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ICAR-CENTRAL SOIL SALINITY RESEARCH INSTITUTE
KARNAL-132001, HARYANA

ICAR-CSSRI/Karnal/Technical Bulletin/2019/07

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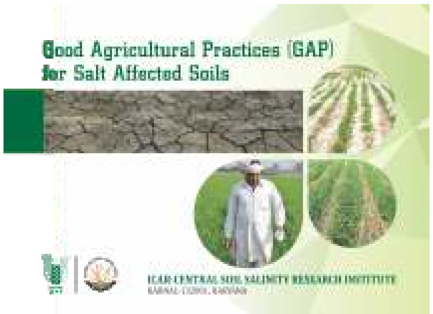
Citation: Jat, H.S, Singh, Jogendra, Yadav, R.K., Kumar, Anil, Rajkumar, Bhaskar, Narjay, Datta, Ashim, Singh, Awtar, Mukhopadhyay, Raj, Prajapat, Kailash, Fagodia, R.K., Yadav, Gajender, Sharma, P.C.. 2019. Good Agriculture Practices (GAP) for Salt Affected Soils. ICAR-CSSRI/Karnal/Technical Bulletin/2019/07 . ICAR-Centrail Soil Salinity Research Institute, Karnal. (pp 60).



Cover Photo : Sodic Soil, Mustard under saline soil, Green seeker based N-application, Bed planting of wheat

Published by : Director, ICAR-Central Soil Salinity Research Institute, Karnal

Assistance : Madan Singh

Printed by : Aaron Media

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FOREWORD

Food safety has gained increasing importance over the years due to its impact on the health of consumers and the growth in the domestic and global trade in food products. Production of safe food is essential for protecting consumers from the hazards of food borne illnesses. Further, food safety is an integral part of food security and also contributes towards increasing competitiveness in export markets. Food safety hazards may occur at different stages of the food chain starting right from primary production and extending to secondary and tertiary processing, storage and distribution, and packaging. It is therefore very important to address food safety starting from the field level. Implementing good practices during on-farm production and post-production processes is of immense importance for assuring a safe food supply. Many importing countries as well as domestic buyers, especially organized retailers, are now requiring producers to implement Good Agricultural Practices (GAP) as a prerequisite for procurement to ensure the quality and safety of their produce. Restoration of soil quality for the required crop production or to limit and/or slowing down the further deterioration is a pre-requisite for safe and quality food. Thus, preventing productive lands to turn in to saline lands would be the key to sustain agriculture growth and productivity in the country. Non-sustainability of agricultural systems evolves around three principal indicators; soil erosion, soil organic matter decline and salinization. Therefore, there is a urgent need to eliminate the unsafe and unceasing components of traditional agriculture to result into quality farm produce. The purpose of this Bulletin is to spread the basic concepts of Good Agricultural Practices (GAP) amongst all the stakeholders in order to promote sustainable agriculture and contributes to meeting national, environmental and social developmental objectives under salt affected regions.

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INTRODUCTION

The concept of Good Agricultural Practices (GAP) has evolved in recent years in the context of a rapidly changing and globalizing food economy and as a result of the concerns and commitments of a wide range of stakeholders about food production and security, food safety and quality, and the environmental sustainability of agriculture. GAP applies recommendations and available knowledge to address the environmental, social and economical sustainability for on-farm production resulted in a safe and healthy agricultural products. The need was felt to prepare the strategies to ensure that all the stakeholders should participate in and get benefit from the application of GAP in the food chain from production to consumption. Food safety issues has gained increasing importance now-a-days because of its significance both from health and global trade perspectives. The production of safe food is essential for protecting consumers from the hazards of food borne illnesses. Hazards may occur at different stages of crop production starting right from the primary production, e.g. residues above permitted levels, microbial contaminants and heavy metals in the produce by use faulty crop management practices. Therefore, it is important to address food safety right from crop production at field level. Implementing GAP at farmers' field for crop production and post-production processes resulting in safe agricultural products is of immense importance in all the agro-ecological systems. GAP, as defined by FAO, are a "collection of principles to apply for on-farm production and post-production processes, resulting in safe and healthy food and non-food agricultural products, while taking into account economic, social and environmental sustainability." In addition, implementing GAP also helps promote sustainable agriculture production in the country and contributes to meeting national and international environmental and social developmental objectives, and also food and nutritional security. Implementation of GAP encourages promotion of the optimum use of resources such as tillage, pesticides, fertilizers, water, and eco-friendly agriculture in salt affected soils. Safe use of pesticides would protect the agricultural workers' health.

