- Biodiversity (Floral); economic medicinal plants - Agro-techniques and improvements for domestication.
- Soil and water conservation, use of vegetative barriers.

Linkages with national and international organizations and VO's will be further upgraded. **Being a public R & D organization, it will be obligatory on our part to undertake long-term high-tech research as well.** In-built mechanism for coordination of the research system with greater credibility and accountability needs to be developed. The organizational structure will be suitably geared to achieve this goal. Updating of infrastructure is an absolute necessity. Modern Information System needs to be put in place. HRD is a priority area particularly in the case of modern research and information systems. Finance has been a constraint not only for setting up a good infrastructure but also for research contingencies as well. All out effort are, therefore, required to be much more visible to attract funds from national and international organizations.

OUR CONCERNS

In view of :

- Environmental constraints and fragility of resources
- Growing human and livestock population
- Low production potentials
- Shortcomings in land use and tenure systems

The only way for sustainability is ALTERNATE LAND USE SYSTEMS.
(Integrated production systems involving crops, perennials and livestock.)

6. SCENARIO

About one-sixth of the world population, 70% of all drylands amounting to 3.6 billion hectares and one quarter of the total land area of the world is affected by degradation and desertification. Degradation has affected nearly one quarter of the irrigated land, one half of the rainfed croplands and three quarters of the rangelands of the world. Among continents, Asia has not only the highest percentage of land degraded in all the three categories but the rate of land degradation is also estimated to be the highest. It is thus, imperative that such a scenario calls for protective, corrective and rehabilitation measures. These measures, however, will vary in different arid areas of the world in view of their specific environmental and socio-economic set up. For example, much of land rehabilitation input can be labour intensive in view of high population density (90 persons/sq. km) in the Indian arid zone. This is not so in American and Australian or Central Asian arid areas of Russia where it has to be essentially a mechanized process. Thus one has to think globally but act locally in rehabilitation of degraded lands to bring them to pristine levels of productivity.

ENVIRONMENTAL SETTING

The Indian arid region occupies 0.32 million sq. km of hot-desert located in parts of Rajasthan (61%), Gujarat (20%), Punjab & Haryana (9%) and Andhra Pradesh & Karnataka (10%) (Fig. 5). This region experiences low and highly erratic rainfall, extreme variations in

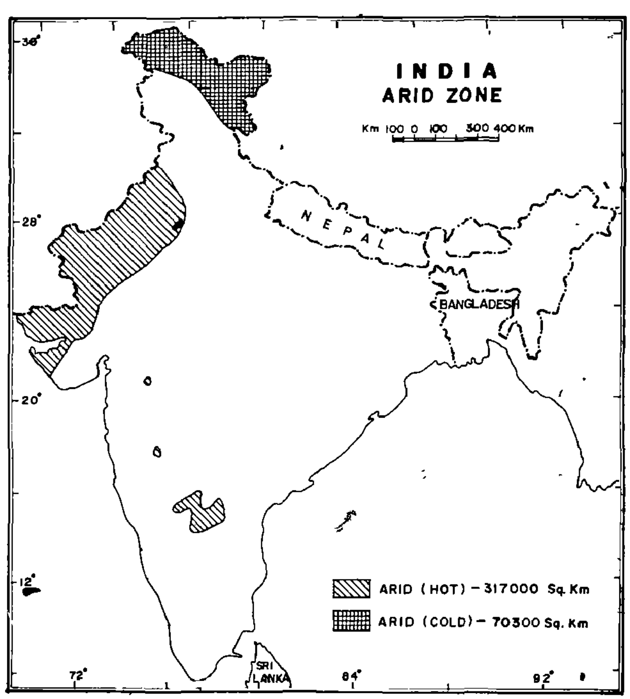

Fig 5. Arid zone of India.

diurnal and annual temperatures, high wind regime and high evaporative demand. The annual rainfall in western Rajasthan varies from less than 150 mm in west of Jaisalmer district to about 500 mm in Jalor district. Arid areas in Haryana, Punjab, Gujarat, Maharashtra, Karnataka and Andhra Pradesh receive rainfall in the range of 250 to 700 mm. The cold arid region of Ladakh receives only 90-120 mm of rainfall in an year. Air temperatures in hot arid zone vary from -2.0° to 49.0°C. The annual evapotranspiration over this region is between 1350 mm and 1900 mm, which is 3 to 5 times higher than the available rainfall.

For generating location specific and need based research, ICAR identified the following agro-climatic zones in India, which broadly represent the arid to extreme arid climatic conditions ;

ICAR (NARP) zone No.	Name of the region	Rainfall (mm)	Major soil
89	Arid western plains of Rajasthan	100-300	Desert (Rhegosolic)
90	Irrigated north Rajasthan	100-350	Desert/grey brown
91	Transitional plains of Rajasthan	300-350	Desert/grey brown
92	Transitional plain of Luni basin	300-350	Desert/grey brown
29	Western zone of Haryana	< 500	Calcareous/sierozemic
88	Western zone of Punjab	< 400	Old alluvial
24	North-west Gujarat	250-500	Grey brown/delatic alluvium/red sandy/medium black
70	Scanty zone of Maharashtra	500-700	Medium/deep black
6	Scarce rainfall zone of AP	500-700	Red loamy/medium black
40/41	Central dry zone of Karnataka	455-717	Red sandy/deep black medium black
—	Cold arid zone of Jammu & Kashmir	83	Skeletal (mountane meadow soils, tarai soils)

Two-thirds of the Indian desert is made up of aeolian sands in the form of dunes and plains of varying degree of hummockiness. The aeolian sediments are low in clay and silt and show a predominance of fine sand. In the southeast of the Thar there is a small extent of older alluvial plain formed by the streams originating from the Aravalli range.

The dune soils are highly sandy, with 75 to 98% sand, and are mainly concentrated in the west of 250 mm rainfall zone. Light brown sandy soils occur extensively in the 250 to 450 mm rainfall zone. These are characterized by a sandy, occasionally loamy fine sand, structureless surface layer and sub-angular blocky sub-soil. The brown light loam are formed on ancient aedian sands, which have also undergone a limited reworking by alluvial activity. Red and black soils occupy the arid parts of Andhra Pradesh and Karnataka.

SWOT

Parameter	Strengths	Weaknesses	Opportunities	Threats
Climate	Well defined monsoon cycles as compared to other deserts	Low and erratic rainfall, High evapotranspiration, Temperature extremes, High winds and solar radiation	Alternate sources of energy can be developed, Evolution of unique vegetation in response to these climatic stresses, Low Disease & pest incidence, clean environment	Desertification gets aggravated by climatic situation, Frequent droughts limit productivity, Instability in production system
Landforms	High biological production potential, Vast land availability	Rocky land-forms have poor debris and hence scarce vegetation, Unconsolidated nature of deposits.	Natural topography (especially rocky areas) helps in water harvesting, Alluvial plains are highly productive, Younger alluvium has more potential for shallow ground water	Aeolian hazards and consequent desertification
Soil	Sufficient nutrient reserve to support rainfed crops and natural vegetation	Poor in soil moisture retention, organic carbon and nitrogen	Easy to till, Self mulching	Prone to wind erosion
Water	Ground water is available in pockets, Traditional water harvesting structures like *Khadins*, Ponds, *Tanka* well developed	Deep, poor quality, Saline/sodic in most of the area, Isolated acquifers with low discharge potential	Rann as source of common salt, Buried channels of water can be exploited, IGNP command area becoming available, Excess water from flash floods can be stored and used subsequently	Over exploitation leading to expansion of dark and grey areas, Water logging and salinisation due to improper use in the Gypsiferous IGNP area, Animals and human beings both consume water from common point leading to water borne diseases

Parameter	Strengths	Weaknesses	Opportunities	Threats
Plant wealth	Rich in diversity and life forms which are well adapted to this area, Complementarity in availability and nutrient content of woody perennials and herbaceous flora	Slow growth, Sparse cover, Poor yielders	Better stand management, Utilization of high value economic plants, Potential source of adapted genes, Can be developed as two-three tiers system in Agro-silvi-pastoral systems	Over utilization aggravates desertification and loss of biodiversity
Livestock	Well adapted good breeds of cattle, camel, sheep and goat	Unplanned breeding and gene dilution; there is high population of unproductive animals	Better herd management, Gene utilization, Grazing management, Nutritional and health care management	Loss of purity
Cropping and Land-use	Highly adapted crops, Well developed traditional farming systems	Low acceptability of technological advancement; subsistence farming	Crop diversification, Integrated farming system, Efficient water Management and utilization	Land fragmentation, Over cultivation on marginal and sub-marginal lands
Human	Man power availability, Traditional wisdom including coping mechanism, Strong social organizational structure	Under utilized manpower, Illiteracy and less receptivity, Rigidity towards traditional organizational structure and livestock system, Resource poor, Drug (Opium) addiction of narcotics, Migratory habits	HRD through vocational training, Alternate sources of livelihood, Collective utilization and management of CPRs	Increasing human population, Under employment

Parameter	Strengths	Weaknesses	Opportunities	Threats
Research	Multidisciplinary competence available	Less emphasis on HRD, Financial constraints, Poor linkages	Modernization of infrastructure, Updating of knowledge and skills of personnel, Increasing collaborative and inter-institutional linkages	Scientific stagnation, poor salary structure compared to other organizations
Development	Adequate developmental agencies exist	Inadequate technical upgradation, Poor technology adoption, Inadequate infrastructure at grass root level and lack of networking, Lack of participatory approach in farming system, Lack of parity in benefit sharing among stake holders	HRD by training and incentives	Poor dissemination of technology, Sectoral planning in development, Lack of coordination among development agencies, Bureaucratic bias for short term gains

LAND USE

The predominant land use system in the arid zone is rainfed farming mixed with animal husbandry. Total cultivated area is 59.2% of which 9% is irrigated. It is expected that with the harnessing of entire surface and groundwater potential for irrigation, nearly 80% of the area shall still continue to be rainfed in the foreseeable future. Owing to ever increasing pressure of human and livestock population, over exploitation of natural resources will further aggravate degradation unless the trend is reversed with strong public cooperation and Government intervention.

Over exploitation of groundwater and unplanned irrigation has resulted in decline of discharge from wells on one hand and salt accumulation in soil , on the other. Opportunities do exist to improve the productivity of the soil by adopting various conservation and ameliorative measures. Strength lies in the resources unexploited hitherto. Gypsum deposits could be gainfully deployed to rehabilitate sodic soils. Livestock is the mainstay of desert people, providing employment to about two-third of Rajasthan's population. **Thus improved livestock husbandry is a must for faster growth rates and better production both in quality and quantity**. There is tremendous potential to deploy environment-friendly animal power for drought purposes.

Land Use in Arid Rajasthan (%)

Years	Net sown area	Cultivable waste land + Pasture land + Trees	Fallow land	Area not available for cultivation*	Forest
1960	39.42	26.03	19.49	14.28	0.78
1970	44.73	25.54	14.50	14.45	0.78
1980	47.44	28.77	14.18	8.25	1.36
1990	49.56	26.36	13.67	8.55	1.86
2000	51.56	24.07	13.15	8.72	2.50
2010	53.56	21.85	12.56	8.90	3.34
2020	54.87	19.72	11.95	9.03	4.43

* Area not available for cultivation includes barren lands and area put to non-agricultural uses.

