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CAZRI VISION 2030

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Central Arid Zone Research Institute

(Indian Council of Agricultural Research)

CAZRI
VISION 2030

CENTRAL ARID ZONE RESEARCH INSTITUTE
JODHPUR 342 003, INDIA

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FOREWORD

The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climate change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach, based on cutting edge science. In this endeavour, all the Institutes of ICAR have revised and prepared respective Vision-2030 documents highlighting the issues and strategies relevant for the next twenty years.

India has about 14 per cent of its area under arid climate, 10 per cent under hot arid, mostly in Rajasthan and Gujarat states, and 4 per cent under cold arid, largely in Jammu and Kashmir state. Because of its harsh environment, agriculture in arid zones is a formidable challenge. The technological interventions by Central Arid Zone Research Institute (CAZRI), Jodhpur have contributed in significant measure to improve agricultural production and to make agriculture a successful enterprise despite fragile production environment.

Although scientists have so far developed technologies based on an understanding of problems that mostly emerge cyclically according to a known pattern of interactions between the atmospheric and landscape variables, in the current century we might face problems that are based more on some hitherto unknown spatio-temporal patterns of interaction between the variables. Climate change is going to be a major challenge for agriculture, especially in the fragile arid environment, and will need strategies that are more robust and based on better understanding of the variable interactions and their timing.

It is expected that the analytical approach and forward-looking concepts presented in the Vision-2030 document will prove useful for the researchers, policymakers and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.

(S. Ayyappan)

Dated the 13th June, 2011
New Delhi

PREFACE

Agriculture in the arid regions of India is now under multiple threat of increasing population pressure, depleted water reserve, degradation of other natural resource base, and above all the anthropogenic warming of the climate. Central Arid Zone Research Institute is addressing the agriculture and natural resources-related problems of Indian arid zone for more than five decades and is monitoring the changes closely in the most affected western part of Rajasthan and Gujarat. It is becoming increasingly clear that the changes arising out of water depletion and global warming may lead to several serious consequences for sustainability of agriculture and livelihood in the near future, and that many of the currently available technologies may not be able to provide solutions to all the emerging problems, unless these are refined and/or replaced by new ones. While the causes and consequences of water problem are straight forward, understandable, and can be addressed using available technologies, the challenges of climate change are more in the realm of unknown, and are, therefore, formidable. Its signatures and their impacts on bio-physical system are still difficult to understand and predict properly. It is, however, becoming increasingly clear that many of the emerging issues need solutions that are embedded in the concept of resource conservation. The traditional wisdom, that used to be practiced, perfected and then handed over to us by generations of land users in this fragile desert, hold key to some of the solutions, while new innovative ideas will be required for addressing some others. The strength of CAZRI from its early research, especially in the fields of sand dune stabilization, range management, grazing practices, rain water harvesting, watershed management, etc., need to be revisited and fine-tuned for application to some of the emerging problems. Taking advantage of new technologies we should also try to understand quickly and to monitor properly the patterns of change, simulate them and find solutions at the earliest. It is also time for us to understand the emerging problems in the cold arid areas for appropriate technological interventions.

This perspective on our Vision 2030 builds on the earlier two Vision documents for 2020 and 2025. I take this opportunity to express my gratitude to Dr. S. Ayyappan, Director General, ICAR, and Dr. A.K. Singh, Deputy Director General (NRM), ICAR, for constant guidance, encouragement and review of previous drafts of this document. I also sincerely thank the Chairpersons and Members of the QRT and the RAC for CAZRI, who were kind enough to advise us on many aspects of research thrusts and future strategies that have enriched this document.

Dr Amal Kar carried out compilation and editing of this important document to its final shape, for which he deserves my sincere thanks. I also thank the other members of the draft committee (Dr. Suresh Kumar, Dr. R.K Bhatt, Dr. A.K Misra and Dr. R.K. Kaul), our Heads of Divisions and Regional Research Stations, and the scientists, especially Dr. B.L. Gajja, Dr. P.C. Moharana, Dr. D.V. Singh, Dr. Anurag Saxena and Dr. S.K. Jindal, who provided some of the basic data for this document. I hope this Vision 2030 document will serve the purpose of invigorating us with a new zeal to take up the emerging scientific challenges and to solve them for a better future of the desert dwellers.

(M.M. Roy)
Director

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AGRICULTURAL SCENARIO IN ARID INDIA

India has approximately 32 million hectare (m ha) area under hot arid zone, which is located in parts of Rajasthan (61.9% of the country's total hot arid zone), Gujarat (19.6%), Punjab and Haryana (8.6%), as well as Andhra Pradesh, Karnataka and Maharashtra (9.9%). India also has 12.2 m ha area under cold arid zone, mostly in the state of Jammu & Kashmir, and partly in the adjoining Himachal Pradesh.

The most problematic area within the hot arid zone is the western part of Rajasthan state, which contains the dominantly sandy Thar Desert of India and Pakistan. During the Quaternary period the eastern boundary of the Thar Desert oscillated several times roughly between the fertile Indo-Gangetic Plains in western Uttar Pradesh and the sandy plains to the west of the Aravalli Hill Ranges in Rajasthan, essentially because of shifts in the monsoon domain. As a result of these shifts vestiges of desert geomorphic processes abound in the landscape of the presently semi-arid fringe of the desert. Presently the desert boundary lies roughly along the Aravalli Ranges, but the increasing human pressure on the thick aeolian sandy deposits on both sides of the boundary, along with a warming trend, the threat of increased dryness, higher wind speed and higher evaporative demands by the plants is not only making the desert and its eastern margin more vulnerable to accelerated wind erosion, but also to acceleration of other desertification processes.