GAP for Sodic soils

Appropriate soil management in sodic soils aims to maintain and improve soil productivity by improving the availability and plant uptake of water and nutrients through enhancing soil physical, chemical and biological activities. Gypsum, a popularly used chemical amendment for reclamation of sodic soils, helps in increasing the soil physical conditions and reduces the toxic effect of sodium carbonates and bio-carbonates on plant growth and development. Appropriate management practices like use of amendments, tillage and crop establishment, crop residue and water management are key factor for mitigation of negative effect in both salt-affected and reclaimed soils. Expected climate change in arid and semi-arid regions aggravates the soil salinity/sodicity due aberrations in temperature, rainfall and faulty management practices. The high salt concentration negatively affects soil physical and chemical properties as well as soil microbial activity, thus causing a decline in soil productivity. Therefore, now the focus has been given on the methods that are appropriate to agronomic, environmental and human health requirements under salt affected soils for safe food production.

GAP for saline soils

The management options for saline soils and water mainly includes the selection of crops, cropping system, best management practices related to sowing, crop establishment, fertilizer, irrigation and other cultural management practices but there seems to be no single management measure to control salinity of irrigated soil to harvest the good crop. Therefore, several crop management practices should be considered in an integrated manner for good and safe agriculture produce. Establishing a good crop stand in saline irrigated soils is a challenging task. Unlike normal soils, the agronomic practices for crop production in saline irrigated soils are different. An ideal package of GAP besides soil fertility, nutrient and irrigation water management can ensure a good crop stand vis-à-vis good yield. Judicious management of resources and efficient use of irrigation water in recycling and blending is of utmost importance in avoiding the salt stresses.

GAP for sustainable soil management

The sustainability of the rice-wheat (RW) production systems on reclaimed sodic soil has become a major concern owing to resodification, declining of ground water table, declining factor productivity and diminishing economic returns in the North-West Indo-Gangetic Plains (NW-IGP) of India. Rice-wheat is the most important cereal based cropping system for livelihood of millions people and is practiced in ~5 M ha. In some areas, the water table is now being depleted at nearly 0.4 - 1.0 m yr^{-1}. Excessive pumping of fresh water aquifer is prone to salinity and sodicity problems leading to impaired physical and biological environment that adversely affects the soil and plant growth. Soil/crop indicators affected by soil salinity/sodicity and their remedial measures through conservation agriculture (CA) for their long-term sustainability are given in Table 1. In post reclaimed phase of salt affected soil, CA based GAP is a way forward to escape secondary salinization and helps in sustainable production intensification and contributes safe and quality food products.

GAP like zero tillage (ZT), crop establishment, adaptable cultivars, residue, water and nutrient management etc. were found more adapted to climate risks rather than conventional practices. The integration of above mentioned GAP in RW rotation improved system productivity and profitability by 10-15 and 20-25 per cent, respectively while reducing 30 per cent global warming potential (GWP). A package of several resource use efficient technologies and practices have been assessed and standardized to address the challenges related to natural resource degradation and climatic risks management. Good agricultural practices (GAP) is required to promote sustainable intensification in salt affected soils with the below stated aims and objectives

Table 1. Characteristic indicators for management of salt affected soil by adopting GAP for quality and safe produce

Soil/ crop indicators	Implications/ problems in salt affected soils	Good agricultural practice (GAP)
Soil organic matter (SOM)	Decline in SOM through fast oxidation and reduction	Crop residue retention moderates soil moisture and temperature and improved SOM and microbial biomass
Soil bulk density	High due to excessive mechanical tillage and salt content	Zero-tillage technology drastically reduced the soil bulk density
Soil porosity and water infiltration	Low soil porosity and water infiltration due to deflocculating soil aggregates and repeated tillage operations	ZT with residue retention improves the soil porosity and water infiltration over time, use of gypsum in sodic soils improves soil physical properties
Aggregate stability	Low aggregate stability due to carbonates and bi-carbonates of sodium	Residue retention and green manuring helps in binding soil particles into aggregates
Low crop biomass	High evaporation and low transpiration.	High transpiration and low evaporation due to surface mulch
Patchy crop growth	Uneven distribution of salts in soil profile because of uneven soil surface	Lased land levelling helps in making even surface which allows uniform salt distribution
Salt accumulation	Salt accumulated on top of the bed which interfere with the crop root growth and development	Permanent bed planting and ridge-furrow technology with residue retention helps in salt accumulation on side of the bed
Water logging	Conventional irrigation method does not regulate the water in the crop root zone properly	Sub-surface drip irrigation in CA helps in regulation of moisture content properly as per the need, SSD for saline water logged areas