The region is endowed with diverse flora and fauna that may be gainfully utilized for various purposes. The endemic biota have developed in perfect harmony with the harsh desertic ambience and may serve as basic gene pool for improvement programmes. The Institute's main strength lies in an integrated interdisciplinary approach for resource appraisal and development including flora, fauna and human factor. Tremendous opportunity exists to utilize a variety of indigenous, hitherto under exploited plants. The plant products may also have industrial uses. Diosgenin successfully obtained from *Balanites* is an example. The grasses, perennial herbs and woody plants endemic to the region form valuable source material for improvement through selection and breeding processes. **Loss of biodiversity is the biggest threat . It warrants immediate corrective measures to avert extinction of valuable genetic material.** A major weakness lies in the non-availability of the inventory of the fauna, insects, birds, wildlife, etc., associated with different types of vegetation and they reflect extinction or conservation of floral biodiversity in the region. The livestock breeds of the area form a treasure asset as they excel in productivity under stress conditions and possess disease and pest resistance.

DESERTIFICATION AND SUSTAINABILITY

The fragile desert ecosystem has been sustaining the vagaries of harsh environment and the activities of man, livestock, wildlife and natural calamities for centuries. The growing pressure of human and livestock population has resulted in considerable degradation of the natural resource base. Overgrazing, insect damage, wildlife activities and indiscriminate destruction of woody plants by the man have accelerated the process of desertification. Yet it has not reached the irreversible stage. Extensive data base on the processes of desertification, resource inventories and socio-economic structure available at the institute can be gainfully utilized in the application of technologies to reverse the trend.

The research efforts are being directed to continuously review the technologies and upgrade them to keep up with population and economic growth for sustainable development.

The tradition bound rural communities of arid zones have been relying on age old time tested practices of cultivation and livestock management. Many alternatives are now available to farmers as a result of continuous research efforts. **Crop diversification is vital for insurance against risk and for this purpose reluctance on the part of the farmers in accepting the change will have to be overcome.** Range of indigenous and exotic plant materials available for cultivation either as supplement to existing crops or as replacements, however, constitute a source of strength. Adoption of integrated farming systems (crops + grasses + trees/shrubs/horticultural crops + animals) may mark the beginning of positive change in the lives of people in the region.

Trends in both agricultural and livestock production vis-a-vis income over the years can be indicators of status of living standard of people. From 1960-61 to 1990-91 the actual per capita income has been low, which is likely to continue even up to 2020. However, there is a potential of vastly increasing the per capita income. This would be possible only if various technological modules for increasing crop - livestock productivity are vigorously followed up. This calls for a serious R&D initiative in this region.

CAZRI is one of the few institutions across the world engaged well over three decades in addressing the issues related to the problems of the arid areas. The efforts were concentrated on development of cost-effective technologies for resource constrained desert community. Developmental programmes like afforestation and sand dune stabilization, have been carried out by state Government agencies over large areas. Since the Thar desert is world's most populous desert, the problems associated with human and livestock populations are endemic to the region. Despite the climatic vagaries, the production of food grains has been only marginally low than the requirement. To minimize deforestation, it is necessary to provide the desert dwellers alternate energy sources for cooking. In this context solar and wind energy has to be tapped both for agricultural and domestic uses. Solar appliances have been developed for cooking food and feed, heating water, making candle, drying agricultural produce, etc. Efforts are now being intensified to make a dent in photovoltics.

Interdisciplinary teams of scientists are engaged in finding solutions to the multidimensional complex problems faced by the farmers in the region in order to increase the productivity of the systems while protecting the environment. Problems of arid areas are different from other ecozones. Research in CAZRI is directed to these issues. **Strength of scientific community is the faculty consisting of specialists from as many as 33 disciplines - perhaps the largest number in any single ICAR Institute in the country.** However, existing research facilities in the Institute need further upgradation. Opportunities appear to be immense as scientists are now encouraged to generate financial resources from external agencies.

PROBLEMS - EMERGING TRENDS

Deserts have their own fascination, unique features and resources. These fragile ecosystems have unique problems as well. The most obvious is land degradation resulting from climatic variations and human activities (unplanned and ruthless exploitation) and increasing pressure of human and livestock population.

At present, nearly 68.32% area of arid Rajasthan (1,42,771 sq. km) is already affected by wind erosion/sand deposition. If destruction of natural vegetation and overuse of marginal lands continue unabated, upto 9% more land may be affected by moderate to severe wind erosion in the next 3-4 decades. Areas affected by water erosion and gully formation have increased @ 0.71% per year from 1958 to 1986 in western Rajasthan. In the year 1986, 355 km^2 area was affected by such degradation. If the same rate continues then by the year 2020, 441 km^2 area will be affected by water erosion.

Low and erratic rainfall and greater demand for water due to increasing population result in over-exploitation of groundwater. The balance between annual recharge and groundwater withdrawal has been disturbed and the water table is fast depleting in about 75% of the area i e. in 198 development blocks of western Rajasthan. As per an estimate, about 50% ground water resource has already been utilized. The water table is falling @ 0.20 to 0.40 m per year in Jhunjhunu, Sikar, Nagaur and Pali districts. With the present trend of water use, it is expected that by 2020 AD a major part of Thar desert will be devoid of economically viable groundwater resource. On the other hand, in the IGNP Phase I area, the water table is rising @ 0.16 to 0.33 m per year leading to water-logging and salinity problems.

Nearly 65% area in the Thar desert has saline groundwater. Therefore, the local population is more dependent on the surface water resources. Water harvesting in the form of village ponds (*nadis*) and *tankas* is common for meeting the drinking water demand of the inhabitants. There is a reduction in catchment area of water bodies from 180 to 220%, over a period of 28 years (1958-86) resulting in 6 to 8 times decrease in their capacity. It is expected that by 2020 AD, these water bodies may slowly degenerate. Greater efforts for their maintenance and protection are needed to reverse this alarming trend.

The area degraded by irrigation with sodic waters and waterlogging is estimated to be 2000 sq. km by 2020 AD. Indira Gandhi Canal is a major canal network in the region (Fig. 6). In command area of Indira Gandhi Nahar Pariyojna, as much as 3195 sq. km area is likely to be affected by water-logging and salinisation by 2020 AD unless projections assume a situation when no technological interventions are made (Fig. 7).

Water being the most limiting factor in this region, dryland farming has been the main occupation. However, the productivity of rainfed lands over years has not registered significant increase. The increase in crop production and productivity has come mostly from irrigated areas. Animals which have higher productivity than the average national productivity have been providing certain degree of sustainability to the system.

North western part of Rajasthan desert is undergoing a great agroecological transformation due to incoming of Indira Gandhi Nahar Pariyojana (IGNP). A great extent of canal command area is being promoted for crop based agriculture thus opening new vistas for economic development. This has also led to water logging and changes in pest

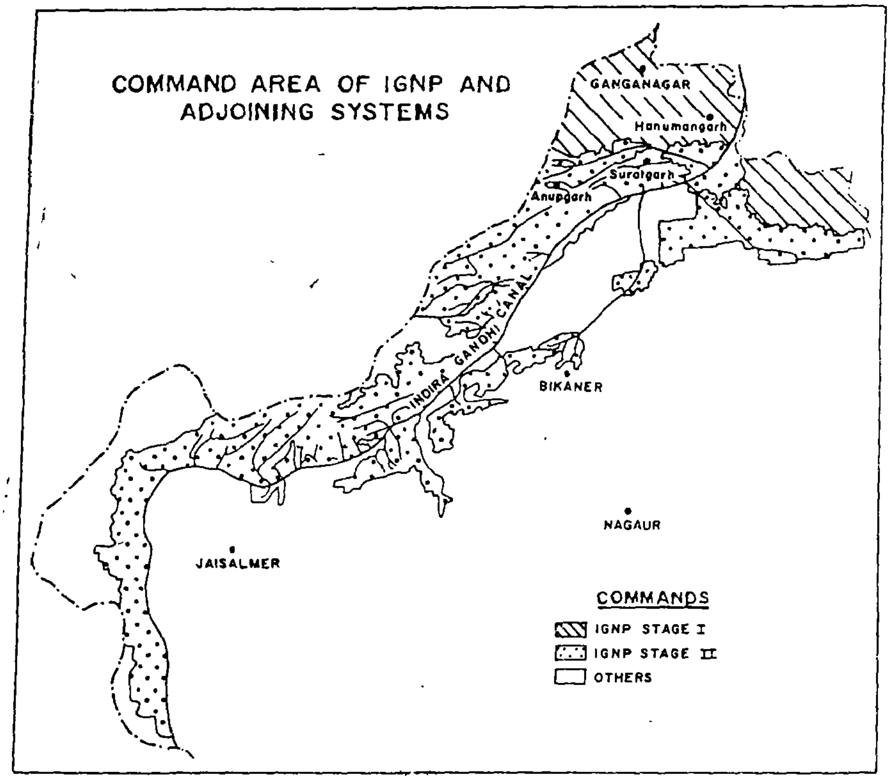

Fig. 6. Command areas of IGNP and adjoining areas

complex and increase in buffalo population. For example rodent *Bandicota bengalensis* and *Nesokia indica* migrated from Punjab to Northern Rajasthan and typical desert inhabitants like *Meriones hurrianae* and *Gerbillus gleadeni* have almost disappeared. Irriga-

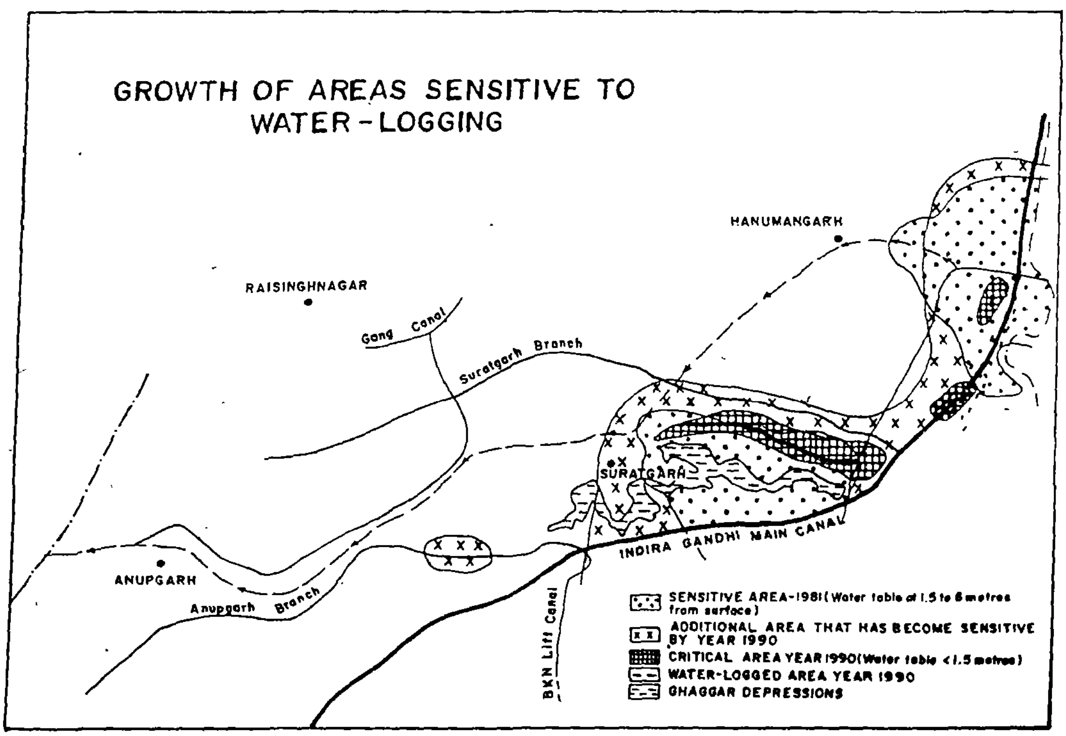

Fig. 7. Growth of areas sensitive to water logging

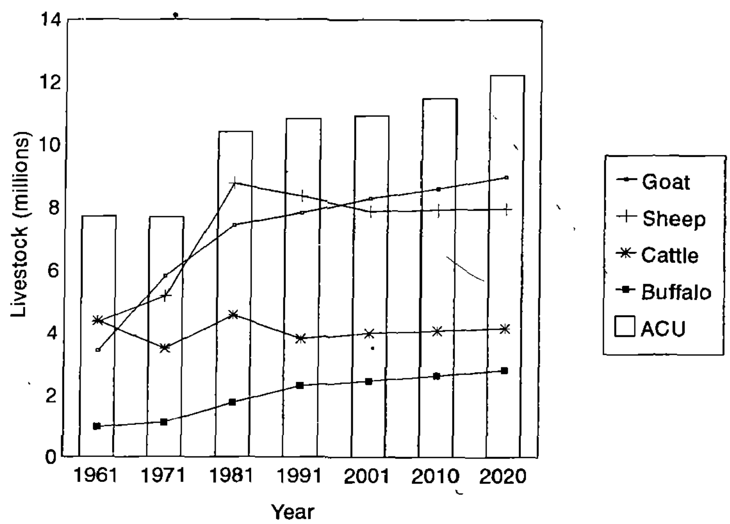

Fig. 8. Livestock population of arid Rajasthan.

tion has also created favourable environment for insect multiplication and xeric insect complex is getting replaced by mesic fauna like jassids and defoliators. With the introduction of irrigation facilities, especially canal irrigation, the buffalo population in arid and semi-arid Rajasthan has increased by more than 218% (23 lakh - 1992 census) during the last 35 years against the national increase of 60%. By 2020, buffalo is expected to gain popularity over cattle in terms of milk production, especially in areas around IGNP.

