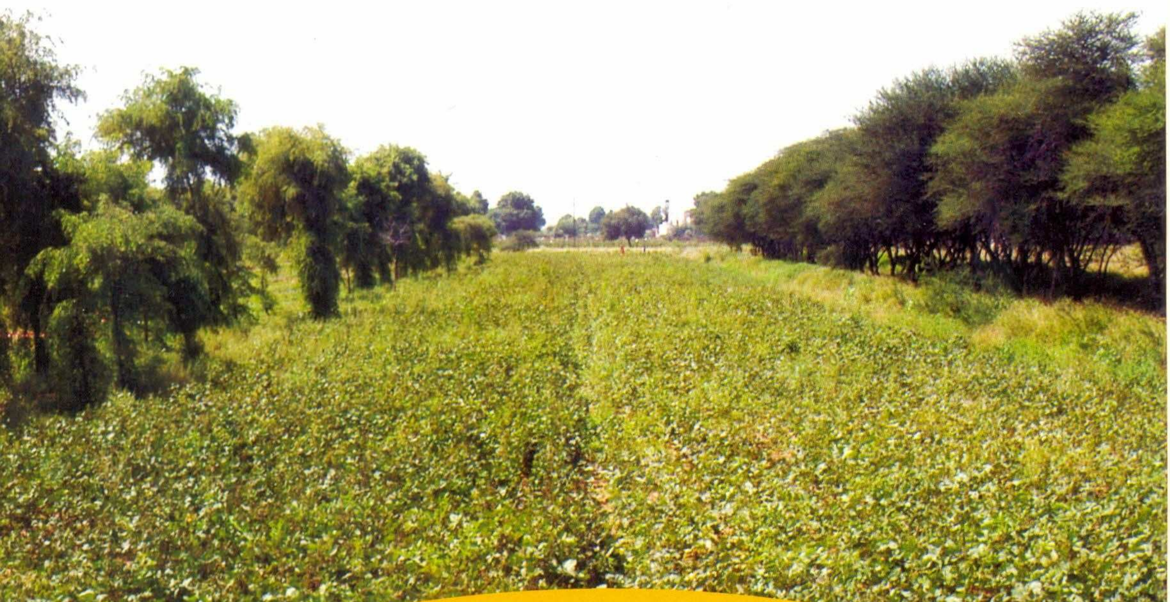
CAZRI FOUNDATION DAY LECTURE

OCTOBER 1, 2014



Dr. A.K. Sikka

Dr Alok K. Sikka has taken over as Deputy Director General (NRM), ICAR. He is also holding additional charge of Deputy Director General (Agricultural Extension), ICAR and his previous position of Technical Expert (Watershed Development), National Rainfed Area Authority (NRAA), Planning Commission, Government of India, New Delhi. Before joining NRAA, he was Director of ICAR Research Complex for Eastern Region, Patna and Basin Coordinator for Indo-Gangetic Basin under the CGIAR Challenge Program on Water and Food. He did hisBachelor's degree from Allahabad University in 1976 in Agricultural Engineering and M.Tech from Indian Institute of Technology (IIT), Kharagpur in 1978. He is Ph.D. in Civil and Environmental Engineering with specialization in Hydrology and Water Resources Engineering from Utah State University, Logan, Utah, USA.

He started his career in the Indian Council of Agricultural Research (ICAR) in 1978 at Central Soil & Water Conservation Research and Training Institute (CSWCRTI), Dehradun. He has a rich and diverse experience of over 34 years in research, institutional and policy issues, teaching, training, extension and consultancy in the areas of soil & water conservation, watershed management, water harvesting, hydrologic modelling, drought studies, climate change, water management, water productivity and farming systems. Dr. Sikka worked in different capacities in India and abroad which include Head of the Centre; CSWCRTI Research Centre, Udhagamandalam; Scientist In-charge, Drought Division at National Institute of Hydrology,Roorkee; visiting Professor at University of Arizona, Tucson, Graduate Assistant at Utah State University; Logan; Utah and as faculty at Oregon State University; Corvallis; Oregon; USA. He has been associated with many internationally supported projects including DFID, ACIAR, USAID, CGIAR, IFAD, World Bank, etc.