Crop diversification	Limited options are available	CA makes it possible by integration of mungbean in to rice-wheat system
Soil deterioration	High rates due to low rainfall and high temperature in arid and semi-arid areas	It can be minimized using residues as surface mulch and through sustainable intensification
Ground water depletion	Transplanted rice require >150 cm of irrigation water	ZT- direct seeded rice (DSR) able to save 25-30% irrigation water, crop diverstification
Multiple nutrient deficiencies	Use of straight fertilizer	Residue retention helps in providing balance dose of nutrients
Fauna and flora	Adversely affect by salt which limits mobility of nutrients	Chemical Ammendments, ZT, residue retention and intensification improved the soil organisms activity

Aim:

- Implementation of GAP in salt affected soils to encourage promotion of the optimum use of input resources such as crop residues, pesticides, nutrients and water for safe and quality agriculture produce.
- To create awareness about the GAP to protect the agricultural workers' health from improper use of chemicals and pesticides.
- To create market opportunities for farmers and exporters for safe and quality food and retain niche markets

Objectives

- To sensitize all stakeholders about safe food production, quality food, and the environmental sustainability of agriculture
- To make aware how hazards may occur in the food chain starting right from the primary production, e.g. residues above permitted levels, microbial contaminants and heavy metals.
- To promote sustainable agriculture and its contribution to meeting national and international environmental and social developmental objectives

Sustainable management of sodic soils through amendments: Gypsum application

Reclamation of sodic soils requires use of amendments such as gypsum or calcium chloride, that directly supply soluble calcium, or other substances, like sulphuric acid and sulphur that solubilise the relatively insoluble calcium carbonate commonly found in sodic soils. ICAR-Central Soil Salinity Research Institute, Karnal has standardized gypsum technology for reclamation of such sodic soils. Based on soil sodicity (pH), the gypsum requirement for light (10% clay), medium (15% clay) and heavy (20% clay) textured soil ranges from 0-10, 0-14 and 0-16 t ha^{-1}. After application of required quantity of gypsum, it needs be mixed in surface 10 cm soil and level graded plots are bunded properly. For effective leaching of gypsum reaction products, the reclamation process should be initiated before onset of monsoon with preferably rice as first crop. Addition of organic matter (i.e. straw, farm yard and green manures) and press mud etc. are also helpful in improvement of health of such soils. Rice, wheat, shaftal, berseem and garlic are suitable crops under moderate sodicity conditions. Since nitrogen is the most limiting nutrient and application of 150 kg ha^{-1} each to rice and wheat is recommended. P and K fertilizers are not required in the initial years of reclamation. After 3-4 years, application of 22 kg P ha^{-1} to rice only and after 7-8 years 22 kg P ha^{-1} every year to both rice and wheat are recommended for sustainable crop yields. About 2.07 M ha sodic soil area has been reclaimed with this technology which resulted in 16-17 million tonnes of additional food grains per year and over 175 million man-days of additional employment generated. In addition to that the soil quality has been improved with good aggregation, higher infiltration resulting in ground water recharge and environmental improvement through soil carbon enhancement after reclamation.

