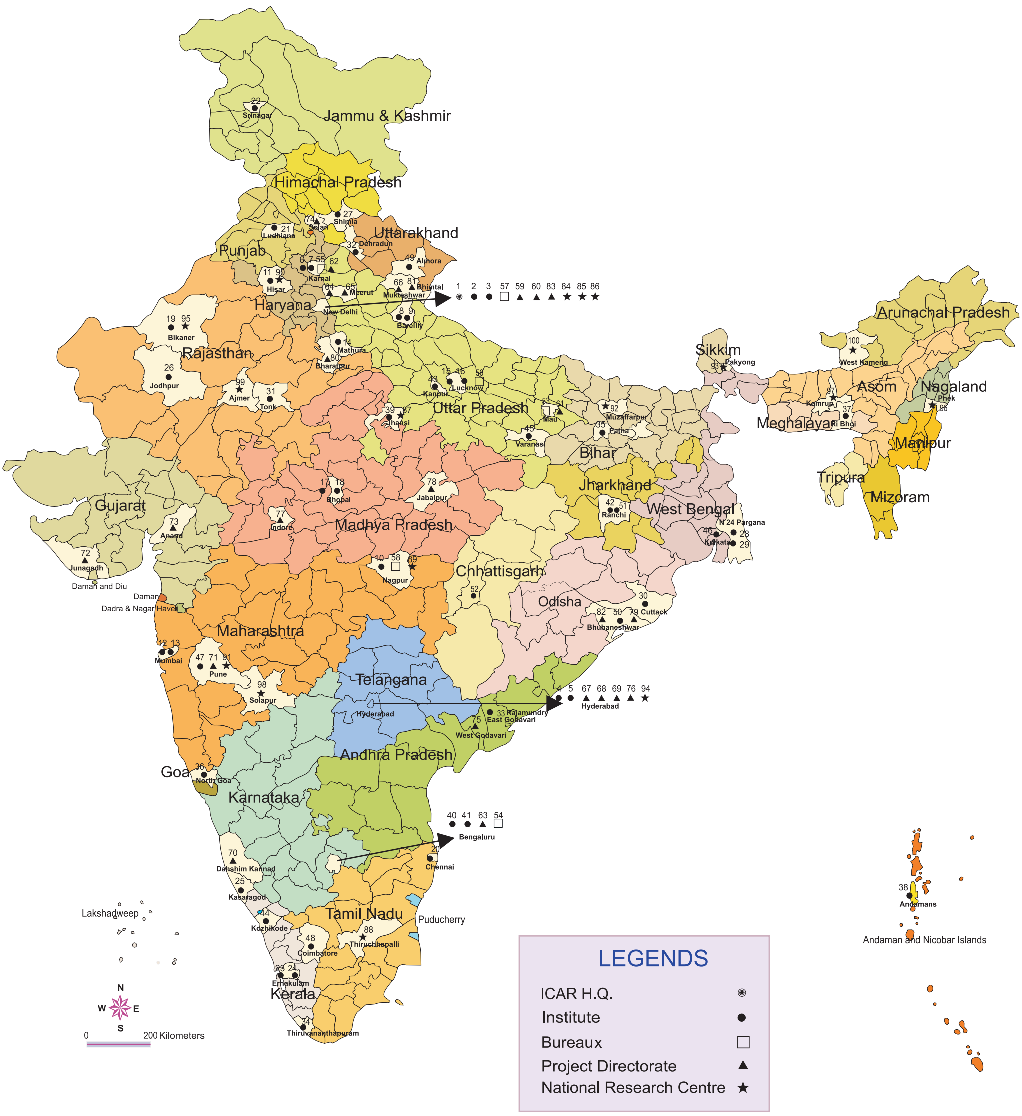
Vision 2050

Central Soil Salinity Research Institute

Indian Council of Agricultural Research

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Institutes, Bureaux, Directorates and National Research Centres



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

Vision 2050

Central Soil Salinity Research Institute
(Indian Council of Agricultural Research)
Karnal- 132 001
(Haryana)
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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-Central Soil Salinity Research Institute (CSSRI), Karnal has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario in the next 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)
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Preface

ICAR-Central Soil Salinity Research Institute (ICAR-CSSRI) is a premier research organization pursuing interdisciplinary research on salinity management and use of poor quality irrigation waters in different agro-ecological zones of the country. The institute charted a successful course right from the beginning and evolved a technology to reclaim alkali soils in its early years of inception. Measure of success is evident from the wide adoption of the technological package with an estimated 2.0 million ha of salt affected lands being reclaimed. The reclaimed area alone is contributing approximately 16 million tonnes of food grains besides generating on-farm and off-farm employment of more than 160 million person days annually. The institute also made significant headways in developing drainage technology to reclaim waterlogged saline lands, high yielding salt tolerant varieties, use of saline/alkali/waste water in agriculture and solving many region specific problems. With impeccable credential of this nature, the Institute has grown into an internationally recognized centre of excellence in soil/water salinity research.

The problems of soil alkalinity, salinity and poor quality waters are likely to increase in the foreseeable future mainly due to expansion in irrigated area, intensive use of natural resources resulting in second generation problems and climate change which is no longer a fashion statement but a reality. Our tentative estimate indicates that area under salt affected soils in India may increase to 16.2 million ha by 2050. The problems of water quality especially polluted waters are also likely to increase exponentially due to increasing urbanization and industrialization. Management of these degraded land and water resources is likely to pose formidable problems because many new pollutants are emerging.

The present document, ICAR-CSSRI Vision 2050 embodies the outcome of joint efforts made by large number of dedicated scientists and valuable suggestions from the Chairman and Members of RAC and QRT of the institute. Several critical areas such as utilization of urban and industrial waste for reclamation, nanotechnology, molecular breeding for multiple stresses, drainage methods for Vertisols, conjunctive and multiple uses of poor quality water, bio-saline agriculture, bioremediation and phyto-remediation have been identified. Technology dissemination needs to be given top priority. This document presents our considered views, not only on what needs to be done, but what can be reasonably achieved by the year 2050 by pursuing research in a network participatory mode with national and international organizations.

I express my gratitude to Dr. S. Ayyappan, Secretary, Department of Agricultural Research & Education (DARE) and Director-General, Indian Council of Agricultural Research (ICAR), New Delhi for his invaluable guidance in preparing ICAR-CSSRI Vision 2050. I am grateful to Dr. A.K. Sikka, Deputy Director General (NRM), ICAR, New Delhi for his personal interest, guidance and suggestions made during the preparation of this document. I also express my sincere thanks to Dr. S.K. Chaudhari, ADG (Soil and Water Management).

I appreciate the efforts of all the scientists in bringing out this document. I am confident that ICAR-CSSRI Vision 2050 would provide research leads on management of salt affected soils and poor quality waters to ICAR-CSSRI as well as other national organization under the umbrella of NARS.

(D.K. Sharma)
Director
ICAR-CSSRI, Karnal

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Context

By 2050, having to feed 1.6 billion people, India will face intense pressure on its land and water resources in agriculture because of diversion of resources to domestic, industrial and other sectors of economy and the likely degradation of these resources. Ever increasing demand for good quality land and water resources in the domestic and industrial sectors has already generated enhanced interest in the utilization of salt affected soils and poor quality waters. While salt affected soils currently constitute 6.74 million ha in different agro-ecological regions, the area is likely to increase to 16.2 million ha by 2050. Similarly, current exploitation of poor quality waters assessed at 3.2 million ha-m per annum needs to be enhanced in space and time to bridge the gap between the water supply and demand. Thus, salt affected soils and poor quality waters including wastewaters represent an opportunity that can be exploited to increase agricultural production and productivity to ensure national food and nutritional security.