He has more than 250 publications in the form of research papers in the international and national Journals/Proceedings, book chapters, bulletins, reports and books to his credit. He is recipient of many national awards including Vasantrao Naik Award-2000 of ICAR for Research Application in Agriculture for outstanding contribution in the field of Water Conservation and Dryland Farming, ICAR Award for Team Research for the Biennium 2001-02, Dr. Rajendra Prasad Puruskar of ICAR for the year 2005-06, Hem Prabha – S.N. Gupta Medal (2000), Certificate of Merit (1989-90) of Institution of Engineers (India), Bhu-Ratn Award 2012-13, Distinguished Alumnus Award, 2014 of SHIATS-DU, Allahabad. He is Fellow of National Academy of Agricultural Sciences, Indian Association of Soil & Water Conservationists and Soil Conservation Society of India. He has been the Chairman/member of many national and international committees.

CLIMATE RESILIENT AGRICULTURE: STRATEGIES AND OPTIONS FOR ARID REGIONS

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Arid and semi-arid regions are characterized by a climate with no or insufficient rainfall to sustain agricultural production. The major distinguishing feature for defining and planning for the arid zone is the low rainfall (below 500 mm or Aridity Index <0.20) with more than 50% inter-annual variability. High wind and solar regimes in the arid region further increase the effect of rainfall variability and the whole complex makes a fragile ecosystem in which small disturbances may cause great loss to the sustainability, which are sometimes irreversible. India has about 0.32 million km^2 area under hot arid zone spread in seven states, in addition to 70.3 thousand km^2 area under cold arid zone. State of Rajasthan accounts for 61.9% of Indian arid zone followed by Gujarat (19.6%), Punjab (4.6%) and Haryana (4%). The remaining hot arid zone of India lies in pockets in Andhra Pradesh, Karnataka and Maharashtra. Leh and Kargil districts of Jammu & Kashmir and Lahaul and Spiti along with some parts of Chamba and Kinnaur districts of Himachal Pradesh comprise the cold arid area of India.

Agriculture including animal husbandry and other allied sectors are the major drivers for sustainable growth and productivity worldwide. However, these sectors are highly sensitive to climate variability. Arid agriculture particularly, is very vulnerable due to wide intra and inter-seasonal climate variability resulting in water scarcity and temperature stress. Variability in south-west monsoon season (June-September) rainfall has profound impact on food grain production. Inter-annual variation of rainfall increases with decrease in total rainfall amounts. Rainfall in arid region is low and its amount decreases from east to west while its variability (coefficient of variation) increases in that direction. The district-wise probability analysis shows that Churu and Jhunjhunu districts have the probability of drought occurrence once in five years, whereas on the western side, Jaisalmer and Barmer have high probability of drought occurrence, i.e., once in two years. Because of low rainfall and its erratic distribution, the productivity of crops, nose dives during the years of drought and due to aberrant weather situations like heat wave, etc. Successive droughts for two or more years have a devastating effect on natural resources, availability of water, production of food and fodder.

Climate variability is not limited to rainfall alone but also due to variability in temperature; relative humidity, etc. Thus have direct and indirect effects on agricultural output. Climate change, attributed mainly to the increased greenhouse gas (GHG) emissions, is likely to further exacerbate the situation in arid regions. Based on multiple climate models and scenarios for CMIP5 data, heat waves in India are projected to be more intense, have longer durations and occur at a higher frequency and earlier in the year. Projections indicate that a sizable part of India will experience heat stress conditions in the future. In northern India, the average number of days with extreme heat stress condition during pre-monsoon hot season will reach 30. It will increase uncertainties and add new risks. Increased temperature is likely to reduce the crop growing period and exacerbate the water and temperature stresses. Projected increase in extreme events such as droughts, floods, heat waves and storms are likely to damage crops. Altered pest scenario will add new dimensions to these challenges. The impact of climate change on livestock may be through direct effects on animal health, growth, and reproduction; disease patterns change in parasites, livestock feed availability; and impacts on area, production and productivity of pastures and forage crops. With fragile natural resources and low adaptive capacity farmers of the arid regions are the most vulnerable to the impacts of climate change/variability.

