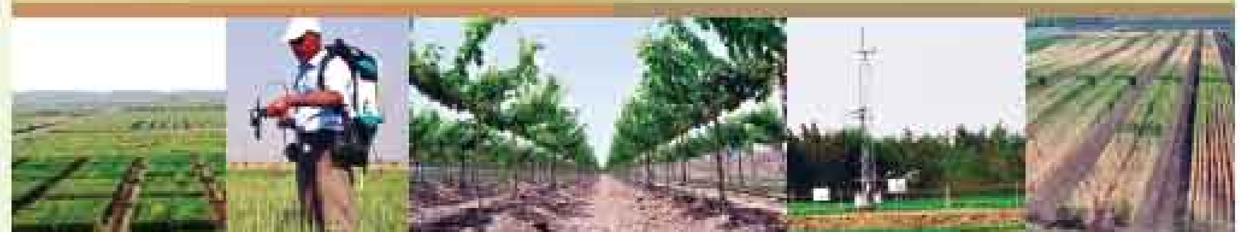
Vision 2050



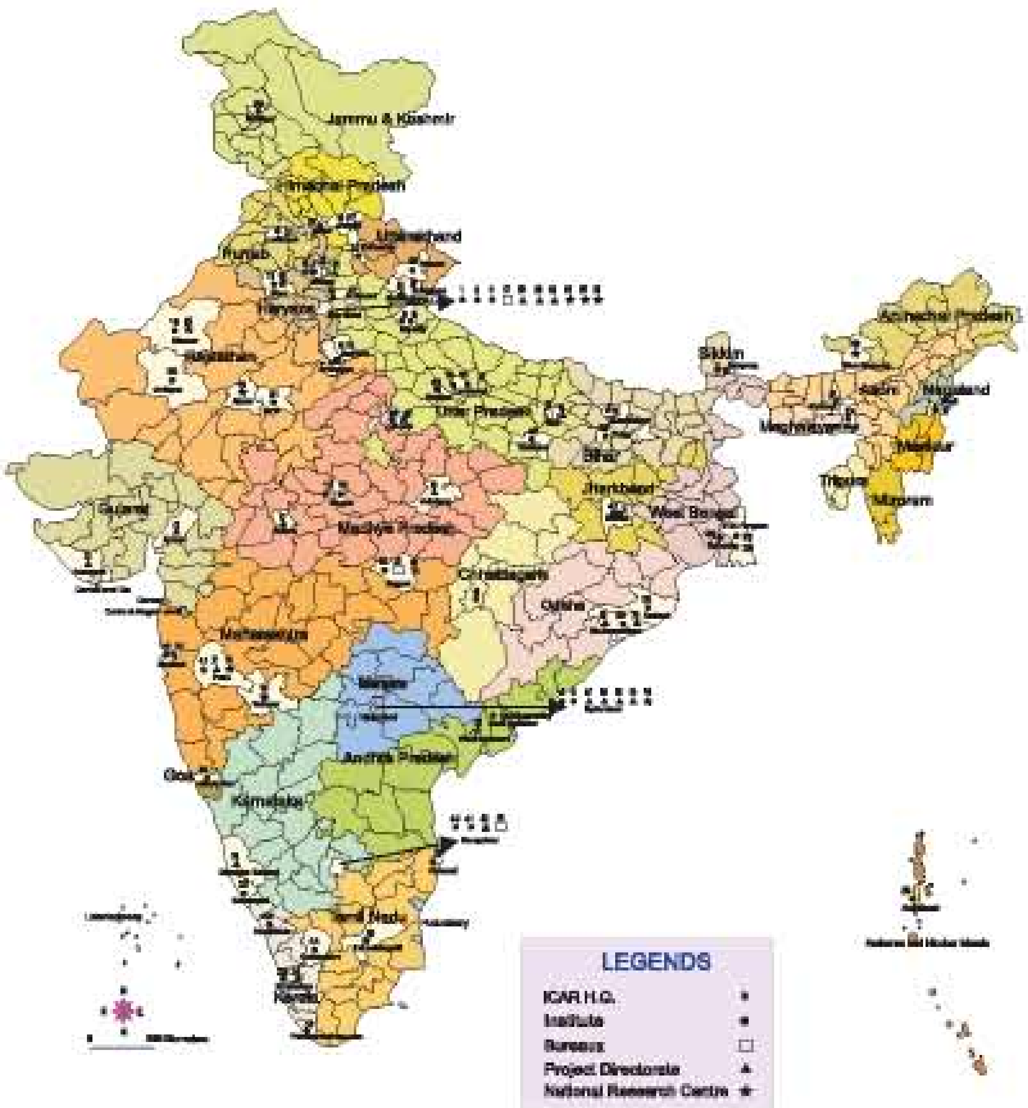
National Institute of Abiotic Stress Management

Indian Council of Agricultural Research

राअप्रस
NIASM

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Institutes, Bureaux, Directorates and National Research Centres



• 64 Research Institutes • 6 Bureaux • 15 National Research Centres • 15 Project Directorates

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Agricultural Universities

LEGENDS

State Agricultural Universities

Central Universities with Agricultural Faculties

Central Agricultural University

Deemed Universities

Vision 2050

राअप्रस
NIASM

National Institute of Abiotic Stress Management
(Indian Council of Agricultural Research)
Malegaon, Baramati 413 115
Pune

www.niam.res.in

Printed : July 2015

संदेश

भारतीय सभ्यता कृषि विकास की एक आधार रही है और आज भी हमारे देश में एक सुदृढ़ कृषि व्यवस्था मौजूद है जिसका राष्ट्रीय सकल घरेलू उत्पाद और रोजगार में प्रमुख योगदान है। ग्रामीण युवाओं का बड़े पैमाने पर, विशेष रूप से शहरी क्षेत्रों में प्रवास होने के बावजूद, देश की लगभग दो–तिहाई आबादी के लिए आजीविका के साधन के रूप में, प्रत्यक्ष या अप्रत्यक्ष, कृषि की भूमिका में कोई बदलाव होने की उम्मीद नहीं की जाती है। अतः खाद्य, पोषण, पर्यावरण, आजीविका सुरक्षा के लिए तथा समावेशी विकास हासिल करने के लिए कृषि क्षेत्र में स्थायी विकास बहुत जरूरी है।

पिछले 50 वर्षों के दौरान हमारे कृषि अनुसंधान द्वारा सृजित की गई प्रौद्योगिकियों से भारतीय कृषि में बदलाव आया है। तथापि, भौतिक रूप से (मृदा, जल, जलवायु), बायोलोजिकल रूप से (जैव विविधता, हॉस्ट–परजीवी संबंध), अनुसंधान एवं शिक्षा में बदलाव के चलते तथा सूचना, ज्ञान और नीति एवं निवेश (जो कृषि उत्पादन को प्रभावित करने वाले कारक हैं) आज भी एक चुनौती बने हुए हैं। उत्पादन के परिवेश में बदलाव हमेशा ही होते आए हैं, परन्तु जिस गति से यह हो रहे हैं, वह एक चिंता का विषय है जो उपयुक्त प्रौद्योगिकी विकल्पों के आधार पर कृषि प्रणाली को और अधिक मजबूत करने की मांग करते हैं।

पिछली प्रवृत्तियों से सबक लेते हुए हम निश्चित रूप से भावी बेहतर कृषि परिदृश्य की कल्पना कर सकते हैं, जिसके लिए हमें विभिन्न तकनीकों और आकलनों के मॉडलों का उपयोग करना होगा तथा भविष्य के लिए एक ब्लूप्रिंट तैयार करना होगा। इसमें कोई संदेह नहीं है कि विज्ञान, प्रौद्योगिकी, सूचना, ज्ञान–जानकारी, सक्षम मानव संसाधन और निवेशों का बढ़ता प्रयोग भावी वृद्धि और विकास के प्रमुख निर्धारक होंगे।

इस संदर्भ में, भारतीय कृषि अनुसंधान परिषद के संस्थानों के लिए विजन–2050 की रूपरेखा तैयार की गई है। यह आशा की जाती है कि वर्तमान और उभरते परिदृश्य का बेहतर रूप से किया गया मूल्यांकन, मौजूदा नए अवसर और कृषि क्षेत्र की स्थायी वृद्धि और विकास के लिए आगामी दशकों हेतु प्रासंगिक अनुसंधान संबंधी मुद्दे तथा कार्यनीतिक फ्रेमवर्क काफी उपयोगी साबित होंगे।

(राधा मोहन सिंह)

केन्द्रीय कृषि मंत्री, भारत सरकार

Foreword

Indian Council of Agricultural Research, since inception in the year 1929, is spearheading national programmes on agricultural research, higher education and frontline extension through a network of Research Institutes, Agricultural Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras to develop and demonstrate new technologies, as also to develop competent human resource for strengthening agriculture in all its dimensions, in the country. The science and technology-led development in agriculture has resulted in manifold enhancement in productivity and production of different crops and commodities to match the pace of growth in food demand.