The livestock population in terms of adult cattle unit (ACU) was 9.6 m ACU in 1983 and is projected to increase to 11.3 m ACU by 2000 AD (Fig. 8). Likewise the fodder deficit on dry matter basis, that was 14.9 m tonnes in 1983 would be 28.2 mts by 2000 AD (Fig. 9). These and subsequent projections are based on past trends. The quality of livestock has been continuously deteriorating in terms of genetic purity. For instance, one of the hardiest and best cattle breeds Tharparkar, is now estimated to have only 10%

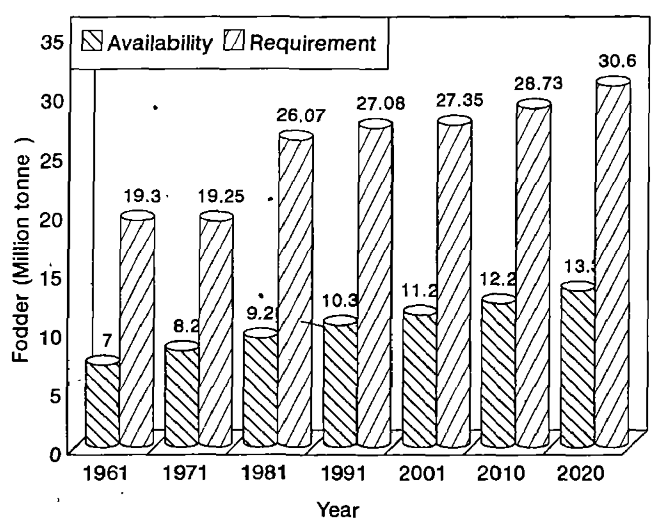

Fig. 9. Forage availability and requirement in arid Rajasthan

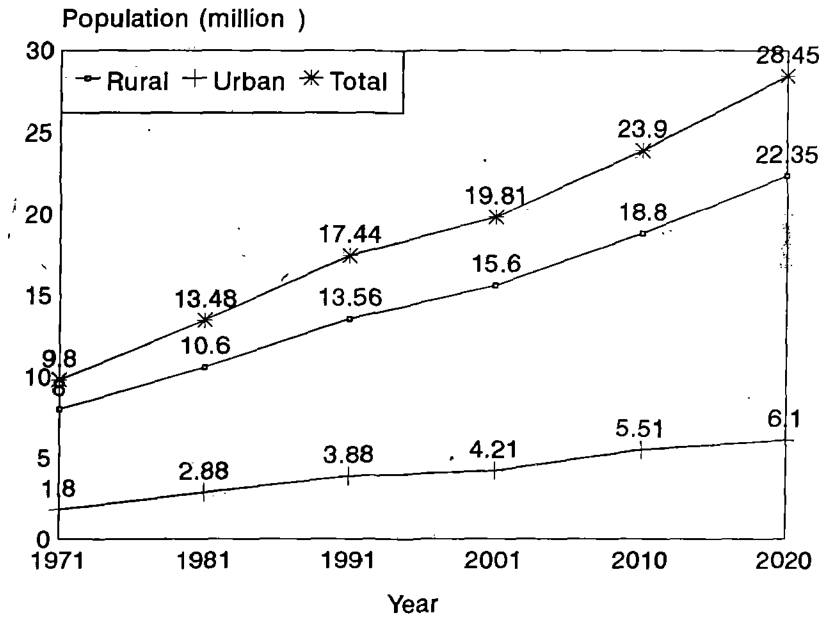

Fig. 10. Human population in arid Rajasthan

purity. There is a shortfall of almost one third of the total fodder requirement. The available feed is largely of poor quality. Large areas of pasture lands are getting degraded due to overgrazing caused by both increase in livestock population and decrease in area available for grazing. Fluctuations of rainfall and extension in cropped acreage further contribute to the problem.

Human population in arid Rajasthan was 17.44 m in 1991 and is projected to increase to 28.45 m by 2020 AD (Fig. 10 & 11). In the past the average size of land holding has been decreasing. It was 17.77 ha in 1951, 14.69 ha in 1961, 10.20 in 1971 and is only 6.0 ha at present. If the trend continues, it is likely to be less than 4.0 ha by 2020 (Fig. 12). Land distribution is uneven. Just 11.2 per cent households own 50 per cent of

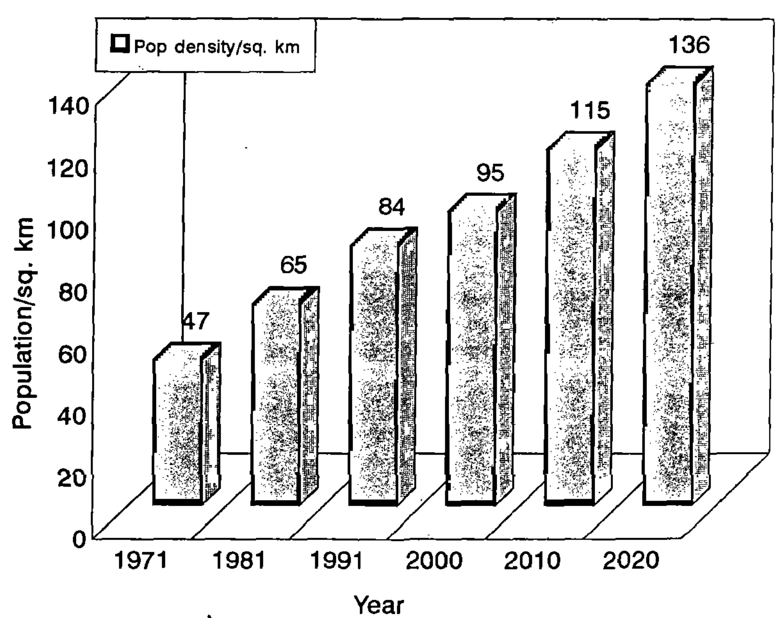

Fig. 11. Human population density in arid Rajasthan

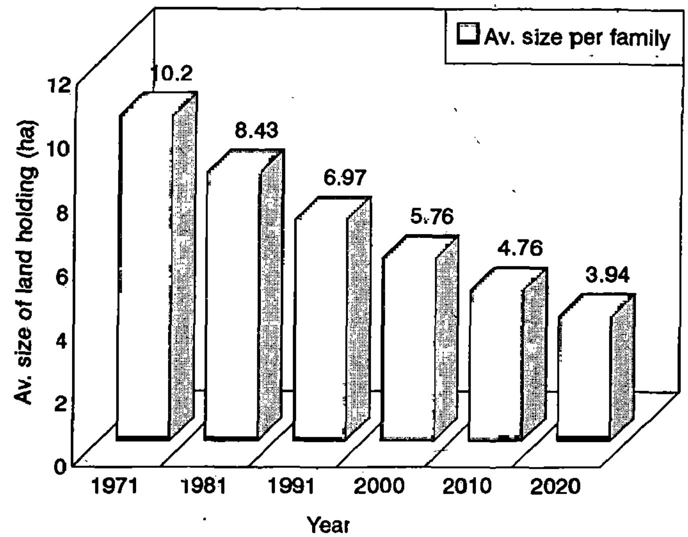

Fig. 12. Average size of land holdings per family in arid Rajasthan

the total land in the region, whereas 47.3 per cent hold only 10 per cent of the total land.

Owing to reduction in average size of land holding the practice of fallow farming has been disappearing and cultivation of marginal lands is on the rise. For example, fallow lands in Barmer district have come down from 73% to 38% in the last four decades. Similarly, in Jaisalmer district net sown area increased from 11000 ha in 1952 to 2,34,000 ha in 1988. Another consequence of population hike is the increase in overall cropping area, being 32% in 1952, 50% in 1991 and is likely to be around 55% by 2020 AD.

As per present trends of crop production in arid Rajasthan, the production of cereals, pulses and oils will be 26.27, 10.71 and 1.52 lakh tonnes by 2020 (Fig. 13) but despite this there is likely to be a decrease in per capita availability (Fig. 14).

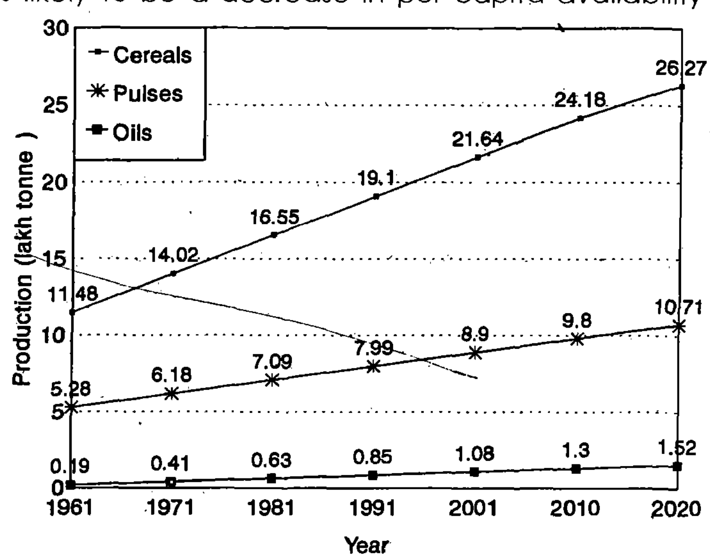

Fig. 13. Production of Cereals, Pulses and Oil Seeds in arid Rajasthan.

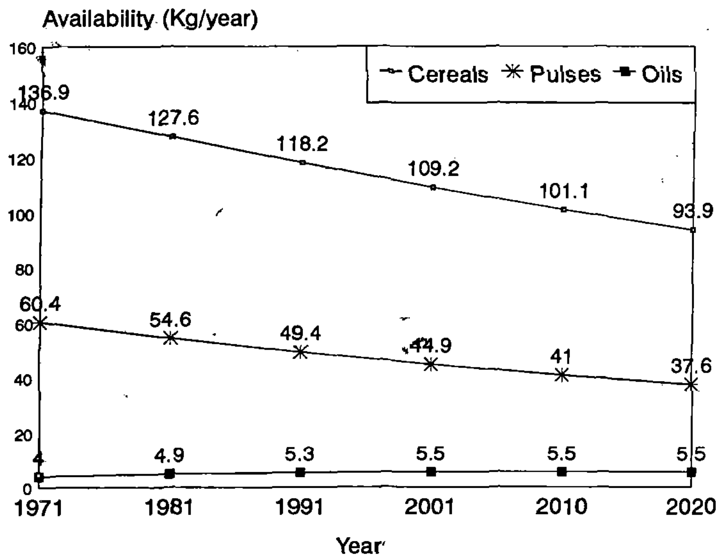

Fig. 14. Per capita availability of Cereals, Pulsdes and Oils by 2020.