Friends, as you all know that agriculture not only suffers from climate change but also contributes to it immensely. According to the IPCC 5th AR (2014), Agriculture, Forestry and other Land Uses (AFOLO) contribute 24% of the total GHG emissions (base year 2010). The main direct sources of GHG emissions in the agricultural sector are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). However, agriculture and forestry sectors can also lead to carbon storage in biomass and soil, acting as sinks. Their management will play an important role in managing climate change.

I would like to draw your attention to a few related issues specific to this region.

Sandy soils have low water holding capacity. Soil organic matter (SOM) breaks down very quickly due to high temperatures. The higher temperatures under changed climate scenario will increase the rate of SOM decomposition. Heavy rains and prolonged droughts are likely to increase soil erosion. Proper combination of physical conservation structures, water and organic matter management will be required to maintain good soil physical, chemical and biological conditions. Higher soil organic carbon increases water and nutrient retention, enhances soil biodiversity, reduces soil erosion and improves nutrient and water uptake by plants. Soil disturbance accelerates reduction in SOM. Management practices that reduce soil disturbance (reduced or no-tillage) and bring about a high accumulation of organic matter should be introduced. Integrated soil-crop-water management can provide optimum physical and biological conditions for crop production. Burning of crop residues should be avoided by all means and recycling of crop residues through composting and manure must be ensured.

Degraded lands are very vulnerable to climate change due to poor status of SOM and soil biodiversity and increased rates of soil erosion. Since these soils are poorly managed they would rapidly respond to improvements in management. Soil erosion by wind or water can be reduced by selecting suitable techniques from a range of soil and water conservation measures already developed. Planting of multipurpose trees, shrubs and grasses will not only sequester/increase soil organic carbon (SOC) but also provide feed for livestock.

Water resources too are likely to be adversely affected by climate change that may reduce the availability or reliability of water supplies in low rainfall zones. Farmers will have to adapt to changing hydrological regimes by changing water management practices. Improvements in run-off management and irrigation technology (i.e., river runoff control by reservoirs, water transfers and land conservation practices) will be crucial. Increasing efforts should be directed toward rainwater harvesting and other water-conserving practices to slow the decline in water levels in aquifers. With rising temperature and increased evapotranspiration demand, any adaptation strategy in agriculture should be oriented toward a shift from conventional crops to types of agriculture that are less vulnerable to evapotranspiration loss. As surface water resources are very meagre in arid zone, the use of groundwater is on rise and resulting in depleting groundwater resources. This in turn is increasing the use of fossil fuels for pumping water and raising the energy consumption for water supply. Management at watershed level is the best approach for efficient use of rainwater. A number of measures are available like contour bunds, graded bunds, *in situ* and *ex-situ* rainwater harvesting, groundwater recharge, conservation tillage, maintenance of vegetation cover, planting grass strips in steeply-sloping fields, terracing for soil moisture conservation, re-use of waste water etc. These may be used in combination as per the need for higher water productivity. Traditional water harvesting structures need to be refined to increase the efficiency. More attention would be required for moisture retention in the soil profile for reducing evapotranspiration, reduction in runoff and deep percolation losses and further enhancing for water use efficiency. Increasing levels of ground water salinity and its usage for irrigation may lead to adverse affects on crop productivity particularly in food legumes. Recycling of wastewater and multiple uses of water should be encouraged in drought-prone regions