Agricultural production environment, being a dynamic entity, has kept evolving continuously. The present phase of changes being encountered by the agricultural sector, such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new pest and diseases, fragmentation of farms, rural-urban migration, coupled with new IPRs and trade regulations, are some of the new challenges.

These changes impacting agriculture call for a paradigm shift in our research approach. We have to harness the potential of modern science, encourage innovations in technology generation, and provide for an enabling policy and investment support. Some of the critical areas such as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy, and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive. Our institutions of agricultural research and education must attain highest levels of excellence in development of technologies and competent human resource to effectively deal with the changing scenario.

Vision-2050 document of ICAR-National Institute of Abiotic Stress Management (NIAM), Pune has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

We are hopeful that in the years ahead, Vision-2050 would prove to be valuable in guiding our efforts in agricultural R&D and also for the young scientists who would shoulder the responsibility to generate farm technologies in future for food, nutrition, livelihood and environmental security of the billion plus population of the country, for all times to come.

(S. AYYAPPAN)
Secretary, Department of Agricultural Research & Education (DARE)
and Director-General, Indian Council of Agricultural Research (ICAR)
Krishi Bhavan, Dr Rajendra Prasad Road,
New Delhi 110 001

Preface

Abiotic stresses, which cause more than 50% losses in crop productivity are the major concerns for food and nutritional security of additional 0.4 billion Indians by 2050. Being a tropical country, India is more challenged with multitude of abiotic stresses. The country has been experiencing losses in productivity due to episodic and frequent droughts, floods, degradation of land, extremes of temperature in addition to pest and disease outbreaks. These problems are likely to aggravate with changing climate that can be a grave threat to food security in the 21st century. Hence, the main task ahead is to maintain the efficiency of agro-ecosystems on long term basis. This can be accomplished by several approaches including those which aim at bridging the knowledge-gaps in mechanisms underlying tolerance to abiotic stresses in plants, livestock and fishes. These efforts should be preceded by efforts to augment our knowledge about stress environments at the finest possible levels.

Need for better understanding of marginal environments, which represent land, water and atmospheric factors in various forms and proportion, is further evident from the fact that about 120.8 million ha constituting 36.5 per cent of total geographical area are degraded due to soil erosion, salinity/alkalinity, soil acidity, waterlogging, and some other complex constraints. The major improvements in countries' food productivity were possible through irrigated agriculture, which has now fatigued and about two-third of the net sown area in India continues to be rainfed with stagnated productivity.

Given the current projections of population, national economy and climate change, it would be a challenging task to increase agricultural output with minimum inputs without compromising sustainability of the agro-ecosystems. Most of the agricultural policies hitherto have had a skewed perspective largely concentrated on technology policies on different agro-ecologies and less on sustainable production systems. Further, the macro policies have overlooked the environmental implications of dichotomy of agricultural and economic development. Therefore, trade-offs between sustainability and productivity need a different research paradigm.

Realizing this, Indian Council of Agricultural Research (ICAR) has taken the lead to scale up its capacity by establishing National Institute on Abiotic Stress Management, Baramati in 2009. The mission of this institute is to develop insight into fundamental causes, strategies for mitigation, opportunities for adaptation, gaps in agricultural policies and education with ultimate goal to enhance income and quality of life of farmers living under harsh agro-ecosystems. Since its founding in 2009, the major emphasis has been development of infrastructure for undertaking multi-disciplinary and multi-commodity research. The institute is proud of its achievements but a lot has still to be done when it is entering into the most robust and vibrant second phase. In due course, it is expected to grow into a full-fledged 'Deemed University' for fully orienting itself to provide a platform for academic and research activities in close collaboration with national and international centres of research.

In search of productive tools for enhancing livelihood of farmers under harsh environments, immediate benefit of science can be realized by translating the knowledge accumulated through decades of research. While the future gains should be focused on research to understand nature, magnitude and intensity of abiotic stressors while harnessing opportunities being offered conservation agriculture, geo-informatics, genomics, phenomics, metabolomics, bioinformatics and nano (bio-) technologies. Moreover, building capacities to manage natural resources without environmental foot prints is crucial to extend benefit of science to farmers and future generation.

With advances in science opportunities are emerging to delineate abiotically afflicted areas by employing GIS and remote sensing tools. Phenomics, proteomics and metabolomics can enable us to understand the response of crops, livestock and fishes to stresses. Advances in genomics can help in improving genetic makeup. Application of nano technology and metagenomics can help us in enhancing efficacy of organic and inorganic compounds as well as engaging novel microbes for mitigating stresses. But ultimately, the 'System Biology' approach should lead to integrated solutions.

The six point strategy, for achieving the short, medium and long term goals of the institute, will include continued efforts to define target abiotic stressors, options for enhancing adaptation, technologies for stress mitigation, development of policies for abiotic stress resilient agriculture, formation of centre of excellence on abiotic stressors by exploring synergies through networking. The guiding principles of this strategy would include; achievement of the highest standards of professionalism and integrity; innovative approaches to combat constraints of harsh environments, links for strong and effective partnerships through wider networks of National and International institutes, upgrading NIASM into knowledge hub and a 'Centre of Excellence' for basic and strategic research on abiotic stressors.

I take this opportunity to acknowledge the guidance received from Dr. S. Ayyappan, Secretary, DARE & Director General, ICAR in preparation of this document. I also appreciate Dr. A.K. Sikka, Deputy Director General (NRM), Dr. S.K. Choudhary, ADG(SWM) and Dr. Mohan Kumar, ADG (Agron & AF) for providing critical comments on the draft. I particularly place on record the sincere efforts and help provided by Dr. J. Rane, and members of PME Cell in compiling of this document.

(P.S. Minhas)
Director
ICAR-NIASM, Baramati, Pune

Contents

Message *iii*

Foreword *v*

Preface *vii*

1. Context 1

2. Challenges 5

3. Operating Environment 11

4. New Opportunities 13

5. Goals and Targets 19

6. Way Forward 23

References 27

Context

Abiotic stresses cause negative impact across the sectors of agriculture (crops, horticulture, livestock, birds, fishes and others) with non-optimal environmental factors those may act independently or in multiples. The stressors like temperature (heat, cold, chilling/frost), water (drought, flooding/hypoxia), radiation (UV, ionizing radiation), chemicals (mineral/nutrient deficiency/excess, pollutants heavy metals/pesticides, gaseous toxins), mechanical (wind, soil movement, submergence) and others are responsible for major reduction in agricultural production. According to world estimates(Wang et al., 2007), an average of 50% yield losses in agricultural crops are caused by abiotic factors. These comprise mostly of high temperature (40%), salinity (20%), drought (17%), low temperature (15%) and other forms of stresses (Ashraf, 2008). Only 9% of the world area is conducive for crop production, while 91% is afflicted by various stressors. As per the current estimates (ICAR, 2010), 120.8 million ha constituting 36.5 per cent of geographical area in India are degraded due to soil erosion, salinity/alkalinity, soil acidity, water logging, and other edaphic problems. Expanding urban agglomerations and industrialization are further contaminating water and land with organic pollutants and heavy metals. Likewise increasing CO_2 and other greenhouse gases are increasing ambient temperature and UV radiation,which not only threaten crops, livestock but also the human beings. Dealing with the abiotic stresses in reality is a highly onerous task owing to their complexity, uncertainty and differential temporal and spatial impacts. The biophysical constraints of harsh agro-ecosystems include the following:

- **Soil Edaphic Constraints:** shallowness, coarseness, stony, low fertility, acidity, alkalinity, salinity, pollutants, hypoxia etc.
- **Water Constraints:** deficits: access and quantities, droughts, saline water, excess/waterlogging)
- **Landscape constraints:** steep terrain, boulders, undulations, sand dunes
- **Unfavourable climatic conditions:** droughts, cyclones, frost, hailstorm, heat/cold wave etc.
- **Socio-economic constraints:** Small and fragmented holdings, low access to markets, poor infrastructure, low literacy, price instability etc.