Broadcasting of gypsum for sodic soil reclamation

Management of poor quality (RSC) water through Gypsum bed chamber technique

High residual sodium carbonate (RSC; 1.25 me L^{-1}) when used for irrigation causes adverse effect on soil physical condition and crop growth. Gypsum bed chamber technique is designed to neutralize high Residual Sodium Carbonate (RSC) or alkalinity of water to minimise its adverse effect on soil health and crop yield. The gypsum bed chamber is a brick-cement-concrete chamber connected to water fall box on one side and to irrigation channel on the other side. Its size depends on the pump discharge rate and RSC of alkali water. A net of iron bars covered with wire net (2×2 mm) is fitted at 10 cm height from bottom of the bed. Alkali/ RSC water flowing from below dissolves gypsum in chamber while passing through gypsum bed and neutralize RSC of water. A gypsum bed chamber of 2×1.5×1.0 m^3 size is sufficient to neutralize 3-4 meq L^{-1} of RSC in water delivered at a discharge rate of ~6 L sec^{-1}. The problem of slow passage of water through gypsum bed chamber can be improved by mixing gypsum and press mud in 4:1 v/v ratio. Such mixing of gypsum and press mud effectively neutralized (~80%) up to 4 me L^{-1} of RSC. Approximately Rs. 25,000-30,000 ha^{-1} as an incremental benefit with benefit-cost (B: C) ratio of 1.5-2.0 and internal rate of return (IRR) of 30-40% can be achieved by the farmers. However, the technique is not recommended for situations where groundwater RSC is > 10 me L^{-1} because such high RSC neutralization requires huge quantity of gypsum and very big size chamber. Under limited canal water availability, alkali water with moderate RSC (~ 3-4 me L^{-1}) can be used in cyclic mode with canal water to minimize the adverse effects on soil health and crop production. Cyclic use of alkali and canal water is found to produce 5-6 and 4-5 t ha^{-1} of rice and wheat yield, respectively in NW Indian conditions. Nitrogen (N) volatilization is one of the major problems in sodic/alkali environment. Therefore, 25% more N is recommended than normal N dose. However, N: P: K @ 120:25:40 kg ha^{-1} is recommended for each of rice and wheat in soils irrigated with RSC water. Additionally, zinc (Zn) @ 25 kg ha^{-1} should be applied for better crop.

Application of farm yard manure (FYM) (10 t ha^{-1}), gypsum (5 t ha^{-1}) and press mud (10 t ha^{-1}) in combination with NPK are more beneficial and sustainable than NPK alone when irrigated with sodic water. Under alkali water irrigation, use of N: P: K @ 120:25:40 kg ha^{-1} + gypsum (5 t ha^{-1}) + press mud (10 t ha^{-1}) helps to achieve ~ 5.0 and 4.5 t ha^{-1} of rice and wheat grain yield, respectively.

Gypsum bed chamber for neutralization of RSC water

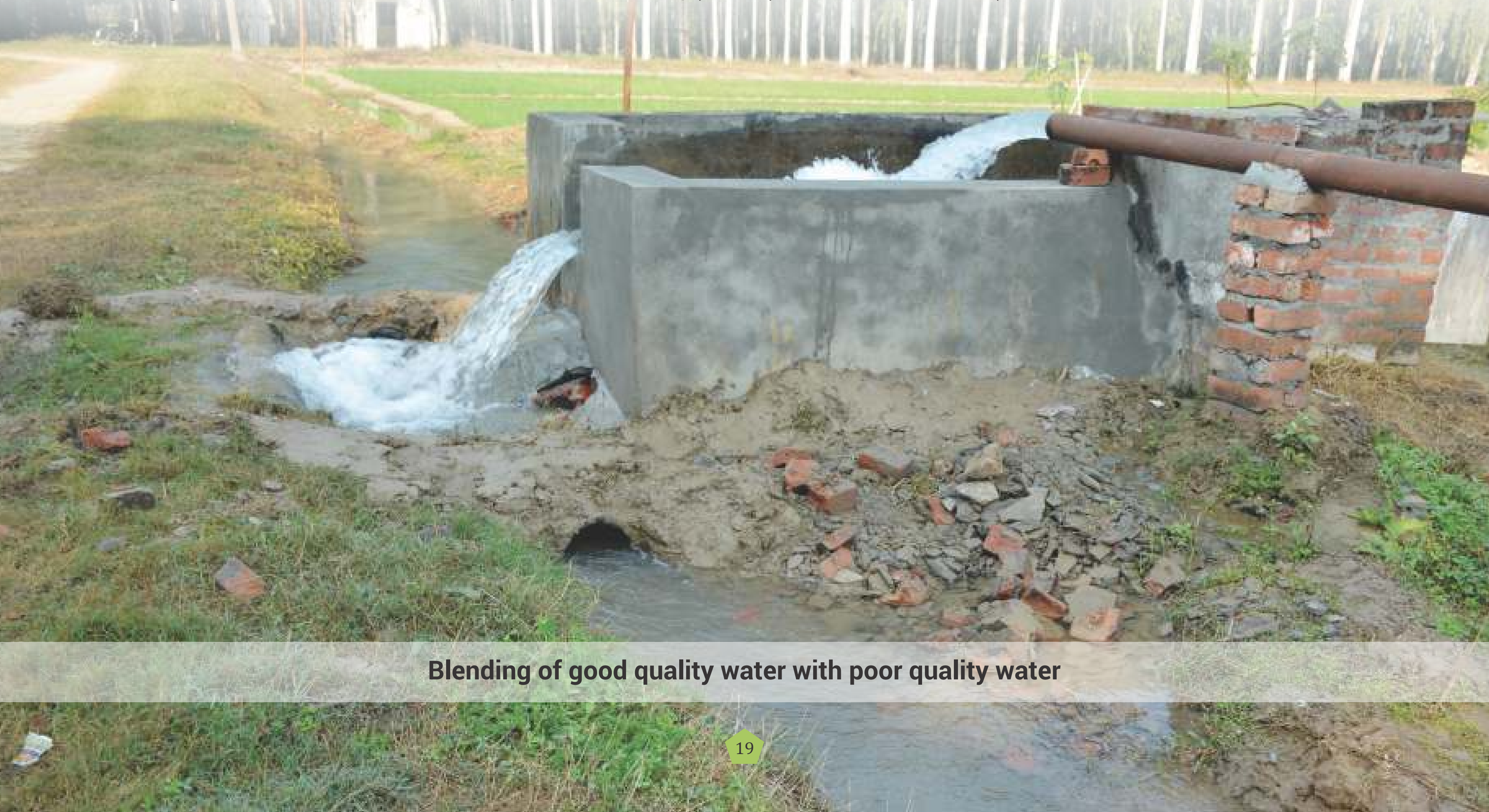
Management of Saline water for irrigation