The value of agricultural and livestock production in Rajasthan was Rs. 900 million in 1960 and the same is expected to be more than Rs. 1.3 lakh million by 2020 AD This rise in value, however, is not expected to lead to proportional rise in per capita income because of increase in rural population that was 6.28 million in 1960 and is expected to be 22.35 million by 2020 AD (Fig. 15).

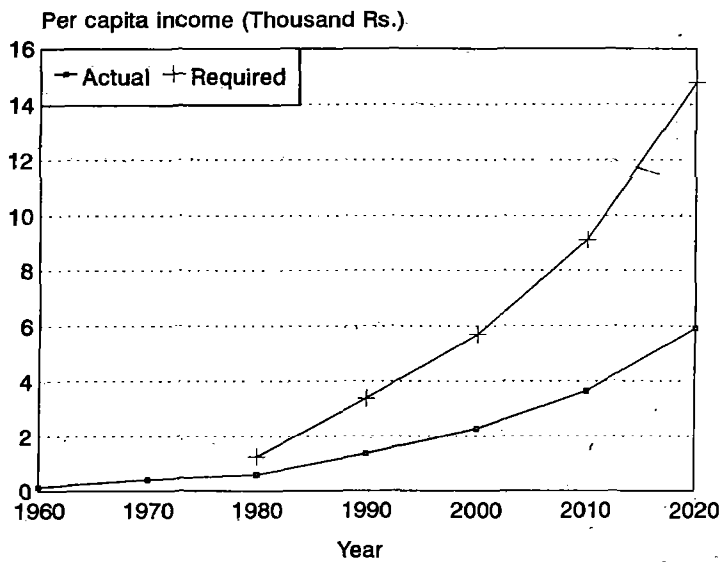

Fig. 15. Actual and required per capita income in rural areas of Rajasthan.

Further overexploitation of natural resources will worsen social disparity and create a host of other socio-economic problems. Though sustainability considerations demand that productivity should increase in proportion, but with the population growth this seems difficult to realize unless some major policy interventions are carried through.

7. PERSPECTIVE

Ecological considerations demand that only judicious exploitation of resources should take place. Economic compulsions, however, are forcing the farmers to cultivate the marginal lands. **The problem is thus essentially that of human ecology. Despite the fact that these valuable natural resources have been over exploited and mismanaged** for several decades, **there exists a great potential for their improvement through management for sustained productivity and development of self-supporting economy.** The great Indian Thar desert has thousands of years of cultural heritage backed up by a wealth of experience on the survival in such harsh conditions. Indigenous technical knowledge (ITK) therefore needs to be thoroughly studied and improved for dovetailing with the technology developed for application in the region.

Values like protecting trees and animals, and orans (grazing lands attached to religious places), water conservation through *Khadins* and *Tankas*, and fallowing etc., have undergone rapid change during the last few decades. Many of these mechanisms of survival and resource conservation are presently under severe strain or even have broken down because of greatly increased demand and weakening of social control and collective concern. There is a need to preserve these time tested values. While applying improved technology, the wisdom of the traditional practices is often lost sight of. **Willing participation of local communities and rural institutions in R&D efforts, therefore, assumes high priority.** Besides, sustainability considerations demand a far greater effort at population control.

During the last three decades considerable research efforts have gone into developing appropriate technologies for sustainable development of arid areas. However, only a few of them have gone to the farmers' fields due to both tardy extension efforts and technological limitations. One of the strategic issues has been greater reliance on top down approach as a result of which the peoples' involvement was negligible. DPAP and DDP could have been the ideal opportunities for demonstration and eventually adoption of many such technologies but due to lack of inter-sectoral coordination and adequate research back-up, these programmes could not make much headway in realising the set out targets and objectives.

By substituting low yielding varieties with high yielding ones, area under arable crops can be reduced by 30 to 40%. Thus, sizeable area which is marginal but cultivated and overused can be relieved from this pressure and brought under pastures alongwith plantation of shrubs, trees and horticultural species for sustained productivity.

As mentioned earlier the population of the arid region will go on increasing and is likely to get doubled by 2030 unless suitable policy decisions are taken to control this trend. The problems are bound to be aggravated more and more resulting in further degradation of natural resources and desertification. Admittedly, further improvement in plant types and conservation and efficient management of rain water can certainly help in increasing the productivity of arable farming in this region. However, it may fall short of meeting the growing demands of food during the years to come. Limitations of low rainfall/drought will continue to loom large as ever. Therefore, a shift to a production system that is more sustainable may be desirable. Incorporation of horticultural and other perennials and animal in the system can provide considerable stability.

It is well known that in **ancient times, animal husbandry was the mainstay of this region. Arable farming occupied only a subsidiary position**. If, water bodies for meeting the drinking water requirement of animals can be developed in water scarcity areas, animal husbandry can be put in place. This eventually may stabilize the productivity of this region at a much higher level. Therefore, **in overall perspective, our endeavour should be to develop an integrated farming system comprising arable and alternate land use systems coupled with livestock management. The efforts can be diverted in gradually enlarging the scope of animal husbandry by upgrading and intensifying research on livestock management linked to forage production.** In such a system a major area of land (particularly marginal and sub-marginal) which is hitherto cultivated can be put under silvi-horti-pasture. Increase in the availability of organic manures from animals will help in greatly enhancing the soil fertility of relatively smaller area of farmers practicing arable cropping. This way, the dependence on fertilizers can also be reduced whose cost is likely to increase substantially in future and may eventually become prohibitive for dryland farmers. **Sand dunes and other degraded lands (both government and farmer owned) when put under grasses, shrubs and trees, with proper management can become inexhaustible sources of forage supply in this region**. This goal can be realised through **mission oriented on-farm research with a farming system perspective and bottom-up (farmer-first and farmer-last) methodology**. When benefits of livestock farming vis-a-vis arable cropping based farming system are demonstrated to the farmers through on-farm research the adoption would be forthcoming. Needless to say that **the farmers have lot of wisdom and they would not hesitate to adopt the new approach once its benefits are unmistakably and visibly demonstrated.** This will necessitate research in areas of direct relevance to the region. Some of the areas requiring **thrust** are :

- On-station and on-farm research on development of sustainable farming systems models (Crops + horticultural crops + trees + shrubs + grasses + livestock) based on socio-economic aspects and land use planning - assessment and fine tuning for different agro-ecological sub regions.
- Integrated watershed management or index catchment and rehabilitation of degraded lands.
- Biotechnological improvement of indigenous trees/shrubs/grasses/crops.
- Biodiversity - identification, agro-techniques and process development.
- Post harvest technology and value addition.
- Desertification monitoring/mapping of desertification parameters.
- Energy management (wind and solar).
- Empowerment of farm women.
- Technology transfer including training.

8. ISSUES AND STRATEGIES WITH OPTIONS

There is a vast gap in the standard of living between poorly endowed drylands particularly in arid zone and high capacity irrigated areas of the country. Enhancement of productivity of arid and drought prone semi-arid areas on a sustainable basis is thus the key issue that defines the national goals under New Agricultural Policy. **Underlying issues are conservation of resources and protection of the environment.** By combining the two, improved quality of life of people can be ensured for the present generation and posterity. Land degradation due to various factors including technogenic processes has been resulting in progressive decline of productivity in many areas. This trend needs to be reversed by appropriate scientific interventions in tune with socio-economic fabric and farming systems perspective.

As stated earlier, population will go on increasing upto around 2030. Thereafter, perhaps it may stabilize. The socio-economic growth entails the growth in human needs as well. This means that the productivity should register an upward trend on a continuous basis to match the growing demands resulting from population and economic growth. This underscores the goal of sustainable development - a formidable challenge indeed. Suitable R&D initiatives can no doubt provide the appropriate answers. They have, however, to match with the task, challenging as it is.

In research, the institutional options available are government organizations, SAUs, Voluntary Organizations (VOs) and Private Sector. In many instances, they all have been working in isolation. Many VOs have a committed cadre, though trained only in a particular aspect which has been a limitation to develop and propagate sustainable land use. Similarly, private sector is better tuned to commodity research. From their traditional fields of chemicals, fertilizers, etc., now they are diversifying to plant/animal improvement and related areas.

The responsibility of integrated research will continue to be shouldered largely by Government funded research systems i.e., ICAR institutes and SAUs. CAZRI, an institution in this category, has hitherto followed a strategy comprising inventorization of resources, development of integrated technologies for their sustained utilization and front line technology transfer. Preparation of resource inventory has been a painstaking and time consuming task. GIS and remote sensing are the options being put to use to overcome this time lag.

In technology development, the client factor was not quite emphasised. Hence, improvement of what the farmer is already doing including refinement of ITKs did not receive the desired priority. For instance, up to 70's greater reliance was on exotics than on indigenous tree/shrub species. The fast growing quality, for obvious reasons, was the criterion in which exotics like *Acacia tortilis* excelled. At the same time, however, efforts should have also been initiated to improve the local species like *Prosopis cineraria, Acacia senegal, Tecomella undulata, Capparis decidua,* etc., which are so much liked by the people. The present research strategy has since taken care of such limitations.

For frontline extension, the institute employed a three pronged strategy i.e., operational research, training of development personnel and farmers apart from mass communication activities like **Kisan Mela** (Farmers' Fair) exhibitions and messages through print and electronic media.

Operational research on sand dune stabilization and management was started as early as mid fifties. This programme was undertaken on government lands. The forest department, thus, could replicate the technique over large areas of government lands. Other agencies could not do so on farmers lands due to application constraints specific to farming system *in vogue*. Further, most of the on-farm research efforts were largely sectoral. Integration among components like dryland farming, arid horticulture, animal husbandry, forage production and amelioration of degraded lands, was not to the desired level. Similarly, training was not adequately linked to on-farm programmes and therefore the impact fell short of the objectives.

In technology transfer, the prime issue obviously is the real participation and adoption by clients i.e. farmers. If the technology does not conform to the socio-economic fabric of the society it will not be adopted, howsoever useful it may be for conservation of resources and protection of environment. Therefore, systems approach integrating all the activities the farmer is pursuing in utilizing the natural resources for his livelihood, on one hand and various extension activities, i.e., training, communication and on-farm research on the other, need to be developed and implemented.

It is abundantly clear that there are no alternatives to this major approach. Only such a strategy can make the desired impact and create models of technology transfer which can be replicated over large areas. The central issue here is the development and formalisation of strong linkages. ICAR institutes and SAUs need to work hand in glove with state departments and VOs with close involvement of grassroot institutions like Panchayat and the farmers. Realising such gaps, the present technology transfer strategy of CAZRI is built on this issue related to farming systems perspective and linkages. Modern tools like PRA techniques can be handy for involvement of people. Gender issue is the other area that merits greater attention. Women folk being the equal partners in agriculture with men, need to be mobilized in a big way. Techniques for developing avenues for employment for raising household income need to be identified and adopted. Sustainability goal can be reached only when the farming system continuously responds to the needs of the society.

In developed countries, sustainability considerations are more directed to quality of produce rather than yield per ha, and also for environment protection. In India and other developing countries burgeoning population regimes set the tone in defining the sustainable farming system as the one which sustains the land as also the increasing yields, apart form environmental and quality considerations. Sustainability of production system is therefore, the major issue of 2000 AD and beyond. On-farm farming systems research backed up by quick resource appraisal and on- station research is the strategic requirement for reaching this goal, in resource poor arid region of India.