Being a tropical country, India is more challenged with multitude of several abiotic and biotic stresses. The country has been experiencing losses in productivity due to episodic and frequent droughts, floods, degradation of land, extremes of temperature and pest and disease outbreaks. These problems are likely to aggravate with changing climate putting forth a major challenge to attain food security in the 21st century. Thus, the main task ahead is to maintain the efficiency of agro-ecosystems on long term basis. Thereby, understanding abiotic stress responses in plants, animals and fishes and enhancing stress resilience are the most demanding areas in agricultural research.

Sensing the unfavourable environment of increasing abiotic stresses dawning on poverty riddled Indian Agriculture in the scenario of global climate change, the report of the Moily Oversight Committee (2006) emphasized the need to focus on abiotic stress management in agriculture. Drought, salinity, heat, cold, pollution, etc. were highlighted in the context of increasing demographic pressure and changing weather, which call to meet the frontal needs of the country. Thus an urgent need was felt for an early establishment of a dedicated research institute on priority. Recognizing the magnitude of influence of climatic change on the already mounting adverse effects of abiotic stresses on various sectors of agriculture, horticulture, livestock, fisheries, etc., the Union Cabinet on 19th January, 2009, approved the establishment of National Institute of Abiotic Stress Management (NIASM); a Deemed-to-be University under ICAR at Malegaon, Baramati, Pune. Establishment of NIASM is the first step to institutionalize abiotic stress research and education in an innovative mode. Its foundation was laid on 21st February, 2009 by Shri S. Pawar, Hon'ble Minister of Agriculture, Consumer Affairs, Food and Public Distribution, Government of India. The aim is to build sustainable and gainful livelihood in abiotically stressed environments by practicing climatically flexible/adaptable farming systems covering all sectors of agriculture through developing a deep insight into the causes and to develop strategies to mitigate abiotic stresses

The institute is mandated to exclusively undertake basic and strategic research in abiotic stresses, develop human resources, create a centralized shared database, and to evolve amelioration tactics using frontier technologies with wide network of research organisations. The institute is bound to fasten this assemblage to advance the reliable and timely deliverables for the benefit of stakeholders.

Mode of Research

Concerted research initiatives on influence of abiotic stresses have been undertaken in the past and are in progress especially in arid, semi-arid and even humid regions, but to hasten the pace of research and re-enforce focus, there is a need to consolidate these initiatives by ensuring synergies between management options and advances in molecular, biotechnological and nano-technological approaches for developing genetically improved crop, livestock and fisheries. Multi-disciplinary teams of scientists comprising agronomists, plant breeders, crop physiologists, soil scientists, biotechnologists, plant biologists, meteorologists, animal and fishery scientists, bio-informaticians, nano-technologists, economists, sociologists, and many others will have to work together for quicker results in the emerging fields of research. This requires improvement in the tolerance of plants and animals to environmental stresses and adoption of practices that minimize their magnitude.

The institute, though in its formative stages, is now strengthening its capacity for basic and strategic research to manage the natural resources. It is getting oriented towards exploring the recent advances in biotechnology, bioremediation, nano-technology and phenomics for enhancing productivity and stability of different agricultural commodities under stressed environments. It will be a key institute for abiotic stress with three independent but interlinked schools to manage atmospheric, drought and edaphic stresses with the support of policy school. This will be complemented by the state of the art infrastructural facilities coupled with highly skilled scientific and technical staff.

Public-Private-Partnerships

The dimensions of the multiple abiotic stresses are infinite and cannot be tackled by any of the individual institutes in isolation. Hence, the importance is given to collective efforts by integrating corporate sectors involved in agribusiness. Abiotic stresses and their impact on different sectors of agriculture is very complex, enormous and intricate, the private sector as such, is not competent enough to handle these issues, unlike biotic stresses. Hence, there is a dire need of collaborative efforts with public-private partnerships. The institute plans to promote such endeavours with industries through both forward and backward linkages in Public-Private Partnership (PPP) mode. This will aid in synergising the policy support in creating a conducive environment to promote and adopt promising technologies contributing for enhanced and sustained livelihood in stressed environments.

Academic Activities

The knowledge generated in the past and that is emerging from recent advances in research have great potential to manage abiotic stresses. So far, this topic has been a small but an integral part of existing syllabus in many of the academic and research institutes. However, this knowledge has to act as contrivance for bringing change in livelihood of millions who are gambling with uncertain rains, low productivity of soils and rare opportunities to revive from stresses in harsh environment. The institute visualises ample opportunities to accomplish this task as it will expand into a Deemed University, wherein various activities of research, education and linking researchers for innovations and disseminating the knowledge are proposed to be put on a fast track. In addition to conventional approach, the mode of education will accommodate experience sharing by progressive farmers, researchers and eminent academicians with national and international reputation and with accomplishments in manging abiotic stresses in agriculture.

Networks

The institute will strongly complement the ongoing research and development (R&D) under national agricultural research system (NARS). It will provide a definite, long lasting and economic solution to the farmers on abiotic stress management in agriculture under climate change scenario. A mission oriented robust national network in research and education will emerge in the areas of abiotic stresses under climate change. This would results in high financial, human and resource use efficiency by eliminating any duplication. The institute will create its own brand name as a custodian of abiotic stress research in India. The ultimate target is to develop a world class 'Abiotic Stresses Referral Research Facility' cutting across all the sectors of agriculture where research scholars, scientists and farmers can endeavour together at ease in minimizing the adverse impact of abiotic stresses.

❑

Challenges

Farmers, scientific communities and policy makers are always concerned about adverse impacts of abiotic stresses on agriculture. However, the renewed and immense attention for management of abiotic stresses emerge from increasing concerns that their intensity and adverse impact can amplify manifold due to climate change and overexploitation of resources. Past endeavours through intensive agriculture practices to meet the demands of ever increasing population have accompanied with land degradation and have consequently increased the magnitude of edaphic stressors. Thus, the national food and nutritional security has become a complex issue determined by climate and non-climate induced stressors which operate independently or in combinations. The major challenges include:

The Changing Pattern of Food and Nutritional Security

Despite the earlier history of famines and continuing patterns of droughts, a remarkable success has been achieved towards food security at the national level. Production of food grains increased nearly five times, from roughly 50 million tonnes in 1950-51 to more than 260 million tonnes in 2013-14. Yet the country continues to face challenges in terms of availability, access, balanced diet, diversity and equity associated with consumption of nutritious food at sufficient levels. While India's current population is 1.21 billion, it is projected to reach 1.6 billion by 2050. Population in urban area will increase from present level of 31 to around 45 per cent by the year 2050. The estimated increase in per capita income of Indians from current level of $ 1219 to $ 6735 in 2050 would lead to change in dietary patterns demanding new crops and value added products. Thus the future per capita demand may be lower for cereals, while the demand for fruits, milk, meat and eggs is likely to increase considerably. For meeting requirement of the burgeoning population, the country will need an estimated 400 million tonnes of food grains by 2050, from a current level of about 260 million tonnes. With increased pressures for land from urban agglomerations, expansion in crop area seems no longer a feasible option and rather it has since long been static around 141 M ha. Thus the only way plausible is improvements in land productivity by increasing the crop productivity, cropping intensity and area under efficient irrigation systems.