Saline groundwater or drainage water with salinity beyond tolerance limits (4 dS m^{-1}) of crops cannot be used directly for irrigation. In saline area farmers are forced to pump saline groundwater to meet the crop water requirement. Judicious use of saline water includes both the direct use of saline water and conjunctive use of saline and fresh water. In Haryana, Punjab and Rajasthan the moderately saline water (EC of 4–6 dS m^{-1}) can be used directly for irrigation within acceptable yield levels of crops without adversely affecting soil health. The average yield reduction for crops, including millet, cotton, mustard and wheat, were less than 20% . However, the blending practice is generally followed in areas where fresh water is available in adequate quantities on demand. The potential for blending depends on the crops, water salinities, quantities of water required and the economically acceptable yield reductions. In sequential use of water under the cyclic mode, the fresh and saline water is alternated according to designed schedule. Sometimes, supplies of fresh water and saline water are applied in different seasons.

Methods of irrigation water: Surface irrigation method is most common in several part of India. Which, generally result in excessive irrigation and salt load. The pressurized micro-irrigation methods (sprinklers and drips) are more efficient as the quantity of water to be applied could be controlled adequately and the salt load is minimized compared to surface irrigation. At the same time crops tolerate higher level of salinity under these systems, particularly with drip irrigation. However, application of highly saline (EC > 12 dS m^{-1}) water through sprinklers could cause leaf burn in many crops.

Cultural practices: To ensure the better germination and crop establishment a pre-sowing irrigation with good quality water and post-sowing irrigation are very important as it helps in leaching out the salts in the seeding zone and the post-sowing irrigation further push the salts deeper into the soil and to maintain better moisture conditions. Light and frequent irrigations are beneficial under saline water use conditions.

Productivity and profitability: Generally the crop yields are 10-15% higher in cycling use of water compared to the mix use. Dilution of saline groundwater through rainwater recharge and subsequent use for life saving irrigation in mustard and wheat crops enhances crop yield by 5 to 20% respectively.



Blending of good quality water with poor quality water

Afforestation of sodic soils using auger hole technology

Afforestation is not only useful for sodic soils utilization but also to improve soil conditions and maintain the ecological balance. In addition to poor soil physico-chemical condition of sodic soils, tree growth is also restricted due to inability of the tree roots to proliferate through hard kankar pan usually found at 0.50 to 1.0 m depth. Therefore, success of afforestation in sodic soils requires modification in root-environment by (a) amending the chemical nature of soil, (b) breaking of hard pan, and (c) application of fertilizers and manures.