Indian Council of Agricultural Research established ICAR-Central Soil Salinity Research Institute (ICAR-CSSRI) in March, 1969. The Regional Research Station at Canning Town was transferred to ICAR-CSSRI in February 1970 to conduct research on reclamation and management of coastal salt affected soils. The Regional Research Station at Bharuch started functioning, initially at Anand, from February, 1989. The mandate was to conduct research on the problems of inland salinity of the black soil regions. To undertake research in situations like surface drainage congestion, high water table conditions, relatively heavy textured soils with indurated pans, Regional Research Station, Lucknow was established in October, 1999. ICAR-CSSRI accomplishments are manifested through widespread adoption of alkali land reclamation package, subsurface drainage technology, spread of area under the salt tolerant varieties, irrigation water management and use of saline water in agriculture.

To have a concise and reliable estimate of salt affected soils of India, mapping of salt affected soils for 16 states has been completed and the maps on 1:250000 scales have been digitized. Total salt affected area has been computed to be 6.74 million ha. Mapping on 1:50000 scale has been initiated in Haryana and other states of India.

Alkali land reclamation technology through chemical amendments developed by the institute has become quite popular and about 1.94 million ha area has been reclaimed with the adoption of this technology. The reclaimed area alone is contributing approximately 15.52 million tonnes of paddy and wheat annually. The reclaimed lands now generate an annual employment of 155 million person days annually. Other attractive biological reclamation options such as cultivation of salt tolerant crop varieties, halophytes and grasses with no or reduced doses of amendments have also been developed to cater to the needs of the resource poor farmers.

Subsurface drainage technology, initially developed for Haryana, has been widely adopted and replicated in Rajasthan, Gujarat, Punjab, Andhra Pradesh, Maharashtra, Madhya Pradesh and Karnataka. More than 1,10,000 ha waterlogged saline soils have been reclaimed so far. The technology had remarkable impact on crop yield, farm income and employment. Cropping intensity increased by more than 100% and crop yields increased by 45% (paddy), 111% (wheat) and 215% (cotton). Stakeholder's participation through Farmers' Drainage Societies and Public Private Partnership model has given good results in the proliferation of this technology.

Sustainability of irrigated agriculture especially based on ground water is threatened because of over-exploitation resulting in alarming decline in the water table. ICAR-CSSRI has developed, installed and evaluated individual farmer based ground water recharge structures at more than 90 farmers' fields in Haryana, Punjab, Uttar Pradesh and Gujarat. The recharge structures have proved highly effective in augmenting ground water, improving its quality (reduction in salinity, alkalinity and fluoride concentration) and enhancing farmers' income by saving submerged crops through recharge of excess water. This technology has also resulted in notable reduction in EC (0.1 to 2.4 dS/m) and RSC (0-8.3) of the ground water besides a rise of water table from 0.5 to 3 m at different sites.

The institute has prepared and published the first approximation water quality map of India. For the sustainable use of poor quality waters in agriculture, the institute has developed and demonstrated technologies like treating alkali water with gypsum, pyrite and distillery spent wash, blending of poor quality water with canal water, cyclic irrigations with good and poor quality waters and pitcher irrigation etc. Because of these sustained efforts, poor quality waters account for 3.2 million ha-m per annum out of the present ground water development of 13.5 million ha-m per annum.

Sustained breeding efforts culminated in the development of high yielding, salt tolerant varieties of rice (CSR 10, CSR 13, CSR 23, CSR 27, CSR 30, CSR 36 and CSR 43), wheat (KRL 1-4, KRL 19, KRL 210 and KRL 213), Indian mustard (CS 52, CS 54 and CS 56) and chick pea (Karnal Chana 1). Basmati CSR 30, a fine grain premium rice variety, has become quite popular. Indian mustard variety CS 56 is suited to late sown irrigated conditions besides having salt tolerance characteristics. During the last 10 years, breeder and TL seeds of salt tolerant varieties amounting to 196 tonne rice, 129 tonne wheat and 6.5 tonne mustard have been produced and distributed by the ICAR-CSSRI to various seed multiplication agencies, farmers and other stakeholders. The estimated area coverage under these varieties is 6.41 lakh ha annually. The value of additional production obtained due to adoption of ICAR-CSSRI salt tolerant varieties has been estimated to be Rs. 25,660 million during the last decade.

An auger hole technology has been developed and standardized for raising forest and fruit plantations on lands lying barren due to salinity/ sodicity hazards. By adopting this technology, state forest departments have raised successful tree plantations on village community lands, Govt. lands adjoining roads, railway lines and canals, and in social forestry programmes. The different agro-forestry models helped reclaim sizeable salt affected lands, thus providing fuel wood and forage to landless labourers and small farmers, besides sequestering carbon.

Large quantities of wastewater generated in urban areas are being used indiscriminately either raw or with little treatment for irrigation to grow selected food crops including vegetables without any concern for the contamination of natural resources and food chain. A number of technological options that do not contaminate the food chain have been developed for the disposal of waste waters. Growing forest plantations with plants like *Eucalyptus,* especially clones like *Bhadrachallam,* is recommended which consume water luxuriously if available in plenty and provide economic returns. Other technological options for safe disposal of wastewater include cultivation of industrial crops, aromatic grasses or flower crops producing high biomass with non-edible economic parts. Drip irrigation for waste water is an equally sound option as it minimizes the contamination of soil and crops.

Uttar Pradesh and Bihar have about 1.52 million ha salt affected soils offering enormous scope to enhance crop production. Some of the technologies developed at Regional Research Station, Lucknow to reclaim such soils are: reclamation of sodic soils with gypsum and phospho-gypsum, land modifications to enhance the productivity of waterlogged sodic soils by harnessing canal seepage and pond based integrated farming system, development of post reclamation resource and energy conservation technologies, alternate land use systems to maximize productivity, development of salt tolerant varieties using participatory approaches, and ground water recharge technologies to reduce fluoride content in the ground water. New and emerging areas of research conceptualized and developed under the aegis of RRS, Lucknow include biological formulations like VAM culture, *Trichoderma* and endobacteria as growth enhancers. A consortia of microbes named as CSR- BIO has been commercialized through 4 industries. In last one year, about 73.5 t solid and 3600 litre liquid formulations have been sold to the famers covering about 5000 ha area under different crops.

The sizeable area of Vertisols and associated soils in Gujarat state alone has gone out of cultivation due to water logging and salinity. Besides, the state is experiencing ground water quality and waste water disposal problems. Highly saline soils can be utilized by cultivating salt tolerant grasses and halophytes for economic production of fodder, fuel and other products. In coastal regions, rainwater harvesting coupled with cultivation of low water requiring crops can ease the water scarcity problems. Bio-saline agriculture techniques for growing economically potential salt tolerant plants and halophytes have been developed to exploit ground water that is too saline to irrigate the conventional crops. Concerted efforts have been made to formulate strategies for effective utilization of treated industrial effluents and biological sludge in agriculture.

The coastal agro-ecosystem in India occupies a sizable area. Agriculture and allied activities are the major livelihood of the people but the productivity is usually low as it is hindered by a cluster of problems. To address these problems, regional station/centres developed a number of technologies such as land shaping, on-farm water harvesting structures to improve drainage and facilitate double cropping, aquaculture, integrated nutrient management, improved *Dorouvu* technology to skim fresh water floating on the saline water, reclamation of abandoned aqua ponds, besides developing rice varieties for deep and medium surface water stagnation during monsoon season. Land shaping helped in harvesting excess rainwater by 848530 m^3, improved surface drainage by 75% and increased farmers' income from Rs. 22,500/- to 1,55,200/- per ha.

Since future agriculture is likely to be constrained by limited availability of land and water, salt affected lands, poor quality ground water and polluted waste waters merit attention. Increasing temperature and evaporation, likely change in the frequency of occurrence of extreme events, frequent climatic aberrations coupled with increasing anthropogenic interventions are likely to increase the extent of salt affected lands and the degree and quantum of poor quality ground water and waste waters. Moreover, the genesis and formation of salt affected soils as a result of pedogenic and geogenic processes and ground water salinity as a result of geo-chemical processes are dynamic in nature and therefore their spatial and temporal extent is also likely to be dynamic. In order to address these problems through scientific interventions, there is a need to understand, identify and clearly spell out the long-term vision of future R&D requirements. This vision document is an attempt to clearly identify and briefly outline the future R&D activities to be pursued at ICAR-CSSRI.