Climate Change and Adaptations in Agriculture

The global atmospheric concentration of carbon dioxide (CO_2), a greenhouse gas (GHG) largely responsible for anthropogenic global warming, has increased from a pre-industrial value of about 280 ppm in 1750 AD to 379 ppm in 2005. Similarly, the global atmospheric concentration of methane, nitrous oxides and other important GHGs, have also increased considerably. This has resulted in warming of the climate system by 0.74°C between 1906 and 2005. IPCC has projected that the global annual temperature is likely to increase in the range of 1.4 to 4.5°C by the end of this century. Overall, the temperature increases are likely to be much higher in winter (*rabi*) than in rainy season (*kharif*). This can cause substantial losses; hence, the crops adaptive to extreme temperatures are essential to enhance resilience of agro-ecosystems to extreme weather. Supra-optimal temperatures will not only affect the agriculture but its allied sectors too e.g. heat stress is projected to decrease productivity of horticulture and also the milk production in livestock. North-ward extension of abundance of fishes such as Sardine and Mackerel and shift in spawning period of some species has taken place due to increase in sea surface temperature. Due to climate change, precipitation is likely to increase as well as decrease in some regions; tropical cyclones will become more intense in future, with larger peak wind speed and more intense precipitation. This calls for focus on crops that can withstand brief periods of water-logging, submergence and heavy winds particularly at the reproductive phases. With underlying uncertainties, precise characterization of the agro-ecologies is essential for designing the best technologies for stress resilient commodities both in temporal and spatial scales.

Aggravating Degradation of Land vis-à-vis Edaphic Stressors

Past endeavours to meet the food demands of ever increasing population have accompanied with land degradation and consequently increased number of edaphic stresses and their levels for crop production. As per recent estimates, 120.8 million ha constituting 36.5 per cent of total geographical area are degraded due to soil erosion, salinity/alkalinity, soil acidity, water logging, and some other complex problems. Soil erosion due to water and wind is the major cause of soil degradation (95 M ha) followed by chemical degradation (24.7 M ha). Over one-third of total geographical area of the country has soil erosion more than the permissible rate of 10 Mg/ha/yr. The area under very severe soil erosion (> 40 Mg/ha/yr) constitutes around 11 %. In quantitative terms, about 5.3 billion tonnes of soil are eroded in India at an average rate of 16.3 Mg/ha/yr. About 8 million tonnes of plant nutrients are also washed away along with eroded sediments. Adoption of appropriate soil and water conservation measures following watershed approach is essential for protecting lands from soil erosion in different agro-ecological regions of the country.

Nutrient mining has increased with intensive cultivation during the post-Green Revolution period and the situation has compounded with low inherent fertility of most of Indian soils (89, 80 and 50 per cent of soil samples analyzed in case of N, P and K, respectively fall under low to medium category). Unfortunately, there is a net negative balance of about 8-10 million tonnes of NPK due to inadequate replenishment through fertilisers and the nutrient limitations are leading to decline in partial factor productivity. In addition, the present micro-nutrient deficiencies are to the tune of 49, 33, 13, 12, 5 and 3 % for zinc, boron, molybdenum, iron, manganese and copper, respectively while that for secondary nutrients like S have also become widespread (41%). These deficiencies are often reflected in poor health of human and livestock. Moreover, the soil organic carbon (SOC) that governs soil productivity is already low in Indian soils and is being negatively influenced by imbalanced use of fertilizers, removal and burning of crop residues, reduced use of FYM and other organics etc. For overcoming these, INMS, SSNM, etc., have been proposed. Further, the soils are getting polluted in some areas with toxic elements from geogenic sources, sewage water, industrial effluents, urban solid wastes, fertilizers etc. For example, nearly 30 million people inhabiting eight districts of West Bengal are exposed to arsenic poisoning through intake of contaminated food. The pollutants thus can enter the food chain and become a potential health hazard to humans and animals.

The productivity of 6.73 M ha land is limited by the existence of salinity/alkalinity. Application of amendments like gypsum is essential to reclaim alkali soils while appreciable leaching of salts and disposal of drainage effluent through well laid out horizontal sub-surface drainage system is required for saline-waterlogged soils. Similarly, about 12 M ha of acidic soils (pH < 5.5) suffer from deficiencies as well as toxicities of certain nutrients and have very low productivity. These soils need liming to neutralize active and a part of exchange acidity and application of fertilizers to ensure adequate supplies of nutrients to crops.

About 12 M ha area is waterlogged and floods prone, where productivity of arable crops gets severely affected. Even the Vertisols in high rainfall areas are mostly kept fallow during monsoons due to water logging and only one crop is raised during the post-rainy season.

Their productivity could be enhanced by practicing raised sunken bed system that permits raising of two crops. Likewise, the waterlogged alluviums in eastern India have water stagnating above ground for over six months in a year. The adverse physical conditions allow only one anaerobic paddy crop with a very low yield potential of less than one t/ha. Hence the challenge is to develop best combinations of resource management practices and commodities or cropping patterns for these edaphic stress prone areas.

Water Scarcity and Quality Problems

Freshwater resources are a critical input for agriculture as well as many other economic activities. With development of water resources, the irrigated area in the country has increased from 22.6 M ha in 1950-51 to 88.4 M ha in 2009-10 and the contribution of irrigated agriculture is more than two-third to overall food production. With 60% of the irrigated farming relying on ground water, India has become the largest ground water based food growing country in the world. However, with overexploitation of ground water resources, water scarcity is one of the major challenges, threatening livelihoods of people and environment. With growing demand for water resources from all sectors, it is projected that by 2050, agricultural sector would require additional 45% water whereas its share is expected to decline by 10%. Unfavourable climatic factors such as erratic rainfall, high evaporative demand, and several droughts, among others, contribute to the increasing water scarcity. Another major uncertainty is the impact of climate change on water availability, and consequently on the agricultural systems.

Therefore, our concerns for future trends and scenarios should centre on enhanced water productivity, sustainability of irrigated ecosystems, livelihood and intergenerational-equity. The major water related challenges in the future scenario of Indian agriculture will have to take care of the growing menace of ground water pollution, soil salinization and gradual decline in productivity especially in those areas, which witnessed the Green Revolution. Overdraft of ground water has increased pumping cost and energy due to lowering of water levels (25 to 30 m in past decade) and poorer farmers are greatly disadvantaged. It is further leading to quality deterioration with intrusion from sea and other poor quality aquifers. Development of recharge measures and prudent use of efficient methods like micro-irrigation are of paramount importance. Insufficiency of fresh water resources also necessitates the supplementation with marginal (saline ground waters and sewage effluents) quality water.

Stagnating Yields in Drought Prone/Rainfed Ecologies

About 58% (80 M ha) of the net sown area in India continues to be rainfed that contributes 40% of the food grain production and supports two-third of the livestock population. Especially 85% of coarse cereals, 83% of pulses and 70% of oilseeds continue to be rainfed. However, the average productivity of the rainfed areas continues to stagnate around 1.1 t/ha against the 4.5 t/ha from irrigated areas. Major rainfed farming communities constitute small and marginal farmers who are resource poor and risk averse. The food production is severely affected by frequent droughts that continue to be a recurring problem for these areas and are expected to increase under the climate change scenario. The country has faced 26 drought years in the last 130 years; with 1987 and 2002 and 2012 being the major drought years in recent times. The drought of 2002 led to reduced acreage of more than 15 M ha of the *kharif* crops and resulted in a loss of more than 10% in food production. Adverse impact of drought as evident from the vast agricultural land left uncultivated and severe forage crisis for animals in the year 2012 in Maharashtra is yet to be ascertained. These problems are likely to be aggravated further by changing climate putting forth major challenge to attain food security in the 21st century. Technologies have been put forth for drought proofing with best compatible cropping patterns and soil and water conservation techniques, yet the large yield gaps continue to exist. There is a need to address constraints in enhancing precision for prediction of events of low precipitation as well as temporal and spatial distribution of rains. Enhancing the inherent tolerance to limited soil moisture stress in crop plants is another major challenge, which can be addressed through molecular biological approaches. Translating the recent advances in molecular biology tools for improving resilience to drought stresses will be the immediate challenge.