Diversity of biota in the agro-ecosystem and its resilience to climate change shows a proportional relationship. There is a growing recognition that conserving and using biodiversity is essential for coping with climate change, while climate change itself poses severe threat to genetic diversity. The conservation and enhancement of biodiversity in agro-ecosystems both above and below ground (soil biodiversity), and management of ecosystem services underpin sustainable farming practices. Biodiversity in all its components (genes, species and ecosystems) increases resilience to changing environmental conditions and stresses, such that genetically-diverse populations and species rich ecosystems have greater potential to adapt to climate change. Genetic resistance to drought, pests and diseases found in crop and animal gene pools, have been key priority of conservation and breeding programmes to improve crop varieties and animal breeds. Therefore, the preservation and sound use of domesticated plant and animal genetic resources and their wild relatives is fundamental to impart resilience to climate change. The traits that may be important for climate change adaptation include tolerance to drought, high temperature, cold, salinity, poor quality water; and resistance or tolerance to pests and diseases. Changes in weed flora due to climate change pose challenge for developing efficient management strategies. *In* and *ex-situ* conservation of wild relatives of crops, endangered and threatened species is of paramount importance.

We are well aware that the farmers of arid region have been practicing integrated farming since ages. Almost every farm family have some livestock and every field have at least tree component. They are aware that increasing diversity of production at farm level is always a better adaptation strategy to improve the resilience of agricultural systems. Diversified production systems reduce vulnerability and enhance adaptive capacity of resource poor farmers, if one or more component fails.

The **diversification of agriculture** that comes from integrating crops, grass, trees and livestock imparts stability in production, efficiency in resource use, and conservation of the environment most importantly enhancing the livelihoods of the farmers in arid region. Successful integration creates synergies between crops, livestock, trees or grasses that result in enhanced sustainability.

Integrated crop-livestock systems benefit ecosystems through increased biological diversity, effective nutrient recycling, improved soil health and preserved ecosystems. Integrated farming systems (IFS) increase the efficiency and environmental sustainability of both the components, viz., crops and livestock. The waste of one is a resource for the other and, thus, optimizes the use of resources and lessens pollution. Manure increases crop production and crop residues and by-products feed animals, improving their productivity.

Inclusion of trees like shrubs and/or grasses in IFS reduce the impacts of weather vagaries (droughts, heavy rains, heat and cold waves, and wind storms), stabilize soils, prevent erosion, incorporate nutrients into deeper layers, increase water infiltration and retention in soil, enrich biodiversity, provide diverse habitats for beneficial predators and pollinators, increase carbon sequestration in addition to more income. Planting trees in agricultural and other lands is cost effective compared to other mitigation strategies. Even diversifying cropping system (mixed cropping, intercropping, relay cropping, crop rotation) is much beneficial and desirable under our agro-climatic conditions compared to monoculture.

Friends, I would like to discuss issues related to crop production in arid regions. We know that contribution of arid agriculture to GHG emission is very meagre but adverse impacts of climate change are likely to be very high. However, with appropriate technical, institutional, socio-economic and policy infrastructure in place, there is a huge potential for good crop management practices (GMPs) and approaches to adapt to climate change and contribute to its mitigation.

In my opinion, **the breeding programmes** of CAZRI and other research Institutions of the region must focus on developing improved varieties that are tolerant to heat, drought, salinity stresses, while maintaining high yield potential under such adverse conditions. Varieties that are developed to resist these conditions will help to ensure that agricultural production continues and even improves despite uncertainties about future impacts of climate change. Simultaneously, they should also be able to make best use of increased CO_2 concentrations. Insect pests and disease resistant varieties will require fewer pesticides and thus, will be more environment friendly.

Increasing water productivity at farm level will be the key management issue. Judicious use of rain, surface and underground water resources, in conjunction with other management practices like nutrient management, pest management etc. can reduce the adverse impacts of weather vagaries and imparts stability to the system. Increasing irrigation efficiency at all the levels will be required. Low pressure drip irrigation systems may be adopted to efficiently use the harvested rainwater for irrigating to high value crops (vegetables, fruits). In irrigated agriculture, conventional irrigation methods (check-basin, ridge and furrow) should be replaced with efficient irrigation methods like drip, micro-sprinkler, and sprinkler irrigation. Irrigated production systems use greater amounts of inorganic fertilizer and other agrochemicals than rainfed systems. Consequently, efforts to reduce greenhouse gases through improved water and nutrient management practices are likely to have more impact in irrigated lands than in rainfed areas.