Elsewhere in the hot arid zone, the western part of Gujarat is experiencing higher intensity monsoon rainfall in recent decade that is also becoming more aberrant. This is causing not only uncertainty in agricultural operations, but also higher soil erosion.

In the cold arid zone in the Himalayas the major constraint, apart from the low precipitation (<150 mm), is extreme temperature variation (+37°C to -35°C in Ladakh), steep and mostly barren slopes and poor soils, except along the narrow valleys of the Indus and its tributaries, which together translate into a very short crop growing period and potentials for developing horticulture and animal-based farming system.

Because of the climatic and terrain constraints the arid areas are generally among the agriculturally least developed ones, unless there is very high financial and technological investment. Despite many efforts, agricultural productivity in all the arid districts of Rajasthan is 'very low' (<Rs.18199 ha^{-1}; Chand *et al.*, 2009), except Ganganagar district, which is under 'low' productivity category (Rs.18199-27955 ha^{-1}). Some other arid districts are also in the very low productivity category (Kachchh in Gujarat, Anantapur in Andhra Pradesh, Raichur and Koppal in Karnataka, Leh and Kargil in Jammu and Kashmir). None of the states having arid districts, however, have the enormity of productivity constraints as found in arid western part of Rajasthan. Barmer, Jaisalmer and Churu are, in fact, the three lowest productive districts in India (<Rs.5000 ha^{-1}), surpassing even the cold deserts of Kargil (Rs.8473 ha^{-1}) and Leh (Rs.15367 ha^{-1}) where the higher productivity despite very limited sown area is partly due to cultivation of some high-value niche crops. Over all, as Chand *et al.* (2009) summarised, rainfall is still a major determinant of land productivity. According to them 1% increase in rainfall contributes to an average 0.43% increase in agricultural productivity, although other factors are also involved. It reinforces the belief that arid western Rajasthan requires very high research attention for sustainable agricultural development, although other arid areas of the country are also important.

Present Scenario in Arid Rajasthan

Despite the fact that overall agricultural productivity in arid western Rajasthan is very low, the situation has vastly improved over the last few decades. Agrarian economy in the region is now at the doorstep of major changes. As the technology-mediated packages of Green Revolution and democracy-mediated infrastructural developments have percolated into the far-flung areas of the region, rural livelihood is experiencing an upswing. It was essentially the progress in agricultural research, exploitation of surface and ground water and concurrent rural development programmes that helped not only to feed the growing human and livestock populations in a region with limited natural resources, but also to produce enough marketable surpluses to make agriculture more viable than before.

While rural electrification has helped large-scale utilization of groundwater for irrigated cropping, mostly in the eastern and the central parts, the commissioning of the Indira Gandhi Nahar Paryojana (IGNP) has transformed large parts of the driest and the dune-covered westernmost districts of Rajasthan into irrigated croplands. Linking of villages through road networks has ensured timely distribution of inputs and marketable produces, and better availability of credit facilities has allowed farmers to take greater risk despite the dangers of drought (32 moderate to severe drought years since independence) and the increasing human and livestock pressure. Between 1961 and 2011 census human population in western Rajasthan has increased by >250%, while between 1956 and 2003 census the animal population has increased by >75%.

Broadly, the current production of cereals in arid western Rajasthan is 5.13 million t, against a demand of 4.73 million t. In case of kharif pulses, the region presently produces 1.12 million t against an estimated demand of 0.41 million t, while in oilseeds the production in the region is 1.71 million t, against an estimated demand of 2.05 million t. While pearl millet, sorghum and wheat are the major cereals, moth bean and mung bean are the major kharif pulses. Groundnut, sesame, castor, rape and mustard, and tarameera are the oilseed crops. Currently the region's demand for fruits is estimated to be 0.26 million t, and that of vegetables 1.40 million t, but the present production is estimated to be <0.1 million t.

Arid western Rajasthan falls under two agro-climatic regions (Western Dry Region and Trans-Gangetic Plain Region), and four agro-climatic zones: (1) Arid western plain, (2) Transitional plain of inland drainage, (3) Transitional plain of Luni basin, and (4) Rajasthan irrigated north-western plain (Fig. 1).

An analysis of the production and income for the mid-2000s shows that in all the four agro-climatic zones of western Rajasthan returns from agricultural sector contribute 26-43% of the total income, the mining sector provides 1.6-1.8%, while the 'other sectors' (including wages/income from service sector, business and allied activities) contribute 56-73% of the income. As is expected, the lowest total income from agricultural sector (including income from rainfed and irrigated crops, horticulture, bovines, ovines, and household industries) is in Arid Western Plain (Zone 1; 25.6%), where the 'other sectors' contribute 72.6%, and mining (mostly sandstone, limestone, gypsum and salts) 1.8%. This is followed by the Transitional Plain of Luni Basin (Zone 3), where the relative contributions of the three sectors are 29.8%, 68.6% and 1.6%, the Transitional Plain of Inland Drainage (Zone 2; 32.1%, 66.3% 1.6%), and the Irrigated North-western Plain (Zone 4; 42.6%, 55.6%, 1.8%). The croplands' contributions to these totals vary from 15.03% (Zone 1) to 30.18% (Zone 4). The implications are that (1) despite more than 70% of the total working population being engaged in agriculture, it can hardly compete with the income from the service and business sectors, and (2) the opening up of opportunities in mining, service and business sectors may gradually create an apathy among the inhabitants to till land, not only due to the poor returns, but also due to large uncertainties involved in input-output ratios from agriculture.