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Challenges

General challenges

Salt affected soils occur almost in all climatic conditions although their distribution is relatively more extensive in the arid and semi-arid than the humid regions. The sizeable irrigated lands in the arid and semi-arid regions have some degree of soil salinization. Dry land and coastal salinity, and sea water ingress are the other challenging issues. Since the nature and properties of the problem soils are diverse, specific approaches are needed to reclaim and manage these soils to maintain their long-term productivity.

A growing body of evidence shows that climate has changed substantially since 1900, that this change is accelerating and that even greater change is likely to occur in the next 100 years. The climate change would cause global rise in temperature, uncertain and erratic rainfall, higher greenhouse gas emissions, deteriorated ecosystem and biodiversity losses. Thus, climate change has the potential to disrupt present day efforts to meet the core obligations and responsibilities articulated by the institute's mission and goals. The operations and programmes to mitigate climate change impacts on agriculture will be highly vulnerable to the magnitude and pattern of climate change as well as on changes in climate extremes. Changing precipitation and temperature patterns as well as increasing atmospheric greenhouse gas concentrations would impact agro-ecosystems at national, regional and local scales in space and time and would have significant implications for programme participation and costs. Since such projections are accompanied by a great deal of uncertainty, policies will have to be flexible enough to adapt to this uncertainty. The ICAR-CSSRI will stride forward with renewed vigour to take up these challenges for the betterment of the farming community and other stakeholders.

Specific challenges

To realize the vision and mission, ICAR-CSSRI will concentrate on the following key areas with strength drawn from the past research and extension experiences and taking into account the emerging challenges being faced by the present day agriculture.

- Preparation of resource inventories of waterlogged salt affected soils and poor quality waters using hyper-spectral analysis and digital mapping.
- Focus on spatial, temporal and anthropogenic changes in the behaviour of salt affected soils in the context of climate change including study of pedogenic processes.
- Development of RS/GIS/GPS/geophysics based decision support systems for prognostics, diagnostics and modeling studies.
- Explore biological reclamation using microbes and application of organic materials including municipal and industrial wastes.
- Enhancing efficiency of using nano-technology.
- Diversification through silvi-pastoral and agro-forestry systems.
- Augmenting ground water depth and quality.
- Focus on issues of water quality including recycling of sewage and industrial effluents for agriculture and decontamination of pollutants by microbes.
- Dry land salinity management and diversification strategies in salt affected arid lands underlain with poor quality ground water.
- Sustaining productivity in post-reclamation phase in relation to soil and water quality *vis-à-vis* organic matter dynamics and carbon sequestration.
- Breeding for multiple stresses in view of climatic changes.
- Design platforms for crops where genes such as *Saltol* and *Sub1* can be embedded in the leading high yielding varieties.
- Management of waterlogged saline lands, which may include drainage particularly in Vertisols, aquaculture and bio-drainage.
- Multiple use of poor quality water for multi-enterprise agriculture to increase water productivity and farmers' income with climate smart farming system.
- Bio-saline agriculture including agro-forestry, agro-horti systems, silvi-pasture systems for fuel wood, forage, energy production and nutritional security.
- Residue management. for resource conservation and higher crop productivity.
- Strategies to ensure double cropping in coastal saline soils and water availability during *rabi* season.
- Studies on rising sea level and consequential changes in submergence and land degradation.
- Reclamation, management and drainage in salt affected Vertisols.
- Secondary salinization in new canal command areas; subsoil salinity and transient salinity management.

- Reclamation and management of alkali soils of central and eastern Gangetic plains; sub-soil sodicity management through municipal and industrial waste.
- Technology transfer, impact assessment and human resource development in the emerging areas, economic feasibility studies of saline/sodic soil reclamation.
- Impact of climate change on salinization and also on soil reclamation and crop yield.

In order to address these challenges, institute would work in a multidisciplinary approach and in a multi-institutional framework so that the strengths of one another could be synergized to develop and extend the technologies.

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Operating Environment

The contribution of agriculture sector to the national Gross Domestic Product (GDP) has declined from 42.8% in 1960 to 13.7% in 2012-13, yet it holds an important position in the Indian economy as agriculture and allied activities employ 48.9% of the total workforce. In spite of declining contribution to GDP, production of food grains increased nearly five times, from roughly 50 million tonnes in 1950-51 to 264 million tonnes during 2013-2014. The population of India is expected to grow from 1.27 billion currently to 1.6 billion by 2050. Population in urban areas will also increase from present 31% to around 51% by 2050. As a result of this whole dynamics, the country will require to produce an estimated 377 million tonnes of food grains by 2050 up from the current level of about 264 million tonnes. While striving to achieve the projected production with more intensive agriculture, there could be a severe strain on land and water resources. Besides it may result in major environmental problems such as degradation of soils from overuse of chemical fertilizers, indiscriminate use of pesticides causing health hazards, decline in crop diversity, over-exploitation and deterioration of ground water quality, water logging and soil salinity.

Since, there is little scope to expand the net sown area to achieve the targeted food production of 377 million tonnes by 2050, it would require increasing the cropping intensity and expanding gross area under irrigation from about 89 million ha to 117 million ha in 2050. For this, we may require about 807 billion cubic meter of water by 2050 and fortified irrigation networks.

The increase in irrigated area as envisaged would lead to secondary salinization consequentially leading to estimated 16.2 million ha salt affected area by 2050 without technological interventions, compared to the current estimate of 6.74 million ha. Thus, preventing productive lands to turn into saline lands would be the key to sustain irrigated agriculture. Intensive integrated efforts for prevention, reclamation and management would be needed in the fields of salt affected soils and poor quality waters for irrigation. Strategies involving technological interventions, development of high yielding varieties, efficient nutrient management, conjunctive use of surface and ground water, application of sprinkler and drip irrigation systems, utilization of municipal and industrial wastes, recharge of ground water, nano-technology, drainage of waterlogged saline soils particularly Vertisols, utilization of treated waste waters, increased use of bio-fertilizers and policy reforms in subsidies and pricing of water will be required to maintain higher water use efficiencies and meeting significantly higher food grain requirement. For ensuring sustainable production from salt affected soils, the operating environment for ICAR-CSSRI is based on the following scenarios.

Global scenario

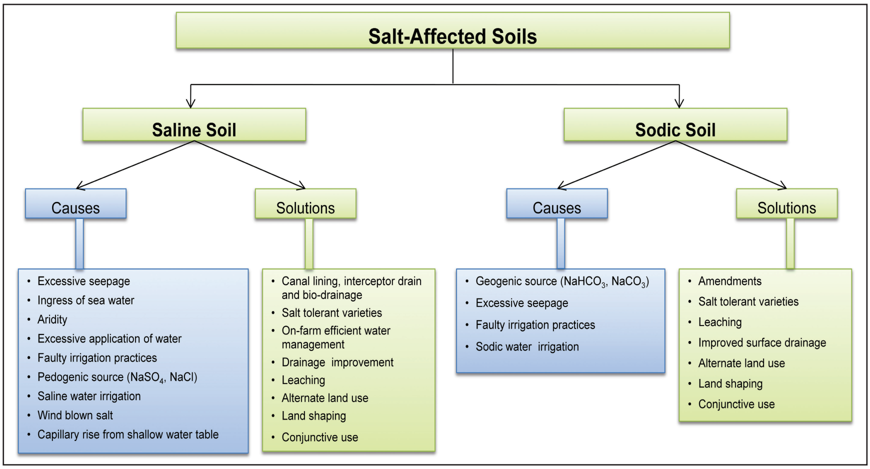
Salt-affected soils are found in arid and semi-arid climates in more than one hundred countries of the world, where many regions are also affected by irrigation-induced salinization. Recently, dry-land salinity has also become a major issue in natural resource management in different continents. The extent of salt affected soils is highest in Asia Pacific region which also include Australia. Countries predominantly affected by land salinization include Argentina, Australia, China, Egypt, India, Iran, Iraq, Pakistan, Thailand, former Soviet Union, and USA. Presently, about 932 million hectares are affected by salinization and alkalinization world-wide, out of which 581 and 351 m ha is affected by sodicity and salinity, respectively.