Planting Techniques: For successful establishment and better growth of tree in sodic soils, digging a 100-140 cm deep auger hole of 20-25 cm diameter is effective. The auger hole can be made with the tractor operated auger. For growing fruit trees, making auger hole in pit (45x45cm) technique proves more successful. Performance of planted trees using this technique has been highly satisfactory than any other routine plantation techniques. The ratio of filling mixture consists of gypsum (chemical amendment), FYM and river sand. The auger hole should be filled with a uniform mixture of original sodic soil and sand (1:1) plus 3 to 4 kg gypsum ($CaSO_4$) + 7 to 8 kg FYM. For fruit trees, original soil and (1:1) + 8-10 kg gypsum + 10-15 kg FYM is recommended. The application of nitrogenous fertilizers (100g plant^{-1}), and zinc sulfate (20g plant^{-1}) is essential at the time of out-planting during rainy season in sodic soils. The application of single super phosphate and ammonium sulfate in two equal split dosages proves beneficial in increasing the growth of trees planted in such soils. Irrigation should be applied at least once in 7 days in first three months and then once in a month for at least one year depending upon the climatic conditions, distribution and frequency of rainfall. Adoption of above mentioned planting techniques and management practices, survival rate of these species can be improved to~80%. The tree species can be selected based on the sodicity tolerance limits of tree species as suggested given in the following table.

Range of tolerance pH_2	Agroforestry & Forest/fruit trees/shrubs
>10	*Prosopis juliflora, Acacia nilotica, Tamarix articulata*
9.6-10.0	*Eucalyptus tereticornis, Capparis decidua, Pithecellobium dulce, Prosopis alba, P. cineraria, Casuarina equisetifolia, Salvadora persica, S. oleoides, Terminalia arjuna, Carissa carandus, Psidium guajava, Zizyphus mauritiana, Emblica officinalis*
9.0-9.6	*Cordia rothii, Albizia lebbeck, Cassia siamea, Pongamia pinnata, Sesbania sesban, Parkinsonia aculeata, Dalbergia sissoo, Kigelia pinnata, Butea monosperma, Punica granatum, Phoenix dactylifera, Achrus japota, Tamarindus indica, Syzygium cuminii, Feronia limonia*
8.2-9.0	*Grevillia robusta, Azadirachta indica, Melia azedarach, Leucaena leucocephala, Hardwickea binnata, Moringa oleifera, Populus deltoids, Tectona grandis, Grewia asiatica, Aegle marmelos, Prunus persica, Pyrus communis, Manigifera indica, Morus alba, Ficus spp., Sapindus laurifolium, Vitis vinifera*

Auger hole technology for afforestation in salt affected soils

GAP for waterlogged sodic soils

About 0.35 million ha sodic lands suffer from shallow water table conditions due to seepage from the canal in Sharda Sahayak Canal Command. Adoption of conventional method of gypsum based reclamation are not suitable for cultivation even after reclamation. This has led to diminishing land and water productivity and loss of livelihood for the farm families in this command.

Pond based farming system : Model for 1 ha based on the concept of physical land reclamation and pond based integrated farming system has been developed. The model comprised of 0.40 ha fish pond up to 1.75 m depth, 0.2 ha cereal crop, 0.15 ha fruit crop, 0.10 ha for vegetable and 0.10 ha for forage crops. The excavated soil spread over the 0.6 ha land helped to raise field least 2 m above the water table. The dikes are used for vegetable cultivation round the year. Remaining portion of the farmland including the trenches is used for more profitable paddy-cum-fish cultivation in kharif. The land (non trench and non dike area) is used for low water requiring crops during dry (rabi/ summer) seasons with the rain water harvested in furrows. Presence of deep furrows in the field provides better drainage condition in the field during the non-monsoon months.

The integrated farming system model comprising rain water harvesting pond, fruit species like papaya and vegetables on dykes, other fruit crops like banana, jamun, aonla, seed spices, woody biomass species like Eucalyptus and Pongamia and a compost pit can help farmers to get a staggered income (net income of about Rs. 52258 ha^{-1}) throughout the year in black saline soil.