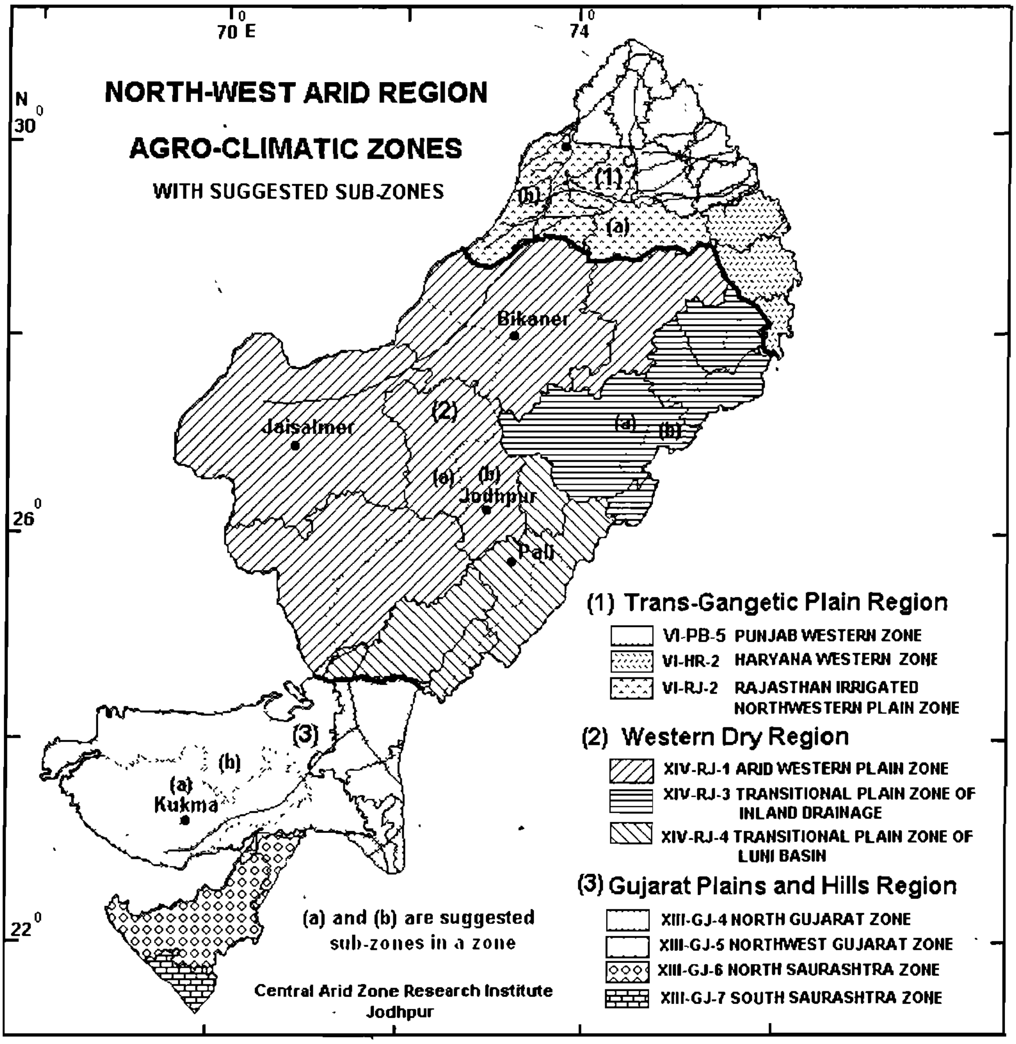

Fig. 1. Agro-climatic zones in the arid north-western India.

In the agricultural sector income from cropping provides 59-71% of the total agricultural income, while livestock rearing provides 28-42%. In Zone 3, the relative contribution from livestock is higher (42.30%) than in other zones, closely followed by Zone 1 (38.74%). In Zone 4 livestock sector contributes only 28.44% to the total income from agriculture. When analysed on income per hectare basis, the contribution from rainfed croplands dropped to 2.71% in Zone 1, and to 7.42% in Zone 4, as compared to 34.71% and 22.62% from irrigated cropping in the two zones, respectively. Rainfed croplands in Zones 2 and 3 that lie in the wetter fringe of the desert, contribute 7.30% and 6.96% of the zones' agricultural income.

Thus, it is not only the extreme vulnerability of rainfed system, but also its potentials that need to be carefully exploited as a crop-livestock-horticulture based farming system for a sustainable future. It also hints at the capacity of the irrigated system to produce much higher than the rainfed system, and support higher bovine population that has better production efficiency in economic terms than the huge number of ovines with smaller economic returns on the vast rangelands that are presently highly degraded. However, the sustainability of the system is becoming uncertain and adverse input-output ratios may aggravate it. Unless a technology-mediated change, backed up by sound policy instruments, is effected in the crucial components of these production systems, there is less scope for improving the agricultural economy of the region as a whole.

Likely Future Scenario

The human population in western Rajasthan is likely to increase from the present 28.15 million (2011 census) to about 34 million in 2031. This will increase the demand for cereals from the present 4.73 million t to 5.68 million t. The demand for pulses is likely to increase from 0.41 million t to 0.49 million t, and the demand for oilseeds from 0.21 million t to 0.25 million t. Assuming a relative stability in the climate and allowing 10-20% adoption rate/year for the new and upcoming technologies, the production of cereals by 2031 will most likely be 7.34 million t, pulses 1.22 million t and oilseeds 1.90 million t. In other words, there is likely to be some surplus over the demands. The livestock population will most likely increase from the present 10.2 million to about 12.6 million by 2031. Assuming that the intensively-cropped irrigated north-west plain zone will be a major producer of surplus crop residues, the feed resources available will then be 43.5 million t against a demand of about 32 million t. This will most likely create a surplus of about 11.5 million t, although production from other zones may not be able to fully meet the demand.