Indian scenario

Alkali soil is formed when carbonates and bicarbonates of sodium, calcium, magnesium and potassium are abundant in the soil. It has pH value >8.5, electrical conductivity (EC) <4 dS/m, exchangeable sodium percentage (ESP) >15 and sodium adsorption ratio (SAR) >10. When the chlorides and sulphates of above said cations increase in the soil, then the formation of saline soil takes place. It has pH value <8.5, EC >4 dS/m, ESP < 15 and SAR <10.

India's total salt affected area is 6.74 m ha, out of which 3.79 m ha is suffering from sodicity and the rest 2.95 m ha is affected with salinity problems (also includes 1.25 m ha coastal saline soils). Salt affected soils exist across the length and breadth of India covering 16 States/Union Territories. The maximum salt affected soils are in Gujarat (2.22 m ha) followed by Uttar Pradesh (1.37 m ha).

The causes for the formation of salt affected soils and their probable solutions for reclamation are graphically depicted below.



For harvesting sustainable production from salt affected soils, the operating environment for ICAR-CSSRI is based on the following scenarios.

- With increasing demand for good quality land and water for other sectors, agriculture will be pushed more and more to marginal lands and fragile environments. So far, we have been able to reclaim about 2.0 million ha salt affected soils. As only 29.7% of salt affected soils have been reclaimed, large scope for reclamation still exists. Considering the future projections made on an all India basis, an area of about 11 million ha is likely to be affected by the problems of water logging and soil salinity by 2025 and 16.2 million ha by 2050. It is likely that with increasing use of marginal and poor quality water, affected area in ground water irrigated regions is also going to increase steeply by the year 2050. Prevention and/or reclamation of this area could substantially alter the food production statistics.
- To prepare effective reclamation plans, we need to have good inventories of salt affected soils, waterlogged soils and poor quality waters besides documenting their characteristics, distribution and use potentials. Excellent inventories of the extent of lands damaged by salinity and water logging in irrigation commands updated at least every five years are very much needed. It should be backed up by a strong mechanism of information dissemination in the form of readily available texts, maps, graphs and associated database to multi users.

- The cost of alkali soil reclamation at constant prices is rising. Over-dependence on finite and non-renewable resources as amendments (gypsum, pyrites) for reclamation is not sustainable in the long run. Due to economic restructuring, likely removal of subsidy on amendments or their reduced availability in future poses the single most serious threat to the progress of reclamation. Alternate technologies like biological reclamation by exploiting the use of microbes, application of organic materials like green manures, FYM, crop residues, municipal and industrial wastes, and diversification into silvi-pastoral systems will assume greater significance. Development of crop varieties capable of being cultivated with no gypsum or little dose of amendments will be an attractive biological reclamation option.
- With the growth in the National GDP at 6.8% per annum during the period from 2000 to 2025 and 6.0% per annum during the years 2025 to 2050, the per capita income is bound to increase by 5.5% per annum. This will not only increase the demand for food but will also have significant implications for the kind of food items consumed. While the per capita consumption of cereals will decrease by 9%, 47% and 60%, with respect to rice, coarse cereals and maize, the per capita consumption of sugar, fruits and vegetables will increase by 32%, 65% and 78% respectively. This will create an additional demand for newer food sources and water.
- If we look at the macro level, India is a water deficit country. The per capita water availability has come down from 1816 m^3 in 2001 to 1545 m^3 in 2011 and is projected to further reduce to 1340 m^3 and 1140 m^3 by the year 2025 and 2050, respectively (UNICEF, FAO and SaciWATERs, 2013). Further, these numbers are likely to be adversely affected by the anticipated climate change in terms of volume, seasonality and spatial distribution. The CWC/MoWR's has projected the total water demand of 1180 billion m^3 in 2050 from the present water demand of 710 billion m^3. However, the water demand for agriculture sector has been projected to be around 68% of the total water demand from the present share of around 78% (CWC, 2011). Therefore, water would be the major constraint in producing enough food for the population at that time. So, improved water management will be called for, like provision of more storage, water conservation by minimizing water losses, increasing food production per unit of water, transferring water to users with higher socio-economic returns and reusing saline, sewage and industrial effluents. Efficient conjunctive management of water

resources at regional level should receive the maximum priority. The situation can be improved through strategies involving river basin as planning unit, community participation in the development and management of water resources, appropriate water pricing policy to encourage resource conservation, rainwater and roof water harvesting, watershed management and inter basin water transfers.

- The quality of water has become a serious problem in river basins. About 70% of the surface water resources and large proportions of ground water reserves have been contaminated due to indiscriminate discharge of wastewater from the industry, agriculture and households sectors which contain biological as well as toxic organic and inorganic pollutants. Most of the polluted stretches of rivers are located in and around large urban areas. Municipal sewage contributes about 75 per cent and industrial pollution accounts for the rest of the point source pollution. Class-I and Class-II cities together generate an estimated 38,254 MLD of sewage (CPCB, 2009). The treatment capacity of 11,787 MLD in 2009 was far behind the requirements. By 2050, the sewage generation from Class-I and II cities will increase by three-and-a-half times to 132,253 MLD, which will pose serious problems if concerted efforts to add wastewater treatment capacity are not undertaken. Ground water is also polluted due to point and non-point source pollution. In some areas, the ground water is not of the desired quality due to geogenic elements. For example, instances of high fluoride have been reported in 13 states, arsenic in West Bengal, and iron in the north-eastern states, Orissa, and other parts of the country. In the canal irrigated lands of Haryana, Punjab, Delhi, Rajasthan, Gujarat, Uttar Pradesh, Karnataka, and Tamil Nadu, ground water is affected due to high salinity, the affected area being over 193,000 km^2 (Thatte et al., 2009).
- Population growth with increasing urbanization and industrialization is encroaching upon the share of agricultural water and is leading to production of large quantities of wastewaters, which are beyond the capacity of natural systems to assimilate. Since the present sewage irrigation practices are primitive, unscientific and more of disposal oriented their use results in progressive and irreversible accumulation of salts, toxic materials and heavy metals in soil and ground water. Health hazards from pathogenic contaminations further multiply the complexities from their use. Key strategies for efficient management of waste water need to focus on augmentation of collection, treatment and safe disposal of waste water; recycling and reuse of municipal and industrial waste water; provision of

appropriate sanitation facilities; and strengthening of institutional and regulatory mechanisms. These strategies will reduce 57% of BOD load and the volume of untreated wastewater generated and may also result in 15% reduction in the demand for fresh water.