Inadequate Policy Support

Given the current projections of population, national economy and climate change, it would be a challenging task to increase agricultural output with minimum inputs without compromising sustainability of the agro- eco systems. Most of the agricultural policies hitherto have had a skewed perspective largely concentrated on technology policies on different agro-ecologies and less on sustainable production systems. These policies tend to favour large farmers especially in irrigated typologies and often do not provide adequate risk protection to small holders. Current developmental policies often fail to anticipate and address the emerging challenges of rising energy prices, climate change and scarce natural resources and agro-biodiversity losses. Further, the macro policies have overlooked the environmental implications of dichotomy of agricultural and economic development. Therefore, trade-offs between sustainability and productivity need a different research paradigm.

❑

Operating Environment

Out of India's geographical area of 328.7 M ha and of 305.6 M ha reported area for land utilization in 2010, forest covers 70 M ha while land not available for cultivation is 42.9 M ha. Permanent pastures and other grazing land cover 10.1 M ha while land under miscellaneous tree crops is about 3.4 M ha and culturable waste land is 12.8 M ha. Thus total cultivable land other than fallow land is 26.3 M ha while total fallow lands are 26.2 M ha. The net sown area with cropping intensity of 137.3 % is 140.0 M ha. With expanding urban agglomerations, there is limited scope for putting more area under cultivation.

As on 2010, cereals, pulses, vegetables, oilseeds and fibre crops occupied 51.4, 12.5, 3.1, 14.9 and 5.7% of the gross cropped area while fruits occupied only 2.3% area. Out of 132 M ha of total area, 42.8 M ha was wholly irrigated while 22.8 M ha area was partially (11.3 M ha) irrigated. On the other hand, 50 M ha area had no access to irrigation. About 58% area sown to rice, 23.8% of maize, 8.7 % of sorghum, 8.6% of pearl millet and 91.7% of wheat, 73.3% of barley, 14.4% of coarse cereals, 32.2% of gram, 4.5% of pigeonpea are irrigated. However, irrigation water received during crucial period of crops vary across the regions and determined by sources of water. The pulses, main source of protein for vegetarians, largely remain rainfed. Projections by IPCC and other agencies are that unless we adapt, global warming will lead to 10-40% loss in crop production in India by 2080-2100. Loss in wheat production in Indo-Gangetic plains would be 4 to 5 million tonnes with 1°C rise in temperature. The demand for milk will increase by 40% in 2050, but shortages of fodder and feed (about 36-40%) will be a limiting factor to raise productivity of milch animals. Forages being the crops of harsh ecologies, inducing stress tolerance and other nutritional measures can play crucial role in reducing vulnerability of animals to extreme temperatures. To meet the demand by 2030, production from aquaculture has to increase by three-fold. Fish, being poikilothermic vertebrate, are more prone to the impacts of global warming. Temperatures regulate embryonic development, growth, fecundity and pathogen infection pattern in fish. An assessment of vulnerability of climatic change on aquaculture is essential to prioritize the strategies.

Indian agriculture is featured by owning of 60% of farm households by poor and marginal farmers with less than four ha land. About 22% of the farm households have less than one ha land. With fewer resources they are unable to afford expensive technologies for improved production. Despite decades of efforts, farming system and cropping systems are not adequately tuned to optimize profit, though some success stories exist with exportable fruit crops. Particularly, the rainfed agriculture is complex, diverse, fragile, under invested, risky, distress prone with wider gaps among improved and demonstrated technological potentials and actual district/state level average productivity (NRAA, 2011). Marginal returns or responses of investments into rainwater management, energy, fertilizers and other inputs are much higher in rainfed area as compared to irrigated well-endowed regions particularly when rainfall and its distribution are not erratic. Further, rainfed agriculture is featured by significant year to year fluctuations in production, market volatilities, distress of primary producers and end-consumers. Hence, farmers of nearly 60% of area sown to crop will have to continue their gamble with weather and marketing system.

It is very likely that with change in temperature and rainfall pattern, agro-climate will shift at local level. It is important that these are categorized and mapped to avoid or lessen the chances of inappropriate land use choices. Complete information on how ground scenario is changing at the block level is a missing link to disseminate recent agricultural technologies to stress prone areas. ICAR has already taken initiatives to map drought prone and other areas through its institutes such as NBSS&LUP, CRIDA etc. However, abiotic stresses often occur in combinations and need finer maps that can integrate climatic as well as edaphic stresses. The broad areas requiring major emphasis to mitigate adverse impacts of climate change are loss of vegetation cover and accelerated soil loss with a potential to prolong the dry periods. The huge and diverse collections of genetic resources in national bureaus may serve as gold mines to search for genes associated with abiotic stresses. A well thought strategy and research network can significantly contribute to accomplish the task of meeting ever increasing food demand of the nation.

❑

New Opportunities

As stated in previous section, the harsh agro-ecologies and soil degradation are threatening the very sustainability of agricultural production and situation is likely to worsen with predicted climate change. For combating the effects of the resultant abiotic stressors, opportunities existing in science and policy initiatives are briefed below:

GIS/RS Tools to Delineate Afflicted Areas

Remote sensing and GIS are becoming increasingly useful tools to delineate abiotic stress at regional level. Precision mapping of cropping characteristics are now possible with high resolution satellite imageries (like IKONOS, Quickbird etc.) which form the basis for assessing the vulnerability of crop species to either a single or multiple stressors. For example, NDVI (Normalized Difference Vegetation Index) is the most sought after index in assessment of drought at national level. Its utility is enhanced when combined with other satellite data derived indices like NDWI (Normalized Difference Water Index) and SASI (Shortwave Angle Slope Index) coupled with soil moisture index (derived from soil water balance approach) and rainfall data. Organizations like NRSC, ISRO are successfully applying these approaches for over two decades, which are transferred to MNCFC (Mahalanobis National Crop Forecasting Centre, DAC, GOI) for forecasting purposes. In this process, the data acquired by MODIS is of great significance. Another composite index, VegDRI (Vegetation Drought Response Index) is being used to monitor vegetation stress across US, which includes Palmer Drought Severity Index (PDSI) and the Standardized Precipitation Index (SPI). Information about soils, land cover, land use, and the ecological setting are the types of biophysical data incorporated into VegDRI. This information is critical because the climate-vegetation response can vary depending on these different environmental characteristics. With further inputs like edaphic factors derived from soil maps, cropping pattern and their responses to stressors, regional models can be put forth for forecasting abiotic stresses using GIS based statistical tools.

Techniques to Assess Abiotic Stress Responses

Hyperspectral technology is the frontier technology, which is currently being explored for detecting and quantifying different kinds of stresses due to soil water, nutrients, soil salinity or atmospheric drought induced plant water stresses. Hyperspectral devices are capable of acquiring information on hundreds of very narrow, defined continuous spectral bands thus making it possible to detect changes in crop plants due to biotic or abiotic factors. The precise identification of the narrow bandwidth of the electromagnetic spectrum, using ground based hyper spectral devices that show changes as a function of stress level will help the incorporation of select bands in the space based sensors for regional scale monitoring of various types of stresses. Free Air Temperature Enrichment (FATE)/CO_2 Enrichment (FACE) system simulates global warming/elevation of CO_2 in small ecosystem of limited height with the infirmity of the thermal radiation and canopy temperature across the plot. Critical analysis of these technical advances may result in more realistic and cost effective methods for elevating temperature and CO_2 in open-air. These technologies will provide opportunities to understand future of ecosystem function in a CO_2 enriched warmer world.

Crop simulation models, that allow the specific management options, offer a relatively inexpensive means of evaluating a large number of strategies. In the changing climatic scenarios it has become imperative to evaluate large number of strategies by using various crop simulation models to reduce yield gaps. To counter the negative effects of climate change, various mitigation strategies can be adopted by using this advanced tool. "Eddy Covariance" model can provide opportunities to understand and to define the target abiotic stress environments and also simulate the environment during evaluation of germplasm for stress tolerance.

Genetic Make-up to Improve Abiotic Stress Tolerance

Transfer of individual functional genes by genetic engineering can increase the abiotic stress tolerance in plants. However, these approaches have not been successful as far as consistency, reliability and visible effects at field levels are concerned, because of multigenic and complex nature of abiotic stress tolerance. Besides, limited knowledge of resistance mechanisms and the genes governing these mechanisms have slowed progress in development of salinity tolerant crops. Development of stress tolerant transgenics using gene transfer approaches needs much more understanding of plant stress-tolerance and gene-regulatory network systems. Apart from feeding regimes and dietary strategies, genetic improvement of livestock is essential to ensure permanent and cumulative changes in performance and this can be accomplished through biotechnological interventions.