The above projections based on landscape stability are likely to be seriously compromised by global warming that is already threatening our agriculture. Surface air temperature in most parts of India has already increased by about half a degree during the second half of the 20th Century. Simulation studies by Hadley Centre (UK) and IITM (Pune) suggest that during the 21st Century annual temperature across arid Rajasthan is likely to increase by 2-5°C. Southern Rajasthan and adjoining areas of Gujarat may experience smaller increases than the north. Both summer and the winter temperatures will witness a gradual increase, which will affect the soil moisture regime and crop growth pattern. In the next 50 years monsoon rainfall is likely to decline gradually by 20-30% in the northwestern part of Rajasthan and adjoining Punjab, while the eastern fringe of arid Rajasthan and adjoining Haryana may experience an increase of up to 25%. At the same time winter rains may gradually increase by 20-40%. Arid Gujarat and adjoining south Rajasthan, on the other hand is likely to experience ~25% higher monsoon rain, as well as higher winter rain. There is also the probability of high magnitude droughts and floods. Such a scenario would most likely lead to higher wind and water erosions, as well as changes in vegetation composition and its degradation. Some of the coastal areas of arid Gujarat may experience sea level rise and consequent loss of land (Rupa Kumar, K. *et al.*, 2006; IPCC, 2007).

Modelling of pearl millet production under different temperature and rainfall regimes in western Rajasthan by CAZRI show that the rise in temperature will adversely affect the potential as well as water-limited yields of the crop across the region, while decline in rainfall will have more adverse effect in the relatively low rainfall areas having light textured soils (e.g., Jaisalmer and Jodhpur) as compared to the areas which receive moderate rainfall and have medium textured soils (e.g., Pali). At Jodhpur and Pali, the biomass and seed yield of rainfed crops will most likely decline by 50-54% over present yield with a rise in temperature of 4°C. With a similar rise in temperature its total biomass at Jaisalmer will perhaps decline by 49%, and seed yield by 62%. The adverse effects of temperature rise will be more pronounced when seasonal rainfall also declines. However, with rising temperature even an increase in seasonal rainfall by 20% may not be able to reduce the fall in pearl millet production (Singh, 2008). Modelling of mustard crop's performance under projected climatic situation at Ganganagar between 2020 and 2080 also suggested 20-40% yield loss due to rising temperature in winter despite irrigation (Boomiraj *et al.*, 2010). Some of the likely impacts of climate change on pearl millet's performance and issues of adaptation are summarised in Table 1.

Table 1. Effect of climate variability on pearl millet performance and adaptation options

Climate parameter	Effects on crops and natural resources	Adaptation options
Late onset of rains	Shorter rainy season, risk that long duration variety will run out of growing time	Early-maturing varieties, exploitation of photoperiods, location specific balanced nutrition at planting
Early drought	Difficult crop establishment and need for partial or total re-sowing	Crust breaking, balanced nutrients at planting, organics application, water harvesting and runoff control, delay sowing (but poor growth due to N flush), exploit seedling heat and drought tolerance
Mid-season drought	Poor seed setting and panicle development, fewer productive tillers, reduced grain yield per panicle/plant	Use of pearl millet variability; differing cycles, high tillering cultivars, optimal root traits, etc; water harvesting, reuse and in situ conservation
Terminal drought	Poor grain filling, fewer productive tillers	Early-maturing varieties, optimal root traits, fertilizer at planting, water harvesting and reuse
Excessive rainfall	Downy mildew and other pests, nutrient leaching	Resistant varieties, pesticides, N fertilizer at tillering
Increased temperature	Crusting/ soil capping, poor plant population (desiccation of seedlings), increased transpiration, faster growth	Heat tolerance traits, crop residue management, P fertilizer at planting to increase plant vigour, large number of seedlings per planting hill

Unpredictability of drought stress	Poor crop establishment (desiccation of seedlings), improper/ faster growth	Phenotypic variability, genetically diverse cultivars, agro-forestry
Increased CO_2 levels	Faster plant growth through increased photosynthesis, higher transpiration	Promote positive effect of higher levels through better soil fertility management
Increased occurrence of sand/dust storms at onset of rains	Seedlings buried and damaged by sand particles	Increase number of seedlings per planting hill, mulching, ridging (primary tillage), wind breaks
Increased dust in the atmosphere	Lower radiation, reduced photosynthesis	Increase nutrient inputs (i.e. K)

For the country as a whole a study has shown that the strong negative impacts of rising temperature on crop yield, and by implication on gross domestic product (GDP), will be difficult to circumvent through increase in rainfall. For example, with 2.0°C rise in mean temperature and a 7% increase in mean precipitation, the GDP in agriculture is likely to fall by 7%. With 3.5°C rise in temperature and 15% rise in rainfall, the GDP will possibly fall by 25%, leading to food crisis and poverty. In areas experiencing temperature rise without any increase in rainfall, the revenue loss is expected to treble with each degree rise in temperature, the revenue decline with 1°C rise being estimated as 3% (Kumar and Parikh, 1998).

With increasing human pressure on the fragile natural resources of the arid zone, concurrent warming of the atmosphere, and strong competition for land and livelihood from other sectors of the country's economy, agricultural scenario in arid zone is becoming more uncertain and complex. As climate change scenarios are unfolding amidst changes in many socio-economic paradigms, including globalization of the market, and as the food producers and the society are trying to adjust to those changes, several new challenges are emerging for the agricultural sector, especially threatening its sustainability. Addressing those emerging issues through research needs first a keen monitoring system to analyse and to understand the different components of the change, and then a robust research agenda backed up by a strong research capability to address the problems.

Implications for Future Research Strategies

The projections made above have deeper implications for agricultural research. The areas that need greater attention are as follows.