9. PROGRAMMES

(A) RESOURCE APPRAISAL AND MONITORING

i. INTEGRATED BASIC AND HUMAN RESOURCE APPRAISAL, DESERTIFICATION MONITORING AND MODELLING

Desertification

Soil erosion/deposition due to wind and water, salt accumulation, degradation of vegetation and technogenic spoils have been identified as the processes of desertification in the arid zone. These need to be monitored over time. Studies will be taken up **to standardize the parameters/indicators for measuring desertification at field level.** Effect of desertification on soil quality will be studied. Representative sites will be selected and **monitored using remote sensing and GIS.** Desertification status maps will be prepared for the arid areas of Gujarat, Punjab and Haryana, as already done for Rajasthan.

Resource appraisal

Integrated basic resource appraisal needs to be carried out in the following areas :

Rajasthan - Churu, Jhunjhunu, Pali districts and extremely arid belt of Jaisalmer - Shahgarh-Tanot sector.

Gujarat - Banaskantha, Rajkot

Arid areas of **Haryana, Punjab, Andhra Pradesh, Karnataka** and **Maharashtra.**

Cold desert - Ladakh (J&K), Lahul, Spitti (H.P.)

Remote sensing and GIS will be the main tools for quick resource appraisal.

Major Land Resource Units (MLRUs)

The appraisal of natural resources, landforms, soil surface and ground water, vegetation, landuse, land degradation and human resources is integrated to form composite units called the MLRUs. These units have provided basis of recommendation for development/conservation measures in Indian arid region. However, the same LRU occurring under varying Agro-met conditions may differ in production potential. Models therefore need to be developed to predict their production potential in quantitative terms. Studies on crop/biomass yield of MLRUs at selected sites in different Agro- ecological and climatic conditions will be conducted. Rigorous testing and validation of models so developed will be carried out in arid areas including Gujarat, Haryana and Punjab.

Environmental impact analyses (EIA)

Variousdevelopmental and industrial projects for irrigation, thermal power, oil and gas are coming up in the arid zone. Some of these have caused environmental problems affecting the production potential of agricultural and grazing lands. There is an urgent need for EIA of (i) Indira Gandhi Nahar Project (IGNP); (ii) Narmada Canal Command area in arid Rajasthan and Gujarat; (iii) thermal power, oil and gas mining and industrial activities; and (iv) Command area under Sardar Samand, Hemawas, Pichiak and Bankli irrigation projects. First priority will be given to studying impacts of Indira Gandhi Nahar Project in terms of water logging and salinisation, particularly in gypsiferous soils. **EIA is proposed to be carried on selected sites to help develop strategies for appropriate interventions.**

ii. SURVEY, MONITORING AND CONSERVATION OF BIODIVERSITY

High number of endemic species and occurrence of large number of sub species in Indian arid zone are due to high phylogenetic platicity and intense speciation resulting from diverse ecological conditions. This natural pool of adapted genes in plants and animals stands threatened due to large scale over-utilization and changed consumption patterns. Also, potential use of this immense biodiversity for the benefit of mankind needs further probing. Efforts to conserve germplasm of domesticated plants and animals have been adequate. Thousands of wild species, however, which are of actual or potential value for future plant improvement programme are yet to be explored. It thus becomes imperative to **initiate survey and monitoring of this biodiversity so as to evolve suitable technology for its conservation especially in the changed scenario of GATT.**

Initiation of such efforts is in line with Article 14 of Agenda 20 of RIO Earth Summit. CAZRI will particularly focus its efforts on plants and animals in the wildness that constitute a vast stretch of grazing land in the desert. Vegetation types and their successional trends on different habitats have thoroughly been studied at CAZRI. Information also exists on temporal limit to natural regeneration upon protection of degraded habitats on different landforms. Some patterns of biodiversity in grazing lands upon degradation along edaphic and moisture gradients were also studied. **It is necessary to strengthen this activity further so that need based conservation options could be evolved.** Development of multi-disciplinary set of recommendations for habitat development and regeneration, has been accepted by IUCN as 'the only way for *in situ* conservation for maintenance of viable populations.

The programme will be guided by the fact that arid ecosystems are fragile zones and respond to perturbations by their further degradation and consequent loss of variability. Further, preparation of biodiversity concentration and sparseness map will help select priority areas for conservation, on one hand, and delineate biodiversity rich areas for exploitation by future generations, on the other. The programme will involve :

- Extensive Survey of floristic and faunal biodiversity in different edapho-climatic situations in order to study pattern in various land uses, land forms and ecotones in different rainfall situations. Land source information will be integrated with biodiversity in GIS perspective for preparing biodiversity maps;

- Intensive monitoring of biodiversity on selected habitats in each edapho-climatic condition so as to understand trends of species loss in different situations; and
- Standardization of conservation techniques for species of interest for sustainable utilization of biodiversity.

B. RESOURCE MANAGEMENT

iii. ARID LAND FARMING SYSTEM RESEARCH

Low productivity of crops and animals under harsh arid conditions is not able to support increasing population. **Productivity of existing cropping systems needs to be enhanced besides developing more productive alternate land use systems.** To realise this, models of arable and integrated farming systems for sustainable productivity and resource base conservation in the region need to be developed through on-station and on-farm research. The programme is sub-divided into three major heads :

Diagnostic study

Monitoring and characterization of physical, chemical, biochemical and microbial changes in arid soils under different farming systems. Measuring secondary changes due to different ameliorative measures.

Input management

Enhancement of efficiency of water, fertilizers, manure, residues and amendments under different farming systems. Refinement of existing water harvesting techniques.

Alternatives

Assessing feasibility of alternative resources to meet nutritional requirement of vegetation. Development of simulation models for predicting efficiency of input utilization and productivity under different farming systems. Resource modelling for planning and management of resources in conjunction with inputs.

iv. REHABILITATION AND MANAGEMENT OF DEGRADED LANDS

Based on present land use and integrated basic resource survey, 7 million ha or 33% of land mass is estimated to be affected by land degradation processes. Besides environmental constraints, large livestock and human population further aggravate the problem resulting in accelerated degradation.

The management of degraded lands entails reducing the hazards of soil erosion through plantation of shelterbelts and wind breaks, rangeland management and pasture development. Rocky lands can be exploited for fuel wood plantation. Saline/sodic lands can be utilized with the use of suitable amendments and crop management. There is a need to explore native tree/shrub species which are useful for conservation/improvement of resources and also possess economic and social values. Use of polymers/organics for quick and efficient afforestation of degraded lands needs detailed investigation.

Existing technology developed at CAZRI can help in rehabilitation of such lands. It needs to be improved, however, and refined in a farming systems perspective to encourage adoption by the farmers.

v. MODELLING SURFACE AND GROUNDWATER RESOURCES FOR EFFICIENT UTILIZATION

Low and erratic rainfall, poor groundwater resources and increasing demand of water have stressed the existing water resources to the limit. Over the years the study on arid zone hydrology and water resources development had been in piecemeal and incoherent. **Frequent droughts and flash floods make it imperative to generate data on long term averages of water and sediment balance**. It is proposed to strengthen the research on various aspects of arid zone hydrology and limited irrigation.

Of late, hydrological models of the distributed system type have received greater importance than lumped system models. The former have certain advantages. They are more physically based and allow a better understanding of the geophysical processes. Apart from higher accuracy, such models can predict the effect of changes within the catchment area due to agricultural and pastoral activities, afforestation, urbanization and mining activities.

With the advent of GIS and satellite remote sensing including microwave, it is now possible to apply distributed system models efficiently. The required data base combines remote sensing data in the form of digitally processed satellite images, digital elevation data obtained by means of photogrammetry and conventional data obtained from the digitization of special thematic map in a numerical environment.

Excessive emission of CO_2 and methane in atmosphere has set in green house effect and global warming. Climate change in either way may thus occur in the Indian desert; more rainfall and better water regime or poor water regime and accentuation of desertification hazard. Consequently hydrological cycle may change. **Hence the need for monitoring of consequences of climatic change on arid zone hydrology.**

In the Indian arid zone, in one out of five years, rainfall is 50% higher than normal and may cause flash floods. On the other hand, two out of five years experience drought, causing decline in ground water. Conservation and storage of excess water generated in a flood year may alleviate the water scarcity situation in drought years. Surface storages are costly and subjected to high evaporation. In many situations, **artificial recharge of groundwater may be more appropriate than surface storage.**

The classical soil and water conservation measures e.g. bunding, furrowing, terracing, etc. are too expensive and difficult to maintain. The farmers need cheap, economically viable and easily implementable practices. With the growing interest in the protection of environment, vegetative measures of soil and water conservation gain importance. More so, arid areas are prone to excessive wind erosion. Indepth **studies are thus warranted to develop solutions with regard to various species that can sustain land and also are economic to the community**.

In the canal irrigated areas of Indian arid zone (canal and well) indiscriminate use of water through surface irrigation methods has caused the problems of waterlogging and salinity, etc. **Sprinkler and drip system of irrigation** having 75 to 95% application efficiency are more suitable for this region having sandy soils and undulating topography. High wind velocity and salinity (more than 4 dSm) restrict the use of sprinkler, but drip system does not have such limitations. High initial cost is, however, a major constraint for adoption of such technologies. **Development of low cost systems along with improved package of practices for high value crops is needed to facilitate adoption over large areas.** Design of lateral line length, network and integrated procedure considering crop characteristics and soil properties for uniformity are the research issues for the immediate future.

vi. IMPROVEMENT OF ANNUAL AND PERENNIAL CROPS

Low and erratic rainfall sets the limit on annuals in providing stability to arid agriculture. Integration of trees, grasses and other perennials in the farming system is thus necessary. There is need to introduce/conserve genetic biodiversity and improve both perennials and annuals to increase the overall productivity.

Crops like pearl millet, clusterbean, mung bean and moth bean grown in harsh areas are more prone to various abiotic stresses like drought and high temperature and also to some soil borne pathogens like *Sclerospora, Fusarium* and *Macrophomina*. The local plant material possesses a high degree of adaptation to these stresses. **Steps will be taken to collect, conserve and characterize such landraces.** Exotic germplasm would also be utilized for the genes for high grain yield, disease resistance and other desirable traits.

In arid legumes, a few traits like indeterminate growth habit, high degree of flower shed, longer vegetative but shorter reproductive growth phase and poor partitioning of biomass need improvement. Mutation breeding provides good chance for induction of desired traits that may not be available in the existing germplasm. Besides, **attempts would be directed towards breeding of specific plant types suited to mixed and intercropping**. Identification of molecular markers linked to specific traits like pollen fertility restoration, heat and drought tolerance, disease resistance would also be undertaken to allow the marker assisted rather than phenotype based selection.

Germplasm collection for introduction of trees and shrubs from isoclimatic zones will continue. Conventional and biotechnological methods will be employed to develop stable and productive genotypes for tree based farming system and plantation on degraded lands. Activities for coming years include : molecular/biochemical characterization of indigenous trees and shrubs (including oil yielding and medicinal plants), preparation of data base for germplasm exchange, determination of mating systems using isoenzymes markers , identification of molecular markers linked to economically important traits and gene transfer for enhancing hardiness, resistance, etc. Work will also be taken up on seed production/certification, wood quality parameters and classification of trees according to their suitability for various uses of wood and standardization of wood preservation, seasoning, etc.

Work on **Arid horticulture** shall comprise : improvement in yield and quality of horticultural crops by standardizing cultivation methods and by identifying superior lines, hybridization, use of biotechnological tools and gene transfer; introduction and evaluation of unexploited and exotic horticultural crops.