Phenomics to Augment Benefits of Genomics

Advances in genomics have tremendously scaled up our capacity to understand the genetic components of crops and other agricultural commodities. A plenty of information about the genes has been generated and can be accessed through public databases. However, the functions of many of the genes have not been very well defined. This can be attributed to lack of techniques to characterize the plants in large scale with high precision for phenotypic data that are needed to match genotypic data for identification of genes responsible for tolerance to abiotic stresses. In this context, plant phenomics has evolved as a robust tool with combination of imaging technology and automation to characterize the plant for various morpho-physiological traits without any destructive approaches conventionally used for plant sampling. Some of these technologies can be employed for characterization of plant responses even under field conditions to accelerate our understanding about the mechanisms of tolerance to various abiotic stresses.

Metagenomics and Nano-technology for Stress-Relief

Metagenomics has redefined the concept of genome analysis, accelerated the rate of gene discovery and heterologous gene expression. This can help in gene mining and identification of novel genes, which confer tolerance to stresses. The method of metagenomic library creation has proven to be an efficient approach for the analysis of uncultivable microbial community. Combining toxicology and genomics i.e. toxico-genomics is a new approach for understanding the genetic mechanism and biochemical pathways leading to retarded growth due to toxicants.

With the assistance of analytical tools like DNA Micro array, MALDI TOF and NMR, etc., investigative methodology has become more simple and reproducible. Revelations from different genome projects (like rice, tomato, buffalo, zebrafish etc.) has potential to contribute to the toxicogenomics. An insight into vast database and advanced algorithms can facilitate gene discovery and better understanding of the effect of environmental stress on physiology and growth of organisms. This can help in elucidating the molecular mechanism of toxicity, gene and protein biomarkers in crops/livestock/fishes sensitive to environmental hazards.

Nano-technology is a world of sub-micronicparticles (1-100nm) which can exhibit pronounced activity in comparison to their original materials. Its impact is visible in engineering, pharmacy, semiconductor and medical devices, domestic goods etc., and recently its interventions are felt necessary in agriculture, aquaculture and environmental remediation. Nano(Bio-) technological innovation can bring a paradigm shift in the conventional technology with more precise and sensitive tools for a sustainable and stress resilient agriculture.

System Biology to Bridge the Knowledge Gaps

The recombinant DNA technologies hold big promise towards the development of crop varieties tolerant to different abiotic stressors. A huge amount of information has been generated on genomes but success obtained so far is not sufficient to accelerate development of stress tolerant crops. This is mainly because a set of genes rather than single or couple of genes play role in stress tolerant mechanisms. Hence, it is necessary to understand the system biology to harness the advances in our understanding about the abiotic stresses at cell, tissues and plant level. Recent developments necessitate the combination of approaches that can collectively impart resilience against abiotic stresses in crops, livestock or fishes. In this context, the systems biology approach, which integrates the series of –'omics' approaches (phenomics, genomics, transcriptomics, proteomics and metabolomics), is emerging as a central field for the next generation of life sciences in which all the sectors of agriculture will get their due benefits.

Bioregulators for Allevaiting Stress

Plant bioregulators (PBRs) play keyl role in the ability of plants to adapt under changing climatic conditions, by mediating growth, development, nutrient allocation and source sink transitions. With the use of specific bioregulators, crop can be grown under various abiotc stresses namely drought, salinity and heat with minimum yield losses. Yield losses in arable crops under drought stress can be minimized by 15 to 20 % with the use of bioregulators. The future prospective is to identify the crop and condition specific bioregulators as well as optimization of the dose, frequency and stage of sprays for achieving the maximum benefits under stress conditions. However, to evolve novel bioregulator technologies, research should focus on efficacy of new compounds in alleviating the tolerance to drought, salinity and high temperature stress across the agro-ecologies. Molecular studies to identify, characterize, classify and validate the responsive genes associated with bioregulators will pave the way for their effective utilization.

Rhizospheric Microbes for Managing Abiotic Stresses

So far, the microbiologists have given priority to isolation, identification and utilization of microorganisms for biofertilization, bioprocessing, bioremediation etc., but mitigation of abiotic stresses has been partially addressed. Recently, National Institute for Agriculturally Important Microbes has taken an initiative for developing a national mechanism to maintain and document the promising microbial isolates. Such efforts have to be extended to identify beneficial microbes that can contribute in harsh agro-ecologies. Since microorganisms represent the significant fraction of molecular and chemical diversity in nature, they contribute to basic ecosystem processes such as the biogeochemical cycles and food chains, as well as maintain vital relationships with higher organisms and plants. Thus the opportunities exist to explore rich biodiversity in the form of microorganisms in soils, plant surfaces and marine ecosystems through strategies that aim at microbes involved in nutrient cycling, salt tolerance, nitrogen fixation, and plant growth promotion under extreme conditions.

Conservation Agriculture as an Adaptive Tool

Conservation Agriculture (CA) is a strategy for mitigating climate change and as an adaptive mechanism for alleviating climate change effect. CA practices can help in sequestering atmospheric CO_2 in the form of soil organic matter, as well as reduction in GHG emissions through efficient production system. CA facilitates soil management without excessive disturbance, protection from erosion, compaction, aggregate breakdown, loss in organic matter, leaching of nutrients etc. This has been successfully proved in limited areas and can be expanded to other regions based on our understanding of agro-ecologies in general and rainfed areas in particular with focused research on residue retention on surface and weed control and identification of cropping systems, machinery, location specific land management practices (ridge furrow/ set furrow/mulching/agroforestry, etc.) for their value in CA and its linkage with carbon markets.

Organic Agriculture: A Possible Support for Stress Mitigation

Organic agriculture is one of the options to mitigate and adapt to climate change. It is an alternative sustainable, eco-friendly production system that assists in biological pest control and crop rotation, supply green manure and composts/FYM to maintain soil fertility. According to an estimate, organic agriculture combined with reduced tillage techniques has the potential to sequester 500 kg C/ha/yr. This maximum organic scenario would mitigate about 4 Gt CO_2 equivalents/yr or 65 per cent of the agricultural GHG. There are opportunities to use this approach for sustainable and eco-friendly farming models that meet on-farm requirement of organic inputs through biochar, biomass transfer from agroforestry for direct application on farm and composting for farm nutrient recycling.

Reoriented Policy Dynamics

The under investment and market distortions especially in the regions having preponderance of abiotic stressors have been mainly responsible for poor R&D, weak institutions and infrastructure and non-pragmatic pricing of inputs and natural resources. Hence, identifying policies that can shape development, dissemination and marketing of technologies to increase agricultural outputs using more resource efficient methods sustainably. Many of the available technologies such as integrated soil fertility management, multiple uses for enhancing water productivity, carbon sequestering practices etc., suffer from low adoption rates. Hence, identifying bottle necks that hinder technology uptake and strengthen capacity to enhance adoption of resource use efficient land water and energy management strategy remains a challenge. This calls for a greater impetus on assessing the costs and benefits of alternative science, technology and institutional innovations and marketing strategies including advanced scientific applications of biotechnology, nano-technology, conservation agriculture, precision agriculture, organic agriculture etc. Analyzing their potential pay offs in terms of yield, growth and food security taking into account the spatial variability of crop, soil and climate issues and assessing the market-led consequences of adoption of such policies at regional and national level is of paramount importance for a pragmatic policy support. Nevertheless suitable governance systems and enabling environment remains an overarching framework.

❑

Goals and Targets

The institute aims to provide dynamic mechanisms and robust tools for managing abiotic stresses that may occur in the present forms or in their amplified version in the future with focus on profit for both farmers and agro-ecosystems. To accomplish this goal, institute will carry-out both basic and strategic research that can complement similar efforts and applied research for abiotic stress tolerance in agricultural commodities that encompass crops, livestock and fish. Research for management of natural resources can significantly contribute in mitigation technologies, while the modern approaches for genetic improvement can evolve tolerant cultivars and thus can help in greening of unproductive land and also enhance productivity gains from abiotic stress prone agro-ecosystems. It is envisaged that an optimistic target of 30% gain in agricultural production from abiotic stress prone agro-ecosystems should be feasible by 2050.