- Need to develop a robust assessment and monitoring system of the state of natural resources, the drivers of change in the resources, and quantification of the rates of changes for reasonable prediction of the likely directions and magnitude of change.
- Need to develop increased heat tolerance in high-value, temperature-sensitive crops.
- Improving the water use efficiency of crops and other economic plants to withstand rainfall abnormalities.
- Finding measures to increase production potentials in rainfed areas.
- Management strategies to face the likely challenges of increased frequencies of droughts and floods.
- Strategy to minimize the runoff in areas of increased rainfall to capture benefits particularly for winter crops.
- Strategy to increase green cover in the sandy terrain to minimize wind erosion and soil nutrient loss.
- Research for mitigating the likely increased pest infestations as a result of warmer climate.
- Improving the rangelands and the animal production system to face the challenges of uncertainties.
- Development of strategies for crop diversification, integrating with livestock sector for a holistic farming system, agro-processing, and marketing to stabilize the income and improve rural livelihood
- Management strategies for pastoral families on migration, who may face newer challenges and resistance due to more scramble for scarce resources, and who may be more unwelcome.
- Research for making available efficient and affordable utilization of the abundant solar and wind energies for the rural masses, which will also address Green House Gas (GHG) emission.
- Research on other climate-sensitive sectors, including energy and forestry sectors to understand more fully the economic impacts of possible climate change in arid areas.

CAZRI: AN INTRODUCTION

Central Arid Zone Research Institute (CAZRI), had a humble beginning in 1952 when, alarmed by the apprehension that the desert in Rajasthan might spread to Delhi and other parts of India, Government of India established a Desert Afforestation Research Station at Jodhpur to carry out research on stabilization of sand dunes and establishment of shelterbelts for containing wind erosion. In 1957, this station was reorganized as Desert Afforestation and Soil Conservation Station. On October 1, 1959 Government of India, on the advice of Dr. C.S. Christian, a UNESCO expert from CSIRO, Australia, reorganised the Station into a major centre for arid zone research, called the Central Arid Zone Research Institute. While proposing the Institute, the guiding principles were spelt out as study of fundamental aspects of the problems and development of principles of control measures. More focus was laid on a holistic approach that recognizes the fragility of the arid landscape and strength of the region in mixed agriculture, consisting of both crops and livestock. In other words, the Institute *was created for research addressing the environmental and livelihood-based issues* of the region, with emphasis on conservation agriculture. This was one of the first International Institutes of its kind funded by UNESCO under its programme of International Studies on Arid Zones. On April 1, 1966 CAZRI was brought under the administrative control of Indian Council of Agricultural Research.

CAZRI has its headquarters at Jodhpur, and four Regional Research Stations at Bikaner, Pali, Jaisalmer (in Rajasthan) and Kukma (near Bhuj in Gujarat). There are also five Experimental Areas at Kailana, Beri Ganga, Bhopalgarh, Jadan and Chandan, attached to Jodhpur, Pali and Jaisalmer stations for studies on rangeland management. The research farms are located in the different edapho-climatic situations to study essentially the hot arid zones in Rajasthan, Gujarat, Haryana and Punjab. The major agro-climatic regions covered under these four states are: (1) Trans-Gangetic Plain Region (in Punjab, Haryana and north-west Rajasthan), (2) Western Dry Region (in the western districts of Rajasthan, covering the Thar Desert), and (3) Gujarat Plains and Hills Region (in Kachchh and Saurashtra, covering the Great Rann of Kachchh also). The immense natural resource variability in these regions, as well as the Indira Gandhi Nahar Paryojana (IGNP) in the very dry western districts of Hanumangarh, Ganganagar, Bikaner and Jaisalmer in Rajasthan, the other canal systems in Ganganagar and adjoining districts of Punjab and Haryana, and the recently-introduced Narmada Canal system in Saurashtra and Kachchh districts of Gujarat, and in Barmer and Jalor districts of Rajasthan, offer an unique opportunity for location-specific problem-solving research and multi-location testing of technologies. The agro-climatic zones provide some of the excellent field laboratories in arid region for research. Another research station of CAZRI is to be located soon at Leh in the state of Jammu and Kashmir to address the problems of cold arid region in the states of Himacha Pradesh and Jammu and Kashmir. CAZRI takes pride in developing since inception 52 research areas for silvopasture, where it conducted elaborate grazing studies and demonstrated the benefits of range management. After developing the research areas CAZRI handed them over to the Government of Rajasthan, except the five experimental areas mentioned above. In 2005, CAZRI handed over 40.46 ha land at the Headquarters to the Ministry of Health for the establishment of All India Institute of Medical Sciences.

During the last five decades of its existence CAZRI has carried out systematic research on understanding and management of region's natural resources, sustainable farming systems, improvements in plant resources, especially the crop plants of the region, livestock production and management, and use of alternate sources of energy. It has produced a number of need-based, viable and cost-effective technologies, demonstrated those to the stakeholders, developed capacity building of the rural masses through training and education, and transferred several technologies to the stakeholders through various development programmes launched by the Govt. of India/ ICAR from time to time.

Notable among the technologies released for adoption are those for sand dune stabilization and wind erosion control, water harvesting, crop, tree and grassland improvement, dryland farming, arid horticulture, alternate land use strategies, pest management, livestock management, energy management, etc. A recent review of research on Indian arid zone is provided in Kar *et al.* (2009). CAZRI provides regular training and demonstration to the farmers, state officials, NGOs and other stakeholders, and holds regular exhibitions, for which it has an Extension wing and three Krishi Vigyan Kendras at Jodhpur, Pali and Kukma. The Institute also hosts the national network projects on rodents and arid legumes, in which several institutes and agricultural universities of the hot and cold arid regions are effectively participating.