Studies will continue on germplasm collection and genetic improvement for stability, higher yield and nutritive value; standardization of cultivation methods for establishment of **grasses and legumes** on degraded/underutilized lands. There is an urgent **need to increase breeder seed production centres for production of seed of important forage species**. Looking to the climatic situation where water is available in canal and watershed areas, seed production of grasses, trees and other crops may be quite effective due to its advantage in disease free seed production environment. Due emphasis will also be given on standardization of agrotechniques and grazing behaviour for grass varieties developed at the Institute.

vii. ANIMAL PRODUCTION AND MANAGEMENT

In the arid region, low and erratic rainfall influences animals' productivity to a lesser extent than crops. **There is, however, a wide gap between the production potential and the actual production in livestock due to inadequate management.** Studies in this area, therefore, need strengthening. Production potential of different breeds under both extensive and semi-extensive system including supplementary feeding is the central issue. Extremes of climatic conditions particularly the rise in the ambient temperature cause changes in the animal productivity. **Work on the animal behaviour, physiology and feed intake under stressful conditions will help in improving the production potential under such stresses.**

This region harbours some of the best breeds of livestock adapted to harsh climatic conditions. Physiological and biochemical studies will continue for adaptability vis-a-vis higher production. Further studies to evaluate suitable indicators for adaptation and production are contemplated. Due to inadequate nutrition, the genetic potential of these animals for productive traits is not expressed fully. Physiochemical and probiotic treatments can help in enhancing the nutritive quality of local feed stuffs. Extremes of the climate affect the water requirement of the animals, rumen environment and certain physiological parameters. Efficiency of digestion of certain nutrients is thus affected. To achieve optimum productivity of the livestock under such stresses, appropriate correction in the composition of the livestock diet is required. ''IBOWMIX'' - a mineral mixture which has been formulated here, is under extensive field level trial. Results achieved so far have shown positive increase in productive parameters of livestock. Efforts will be made to evaluate different feed concentrates in conjunction with IBOWMIX mixture at different locations for further improvement.

A majority of desert livestock are range foraging. Detailed survey of the forage varying in floral composition, nutrient levels and digestibility is thus warranted. Nutritional constraints like lignin and tannins are also present in some of the desert feeds. Work on development of techniques for inactivating/removing these limitations by physio-chemical and biological treatments will be strengthened. Microbes with their specific capacity for degrading variety of components and chemicals have proved to be of use for delignification, etc. The native microflora will be screened for such microbes. Strain development programme including genetic manipulation will be undertaken and techniques will be standardized for commercial use. As the rumen microfloral composition plays an important role in the nutrition of the livestock, microfloral changes under the influence of dietary composition and environmental stresses will be studied. Appropriate model of the ruminal microbial manipulation and feed alteration will be developed.

The average fish production from natural reservoirs in Rajasthan varies from 10-14 kg ha^{-1} In some areas particularly in medium sized irrigation reservoirs under Hi-Tech aquaculture, higher production upto 100 kg ha^{-1} is reported. **Large tracts of land in IGNP command area is now waterlogged. These sites could be exploited for hitech aqua-culture. Brackish-water fish culture can be practised in areas having such ground waters unfit for agriculture**. Studies on these lines are contemplated.

Increasing **buffalo** population in irrigated areas will necessitate studies on population dynamics of breeds, their adaptability, management, health, reproduction, milk production, etc. and establishment of breeding and health services.

Cheap local resources will be exploited for constructing suitable housing system for providing comfortable micro environment to the humans and animals.

Poultry production, a common practice in semi-arid region has also a good potential in arid areas. Management practices including housing for extremes of climate to mitigate the environmental stress, need to be developed.

viii. NATURAL PRODUCTS AND AGRO-TECHNIQUES OF UNEXPLORED AND UNDER-UTILIZED ARID ZONE PLANTS

Indian desert abounds in economic plants. **There are a large number of species - still either unexplored or underutilized for products of economic value. Phytochemical investigations on these species need further strengthening.**

Triacontanol an effective plant growth regulator occurs in wax part of the plant extract. Desert plants are potential source for triacontanol. It has already been found to occur in *Tephrosia falciformis, Prosopis cineraria, Prosopis juliflora, Cordia myxa, Acacia senegal*, etc. Extensive screening of plants for triacontanol is underway. *Arnebia hispidissima* has been found to contain naphthazarins known to have anticancer activity. Work on *Tecomella undulata* and *Ziziphus* species has recently been initiated. **Systematic chemical investigations on arid zone plants may lead to the discovery of new bioactive constituents and/or new sources of known bioactive compounds.**

Ethephon induced gum experiments on *Acacia senegal*, that otherwise yields little or no gum in India, have been initiated. The gum so obtained conforms to the specifications laid down in Pharmacopaedia of India for Indian gum. Efforts are underway to make induced gum exudation cost effective.

A know-how has been developed for the isolation of candelilla wax from *Euphorbia antisyphilitica* in the laboratory. Many other such plants need to be studied for products of industrial and pharmaceutical importance. In view of shortage of oil in India, any unconventional renewable source of oil whether edible or non-edible would add to the country's economy.

Balanites roxburghii fruits have been identified as potential source of diosgenin (from pulp) and vegetable oil (from seed). High diosgenin and high oil yielding genotypes have been identified. Vegetative propagation can be employed for their multiplication. Similarly, *A. senegal* trees responding favourably to ethephon treatment for gum-exudation can be used for propagation of true to type plants.

ix. AGRO-PRODUCT PROCESSING AND VALUE ADDITION

Improved mechanization processes for structure, preparation, compaction and transportation of fodder will be developed for making user friendly packages of the technology.

Chemical and physical treatments and biological agents like lignolytic fungi, etc., have tremendous potential for degradation of various locally available substrates. Isolation, strain development, genetic improvement and technology formulation based on these strains will be undertaken keeping in view the extremes of the environment.

Technologies developed by the Institute for ensiling and similar fermentation processes have shown that nutrient loss can be avoided to a great extent by effective preservation process. The formulations for different feed material and the methodology for each will be standardized. Organic wastes from agricultural activities constitute a major source of crude biomass with large potential for nutrients and energy. Biological processes including fermentation offer possibilities for utilization of wastes for food, fodder and fuel.

Post-harvest losses are quite substantial in arid areas. Proper utilization of agricultural produce, recycling of agricultural waste and post-harvest storage of various edibles need greater attention in future. User friendly packages for processing and value addition of agro-products need to be developed. This work may eventually lead to appropriate post harvest industries vital for sustaining high agricultural/horticultural productivity and improved profitability. Such development may generate rural employment, reduce poverty and contribute towards overall upliftment.

x. INTEGRATED PEST MANAGEMENT

Integrated research efforts will be concentrated on bioecology of pests in existing and changed arid agricultural ecosystem and status of key insect pests, diseases, nematodes and weeds. This information will then be used in the testing and controlling pest outbreaks and forecasting models.

Identification of indigenous biocontrol agents for key pests. Development of appropriate technology for their mass multiplication for research work will receive more attention.

Screening and search for resistant plant material and study of host-parasite interaction will continue to receive special attention. Besides, identification and application of morphological, biochemical and biotechnological tools to induce resistance in ideally productive but susceptible cultivars will be taken up. Development and field testing of IPM schedule and review of IPM technologies and remodelling of research to meet the demands of prevailing scenario will be further strengthened.

xi. FARM MACHINERY AND POWER, AND NON-CONVENTIONAL ENERGY SYSTEMS

The arid region is blessed with plentiful of sunshine. In Jodhpur, on an average 6 kwh/m^2/day solar radiation incident on horizontal surface is received.

At CAZRI, numerous solar gadgets have been developed. Further work is needed to make these **more efficient and cost effective and develop large size gadgets for community use.** The solar candle machine developed here has been commercialized by National Research Development Corporation, New Delhi. Further work on the use of advance glazing (like TIM) in the candle machine to improve its utility, is required.

The dryers developed need to be optimized considering various parameters, which play a key role in drying the different types of materials. The know-how developed on few solar water heaters (SWHs) has been adopted by the users. Further, improvements (TIM, etc.) are required. Efforts also need to be directed to develop water cooling system.

Development of low cost solar cells based on the film, storage of energy, etc. is the area that needs strengthening. Appropriate photovoltic systems for different applications need to be designed and developed.

Precipitation over arid region is not only erratic but also of short duration. Soils are light with low moisture retention capacity. All the agricultural operations are to be carried out within a short period. **Efficient implements, equipments and tools are thus necessary.** Efforts would be made to improve the efficiency of locally available tools and implements. Simultaneously, new cost effective tools and implements will be designed, developed and tested in the field.

Animal power is still important for agricultural operations and transportation for small holders. Greater efficiency needs to be infused into the system including the animal driven implements.

Efforts would be made to analyze each agricultural operation in terms of energy input. A major portion of labour input is spent in weeding operation in arid areas. Appropriate technology for weeding is thus warranted. **Effort would be made for refinement of ITK on weed management in the region.** New weeding tools/implements will also be designed and tested for different power sources like manual, animal and mechanical.

C. TECHNOLOGY ASSESSMENT, TRANSFER AND TRAINING

xii. ON-FARM RESEARCH IN FARMING SYSTEM PERSPECTIVE

An Institute level study reveals that only 22% of technologies are transferred to farmers. Concerted efforts are needed for bridging this gap. Keeping this in view a comprehensive plan of on-farm research has been formulated.

The existing farming system will be thoroughly studied. Input-output relationship will be analyzed for different components. An assessment will be made as to what extent this relationship can be improved (in terms to output) by applying the research recommendations. A balancing exercise will be carried out between resource conditions and farmers socio-economic conditions/priorities for selection of appropriate technological options. Over emphasis to either of these two issues will be avoided. Farmers will be the equal partners in programme planning and implementation. The issues related to farm women need greater focus, considering their role and responsibilities in arid land farming systems.

ITKs will be identified. On station research will be carried out for their refinement to fit them in the technological packages. Focus would be on integration of various components; dryland farming, animal husbandry, amelioration of degraded lands, CPRs and appropriate utilization of limited groundwater resources (where ever possible) for irrigation. Value addition through post-harvest technology, introduction of economic/medicinal plants, hi-tech means, etc., will be promoted. Enhancement of forage resources will be a priority issue to bridge the gap between supply and need for upgrading livestock productivity.

Of late, only a small group of scientists has been involved in on-farm research. Efforts are underway to ensure that **at least 80% of scientists devote their 20% of time to on-farm research and training**. A core group of nearly 50 scientists is being deployed to take up on-farm research as a major area of their performance. Scientists are being encouraged and provided facilities to carry out location specific research on farmers fields.

xiii. SOCIO-ECONOMIC INVESTIGATIONS AND EVALUATION

Socio-economic surveys are an integral part of basic resources survey. Concerted research efforts are needed on Socio-economic surveys of livestock/land distribution, standardizing socio- economic variables for desertification modelling and cost of cultivation.

Only a few of the technologies on annual and perennial crops so far generated have found favour with farmers. There is need therefore, to further strengthen the research in the areas encompassing all the facets of on-farm production consumption-cycle. It will involve identification of short comings of technology through on-farm research market linkage studies of major crops grown in the region; employment and income generation aspects of alternate land use systems and prospects of value additions in the existing or alternate cropping systems.

Technologies generated need to be economically evaluated. Inputs that do not negatively affect the environment or the system that regenerates the natural resource base but are not economically viable, will not be accepted by the farmers. Many technologies have been found to be economically viable on research farm but their adoption at farmers field is not encouraging. Economic evaluation of technologies in the course of on-farm research can effectively answer such questions.

Rich and varied livestock wealth of this region has not been fully utilized. The per unit production continues to be low due to various factors including weak market linkages. Physiological and nutritional aspect of animals like sheep and goats have been the main areas of research so far. Cattle also need equal attention considering their growing number in the region. Documentation and analysis of processing, storage and market infrastructure for livestock produce are the other researchable issues that need to be pursued.

xiv. TRAINING, COMMUNICATION AND FEED BACK ANALYSIS

Technology demonstration and people's participation have become primary preoccupations within development efforts. Such initiatives would be more effective if people have required level of knowledge and positive attitude to analyse the benefits of technology. Technical know-how is thus essential. Strong training and media unit can help reaching this objective.