- The priorities for agriculture sector defined in the new national water policy entail development of water use efficient crops, adoption of rainwater harvesting and watershed management techniques, reduction of subsidies on power supply particularly for pumping water, prevention of ground water exploitation by introducing differential pricing, rewards and punishments and implementation of National River Linking projects which aim to connect 30 rivers to generate 175 trillion litres of water. All these proposals would have a significant impact on the strategies to be adopted for the management of salt affected soils and poor quality waters.
- Nearly 80% of India's population depends on fuel wood as a source of energy. Presently only 10% of this demand is being met. The demand-supply gap has to be bridged through afforestation. Areas, identified as suitable sites for afforestation include salt affected community lands, undulating lands subjected to saline seeps, strips along canals/ branches/distributaries to utilize seepage and coastal saline areas including salt flats. About 1.62 million ha of the projected 16.2 million ha salt affected soils in irrigation command by 2050 will have the potential for afforestation/agro-forestry. Afforested lands would also serve as additional sinks for carbon sequestration and thus help temper the global warming trends. With an increasing concern for conservation of nutrients, there will be need to cultivate nitrogen-fixing trees. Availability of fodder is also meagre and meets only 50% of the demand. This will require diversification of land, use particularly of degraded lands, into silvi-pastoral systems for N fixing associations as well as leguminous pastures to improve the soil and feed quality.
- There will be a need to intensify research on enhancing salt tolerance of cereal, oil seed and pulse crops besides horticultural and vegetable crops. The new varieties/genotypes besides being tolerant should be capable of giving high yields. With the threat to biodiversity of crop species, there will be an increasing need to conserve the germplasm of various wild relatives of crops in saline and dry land habitats, coastal saline soils etc., which could serve as useful donors of resistant genes in breeding programmes to cope with abiotic stresses. Further, productivity improvement, value addition, post-harvest handling and marketing issues of already existing trees,

herbs, shrubs, grasses in salty environments will become a priority research agenda in near future.

- Over 1.25 million ha of soils in the coastal tracts of India are afflicted with the problems of salinity. High rainfall and impeded drainage contribute to the serious problems of deep-water submergence and water logging. The problem is likely to assume serious dimensions in future with the anticipated rise in sea level of 1 m due to global warming. Such a scenario will have serious consequences as the coastal saline area might increase several folds.
- In the coastal regions, estimated 45% increase in water demand by 2050 compared to current scenario would lead to increased pressure on ground water withdrawal due to limited surface water storage potential. Heavy ground water withdrawal would cause sea water ingress, increase soil salinity and pollute soil and water with heavy metals like arsenic, which in turn might reduce the crop productivity during *rabi* season. Therefore, measures for harvesting rainwater during *kharif* and its use during *rabi* have to be developed. Besides crops, which can be grown with little water under high salinity conditions, need to be explored. Development of strategies for seaweed cultivation in association with fish farming in coastal areas will receive highest priority. The traditional methods of irrigating nurseries and high value crops in coastal areas through skimming wells are also facing problem of saline water intrusion caused by over pumping. Recent introduction of large-scale saline aquaculture (shrimps, prawns etc.) has resulted in large scale intrusion of sea water in inland areas and is leading to ecological destruction. There is a need to explore alternatives like paddy-cum fish culture combined with brackish water aquaculture. The environmental consequences of brackish water aquaculture in terms of soil and water contamination will need attention.
- India has a vast tract of land occupied by Vertisols. These soils are adversely affected even at low salt and exchangeable sodium because of poor soil physical conditions attributed to their high clay content. Due to the occurrence of "pseudo" water table, run off and soil erosion is also more. At present, salt affected Vertisols occupy an area of about 1 million ha in the Gujarat alone while the problem is becoming serious in other states like Karnataka, Maharashtra and Rajasthan. Restoring the productivity of these lands post their salinization is much difficult as compared to alluvial sandy loam soils of Indo-Gangetic plains. Since the costs of installing and maintaining the drainage system are high, evolving ideal soil

and water management strategies and developing multi-enterprise agriculture seem cost-effective alternative options. Evolving salt tolerant plants or identification of economically important salt tolerant plants could also provide an alternative for the utilization of such problematic soils.

- The ICAR-CSSRI has generated alkali soil reclamation technology under limited set of conditions. In many situations, there could be large number of institutional, socio-economical, psychological and other constraints that play a role in enhancing/retarding its adoption by the target group. The 'package of practices' approach, often favoured and recommended, in technology transfer is not relevant for the marginal farmers and in areas with agro-climatic variability. The farmers should be able to select from a basket of technological options, so that they may tailor them as per the requirements of soil, water and other resources. There is also the need to enhance the decision making capability of farmers through development of decision support systems.
- Rising costs of agricultural operations, energy, shortage of labour and deteriorating soil health pose serious challenges to the sustainability of agriculture on reclaimed alkali soils. These challenges require modifications in the existing cropping systems or devising new cropping systems suiting to the changed scenarios.
- The frequency and intensity of climate change triggered disasters like cyclones, tsunamis, droughts, floods, cold and heat waves have significantly increased in the recent past. These disasters cause huge loss to human and cattle, and also adversely affect land and water resources. There will be need to prepare frameworks to monitor changes in soil and water quality induced by such disasters and to develop strategies to negate/moderate such impacts on soil health, water quality and society.
- So far, the Governments at the central and state levels were responsible for developing necessary infrastructure for installation of subsurface drainage for management of saline soils, providing subsidies for chemical amendments like gypsum for management of alkali soils and managing water distribution. With the rising costs and pressures to withdraw/reduce subsidies to the agriculture sector, Public Private Partnership (including civil society organisations and various stakeholders) has to be formulated for speedy implementation of reclamation projects. Civil Society Organisations as well as Farmers' Organisations can help small farmers in adopting modern technologies and for establishing forward and backward linkages,

required to increase their income.

- To keep pace with the increasing extent of salt affected soils and poor quality waters in the country owing to various pedogenic and geogenic processes along with changing climatic scenarios in the next four decades, infrastructural modernization would be the major task. Continuous updating of database of salt affected soils would be the foremost priority. It requires collection of remotely sensed data from NRSA and its digitization for end to end solutions. Infrastructure and instrumentation for developing efficient materials for soil reclamation and enhancing tolerance to salts using nanotechnology and material science will be developed. Facilities for synthesis, characterization and testing for end users will also be generated. Infrastructural facilities need to be modernized for sub-surface and mole drainage technologies for the reclamation of saline soils including salt affected Vertisols. Laboratory facilities for testing of subsurface drainage pipes, envelope materials and machinery components along with simulation infrastructure for climate change, regional salinity-crop measurement and modelling systems including decision support and expert systems need to be developed. Improving genotypes with higher salt tolerance and high yield requires integration of newer innovative approaches with traditional breeding methodologies. Phytotrons for phenotyping along with high throughput genotyping platform besides facilities for transgenics, proteomics and metabolomics would be essential. New age information technology and libraries for keeping pace with databases and digital libraries would be required. Separate cold storage facilities for germplasm and seeds along with seed processing facilities and power backup requires to be developed. Infrastructural strengthening in terms of new research farms, microplots, rain shelters, hydroponics and farm machinery would also be required.
- For undertaking new strategic research, human resource development will be highly crucial. Since the research tools are becoming sophisticated, training and capacity building will be needed in emerging areas such as GIS, remote sensing, biotechnology, genetic engineering, nano-technology, precision farming, climate change, value addition and processing techniques of salt tolerant plants and halophytes, microbial studies, ground water recharge and modelling, waste water use, saline aquaculture and sea weed cultivation etc. With liberalization, the skills and incentives to scientists, technicians and other personnel have to be upgraded in order to attract and retain good talent and keep them motivated. Research projects

would have to be increasingly of an applied nature and location specific to address a problem in an interdisciplinary, holistic and farmer participatory approach. Effective linkages would be needed with other national, international, state and voluntary agencies to address the problems. Farmers' fields have to be our laboratories and the farmers our research collaborators.

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New Opportunities

The opportunities for salinity researches are enormous due to the size and diversity of the country, where all kinds of salt affected soils and waters of varying quality are encountered and require specific solutions. Newer technologies being unveiled in different areas of science like biotechnology, nano-technology, genomics, phenomics, space science, ICT etc. can be integrated into the existing approaches for the improved management of salt affected soils and poor quality waters. Such integration would lead to higher economic returns to resource poor farmers.