More than 150 villages in western Rajasthan have been reached directly by CAZRI for on-farm demonstration of its technologies. CAZRI also provides training and advisory services to dryland farmers and other stakeholders of the region. An Agricultural Technology Information Centre (ATIC) caters to the needs of the farming community and others interested in the technologies and produces of CAZRI.

CAZRI's VISION

Vision: A greener, climate-resilient arid land with well-managed and sustainable agriculture that provides improved livelihood options and conserves the scarce natural resources.

Mission: To strive for providing appropriate, low-cost technological options for sustainable use of natural resources in the arid regions linked to improved livelihood, and also to monitor and combat drought and desertification.

Objectives: To undertake basic and applied researches that will contribute to the development of sustainable agriculture with improved livelihood options in the arid region; to act as a repository of knowledge on the state of natural resources and desertification; to provide training to the stakeholders in relevant scientific areas; and to collaborate with relevant national and international institutions to achieve the above.

Functions

1. Assessment and monitoring of natural resources for drought and desertification.
2. Research for genetic improvement of arid zone plants and production of quality planting materials.
3. Research for improving arid land farming systems through better stress management in cropping systems and livestock production systems, and also for range improvement.
4. Research for value addition of arid zone products that may help to create a value-chain linking stakeholders at different levels.
5. Research for efficient energy management and farm tool development at affordable cost at village level.
6. Technology dissemination, socio-economic assessment, and capacity building of the stakeholders.
7. Collaboration with different national and international institutions in the above fields for knowledge sharing and improvement of skill.

HARNESSING SCIENCE

Considering the challenges arising from scenarios of climate change as they unfold, the growing imbalance between supply and demand that is leading to resource degradation and desertification, the demand from other sectors of the economy for land and water resources, as well as more attractive and assured livelihood options from the non-agricultural sectors that pull manpower, CAZRI has to strengthen research that helps in sustainable production from a reduced land area with an adverse water balance and with a reduced manpower available for agricultural sector. This calls for not only use of improved scientific knowledge, but also better management practices.

Arid land management and desertification control are the two major objectives of the Institute. To achieve these goals under a fast changing scenario, it is necessary to enhance our understanding of the drivers of change (both natural and human-induced), the rates of current atmospheric and land surface processes, their impact on resource availability and distribution, as well as our capacity to model the parameters for future trends. Also important are creation of database on nature, extent and severity of drought and desertification, and improving our understanding of the vulnerability of land and population to droughts and desertification. The system of assessment and monitoring will, therefore, be strengthened through the use of ground-based instrumentation, digital remote sensing and GIS that will also lead to creation of database and simulation modeling.

For sustainability of arid farming systems, a symbiotic relationship between natural environment and arid agriculture is to be perceived and re-emphasised. Our endeavour shall be to increase the potentials of arid land production systems without depleting the local biodiversity, mining of soil and water resources, or hampering the system's resilience capacity.

Sand dunes and other degraded rangelands (both government and farmer-owned), when put under grasses, shrubs and trees, with proper management, can become inexhaustible sources of forage in this region, which in turn may unleash the captive potentials of livestock sector through management practices. Rangeland management will, therefore, be taken up through a mission-oriented on-farm research with a farming system perspective.

Simultaneously, plant biodiversity of the arid region has to be maintained and harnessed scientifically for improving the livelihood of the rural people. Plants like *Commiphora wightii* (guggal) are now on the verge of extinction due to over-exploitation, while others like *Aloe vera*, *Citrullus colocynths* (tumba), *Salvadora oleoides*, *Acacia senegal*, etc., have received belated attention for medicinal, industrial and food values. Technologies for deriving benefits from these and other local plant materials shall be strengthened.

Conservation agriculture will be a crucial tool in countering the negative impacts of climate change. Watershed management, with appropriate mix of different components of the agri-horti-silvo-pastoral system, crop diversification and better utilization of rainwater through soil and water conservation structures, shall be propagated.

By replacing the conventional low-yielding crop varieties with improved high-yielding ones, and by optimizing agro-techniques commensurate with the changing crop calendar, the areas under arable crops can be reduced by 20-30% without sacrificing total grain production. For this, one of the major requirements is to genetically improve the adaptation, stress tolerance and other necessary traits of the plants to provide higher yields of grain and/or fodder. Developing the short-duration and resistant cultivars through selection and bio-technological mediation will ensure that whatever is planted/sown does not become a victim of uncertain weather.

CAZRI has developed a number of improved varieties of ber, pomegranate, aonla, etc., that are mostly sold in the market as raw products. Adding value to these fruits will vastly improve their market potentials and help in development of nurseries, thereby ensuring rural employment, nutritional security of the people, soil fertility build up and environment conservation.

Ovines are mostly the drivers of small and marginal farmers' economy in the region. While the stock is partly sold by stakeholders to brokers for meat, the milk is consumed at home due to its perishable nature and odour. Through research CAZRI has eliminated the odour and has prepared products like *kulfi*, *paneer*, whey, etc., with a shelf life that is much higher than previously. This has opened up the scope for improving the ovine-based economy of the small holders. Further improvements are now necessary, backed up by market demands.

Arid areas are well-endowed with solar and wind energy, and there is vast scope for their systematic harnessing for agricultural and domestic uses.

CAZRI has so far developed some low-cost solar appliances for cooking food and feed, heating water, making candles, drying agricultural produces, etc. Research will be strengthened to derive also the benefits of photovoltaics, chemical cells, etc., in effective utilization of the clean energy sources at affordable cost by the rural masses.

In short, CAZRI endeavours to utilize the available scientific knowledge and tools in addressing the following issues.