Inter and intra-seasonal climate variability poses high uncertainties and risks for crop production in arid agro-technologies. Length of favourable growing season of rainy season crops may increase or decrease depending upon the rainfall amount and its distribution. Change in sowing time along with alteration other crop management practices may be required. Contingency crop planning (technologies and required inputs) is pre-requisite to combat weather vagaries like delayed onset of monsoon, prolonged dry spells, droughts, floods, heat wave and cold wave. ICAR has prepared district level contingency plans so far for 576 districts in the country in consultation with its institutes, State Agricultural Universities, KVKs and line departments of different states. These plans also cover contingency measures for livestock, fisheries, horticulture and poultry sectors also

Integrated use of organic matter (FYM, compost, crop residues, green manure), bio-fertilizers and chemical fertilizers, what we call as Integrated Nutrient Management (INM) not only meets the crop's nutrient requirement but also increases water use efficiency and soil biodiversity. Inclusion of legumes in cropping system reduces fertilizer requirement in addition to other obvious advantages. More efficient application methods of manures and fertilizers, precise nutrient management as per soil analyses can contribute to deliver nutrients according to crop demand. Nitrogen use efficiency is very low resulting in economic losses and environmental degradation. S-coated urea has been found to be very effective in increasing N-use efficiency in arid zone. Sandy soils dry very quickly at surface. Therefore, the zone of nutrient management might need to be deeper. Foliar nutrition of crops is another strategy for enhancing crop productivity during seasonal and abnormal weather situations.

Many believe that arid regions being extremely dry zones may be free from pest and diseases, but the real situation is contrary to this belief. The regions suffer greatly due to variety of insects and rodents infestation and fungal, bacterial, viral and nematode diseases to annual as well as perennial crops. Pest management strategies that are efficient and do not produce adverse side effects are more desirable. These include applying integrated pest management (IPM) strategies, where ecological pest control is used in preference to hazardous pesticides.

Arid agriculture is mainly livestock based and, therefore, needs adequate attention of all of us for their enhanced productivity *vis a vis* climate change. We all are well aware that a large number of animals are maintained on degraded lands or poor quality fodder. The desert livestock may make some contribution to GHG emissions but not much in production and income. We have good breeds (cattle, sheep and goats), adapted to harsh climatic conditions and responsive to better feeding and management conditions. Considering shrinkage, that too of poor quality grazing resources, there is need for developing and adoption of semi-intensive and intensive production systems.

Major productivity gains have been achieved through breed improvement, balanced nutrition, health care, as well as general improvements in animal husbandry. Extending these approaches to small scale systems, where there are large productivity gaps, is important. Breeding programmes will need to account for higher temperatures, lower quality diets, greater disease challenges, and food demands. Farmers' and herders' access to breeds better adapted to changes and knowledge of feeding, health care and management will be fundamental for increasing production.

Grazing management during summer months will be essential to alleviate thermal stress. For example, grazing during early morning and late evening will reduce thermal stress. Supplemental feeding may be required even for maintenance of body weight as the quality of grazing resources is very poor during summers. Physical modification of the environment through shade, improved ventilation, combination of wetting and ventilation can be made in the animal shelters to eliminate thermal stress.

Wherever possible, controlled and rotational grazing should be practiced, which can be adjusted to the frequency and timing of animals grazing needs and better suits these needs with the availability of pasture resources. Rotational grazing gives the grasses an opportunity to regenerate and gain sufficient good quality biomass. This enhances the quality and digestibility of the forage and improves the productivity of the system. Rotational grazing is possible on managed pasture systems.