Remote sensing and GIS technology: In this technology sensors placed on the ground, in the air or in satellites catch the multi-spectral images, which are used to interpret for the following:

- To detect salt affected soils, which are yet to be reclaimed as well as areas undergoing secondary salinization. The precise identification of new salt affected areas would provide opportunities to extend the technologies in these areas.
- Identification of areas under resodification after reclamation.
- To enhance our capabilities to forecast the seriousness of soil degradation.
- To prepare accurate national inventories of salt and nutrient load in soils, vegetation, rivers etc.
- Early forecasting of areas prone to water logging and soil salinization.
- Proper distribution of water of canal systems leading to improved decision making.
- To identify types and health of crops as affected by water logging and soil salinity.

The existing technology is being upgraded for applications in agriculture in terms of resolution and precision.

Probabilistic modelling: Modelling can be of benefit in understanding risks related to salinity build-up, secondary salinization, resodification, water availability on regional and basin scale, deterioration of water quality, use and reuse of poor quality ground and drainage waters and agriculture production. The opportunities provided by technologies based on remote sensing and modelling is constrained by the ability to have ground truth and validation of the generated information.

Biotechnological approaches: The power of biotechnology as a tool to address issues hitherto unresolved for harsh saline environments is evident from the following issues and strategies for the development of salt tolerant high yielding varieties.

- Introgression of salt tolerant quantitative trait loci (QTLs) like *Saltol* into popular rice varieties of the region enhancing their salt tolerance potential following backcrossing approach and identifying plants with desired genes in every generation to minimize the duration for the development of new salt tolerant varieties.
- Introgression of submergence tolerance QTL *Sub 1A* into popular rice varieties especially for coastal region following marker assisted backcross breeding to enhance the submergence tolerance of rice varieties besides significantly enhancing their economic yield.
- Tolerance to pests and disease can be enhanced by incorporating bacterial blight resistance genes (*xa 5, xa13* and *xa21*) and blast resistance genes (*Pi-2t* and *Pi-9t*) into high yielding rice varieties through molecular breeding approach
- Development of recombinant inbred lines and near inbred lines from salt tolerant and sensitive lines of different crops for the identification of QTLs for salt tolerance
- Development of transgenic lines by transferring different genes conferring salinity tolerance into desired crops to enhance salt tolerance potential of different crops.

Bioremediation products: Development of bioremediation products like microbial formulations through identified microbes to reclaim saline/ sodic soils and remediate poor quality waters laden with heavy metals. While application of such microbial formulations to degraded soil would enhance crop growth, poor quality waters contaminated with heavy metals can be remediated for safe use in irrigation once passed through a medium containing such microbes.

Nanotechnology: Nano-filtration, nano-materials and nano-particles have the potential to enhance efficiency of chemical amendments for reclamation of alkali soils and alkali waters and/or develop effective alternative amendments for their reclamation. Nano-particles could also be used to enhance efficiency of fertilizers and other chemicals, water purification and waste water treatment. These could also be used to develop nano-sensors for non-destructive monitoring.

Water conservation technologies: Increasing rainwater use efficiency, irrigation through alternate wetting and drying, developing low water requiring crops, recycling and reuse of good and poor quality waters, reclamation techniques to increase the usage of reclaimed water from ground, industrial and municipal sources and identifying low water and salt tolerant growth stages in life cycle of different crops can have significant impact on crop's ability to tolerate water and salt stresses and/or ability to conserve water. These could also help to bring more areas under irrigation besides reducing impacts of climate change on the deterioration of water resources. These technologies have the potential to save water in agriculture and as a result are becoming more relevant.

Precision farming: By using satellite data to monitor soil condition and plant growth, precision farming can help fine tune the placement of seeds, fertilizers and chemicals and application of water use at the right place and at the right time. It can potentially increase production and reduce production costs. Real-time kinematic global positioning system allows a tractor to position itself within an accuracy of 2 cm, thus reducing inefficiencies stemming from overlapping of input application or deep percolation losses.

Utilization of municipal and industrial waste: Due to increased urbanization and industrialization the generation of municipal/ industrial waste is increasing rapidly and its disposal has become a challenge. Research efforts are needed to use them in salt affected soils as reclamation agents as the sources of gypsum or pyrite are limited. The use of municipal/industrial waste will also contribute to ***'Swachh Bharat Abhiyan'*** especially near cities, where heaps of municipal wastes are occupying good agricultural lands besides giving filthy look and creating pollution.

Post-harvest and value addition: Food saved is food produced. With the concept of global village in place, surplus food needs to be processed for value addition for domestic consumption and export. The institute in association with its collaborators would initiate measures in this regard especially with respect to halophytes and seaweeds etc.

Marketing innovations: Agricultural marketing is now getting liberated and private players are participating actively in the process. Several innovative and alternate marketing systems are in place. This ongoing liberalization process and entry of private players in agricultural marketing have assumed an important dimension. A strong supply chain of inputs and sale of produce needs to be developed through multi stake holder partnership.

Management of energy and agricultural wastes: Energy requirement in agriculture is growing rapidly due to mechanization and intensification. To meet the future energy demand as well as to reduce the dependence on conventional (non-renewable) energy resources, there is a need to explore the alternative (un-conventional or renewable) energy sources from biological or natural resources. Bio-fuel from potential crops (e.g. sugar beet, Jatropha etc.) suited to coastal regions need to be explored. Coastal regions are highly suited to generate energy from natural sources such as wind, waves and tides etc. These alternative energy sources can be harnessed for agriculture in the coastal regions.

Bio-risk management: Bio-risk is increasing in agriculture due to climate change and increase in trans-boundary movements of insect-pests and diseases. It adds to the cost, reduces food production and adversely affects farm income. To overcome the problem of bio-risks, efforts would be made to develop effective and integrated risk-and-disaster management production systems and institutional mechanisms, which would bear risk. Bio-risk intelligent system (such as early warning systems for heavy rainfall, climatic disaster, drought indicators, migratory movement of bio-risk agents, etc.) would be developed for taking informed decision at the local, regional and national levels.

Information and communications technology: This can be an effective tool to manage salt affected soils and poor quality waters as farmers can be exposed to newer technologies and improved practices through these techniques in a faster and cost effective manner.

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Issues and strategies

To meet the burgeoning food requirement of the country, focus has to shift to degraded areas. Productivity potential of the salt affected areas in the country can be harnessed by adopting the curative as well as preventive measures. High degree of sophistication in our ability to predict resource degradation under existing/emerging situations would result in early forecasting of areas prone to water-logging and salinization. Sustainability of the reclaimed lands is an important issue. Further, the emerging issues of resodification and secondary salinization have to be addressed. The search for appropriate reclamatory materials for alkali soils has to be enlarged in view of finite source of gypsum. Use of poor quality waters in agriculture has to be enhanced besides addressing the water quality concerns. High yielding crops with higher salt tolerance having commercial values need to be developed on priority. Newer technological approaches of remote sensing, GIS, nano-technology, molecular biology, biotechnology, bioremediation etc. has a major role to play in addressing these issues. The important issues along with the strategies for providing end to end solutions are mentioned in the table below.