- Assessment and continuous monitoring of arid zone land surface and atmospheric processes through land and satellite based systems, and creation of digital database towards a land information system will be basic to an understanding of the unfolding impacts of climate change and human use patterns on the natural resources. Simulation modelling based on time series analysis of the rates and direction of process change will help to find out the matrix of likely future process changes, their likely impacts, and the types of intervention that would be needed for resource conservation and alternate land uses.
- Desertification assessment and monitoring at periodic intervals, drought assessment in near-real time and a system for identification of areas vulnerable to drought, as well as early warning of drought shall be carried out to address the issues involved.
- Development of sustainable farming systems (arable crops + horticultural crops + trees + shrubs + grasses + medicinal plants + livestock, etc.) and alternate land use strategies, suitable for the evolving socio-economic conditions, and within the broad framework of agro-climatic zones are envisaged.
- Research methodologies for development of wastelands that constitute ~30% of the arid zone, will be fine-tuned and the viable technologies will be implemented in village situations to demonstrate their potentials for employment and resource generation.
- Management of surface and groundwater for efficient input utilization and integrated watershed management wherever possible, will be crucial to sustainable land use. Harnessing multiple water productivity needs to be given high priority in canal command areas.
- Pressurized irrigation for efficient use of water and other inputs to conserve water will receive a high priority. CAZRI will also try to contribute in some component research that may complement the efforts by other

research and development agencies to generate technologies for recharging the depleted aquifers.

- Improvements in indigenous trees/shrubs/grasses/crops, as well as the underutilized plants, particularly for drought and pest resistance and early-growing traits, shall be undertaken.
- Enhancing the productivity of livestock through feed, fodder and health management will continue to receive high priority.
- Integration of livestock in farming system, their multiple use and value addition of livestock products shall also find priority.
- Research on improvement of soil health, adopting organic farming, improved nutrient availability and eco-friendly IPM techniques shall be continued.
- Design and development of efficient and low-cost tools and implements for various agricultural operations, including tillage and post-harvest, will be continued to reduce drudgery in field operations.
- Harnessing of renewable energy (solar/wind) and its use at affordable price for different farm and domestic operations will receive high priority. Application of photovoltaics and finding potentials for hybrid fuel cells will be explored.
- Augmentation of post-harvest technology for the arid zone produces and their value addition to minimize losses, generate employment and increase profitability will be continued. Avenues for market chains are to be explored and suggested for higher economic gains of grassroots producers and ultimate consumers through people's participation.
- Technology transfer, human resource development and capacity building will be strengthened for faster diffusion of technologies to stakeholders.
- Utilizing the gains in IT sector, the modalities for exchange and sharing of information, knowledge, expertise, experiences and technologies will be improved to ensure that scientists and stakeholders are able to find viable solutions together.

STRATEGIC FRAMEWORK

Goal	Approach	Performance measure
Natural Resources Monitoring	Integrated assessment of the state of natural resources (climate, landform, soils, vegetation, surface and groundwater, land uses and land degradation) at semi-detailed scale	Land resources assessment reports and digital resource maps at district/tehsil level
	Quantification of plant biomass, soil carbon and carbon sequestration for technological options to improve nutrient availability	Database on status and establishing techniques for improved availability under different uses
	Quantitative analysis of regional patterns of land use systems and changes therein	Time series maps on major land uses and their interpretations
	Analysis of soil biological activities for their efficient utilization in production systems	Database on status and availability under different land uses and agro-climatic situations; technologies for improved availability
	Simulation of the impacts of future climate change on land resources and crops	Development of research strategies; simulation results
Monitoring of Desertification	Desertification assessment and mapping at periodic intervals	Time series maps on regional patterns of desertification
	Soil fertility assessment and monitoring under different land uses	Regional database and maps on the major and micro-nutrients under different land uses
	Quantification of land surface processes under different terrain conditions for soil and water conservation	Analytical results from ground-based instrumentation of sediment flow and terrain deformation

Monitoring of Weather Variability	Continuous monitoring of weather parameters	Digital database of daily weather parameters from CAZRI stations, other networks, and their interpretation
	Assessment of droughts and floods, their effects on crop plants	Analysis of the monitored regional patterns and their impacts on agriculture
	Agro-advisory based on short and medium range weather predictions	Weekly agro-advisory bulletins
	Development of agricultural contingency plans for adverse weather conditions	Reports on contingency plans during drought, cold wave, etc.
Integrated Farming Systems	Diversified farming system having multiple productivity of livestock, crop, horticultural, medicinal, and silvipastoral species	Alternate land use options comprising suitable combinations of plant species and livestock for different sizes of land holdings in different agro-climates
Soil and Water Management	In situ moisture conservation, rain water harvesting for *khadin*-based and other pond-based production systems	Optimized production systems with multiple water productivity
	Integrated watershed management for livelihood generation and groundwater recharge	Improved livelihood with sustainable resource conservation
Management of Degraded Lands	Grazing land management of common property resources in participatory mode	Productive grazing lands with enhanced carrying capacity on long term basis
	Innovative sand dune stabilization studies using vegetative, mechanical and chemical means	Sand dunes as production systems in both privately owned and public sand dunes

	Rehabilitation technologies for lands degraded due to mining, water logging and salinization	Sustainable and productive land use options along with their rehabilitation
Precision Farming	Management of hydro-climatic extremes through pressurized irrigation, organic farming and other means for enhancing water and nutrient use efficiency	Optimized water use and canopy management for maximum productivity
Drought Physiology and Agrotechniques	Physiological basis of abiotic stress tolerance, plant water relations, C-assimilation, root growth pattern	Climate-resilient cropping techniques, including INM, IWM for enhanced input use efficiency
	Integrated nutrient management, conservation tillage, weed management and recycling of farm waste	
Biodiversity Conservation and Genetic Enhancement	Exploration, collection, introduction, evaluation, conservation and maintenance of germplasm of arid crops, pasture grasses, shrubs and agroforestry trees and development of promising varieties for divers situations.	Elite genotypes/varieties selected/developed, maintained and adopted by the farmers
	Selection, characterization and development of drought, salinity and high temperature tolerant/resistant genotypes.	Climate-change-ready varieties developed
	Evaluation of crops for resistance to diseases and pests and development of breeding materials	Biotic resistant genotypes selected
	Development of repository of germplasm for accessibility to the researchers	Germplasm shared