For **animal feed management**, the crop residues represent major part of the diet of ruminants in crop-livestock farming systems. Grazing animals gets poor quality dried grasses except during few months of rainy season. While these resources provide inexpensive feed source, they are usually of low digestibility and deficient in crude protein, minerals and vitamins. The low digestibility substantially limits animals' productivity and increases CH_4 emissions. Livestock diets require more energy-rich feeds to support higher levels of milk, wool and meat production. Increasing the digestibility of feed rations by improving the quality of crop residues or supplementing diets with concentrates will substantially increase productivity and reduce CH_4 emissions. Milling by-products, oilcakes, and other agro-industrial by-products, combined more effectively with basal diets to enhance the animals' use of the feed, can be used. As far as possible, locally available ingredients should be used to reduce the cost of feed. Supplemental feeding of vitamin-mineral mixtures improves the feed conversion efficiency. Feed conversion efficiency can also be increased by improving animal health through better veterinary services, preventive health programmes, proper shelter and improved water quality. Growing fodder crops will become economically competitive as demand for animal products increases.

Climate change may increase the frequency of occurrence of the existing diseases or induce emergence or re-emergence of new diseases in the arid livestock, therefore effective **health care systems** should be evolved. Vigilant surveillance system can check the outbreak of diseases and consequent losses. Losses can be minimized through timely and coordinated vaccination programmes. Herders and farmers should get training for early detection of diseases and recognition of new threats.

The condition of **rangelands** is very poor and requires immediate attention of researchers, policy planners and farmers. Introduction of grasses, shrubs and fodder trees can minimize further degradation and improve condition, but grazing management will be required to keep grasslands in good condition. Mixed herds of grazers and browsers make the best use of rangeland resources.

Livestock feed poor in quality as well as digestibility results in increased emission of CHGs like methane. Feeding balanced diets to livestock, according to their requirements depending on growth stage, milk production, etc. meets their requirements, improves digestibility and reduces emissions. Inclusion of oils in grain diets and inclusion of legumes in feed also reduce GHG emission. Another major source of emission is manure. Proper collection, handling and storage of manure may reduce emissions. Composting and use for biogas reduces emissions and makes the best use of manure. Use of cow dung cakes for heating and cooking purposes must be discouraged.

Coming to **energy use** in agriculture in arid regions, I would like to emphasize that the small and cost effective farm machinery is required not only for increasing the energy efficiency and reducing the drudgery, but also in mitigating the likely effects of climate variability. You all know that use of tractor drawn farm machinery has been increasing which has resulted into increased use of non-renewable fuel. Likewise, use of electricity is also increasing for pumping out groundwater, threshing of grain, and post-harvest processing. Production of chemical fertilizers also needs energy. It is, therefore, essential that we improve energy efficiency and use diverse energy sources with emphasis on renewable energy. I am happy that CAZRI has contributed immensely in developing a variety of solar thermal and photovoltaic devices for rural sectors.

Solar power (photovoltaic or thermal), wind and geothermal energy are all sources of energy that are available for both large and small applications. Renewable energy is being used on farms. Use of solar pumps for irrigation is one example. Use of solar devices for domestic use as well as in post-harvest processing can reduce carbon footprints significantly. Use of cow dung cakes must be replaced by biogas, or solar thermal devices. Where it is not possible or accepted, clean cooking stoves should be promoted which make food preparation more energy efficient and reduces health hazards.

GHG emissions from cropping systems can be reduced by adopting improved management practices like, use of energy efficient farm machinery, solar pumps for irrigation, balanced nutrient application through organic and inorganic sources according to soil test crop response, use of sulfur coated urea, split application and band placement of urea, better manure preparation and application methods, use of crop residues as mulch or for composting.