Small holders in arid zone require more critical knowledge because their risk taking capacity is low. Socio-economic and agro-climatic conditions are also not favourable. Adequate communication support is thus a circumstantial requirement. This will require proper coordination between technologists and extension personnel. Different categories of developmental personnel need different type of training, i.e. vocational popular and specialized, etc.

To carry out these tasks effectively, **the communication, documentation and training infrastructure need a great deal of strengthening of scientific and technical manpower and modern facilities/equipments.**

Feed back is integral to any programme/activity for desired dynamics. Periodic evaluation of programmes/activities gives feed back to policy makers, programme designer and executor for desired improvement. It is a continuous process. There could be a number of ingredients that are not observed in the initial stage of the programme and appear only during the course of implementation. **Feed back analysis is thus essential for development of appropriate training strategy including refinement of training content and methodology based on changing needs and job requirement as well as for redesigning of media-mix.**

9.1&2. Programme Activity – Setting of Objectives and Goals an a Time Scale and Funding Needs (Rs. in lakh in brackets)

Goals/Objectives	1996-2000	2001-2005	2006-2010	2011-2050	2016-2020	Total
I. Integrated basic and human resource appraisal, monitoring desertification and modelling.						
Resources appraisal in arid region.	------- (10)	------- (5)	------- (5)	------- (5)	------- (5)	30
Linking Major Land Resource Units (MLRU) with biological productivity under different Environments.	***** (3)	------- (1)	------- (1)	------- (1)	------- (1)	7
Suitable action plan for sustainable development based on user defined and participatory resource appraisal.	-------	-------	-------	-------	-------	-
Environmental impact assessment of developmental projects in arid region.	------- (2)	***** (3)	***** (3)	***** (3)	***** (3)	14
Standardization of parameters/indicators and monitoring desertification.	***** (5)	***** (4)	------- (3)	------- (2)	------- (1)	15
Desertification status in arid north-west India through remote sensing and GIS.	***** (4)	***** (4)				8
II. Survey, monitoring and conservation of biodiversity						
Survey and documentation of biodiversity in different edapho-climatic conditions.	------- (10)	***** (20)	***** (20)			50
Studies on Indigenous Technology for conservation of biodiversity and standardization of conservation techniques.	***** (15)	------- (5)	***** (20)	------- (5)	------- (5)	50
Intensive monitoring of biodiversity in selected habitats.	------- (5)	------- (10)	------- (15)	------- (20)	------- (25)	85
III. Arid land farming system research						
Physiological basis of low productivity and impact of environmental stresses on microbial population, and status of soil and plant nutrients under different cropping systems/ farming systems.	***** (15)	***** (15)	------- (5)	------- (5)	------- (5)	45

Integrated plant of nutrient farming management under different cropping system and utilization of on-farm wastes.	***** (10)	***** (10)	------- (2)	------- (2)	------- (1)	25
Evaluation of stress tolerant cultivars, tillage, plant density, irrigation, nutrient management, etc., for increasing productivity.	***** (8)	------- (2)	------- (2)	------- (2)	------- (2)	16
Refinement of existing water harvesting techniques.	------- (5)	------- (5)				10
Development of feasible models of integrated farming systems for resource conservation and sustained productivity.	***** (4)	***** (4)	***** (4)	***** (4)	***** (4)	20
Modelling of resource base for optimum productivity.		***** (4)	***** (4)	***** (4)	***** (4)	20
Assessment of alternatives (recycling of industrial effluents and sewage water) for afforestation and crop production.	***** (9)	***** (8)	-------	-------	-------	17
IV. Rehabilitation and management of degraded lands						
Characterization of problem sites.	------- (1)	------- (1)				2
Testing and evaluation of *in-situ* moisture conservation and planting techniques for establishment of trees.	------- (2)	------- (2)	------- (2)			6
Mechanical measures for combating degradation and rainwater harvesting.	***** (2)	***** (2)	------- (1)	------- (1)	------- (1)	7
Evaluation of alternate land use systems.	***** (2)	***** (2)	------- (1)	------- (1)	------- (1)	7
Nutrient management and changes in soil biomass production and environmental impact analysis.	------- (1)	***** (2)	***** (2)	***** (2)		7
V. Modelling surface and ground water resources for efficient utilization						
Water and sediment budgeting and process studies in drainage basins using numerical techniques, remote sensing and GIS.	***** (15)	***** (15)	***** (15)	***** (15)	***** (15)	75

Effects of climate change on surface and groundwater resources.	------- (2)	------- (3)	***** (10)	***** (8)	***** (7)	30
Evaluation of groundwater potential and its artificial recharge along buried prior channels and other areas.	***** (5)	------- (3)	------- (2)			10
Identification/upgradation of effective soil and water conservation/ harvesting practices using indigenous knowledge for integrated watershed management.	------- (2)	------- (2)	------- (2)	------- (2)	------- (2)	10
In situ and field runoff farming for efficient use of limited/scarce rainfall.	------- (2)	------- (2)	------- (2)	------- (2)	------- (2)	10
Efficient management of scarce and saline sodic waters under surface, sprinkler and drip systems of irrigation and modelling in relation to water balance.	***** (10)	***** (6)	***** (5)	------- (3)	------- (2)	26
VI. Improvement of annual and perennial crops						
Introduction, collection and evaluation of germplasm and genetic improvement of annuals, trees, shrubs, grasses and horticultural crops.	***** (30)	***** (30)	------- (6)	------- (5)	------- (5)	76
Identification of biochemical/molecular markers for studying genetic polymorphism and association with various stresses, and estimation of mating systems.	***** (20)	------- (5)	------- (5)	------- (5)	------- (5)	40
Use of biotechnological tools in genetic improvement.	------- (3)	***** (9)	***** (9)	***** (9)	-------	30
Quality seed production/ planting material for annuals and perennials.	------- (7)	------- (7)	------- (7)	------- (7)	------- (7)	35
Agrotechniques and quality assessment of trees, shrubs, grasses and horticultural crops.	------- (7)	------- (7)	------- (7)	------- (7)	------- (7)	35
Identification and transfer of genes responsible for pest and disease resistance through bio-technological approaches.	------- (9)	------- (7)	***** (8)	***** (8)	***** (8)	40

VII. **Improvement in animal production and manage-mental**	1996-00	2001-05	2006-10	2011-15	2016-20	
Optimization of production performance and shelter management for livestock.	***** (5)	***** (5)	***** (5)	***** (3)	------- (2)	20
On-farm testing a suitable poultry production model for arid region.		------- (4)	------- (4)	------- (4)	------- (4)	16
Physiological, biochemical and hormonal attributes for adaptation and production.	------- (3)	------- (2)				5
Nutrient value, requirement and treatment of desert feeds and mineral mixtures for livestock under stress and modelling of feeding systems.	***** (10)	------- (2)	------- (2)	------- (2)		16
Evaluation of beneficial microbes for optimal feed utilization through treatment and rumen ecosystem modelling.		***** (7)	***** (6)	***** (6)		19
On-farm testing of fish culture in brackish waters.	------- (1)	------- (1)	------- (1)	------- (1)		4
VIII. **Natural products and agro-techniques of unexploited and underutilized arid zone plants**						
Chemical investigation of plants for triacontanol and other bio-active compounds.	***** (6)	***** (6)	------- (2)	------- (2)		16
Gum, resins and other exudations from arid zone trees and shrubs.		***** (6)	------- (2)	------- (2)		10
Oil and products of industrial and pharmaceutical importance from arid zone plants.	------- (8)	------- (8)				16
Development of Agro-techniques for potential economic plants.	***** (3)	***** (3)	------- (2)	------- (1)	------- (1)	10
IX. **Agro products processing and values addition**						
Preservation systems for surplus fodder for maximum value retention and effective utilization	------- (6)	------- (6)	------- (6)	------- (6)	------- (6)	30

Improved utilization of agricultural wastes (including animal wastes) for biomass and energy production.	------- (5)	***** (7)	***** (8)	***** (8)	***** (7)	35
Techno-economic studies of processing industries for utilization of agricultural waste and by-product.	------- (9)	------- (9)	------- (9)	------- (9)	------- (9)	45
Integrated post-harvest management for durables/ perishables and spices.	***** (9)	***** (9)	***** (9)	***** (9)	------- (4)	40
X. Integrated pest management						
Survey and surveillance and eco-biology of important pests and development of forecasting models.	------- (12)	***** (20)	***** (20)	***** (20)		72
IPM with special emphasis on biocontrol, biopesticides and third generation pesticides.	***** (10)	***** (10)	***** (10)	------- (4)	------- (4)	38
Impact of irrigation on pest ecology.	------- (1)	***** (3)	***** (3)	***** (2)	------- (1)	10
XI. Non-conventional energy systems and farm machinery power						
Design and development of solar/ wind appliances and application of transparent insulation material (TIM).	------- (2)	***** (5)	***** (4)	------- (2)	------- (2)	15
Development of improved solar/wind hybrid systems with alternate materials.	***** (4)	------- (2)	------- (2)	------- (2)		10
Opto-electronic characterization and development of cost effective thin film solar cells and P.V. systems.	***** (4)	***** (4)	------- (2)	------- (2)		12
Development of green house/ polyhouse.	------- (2)	------- (2)	------- (1)			5
Design, development and field testing of cost effective farm equipments and tools and analysis of energy efficiency.	------- (2)	------- (2)	------- (2)	------- (2)	------- (2)	10
XII. On farm research in farming systems perspective						
Listing and testing of the efficiency of ITK and its refinement.	***** (10)	------- (5)	------- (4)			19

Evaluation and popularization of technologies under different agro-climatic, socio-economic and cultural conditions.	***** (5)	***** (5)	***** (5)	——— (3)	——— (2)	20
On-farm specific problem oriented research and preparation of technological package options.	——— (4)	——— (4)	——— (4)	——— (4)	——— (4)	20
Use of PRA and other modern approaches for maximum people's participation.	***** (4)	——— (2)	——— (1.5)	——— (1.5)	——— (1)	10
Identification of sustainability indicators.	——— (3)	——— (2)	——— (2)	——— (3)		10
XIII. Socio-economic investigation and evaluation						
Studies on market linkages, value addition, employment prospect and other socio-economic factors governing resource use and cost of cultivation of crops in different farming systems.	***** (8)	——— (3)	——— (3)	——— (3)	——— (3)	20
Economic evaluation of management technologies in a farming system perspective.	***** (8)	***** (3)	——— (3)	——— (3)	——— (3)	20
Identification and standardization of socio-economic variables for desertification modelling.	——— (1)	——— (1)	——— (1)	——— (1)	——— (1)	5
Livestock and farm management livestock production, product processing and market linkage studies.	***** (5)	***** (5)	***** (5)	——— (2)	——— (2)	19
XIV. Training, communication and feed back analysis						
Characterization and development of courses for different categories of personnel.	***** (4)	***** (4)	***** (4)	***** (4)	***** (4)	20
Peripatetic training programmes.	***** (30)	——— (5)	——— (5)	——— (5)	——— (5)	50
Modern media production and analysis of media mix for rapid technology dissemination.	***** (130)	——— (25)	——— (20)	——— (20)	——— (20)	215
Evaluation of different mechanisms for collection of feed back and constraint analysis.	——— (2)	——— (2)	——— (2)	——— (2)	——— (2)	10

***** Major activity

——— Normal activity

Regional Research Station in Cold Desert

Cold desert region in India occupies an area of 70,300 sq. km mainly in Leh and Kargil districts of Jammu and Kashmir, Lahaul and Spiti districts of Himachal Pradesh. These areas are closely associated because of their physiographic locations. This region presents an entirely different and unique set of agro-ecological conditions. The productivity in the region is dismally low. People inhabiting this region therefore, have been facing extreme disparity compared to better endowed areas of our country. Improving the productivity of this region is, therefore, national priority. The available data base that can help guide developmental planning of this region is far too inadequate. Hence, the need for a full fledged Research Station at a suitable location in this region. Some of the activities proposed for cold desert are already reflected in Chapter 9 (Page 39). Suitable technologies and practices will be developed.