Pond based farming in salt affected soils for livelihood security

Bio-inoculants to nulify adverse effect of salts

CSR-BIO formulation is a bio growth enhancer in sodic as well as in normal soils. This is a microbial consortium of *Bacillus pumilus, Bacillus thuringensis* and *Trichoderma harzianum* cultured in a dynamic media. Soil application of CSIR-BIO at a week before first fertilization and foliar spray at critical growth stages improved fruit yield and profitability by about 20% in tomato crop. In case of banana; CSR BIO application for bio-priming in primary hardening stage, in soil at planting and 5 months after planting followed by foliar applications after 7 and 9 months of planting, increase yield and profitability by approximately 16 %. Its use reduces requirement of agro-chemicals for plant protection by ~47 and 33% in tomato and banana, respectively compared to non-adopters. Overall farmers can get 15-30% additional crop yields by application of CSR-BIO in sodic as well as in normal soils.

Another bio formulation, Halo Azo (N-fixers) and Halo PSB (P-solubilizers) have also shown promise in rice and wheat performance in salt affected situations. Results showed an increase of 11.5% and 14.0% in yield of paddy and wheat, respectively. Farmers can get about 12, 14, 20% higher grain yield of paddy and wheat by use of Halo-Azo, Halo-PSB and Halo Mix (Halo-Azo+PSB+Zinc) bio formulations, respectively compared to control. These bio formulations can be applied through seed treatments or seedling root dip or soil application with FYM/compost. In addition to improvement in crop yields, use of these formulations significantly increases soil organic carbon, available N and P content and substantially reduces soil pH and exchangeable sodium percentage.

In-vitro bio-hardening in banana against sodicity and diseases: Protocol has been standardized for 3 tier in-vitro biopriming of multiple shoots in tissue cultured banana var. G-9 plantlets using three salt tolerant bacterial isolates CSR-A-16 *(Lysinibacillus sphaericus)*, CSR-A-11 *(Lysinibacillus fusiformis)* and CSR-M-16 *(Bacillus licheniformis)* and recommended for northern plains of the country. Farmers have recorded that cultivation of treated plantlets produce ~20% more yield than untreated plantlets in normal soils.

ICAR-FUSICONT: This bio formulation is effective in controlling the *Fusarium oxysporum* f.sp. cubense Tropical race 4 (Foc TR-4) in Grand Naine variety of banana in Uttar Pradesh and Bihar. The use protocol comprises drenching of secondary hardened tissue culture plantlets in nursery with 1% solution of ICAR-FUSICONT before planting in main field, followed by soil drenching with 2% mixture of ICAR-FUSICONT at the critical stages of the crop growth. The application of ICAR-FUSICONT is more effective when adopted at cultivators community levels. 6% as compared to > 46% recorded in non-adopters fields. It has potential to increase banana yield > 200% over non-adopters.

Bumper crop of banana in Bio-inoculants treated plots

Sub-surface drainage for management of waterlogged saline soils

Subsurface drainage (SSD) is an effective technology for the amelioration of waterlogged saline-irrigated lands by maintaining water table below desired depth and draining excess water and salts out of the waterlogged saline soil area. A SSD system consists of an underground network of filter covered pipe drains installed at designed depth and spacing below the ground surface. Saline drainage water is disposed off under gravity or by pumping from a sump well into link/main drains, streams, rivers or evaporation ponds. The SSD technology reclaims moderately to highly waterlogged saline or saline-sodic areas in alluvial and black soil regions in 3-4 year period. The soil salinity (ECe) reduces from severely high category (>32 dS/m) to slightly or normal (~4 dS/m) in 2-3 years period after implementation of SSD system. Averaged over different crops (paddy, wheat, cotton and sugarcane in eight states) adoption of this technology increases cropping intensity, crop yields and farm income by 25-80, 30-120 and 200-300%, respectively leading to B/C ratio of 1.5-3.2 and with a internal rate of return of 20- 58%. It also generates additional employment around 128 man-days per ha per annum.

The preferable slope of 0.1% in the direction of main drain is recommended. In the monsoon climatic condition, leaching should be carried out preferably during the monsoon months. Average water requirement for leaching of salts is 30-36, 36-48 and 48-60 cm in light, medium and heavy textured soils, respectively. In arid and semi-arid regions of northwest India, rice and cotton can be grown during kharif season while during *rabi* season wheat, barley and mustard can be grown. Salt tolerant varieties of rice (CSR30, CSR36, CSR43, CSR46, CSR56), wheat (KRL210, KRL213 and KRL283) and mustard (CS56, CS58 and CS60) developed by CSSRI can be adopted in initial reclamation phases. In case of transplanted crops, the number of seedlings per hill should be increased twice. To compensate for mortality of young seedlings and poor tillering 20% higher seed rate /closure plant spacing than for normal soil is recommended. 25% higher dose of nitrogen fertilizer is suggested in split doses to reduce nitrogen loss through volatilization, denitrification and nitrate leaching.