MANAGING LOSSES AND RISKS

Like others, productivity in the arid regions too suffers substantial losses during harvesting, transport and post-harvest processing resulting in wastage of money and reduced efficiency of production resources. As they say, money saved is money earned. Reducing such losses will make additional availability of food, fodder, fibre, fuel etc. for food and environmental security and increased efficiency of production. Harvesting losses can be minimized by using and harvesting at appropriate stage with proper machinery. Postharvest losses of crops can be reduced by improving infrastructure for packaging, storage and transport; control of temperature and relative humidity; and with chemical and biological compounds. The meat and dairy sector will require more efficient refrigeration in order to maintain the food cold-chain, to cope with increasing temperatures resulting from climate change. Managing crop/produce losses during hailstorm, frost, floods etc. still a challenge. The recent crop losses due to hailstorm across the country alert us for both long term preparedness and short term management strategies for extreme events.

As mentioned earlier, crop diversification and diversified farming systems reduce risk and stabilize income. Under National Action Plan on Climate Change (NAPCC) programmes, diversified farming systems and off-farm income activities will be promoted to stabilize income. Weather-based insurance schemes reduce the risk and encourage farmers to adopt improved practices. Seasonal and medium range weather forecasting have to be strengthened, and weather based agro-advisories have to be disseminated through ICT based systems. Education, training and knowledge have to be critical for the stakeholders. As the communities will be more informed, the chances of adoption and success will be more.

I have highlighted the issues and concerns of climate change in arid agriculture. In my opinion the future agriculture, by whatever name you call it will have to address the issues of food security and climate change simultaneously. I am flagging a few points in this regard:

- It should be efficient as well as sustainable to provide sufficient, nutritious and safe food for the present and future generations.
- It should adapt and build resilience to climate change to reduce vulnerability to drought and other extreme events.
- It should lower GHG emissions and increase carbon sequestration.

CLIMATE SMART AGRICULTURE

In recent years we have been talking about Climate Smart Agriculture (CSA) and we feel that it will address all these issues. CSA in-fact integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. In other words, CSA is a sustainable agricultural production strategy seen through the lens of climate change. It focuses on maximising farm output in changing climate scenario and also attempts to mitigate the ill effects of climate change (mitigation). In Indian context, our focus is on climate resilient agriculture, with emphasis on adaptation to climate change through climate resilient practices for meeting our food demand. Adaptation to climate change may also have co-benefits of mitigation as well. There is a great value in integrating co-benefits of mitigation with adaptation in reducing the undesirable impacts of climate change.

The National Action Plan for Climate Change (NAPCC) for India was initiated in 2008 to critically address the challenges posed by climate change. National Mission on Sustainable Agriculture (NMSA) is one of the eight missions of the NAPCC. Initiated under NMSA, National Initiative on Climate Resilient Agriculture (NICRA) project of the ICAR has made excellent beginning towards climate resilient agriculture with long term strategic research (crop, animal, fodder, etc.) and demonstration of climate coping technologies on real time basis. Technology demonstrations at 100 villages throughout the country under NICRA, including four in Rajasthan (Jodhpur, Bharatpur, Jhunjhunu and Kota), have demonstrated confidence in enhancing climate resilience through smart practices and technologies. However, concerted efforts are required for up-scaling those practices through on-going schemes/programmes of the Government including NMSA.

WAY FORWARD

Farmers and herders have been adapting to socio-economic and environmental changes for centuries, but the rate of change is becoming too fast for them to be able to respond. Local coping mechanisms alone might no longer suffice. Technological and policy support will be inevitable.

Land should be put to proper use. Integrated livestock centric farming system would be an excellent strategy for managing the sustainable productivity of arid lands under changing climate scenario. In view of high livestock population in this region, areas with high potential for intensive and extensive livestock production should be delineated to improve productivity. Besides activities on conservation and improvements of local breeds, their feed and fodder management, and health care should also be strengthened.

We should also strengthen our activities on region specific stress tolerant crops, fodder grasses varieties; besides water, soil, nutrient and pest management strategies. Likewise we should be ready with micro level contingency plans for specific situations.

There is a need to identify land with high production potential, and high potential for carbon sequestration. Soil tillage is the single most energy-consuming operation in crop production. Practices such as reduced and zero tillage have the potential to bring about significant energy savings. Maintenance of farm machinery increases energy efficiency.