Institute's Overall Goals

To build sustainable livelihood in agro-ecosystems constrained by abiotic stresses by practicing climate resilient farming systems through a deep insight, adaptation techniques, mitigation strategies and acceptable policies by effective convergence of research output.

Institute's Objectives

i. To enhance our understanding of existing and future abiotic stress environments that can influence food production
ii. To develop screening techniques and evolve stress tolerant genotypes/ breeding stock/strains of crops, livestock and fish through mining and deploying novel genes implicated in tolerance to abiotic stresses
iii. To evolve technologies for mitigation of drought, edaphic and atmospheric stresses through frontier science tools
iv. To develop human resource through advanced training and capacity building on the use of modern tools and techniques
v. To conduct policy support research on abiotic stress management in collaboration with institutes/organizations/SAUs
vi. To enhance efficiency of use of natural resources and to make the agriculture more economical, productive and sustainable
vii. To forge national and international linkages on abiotic stresses

viii. To establish NIASM as a knowledge hub, advanced research and policy support centre for management of abiotic stresses with a robust interactive information system to cater to the needs of agricultural communities in harsh environments

The Institute will implement important research programmes in a thematic mode and will focus on strategic human resource development for long term management of different stresses with the participation of wide network of Indian and International institutes involving visiting fellowships and exchange programmes. These are further categorized under short-term, mid-term and long term targets, as follows:

Short-term Targets

Goals	Action Points
Assessing and understanding abiotic stress environments	• Assessment of abiotic stresses: mapping of abiotic stressors, impact, vulnerability; yield gaps; existing options for mitigation and adaptation • Estimation of the losses in agricultural productivity for selected crops, livestock, fish and poultry
Identification of stress resilient genotypes, crops, livestock, fish	• Standardization and development of plant phenomics procedures to support genomics for drought, heat and salinity tolerance • Development of hyperspectral remote sensing and crop simulation models as tools to detect/assess water, nutrient, salt stresses • Development of molecular approaches to identify traits and genes associated with drought, atmospheric and edaphic stresses • Exploration of genetic resources to identify stress tolerant traits, genes protein biomarkers etc.
Adaptations for abiotic stressors	• Conservation agricultural practices for enhancing crop productivity and resource-use efficiency • Identification of bio-regulators to alleviate stress • Exploring culturalable and unculturable microbes for mitigation of abiotic stresses • Bacterial biodegradation and nano (bio-) remediation of priority contaminants • Design and development of livestock and fishery structures for heat stress management • Improving input use efficiency in abiotically stressed environments • Development of multi parameter stress indices for application in agronomic management • Brood stock management, breeding and seed production of fin fishes in abiotic stressed farms
Human resource development	• Expert consultations on abiotic stresses in crops, livestock & fish • Developing novel and practical syllabus • Establishment of linkages with national/international institutes
Policy support	• Supporting policy for Climate Friendly Farming practices • Institutional and policy aspects to minimize impacts of stresses • Develop consortia of policy researchers

Mid-term Targets

Goals	Action Points
Stress resilient crops/ livestock/fish	• Elucidation of genetic basis of adaption to abiotic stress environment and identification and functions of novel genes • Validation of molecular biology methods to improve abiotic stress resistance through multi-location experiments • Identify low inputs responsive cultivars suitable for location specific conservation agriculture • Novel genes from microbes that confer tolerance in crop plants
Stress mitigation	• To develop and standardize bio-regulator mediated drought, heat and salinity stress tolerance technology for major crops • Investigations on the effect of aerosol on radiation, energy balance, crop growth and yield in major cropping systems • Package of agronomic practices for mitigating stresses in crops including horticultural crops • Development and impact-evaluation of production technologies on resource management under abiotic stress environments • Technologies for detoxification of priority pollutants and nutrient recovery from waste • Development of techniques for reducing methane and nitrous oxide emissions from ruminants • Exploring microbial genomics to manipulate rumen microbiota for mitigating methane emission
Enhancing sustainability in harsh agro-ecologies	• Increased adoption of conservation agriculture practices for rainfed conditions • Increasing the use efficiency of soil water and nutrients and/or fertilizer for better soil health and increased productivity • Soil carbon sequestration under organic farming/INM practices • Evaluation of alternative cropping system including bioenergy crops • Developing sound forecasting and forewarning tools for invasive and destructive crop pests • Promoting water accounting protocols at farm level and to use of micro level irrigation systems and other water saving techniques • Design and development of precise machineries/engineering structures/ energy conversion technologies for abiotic stress management in agriculture, livestock and fisheries sectors

Long Term Targets

Goals	Action Points
Enhanced resilience of farming system and mitigation of stresses	• Development of efficient water management practices under changing climatic scenarios • Assessing the impact of management (i.e. tillage, crop rotation, residue management, etc.) on soil carbon sequestration • Modeling the likely effect of regional aerosol climate such as Atmospheric Brown Cloud (ABC) on crop growth and productivity in different agro-ecological regions of the country • Development of region based remediation strategies for stresses • Pyramiding of genes for stress resistance and high yield traits • Transgenic fish for growth and as bio-indicator of aquatic pollution • Building climate resilient livestock through cloning and transgenic techniques coupled with phenotypic evaluation

	• Development of system biology approach to understand different signaling pathways in responses to abiotic stresses • Develop genotypes to withstand sub-mergence and anoxia through systems biology approach • Wider diffusion of new abiotic stress tolerant crop technologies and management practices especially in rainfed agriculture • Development of decision support systems for precision in water and nutrient management • Data base/repository of information on abiotic stress management
Policy support and education	• Techno-economic impact assessment of stress tolerant plants and management technologies for their adoption and dissemination • Harnessing modern information and communication technologies for technology dissemination as well as for interfacing with farmers • To study institutional innovation (demand driven agricultural extension, women participation, crop insurance etc.) to enhance the productivity in rainfed ecologies via minimizing losses by stresses • To act as an umbrella school regulating the higher end biological research under biosafety limits
Enhanced sustainability of agriculture under harsh environment	• To assess soil qualities under different edaphic stress conditions and technology transfer for increased resilience of soils for sustainable agriculture production • Developing effective management strategies for destructive and invasive pests of major food and horticultural crops under changing climatic conditions • Development of climate ready crop/multi stress tolerant and new technologies that address climatic variables • To identify and develop the best combination of resource management options to manage water deficits in agriculture • To develop novel management options carbon trading under clean development mechanism

❑

Way Forward

The operational strategy of the institute is to focus on basic research on abiotic stresses faced by the country, strategic human resource development, robust databases and amelioration approaches using frontier technologies with the participation of wide network of national and international centres. The comprehensive strategy of the institute prioritizes characterization of the occurrence and magnitude of various abiotic stresses impacting agriculture sector. This will provide a rationale for basic and strategic research that aim at agro-ecology-specific stress-mitigation and adaptation technologies for crops, horticulture, livestock and fisheries. This will be facilitated by development of world-class infrastructures and scientific manpower necessary for center of excellence in abiotic stress management.

Assessment of available inputs and their use in a synergistic manner, preventing losses, judicious allocation of inputs among the competing demands for maximizing returns and development of site-specific technologies are the means of achieving high resource use efficiencies for sustainable agriculture. NIASM being a deemed to be University and by virtue of its strategic location, is an ideal place to become a center of excellence in abiotic stress research not only in India but also at the global level. It will be the leading center for coordination of abiotic stress research and data repository on all kind of drought, edaphic and atmospheric stresses. Joint adaptation and mitigation actions against climate change that can be implemented today across a wide range of land and water resource management solutions should provide both adaptation benefits in short term and mitigation strategies on long term basis.