9.3 LINKAGE, COORDINATION AND EXECUTION ARRANGEMENTS

LINKAGES

As an apex research organization in the field of desert technology, CAZRI will have to maintain the existing and develop new linkages at state, national, regional and international levels. Linkages are envisaged with CGIAR Institutes, CABI, UN Agencies while existing ones (foreign national agencies like US- PL 480, Agriculture Canada, Government of Israel, JIRCAS, etc.) need strengthening. Within the country, further cooperation needs to be pursued with ICAR Institutes, SAUs, concerned state departments, NABARD, VOs and local bodies. Lack of development and maintenance of linkages has been a limitation of many institutions including CAZRI. Serious efforts in the area are required to enhance the quality of research output on one hand and diffusion of technologies to the target groups, on the other. The Institute has recently undertaken a programme for integrated development of a few selected villages in various districts of western Rajasthan. The sphere of activity could be extended, subject to favourable response of the target populace.

Application of research cuts across boundaries of regions and nations. Information and flow of funds strengthens the Institute's capability in knowledge, manpower and infrastructure development. The newer and innovative avenues of research also emerge through constructive interactions. In the past, collaboration of CAZRI with CSIRO, Australia; UNESCO's Arid Land Programme, Indo-Canadian, Indo-Japanese and Indo-US programmes have been very fruitful. A number of training courses for research officers of Afro-Asian countries sponsored by International Institutions like UNESCO, UNEP, FAO, DANIDA, etc., have been successfully organized More are in the offing.

TRAINING

A large number of technologies for sustainable development of arid ecosystem have become available through multidisciplinary research at CAZRI for the last four decades. Quite a few of these have already been fine tuned and tested on farmer field

National and International Collaboration

Area of collaboration	Institute/Organization International	National
Resource appraisal and desertification	ITC, CSIRO, ICASALS, DESCONAP, ACSAD, UNEP, UNESCO	NBSS&LUP, NRSA, CGWB, RSEB, ONGC, State Deptt. of Irrigation and Agriculture, Forest
Monitoring, conservation and utilization of biodiversity	SCOPE, UNESCO	BSI, ZSI, WWF, Universities, State Department of Forestry
Arid land farming system research	ICRISAT, UNDP, FAO, ICRAF, UNEP	SAU, NRCAH, CSWRI, CRIDA, State Deptt. of Forestry and Irrigation
Rehabilitation of degraded land	IPALAC	RMDC, NWDB, CSSRI
Modelling surface and groundwater resources for utilization	IBGP, IAHS	Soil Conservation Deptt., IIT, WTC, CIAE, NIH, CGWB, GWD, Irrigation Deptt.
Improvement of annual and perennial crops	ICRISAT, IITA, ICARDA, CSIRO, Israel, IPGRI, FAO, CGIAR, CIDA, OFI, DANIDA	NBPGR, ICFRE, SAUs, YSPUH&F
Improvement in animal production and management		NDRI, CIRG, CSWRI, CARI, RAU, IVRI, IMT, BAIF, CIFE, CIFRI, CMFRI
Natural products and agro-techniques of unexplored and under- utilized arid zone plants	NIH, USA	CDRI, NIN, CIMAP
Agro-product processing and value addition		CIPHT, CIAE, IGFRI, CCSHAU, BAIF, TERI, IIT, NCMRT, IIM, CFTRI, CISH
Integrated pest management	ICRISAT, UOH, Israel	NCIPM, Univ. of Mysore, RAU
Non conventional energy systems and farm machinery power	NPAC USA, IPE	IIT, DNES, DST, REDA, NRDC, CIAE, RAU, CCSHAU
On farm research in a farming system perspective		State Governments (Rajasthan, Gujrat, Haryana)
Socio-economic investigation and evaluation		RAU, GAU, NRCC, IIM, CSWRI, NDRI, IVRI, NCGR, CIRG, IGFRI
Training, communication and feed back analysis		State – line departments

under different agro-climatic situations. For sustained impact there is a need to have trained and motivated developmental personnel at various levels. It is therefore, proposed to strengthen the Institute's programme on technology transfer by establishment of the following training and communication units :-

1. National Centre on Desert Technology
2. Trainers Training Centre
3. Farmers Service Centre

1. **National Centre on Desert Technology** will provide six months training course to in-service personnel of State Governments and other organizations so as to prepare a Core Group of officers in different states for formulation and execution of various developmental plans. The center will also be open to international clientele.
2. **Trainers Training Centre** : The Institute has been organizing training of development personnel as sponsored by various state government and other organizations. Considering the importance of training in technology transfer, a regular training mechanism needs to be developed. To this end, a new Trainers Training Centre needs to be established at the Institute.
3. **Farmers Service Centre** is desired to give a single window service to farmers for solving their problems on agricultural and related issues. This will promote a dialogue for efficient rapport and feed back between farmers and scientists directly.

COORDINATION ARRANGEMENT

The Institute is organized into eight multi-disciplinary divisions. Heads of Divisions/Project Coordinators coordinate the research programme as decided and approved by the Research Council and National workshops of Coordinated Projects. Inter-divisional and inter-institutional coordination is performed by the Director assisted by the Research Management and Coordination Unit. At the National level, programmes are coordinated by the Deputy Director General (Soils, Agronomy and Agro-forestry) ICAR.

Coordination among research, training and development sectors is most crucial to technology transfer and adoption by the farmers. This has been a missing link. A sound coordination system with built-in-accountability needs to be developed.

EXECUTION ARRANGEMENTS

Central Arid Zone Research Institute will continue to execute its research programme through a strong core of scientists representing more than 33 disciplines. The focus of research will be on programme approach in a mission mode. Therefore, emphasis in the proposed plan has been given to on-farm research with people's participation. In this farming system approach, development agencies and NGO's are going to have a pivotal role in promoting community participation, dissemination of technology and community maintenance of the assets and systems so developed.

9.4 CRITICAL INPUTS

The Institute has adequate infrastructure for research. Modernization and updating of facilities is, however, required. Scientific skill requires upgradation particularly in the disciplines where less manpower is available. HRD is a priority. Training of scientific manpower in advanced areas of research in International Institutions in India and abroad will be desirable. Scientific exchange through participation in international seminars, symposia, etc. needs to be encouraged. Inter-disciplinary research needs greater focus than hitherto. A system of accountability for such team work needs to be built up. In future CAZRI may require additional scientific manpower and skill to achieve the goals envisaged in the plan. Upgradation of certain laboratories with sophisticated instruments is required. The research farm facilities also need to be further strengthened. Collaborations with national and international scientific research organization will help in multi-dimensional growth.

9.5 RISK ANALYSIS

In the desert ecosystem, annual as well as perennial crops face uncertainties due to erratic rainfall, frequent droughts, extremes of temperature and wind regimes. Besides, these ecological limitations are further constrained by social and biotic risk factors. Research and development efforts in this region are aimed at improving the overall natural resource base for stabilizing and enhancing the productivity. Therefore, these investments cannot be compared strictly on the yardstick of economic gains. The overall social upliftment and creation of assets and better environment should also be kept in view. The nature has bestowed this region with a unique endemic flora and fauna. Further the society over the centuries of struggle in the harsh environment has learnt to survive and get acclimatized through development of indigenous knowledge acquired over generations of experience.

There exists a great scope of not only the reconstruction of Indian arid zone beyond self reliance but this unique land mass has the potential to be a belt of fodder for the country, source of rare herbal medicines and products of industrial importance, milk and meat products, recreation and tourism. Past experiences show beneficial outcome. Concerted and joint efforts of research organizations, developmental agencies and people at large can pay rich dividends in achieving this endeavor.

9.6 OUTPUT AND EXPECTED SITUATION

Besides monitoring and appraisal of natural resources and biodiversity information, packages for integrated farming involving annuals, perennials, animals, etc., will be available for different agro-climatic sub-regions within arid zone. This information will be need based, cost effective and location specific as greater emphasis has been given to on-farm research with people's participation. These efforts are likely to be upgraded with the present policy of ICAR on strengthening of KVKs, Institute-Village linkage project and National Agricultural Technology Project (NATP).

It is expected that larger adoption of technological capsules would result in increased production per unit area that eventually may release land for pasture development. Fodder is in short supply specially during the years of poor rainfall which will necessitate establishment of fodder banks and recycling of agrowastes.

10. PROJECT REVIEW, REPORTING AND EVALUATION ARRANGEMENTS

Reviews at specified intervals through the expert panels (peer review) and other high power committees will be carried out for mid-term and project completion appraisals of the proposed programmes. In addition to present quinquennial review system of the entire institutes' performance, individual programme may also be reviewed by expert panels at specified intervals.

Considering the National Agricultural Policy for bridging the gap to obtain social equity between high capacity irrigated areas and arid and semi-arid environments with preponderance of drylands, CAZRI has three broad commitments :

i) Resource appraisal and inventerization (along with human factor) of arid ecosystem in the country.

ii) Development of appropriate technologies for sustainable production in arid areas that also entails all time conservation of resources and protection of environment.

iii) Frontline technology transfer including training. Resource inventories can guide not only the problem identification for development of management technologies but also the technology transfer. Apart from CAZRI, other institutions and developmental agencies including VOS, can make use of this strong data bank.

Within the arid-zone, the desert (Thar) ecosystem (Western Rajasthan, parts of Gujrat and Haryana) is the most vulnerable and fragile sub-zone from sustainability considerations. Technologies developed at the Institute are now being assessed in a farming systems perspective for fine tuning. CAZRI is committed to provide appropriate farming system models of integrated technology for replication in various developmental programmes aimed at arresting desertification and upgrading the productivity on a sustainable basis.

Most of the programmes identified in the plan are of long term, which will require dedicated efforts at each level of participation. Besides Institutional support, generation of resources would be needed through externally funded projects and consultancies at national and international level.

11. RESOURCE GENERATION

Till last decade agricultural research was primarily financed by the Government. With the expansion of agricultural research network, use of sophisticated equipments and new research fields like biotechnology, the funding needs are on a rise. In the beginning of this decade it became imperative to generate funds especially for the advanced areas of research. Since 1990, CAZRI has generated funds to the tune of more than Rs. 500 lakh from national agencies and about Rs. 150 lakh from international agencies. However, there has been hardly any effort to acquire funds from corporate sector or other private sources. In the coming years, it is envisaged to generate resources through internal resource management by making best use of land resources, products and technologies available with the institute. The major share will have to be generated by resource mobilization from external funding agencies, through trainings, consultancies, contract research projects, etc. To achieve international competitiveness and claim intellectual property rights, it will be necessary to characterize plant and animal genetic resources. International collaborations will have to be scrutinized in the light of national interests.

The Institute has 14 ongoing projects funded by external agencies including foreign Governments. These are covered within the major programmes and thrust areas of the Institute. Hence, the priorities set for the next five years are not likely to be altered.

The task for realising the mandate as per the priorities may also be governed by inter play between certain trade offs and pre-requisites. Upgradation of existing infrastructures including personnel policies, HRD, collaboration and exchange of information with national and inter-national organizations for excellence in research and training and generation of funds are some of the important pre-requisites for carrying out the mandate of the Institute in the years ahead.