Efficient farm machinery using renewable energy source - solar, thermal, bio etc. - needs to be developed and popularized. Emphasis is needed 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.

Increasing SOM levels in degraded soils can convert them into carbon sinks and contribute to climate change mitigation. Therefore, restoring degraded lands and increasing the level of organic carbon should be a priority action.

Canal irrigation projects in arid zones of Rajasthan have changed the landscapes and are also leading to second generation problems of waterlogging, salinity etc. It may be worth considering these emerging scenarios while prioritizing research at the Institute. Water management in arid and semi-arid regions assumes great importance, and more focussed research needs to be carried out keeping in view the emerging scenarios.

I am very happy that CAZRI has established a new Regional Research Station at Leh, and all out efforts should be made to initiate cold arid zone research. Networking and partnership should be strengthened to address some of the above issues.

In the end, I must say that the climate-smart agricultural practices will be unique to different agro-ecological conditions and farming situations, but they will share some common aspects. They must conserve natural resources (soil and water resources, biodiversity), maintain ecosystem in good health, increase efficiency (water, nutrient, energy, feed), recycle resources (water, organic matter), adapt to climate change (drought, high temperature, disease, pest tolerant /resistant varieties and breeds), increase resilience to climate variability (suitable varieties, altered agronomic management, contingency plans, fodder banks, appropriate shelter for livestock) besides decreasing emissions and increasing carbon sequestration.

I have expressed my concerns and also possible research and development issues for mitigating the ill effects of climate change. On this happy occasion of **CAZRI's Foundation Day,** I appeal to the scientific community of this great Institution to address these issues and come out with appropriate solutions for the arid regions of India. Your endeavour in this direction will also help pave the way for arid regions of other nations as well.

I wish you all the best.

The **Central Arid Zone Research Institute**, or CAZRI, as it is popularly known, was first established as Desert Afforestation Station in 1952 and was later expanded into Desert Afforestation and Soil Conservation Station in 1957, and finally upgraded to a multidisciplinary research institute in 1959 under Indian Council of Agricultural Research, New Delhi. There are five Regional Research Stations of the Institute located in different agro-climatic zones to work on location-specific problems. The Institute has the mandate to undertake basic and applied research that will contribute to the development of sustainable farming systems in the arid ecosystem; to act as repository of information on the state of natural resources and desertification process and its control, in the form of digital database; to develop livestock-based farming systems and range management practices for the chronically drought-affected areas depending on livestock species; also aquaculture in water; to utilize high and precision technologies in production systems; to provide scientific leadership and to develop collaboration with State Agricultural Universities, State line departments and other national and international agencies for generating location-specific technologies and transfer of the technologies; to act as a center of learning for arid land management technologies; and to provide consultancy and other services for utilizing the available expertise.

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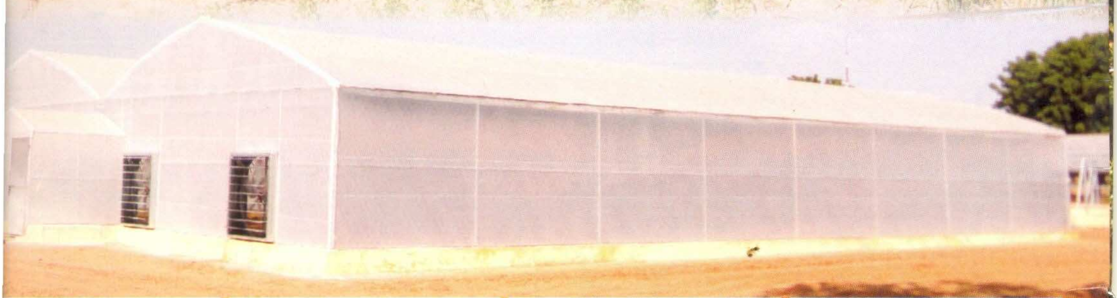




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Evergreen Printers 9414128647