S. No.	Issues	Strategies
1	Developing reliable databases and land use plans for salt affected soils	Updating available information on the extent and distribution of salt affected soils, water-logged saline soils and poor quality waters using remote sensing and GIS, digitization for end to end solutions, establish reclaimability and potential uses
3	Sustainability of reclamation technology	Diagnostic studies, new reclamative materials like municipal and industrial wastes, nano-technology approaches, balanced nutrition, use of organics and resource conservation techniques
4	Resodification of reclaimed alkali lands	Diagnostic studies, following recommended package of practices, bio-drainage to control shallow water table
5	Improving efficiency of amendments	Establish soil-water-amendment interaction, crop diversification, organic matter application
6	Replicability under resource constraints	Refinement in technology, selection of crops, irrigation and drainage requirement, resource conservation techniques
7	Reclamation technology for waterlogged salt affected soils	Identify constraints, development of viable subsurface drainage/ bio-drainage technology, envelope materials and machinery components
8	Secondary salinization of canal command areas	Interventions for irrigation system improvement and management of shallow water table, land shaping, bio-drainage, establishment of benchmark sites

9	Drainage in Vertisols	Identify constraints, feasibility of mole drainage
10	Agro forestry systems for sodic soils and waterlogged saline lands	Development of tree/grass based land use systems, assessing and minimizing constraints of community owned lands
11	Alternate drainage technology for different agro-climatic regions and low cost drainage material	Refinement of technologies and testing of locally available drainage material and multi-tier subsurface drainage approach in FSR mode
12	Impact of drainage effluents on local / regional level and options for safe disposal	Preparing analytical framework for various options with major emphasis on *in-situ* use and disposal
13	Eco-friendly strategies of conjunctive use	Regional scale crop productivity models, decision support system, regional surface and ground water interaction
14	Devise suitable disposal and use strategies for poor quality waters, domestic and agro-industrial effluents	Establish tolerance limits of crops, appropriate technology for application, evaluate impact on crops and soil, pollution hazards and ecological effects including impact on human health, identifying microbes for bioremediation of polluted waters, use of micro irrigation
15	Development of salt tolerant and high yielding varieties	Breeding varieties capable of high tolerance and high sustainable yields, exploitation of salt tolerance genes from wild relatives, identification of genes/ QTL's and their pyramiding for developing tolerant varieties
16	Breeding crops for multiple stresses	Development of climate resilient varieties capable of tolerating multiple stresses
17	Increasing intensity of cropping in coastal areas	Rainwater management including drainage, land shaping, efficiency of fertilizers, multi-enterprize agriculture
18	Reclamation technology for areas with deficit irrigation	Development of suitable water harvesting measures, tolerant crops/varieties and alternate land use systems
19	Human Resource Development	Arrange training, collaborative and contract research for institute scientific staff; arrange training for Govt. and non-govt officials at various levels. Upgradation of skills of scientific and technical staff in cutting edge research areas
20	Technology evaluation and transfer	On farm farmer participatory research, demonstration trials, impact analysis of already developed technologies

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Goals and Targets

The next three and half decades will witness widespread changes in resource base, resource quality and productivity in response to the increasing food demand and climatic change. Since the climatic factors directly govern the pedogenic and geogenic processes, extent of salt affected soils and poor quality waters will be highly influenced by these variables. Major increase in salt affected areas will be due to faulty irrigation practices in irrigation commands, seawater ingress in coastal areas and climate change. Although the broad focus of ICAR-CSSRI will remain the same i.e. reclamation and management of salt affected soils and poor quality waters in different agro-ecological regions of the country, priority and problem solving approach would vary drawing the synergy of emerging frontiers of science.

During the next 35 years ICAR-CSSRI will aim at the following major goals

- Resource inventory and pedogenic processes of salt affected soils and waters
- Reclamation and management of salt affected soils
- Remediation and management of poor quality waters
- Crop improvement for abiotic stresses
- Alterative land use systems
- Climate change adaptations
- Transfer of technology, impact assessment, value addition and market linkages
- Human resource development

Precise targets for each of the goals, expected achievements/outcome and expected impact are discussed below:

Targets	Expected achievements/ outcomes	Measurable outcome and expected impact
Resource inventory and pedogenic processes of salt affected soils and waters		
Database on salt affected soils	Digital database on distribution and extent of salt affected soils at farm scale will be made available to the users	Farm-scale maps, digital database, real-time information on salt affected soils
Database on poor quality waters and waste waters	Digital database on distribution and extent of poor quality ground water and waste water will be made available to the users	Localized ground water maps, digital database, real-time information on waste water availability

Basic studies on pedogenic processes on soil salinity and sodicity	Enhanced understanding through basic studies related to climatic impacts on genesis of salt affected soils, pedogenic and geogenic processes, morphological and micro-morphological changes in soils owing to anthropogenic reasons	Fundamental processes, concepts, models will be made available
Reclamation and management of salt affected soils		
Reclamation and management of inland saline and sodic soils	• Development of reclamation technology packages for inland saline and sodic soils • Development of technology packages/ agro-techniques for productive utilization of salt affected soils	Area reclaimed, increased crop productivity, increased farm income, enhanced nutrient use efficiency, increased water-use efficiency, resource conservation, input savings, improved soil health and quality
Reclamation and management of irrigation induced salt affected soils	• Evolving preventative measures to safeguard resource base in irrigation commands • Development of technology packages for reclamation of secondary salanized lands • Development of technology packages for sustainable agricultural production on salt affected soils	Area reclaimed, reduction in waterlogged area, Increased crop productivity, enhanced nutrient use efficiency, increased water use efficiency, resource conservation, input savings, improved soil health and quality
Reclamation and management of coastal salt affected soils	• Technology packages for sustainable agricultural/ aquaculture production in coastal saline areas • Contingency packages for adoption during natural calamities	Increased crop productivity, enhanced nutrient use efficiency, energy conservation, reduction in drudgery, input savings, improved soil health and quality
Reclamation and management of salt affected Vertisols	• Development of reclamation technology packages for salt affected Vertisols • Development of technology packages/ agro-techniques for productive utilization of salt affected Vertisols	Area reclaimed, energy conserved, increased crop productivity, increased farm income, enhanced nutrient use efficiency, increased water use efficiency, resource conservation
Remediation and management of poor quality waters		
Remediation and management of saline and alkali waters	• Technology packages for remediation of saline and alkali waters. • Technology packages for productive utilization of saline and alkali waters in agriculture.	Increased crop productivity, enhanced farm income, improved water use efficiency, salt balance in soils, improved soil health and quality

Remediation and management of waste waters in agriculture	• Technology packages for remediation/ bio-remediation of waste waters. • Technology packages for productive utilization of waste waters in forestry/ flowers/non-food crops.	Increased income, increased water use efficiency, improved status of heavy metals in soils, health of micro flora and fauna
Remediation and management of drainage and industrial effluents	Technology packages for productive utilization of drainage and industrial effluents in agriculture/forestry/flowers/ non-food crops	Increased income, increased water use efficiency, improved status of heavy metals in soils, health of micro flora and fauna
Productive utilization of poor quality waters in agri-aquaculture	Development of technology packages for enhancing productivity of poor and marginal quality waters through aquaculture	Increase in farm income, increase in water productivity, systems stability, climate resilience, clean environment
Crop improvement for abiotic stresses		
Development of salt and multiple stress tolerant varieties for climatic aberrations	• Assessment of plant genetic resources with higher tolerance to salinity and related stresses. • Development of crop varieties for multiple stress conditions	Genetic resources assessed, crop varieties developed, area covered under tolerant varieties, increase in farm income
Breeding crops for bio-fortification	Development of crop varieties for bio-fortification	Crop varieties developed, area covered
Basic studies for enhancing input use efficiency	Development of varieties with higher inputs use efficiencies	Increase in nutrient and water use efficiency, extent of tolerance to salinity
Alternative land-use systems		
Alternative land use systems for dry land salinity	Technology packages involving agroforestry, agri-horti, agri-silvi-pastures, bio-saline agroforestry on degraded saline soils of dry land regions	Increase in farm income, reduction in drudgery, reduction in rural migration, resource conservation, improvement in soil health and quality
Climate change adaptations		
Developing comprehensive technology packages for climate change adaptations	Technology packages for climate resilient agricultural production systems	Climate resilient agriculture, stability, increase in farm income, salt and water balance and energy conservation
Developing crop-fish-animal husbandry systems for changing climate in coastal areas	Development of integrated farming systems and multi-enterprise systems for sustainable livelihood and nutritional security	Climate resilient agriculture, increase in farm income, energy conservation and resource recycling