A six-point hexagonal interlinked strategy would be adopted to accomplish the vision and goals of the institute and to enhance efficiency and effectiveness of the research endeavours (Fig. 1). The institute will focus all its efforts towards gaining climatically sustainable livelihood under the abiotically stressful environment. Thus the future strategy will be concentrated on following key aspects:

Defining Target Abiotic Stressors

Institute will assess and quantify the effects of major abiotic stresses on agriculture and develop repository on information to serve as a centre

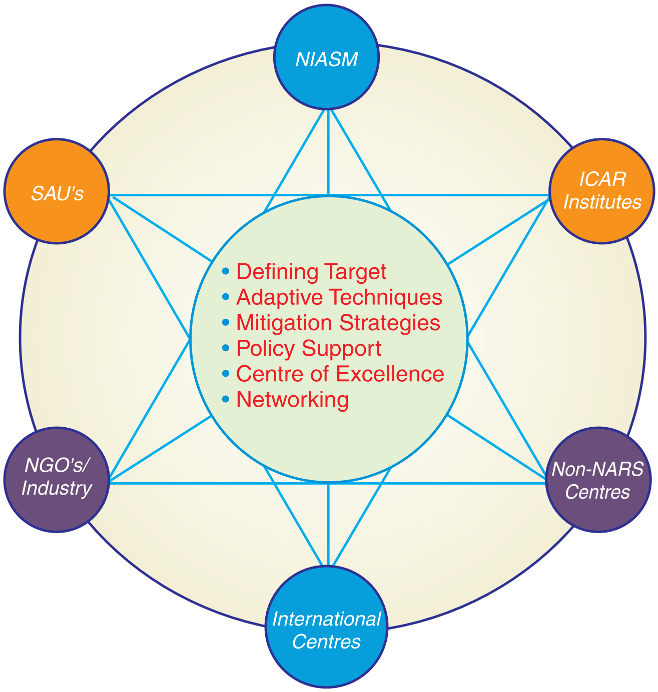


Fig. 1 Institute's strategy for achieving goals

of knowledge sharing. This will be achieved through focus on extent, area and magnitude of abiotic stresses such as drought, high temperature, water logging, salinity, alkalinity, acidity, nutrient toxicities/deficiencies, pollutants/contaminants including geogenic like F, Se, As, etc. In addition, attempts will be made to quantify direct and indirect effects of abiotic stresses on productivity of crops, livestock, poultry and fisheries. This exercise is expected to define environmental characterization criteria and quantify impact of climate change through proven models on the atmospheric, drought and edaphic factors. Further, this will lead to the finalization of National Map of Abiotic Stresses as well as in developing online data bases on abiotic stresses.

Enhancing Adaptation

A detailed investigation on adaptive strategies in crops, livestock and fishes under stressed regimes will form an important component of the institute's overall strategy. This will be accomplished by employing 'omics' sciences that are emerging as robust tools to understand relevant genes and traits for genetic improvement of food, fibre, fodder and horticultural crops as well as in livestock and fisheries. The knowledge gap in accelerating application of biotechnology for abiotic stress tolerance will be bridged through system biology approach that can address gene network associated with stress tolerance mechanisms in plants, animals and fisheries. Enzyme or nano-sensor based detection kit can be developed for early detection and diagnosis of abiotic stress in aquaculture industry.

Substantial resources will be put in developing screening techniques by involving phenomics, metabolomics and genomics to identify stress tolerant genotypes/breeding stock/strains of crops, horticulture, animals and fishes. This is expected to accelerate gene and trait identification for tolerance. Techniques for transgenics and cisgenics will help in enhancing tolerance to abiotic stresses in plants. This will also facilitate functional genomics approach to elucidate role of gene and their network and will lead to augmentation of genomics data for use through bioinformatics. To assess the negative and positive impacts of stress on major cultivable fish species, experiments will be conducted at different levels of temperature, salinity, pH, and photo period. Focus will be on indigenous crop, fish and animal genetic diversity to retain critical adaptive genes and genetic traits as an insurance against unanticipated climate change using ex-situ methods.

Technologies for Stress-mitigation

In addition to conventional approaches, frontier science tools such as nano-technology, geo-informatics, toxico-genomics will be employed to evolve technologies to alleviate stressors. The focus will be on developing suitable soil-water-crop management technologies/ strategies along with customized plants for climate resilient agriculture. Bioremediation techniques will be employed to deal with pollutants. Phytochemical and nanoparticle will be evolved to combat stressors for sustainable agriculture. Both abiotic and biotic components threatening the sustainability of agro-ecosystems will be addressed to develop an ecosystem approach. Simulation models will be developed to predict the impacts of abiotic stresses and put forth alternative mitigation strategies.

Policies for Abiotic Stress Resilient Agriculture

Research on policy support for abiotic stress management will focus on analyses of impact of climate change on vulnerability of agriculture and allied sectors and assessment of adaptation/mitigation measures. Networking with NARS will support institute's effort to develop a comprehensive data-base on the extent of effect of different abiotic stresses on crops, horticulture, animals, fishes and other sectors. Research will also explore options to add values to farm produce for nutrition security, livelihood and income generation.

Centre of Excellence on Abiotic Stressors

The institute will act as a fully autonomous organization by acquiring the status of Deemed University of international stature and becoming the foremost centre on abiotic stresses management. Emphasis will be on development of human resource through advanced training and capacity building on the use of modern tools and techniques in abiotic stress research and management.

Institute will serve as academic and research platform to facilitate international scientists to work along with national scientists, research scholars and trainees on its premises, thus enhancing the capacity and capability for abiotic stress management through basic, strategic and policy support research. This will enable the institute to be a Centre for Academic Excellence for research, post-graduate education and human resource development in abiotic stress management.

Synergies through Networking

Institute will orient its research to complement efforts by other institutes to understand abiotic stresses. Collaborative research efforts will be promoted through public-private partnership in view of complexity and expenditure in tackling abiotic stresses. While carrying out high-end basic research to meet the challenges of climate change induced abiotic stresses, the institute will also give due consideration to the location-specific strategic research in collaboration with institutes both within and outside NARS. In addition, the institute will encourage the researchers to get acquainted with experts from abroad on aspects of abiotic stress management. Efforts will be made to capitalize on the investments on abiotic stress research by international agencies to upgrade the national programmes. This will be accomplished by organizing international conventions/conferences/seminars on abiotic stress research.

In conclusion the major output expected from the institute will include maps indicating vulnerability at district level and database on abiotic stresses, screening protocols to identify stress tolerant crops, livestock, fish and birds, genetic stocks of crops, stress tolerant livestock, fishes, feasible technologies to mitigate stress and enhance resource use efficiency, endophytes inducing stress tolerance, national and international networks to address different aspects of abiotic stress management and ultimately a 'Centre of Excellence' for education and research on abiotic stressors.

❑

REFERENCES

Ashraf, M., Athar, H.R., Harris, P.J.C. and Kwon, T.R. 2008. Some prospective strategies for improving crop salt tolerance. *AdvAgron* 97: 45–110.

ICAR. 2010. *Degraded and Wastelands of India Status and Spatial Distribution*. Indian Council of Agricultural Research, KAB-I, Pusa, New Delhi.

IPCC. 2007. Climate Change - Impacts, Adaptation and Vulnerability. Parry, M.L., Canziani, O.F., Palutikof, J.P., vander Linden, P.J. and Hanson, C.E. (eds) Cambridge University Press, Cambridge, UK, 976.

NCAER. 2013. *Agricultural Outlook and Situation Analysis: Reports Quarterly Agricultural Outlook Report: January–March 2013*; National Council of Applied Economic Research, 11, I.P. Estate, New Delhi.

NRAA. 2011. *Challenges of Food Security and its Management*. National Rainfed Area Authority (NRAA), NASC Complex, DPS Marg, New Delhi.

Singh, R.B. 2010. Towards a Food Secure India and South Asia: Making Hunger History. APAARI, Bangkok.

Wang, W., Vinocur, B. and Altman, A. 2007. Plant responses to drought, salinity and extreme temperatures towards genetic engineering for stress tolerance. *Planta*. 218:1-14.

NOTES

Laser typeset at M/s Print-O-World, 2568, Shadipur, New Delhi 110008 and printed at M/s Royal Offset Printers, A-89/1, Naraina Industrial Area, Phase-I, New Delhi 110 028.