Molecular and Biochemical Aspects for Plant Improvement	Biochemical and molecular assessment of genotypes for abiotic stress tolerance and their use in improvement programme	Genotypes selected and developed for diverse environment
Improve Production of Quality Seeds/Planting Material	Production and multiplication of quality seeds (breeder and TFL seeds) and planting material of arid crops/trees/shrubs	Quantity of quality seeds produced. Contribution of quality seeds/planting materials in the improvement of socio-economic status of the farmers
	Technology development to produce quality seeds/ planting material	Easy accessibility of the quality seeds/technologies at different clientele level
Integrated Pest Management (IPM) for Safe Production	Selection, multiplication and bioformulations of bio-control agents and bio-pesticides for management of diseases, nematodes and insect-pests of crops, trees and shrubs for harvesting good yield without use of chemical pesticides	Number of bio-formulation and bio-pesticides, developed, tested and multiplied for use
	Dynamics of insects and pest in farming systems and development of IPM schedules in the changing scenario of climate change	IPM schedule developed, adopted and its contribution in increases in crop yield
Sustainable Livestock Management System for Better Productivity and High Value Products	Research on value addition to feed/fodder, area-specific mineral mixture for livestock production, animal health and diseases management	Increased animal production and living standard of livestock rearers

Address Climatic Risks in Livestock Farming	Technologies for livestock – plant interaction with emphasis on nutritional disorders and developing corrective measures through supplements/shelter, etc., for drought management	Improvement in health and productivity of livestock
Changing Livestock Species Proportion in the Region	Studies on adaptability, health, reproduction and production system of buffaloes in irrigated areas	Improvement in livestock fertility and production in the region
Providing Feed and Fodder Security	Identification and evaluation of locally available feed resources with appropriate methods for storage of fodder and its processing /creating fodder banks	To mitigate drought impact and scarcity
Development of Solar and Renewable Energy Devices	Assessment of new and renewable energy sources	Ensured functioning and ease of operation of the developed systems
	Evaluation of solar cells and auxiliary power systems	Energy saving and higher benefit cost ratio
	Integrated hybrid structures and devices for rural and agricultural applications	Linkages with entrepreneurs for commercialization
	PV based micro-irrigation systems for arid zone farming	Long term performance
	Cool chambers and poly-houses	
Development of Farm Machinery and Tools	Appropriate seeding devices	Higher efficiency with increased output
	Mechanized weeders and FYM applicator	Field testing and improved benefit cost ratio
	Efficient tools for inter-cultural and harvesting operations	Linkages for adoption
	Equipment for precision arid agriculture	

Post-harvest Technology and Value Addition	Establishing processes and developing equipment to add value to agricultural produce	Features and novelty of the developed process and engineering equipments
	Quality assessment of the developed product	Quality of the product at different intervals of shelf life
	Improving shelf life of produce	
Technology Dissemination	Developing appropriate tools and methods for effective dissemination of technologies	Adoption status at farmers' field
	Capacity building of stakeholders	Updating knowledge
	Integrated rural resource management through satellite links of village resource centre	Solution to various farm level problems
Socio-economic Monitoring, and Impact Assessment	Socio-economic parameters for development and change and Impact assessment of various technologies	Socio-economic analysis
	Gender issues and women empowerment through capacity building	Improved livelihood status
Agri -business Development	Involvement of different stakeholders in agricultural trade and export	Policy input for better returns to farmers
	Market linkages and value chain of agricultural produce	
Capacity Strengthening through Training at National and International Level	Improve research efficiency by qualified manpower.	Capacity building

EPILOGUE

Located in the monsoon climatic regime, the arid lands of India are one of the most thickly populated deserts in the world, where rainfed agriculture has taken roots several millennia ago, and has evolved as an imitable system despite modernization. Due to very high population pressure and indiscriminate use of the scarce natural resources, many areas of the arid zone have started facing problems of water scarcity and natural resources degradation. Another major threat facing the arid areas is climate change, and more specifically the problems associated with rising temperature and more aberrant rainfall. As a result of these threats agriculture in the region is facing an uncertain future. Yet, the region has to produce more from the available finite land resources to feed its increasing human and livestock population.

Central Arid Zone Research Institute dreams of a well-managed and climate-resilient arid land, where the vast rural communities can derive livelihood support from sustainable agriculture under a symbiotic relationship with the nature. The institute strives for better understanding of the dynamic relationship between the atmosphere-lithosphere-biosphere-human continuum, and for developing time-tested and affordable technologies on the basis of improved understanding of the system, which will address the problems faced in sustainable use of the land.

Considering that many of the emerging issues of agriculture arise from the high human pressure on the land and from climate change, and that many of the problems may not be amenable to the known sets of technology and prescribed remedial measures, CAZRI pledges itself to a better understanding of the involved parameters through modern methods, and to carry out focused research to develop affordable technologies that would at least help to maintain long-term sustainability of the system and improve the livelihood opportunities through value addition to the agricultural produces and encouraging market chain. The inherent strength of the region in livestock-based farming system, agro-forestry, diversified agriculture, conservation agriculture and range management will continue to receive the needed attention, while new scientific methods will be applied to make the crop plants more resistant to emerging stresses, and at the same time make them more productive.

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