Restoration and conservation of mangroves in coastal areas	Development of technology for conservation of mangroves and management of acid sulphate soils/ wetlands	Stability of ecosystem, increase in income, energy conservation and resource recycling,
Development of contingent plans for extreme events, cyclones, tsunami and other natural calamities	Contingency packages for rapid restoration of farm activities following natural calamities in coastal areas	Climate resilience, stability, increase in farm income, and energy conservation
Transfer of technology, impact assessment, value addition and market linkages		
Transfer of technology, evaluation and impact assessment	• Farmers' participatory models for effective transfer of technology. • Agro-centres for resource poor farmers in different salt affected eco-regions.	Number of frontline demonstrations carried out, exhibitions and training programmes organized, number of technologies popularized
Developing market linkages for rapid commercialization of developed technologies	• Exploiting market intelligence for rapid commercialization of technologies. • Development of producers' participatory approach in marketing against farmers' exploitation. • Evolving possible measures for value addition.	Increased farm income, reduction in farmers' exploitation, reduced wastage of farm produce, technologies commercialized
Agri-economic policy research in salt affected soils	Development of policy guidelines for regulating agricultural/farm activities in salt affected areas	Policy guidelines, reduction in drudgery, equity, quality, stability
Human resource development		
Capacity building of resource persons and stakeholders	Capacity building through trainings at national and international levels to address emerging challenges in the field of management of salt affected soils and use of poor quality waters	Training programmes conducted, number of people trained, increase in knowledge, increase in agri-entrepreneurship

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Way Forward

Soil salinization and sodification are dynamic processes mainly governed by changes in natural conditions including climate change. The problems of soil salinity, sodicity, water logging and poor quality waters are likely to increase in future due to planned expansion in irrigated area and non-judicious exploitation of natural resources to meet food, fodder, fibre and timber demand of the burgeoning human and livestock populations. Present rate of reclamation is inadequate to arrest the growing areas under salinization and sodification. Discounting the reclamation of salt affected lands at the present rate, tentative area under salt affected soils will be nearly 16.2 million ha by 2050. Crop production on such lands will face multiple stresses due to less availability and poor quality of irrigation water, occurrence of extreme events, climatic aberrations, specific ion toxicity, re-sodification etc. In these situations, the role of non-traditional approaches and technological innovations will be of utmost importance. ICAR-CSSRI will harness the potential of frontier sciences to develop technologies for reclamation and management of salt affected soils and poor quality waters for enhanced agricultural production. To synergize these efforts, the Institute will have to collaborate with partners in technology development as well as its dissemination. For this, the role of NGOs, corporate partners, farmers' associations/organizations and policy makers will be very crucial. Appropriate strategies will be adopted to achieve the targets and to address the challenges, smoothly adjusting with the changing environment and deriving benefits from the same. Some of the cutting edge research themes, which will improve the visibility of ICAR-CSSRI will be:

- Development of decision support systems for judicious use of salt affected soils and poor quality waters
- To explore the possibilities for utilization of municipal and industrial waste for reclamation
- Use of nano-technology in remediation of poor quality waters, waste waters, and reclamation of saline/sodic soils
- Bioremediation of industrial effluents and its reuse in agricultural production programmes
- Multi-enterprise agriculture systems for nutritional security, quality, clean environment and energy conservation in salt affected areas

- Exploring salt affected soils and poor quality waters for bio-energy and bio-saline agriculture in degraded ecosystems
- Ground water recharge to arrest falling water-table and improving the quality through dilution
- Solute transport to predict ground water contamination by pesticides, weedicides, fertilizers and other agrochemical inputs
- Development of suitable methods of drainage particularly for Vertisols
- Breeding salt tolerant crop varieties involving biotechnological, cellular and molecular approaches
- Development of robust molecular markers/products/varieties/genetic stocks using molecular marker approaches

ICAR-CSSRI will focus on developing innovative and creative technologies for the emerging issues of soil salinity, sodicity, water logging, poor quality waters, heavy metal toxicity and bio-saline agriculture. It would document their impact on soil-water-plant-human continuum. The institute will sensitize and facilitate policy interventions to upstream, upscale and speed-up the rate of reclamation through viable technologies.

ICAR-CSSRI will shoulder the major burden while sharing the responsibility to ensure sustainable agricultural development in salt affected areas. Although management of salt affected soils catches the immediate attention of all concerned as it helps augment productivity, the various agro-ecological factors demand that it should be mandatory to have a holistic approach and special attention to their interaction matrix. Only through this, one can ensure sustainability of the agro-ecosystems and betterment of the farming community. In a highly motivating working atmosphere, the scientific community of ICAR-CSSRI will draw inspiration from its past unmatched achievements and move forward towards the goals articulated in this vision document.

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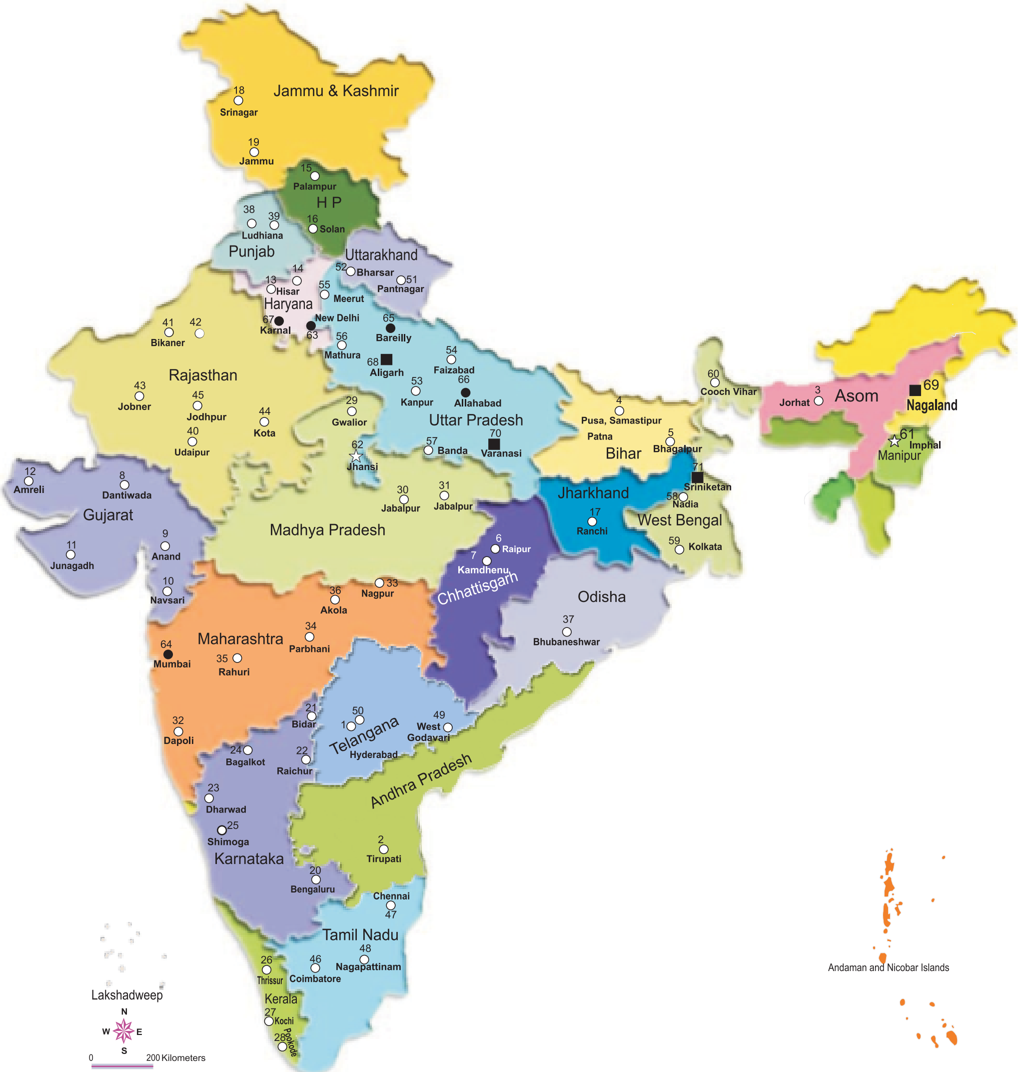

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