Installation of sub-surface drainage in waterlogged saline areas

GAP for managing waterlogging in canal commands - Bio-drainage

Bio-drainage is the transpiration of excess soil water using bio-energy through deep rooted fast growing tree species with high rate of transpiration (HRT). Such trees absorb water from the capillary fringe located above the ground water table. Evaporation takes place from the soil up to a depth of 4 m. Therefore, this 4 m soil depth should remain free from waterlogging to minimize secondary salinization of soils and to sustain the crop productivity in canal commands. Suitable Species for bio-drainage have been categorized in three classes (1) fast bio-drainers: Eucalyptus hybrid, *Eucalyptus tereticornis* C-10, *Eucalyptus tereticornis* C-130, *Acacia ampliceps* and *Prosopis juliflora*, (2) medium bio-drainers: *Eucalyptus tereticornis* C-3, *Callistemon lanceolatus* and *Melia azedarach* and (3) slow bio-drainers: *Terminalia arjuna* and *Pongamia pinnata*. *Casuarina glauca* was also found to be most tolerant species which withstood waterlogging.

Plantation for bio-drainage can be either block plantation or strip/ridge plantation. For block plantation, depending upon area, number of plants can be decided as per the species characteristics and spacing requirement. For strip plantation, ridges are constructed in north-south direction along the bunds of waterlogged agricultural fields. Ridge to ridge distance can be kept 50-60m and the ridge should be at least 2-3 m wide at base, 2 m at top and 0.5 m in height. For example, two rows of genetically superior clonal plants of *Eucalyptus tereticornis* (Mysore gum) can be planted at a spacing of 1m x 1m on the top of ridge at ridge to ridge distance of 66m resulting in a density of 300 plants ha^{-1}. The total area under strip-plantation of *Eucalyptus tereticornis* works out to be 4% of each ha (390 $m^2 ha^{-1}$) and rest of the 96% area is available for agricultural crops, thus it becomes an agroforestry model of bio-drainage. Strip plantation of Eucalyptus as per above specifications has been found to lower water table by 43 cm in fourth year of plantation and increased wheat and rice yield by 1.7 and 1.3 fold, respectively. In addition, the plantation produced ~35 t ha^{-1} of wood dry biomass and sequestered 15 t ha^{-1} of carbon. Benefit-cost ratio at the discount rate of 12% of first rotation (5 years and 4 months) of strip plantations can be as high as 3:1 and reaches >100:1 for next 3 to 4 rotations due to negligible cost of maintenance of coppice Eucalyptus.

Eucalyptus plantation on farm boundaries for bio-drainage

Farm pond technique, a gap to manage coastal waterlogging

The coastal agriculture is less profitable due to degraded (saline) soil and water quality, mono-cropping with traditional rice in kharif and scarcity of good quality irrigation water. The farm area is converted into on-farm reservoir to harvest excess rainwater. The dug-out soil is used to raise the land to form high and medium land situations besides the original low land situation in the farm for growing multiple and diversified crops throughout the year instead of mono-cropping with rice in Kharif season. The pond is used for rainwater harvesting, irrigation and Pisciculture. Poultry/ livestock farming can also be practiced in the farm along with crops and fishes with the use of pond water. The high land free from waterlogging in kharif with less salinity build up in dry seasons and thus can be used for multi and diversified crop cultivation throughout the year. Simultaneous cultivation of rice and azolla is recommended for higher crop yield. This helps in the storage of rainwater that can be used to irrigate 80% of farm land, improvement of surface drainage (about 75%), increase scope for cultivating crops in rabi/summer season under salt affected soils, multi-cropping, fishes and or livestock, less risk of single crop failure and better soil health. The farm pond technology provides the scope for practicing diversified cropping round the year and integrated farming, creating irrigation facility, reducing salinity and improving drainage conditions in coastal agro-ecosystems of the country.

High ridge and deep furrow technique for coastal areas

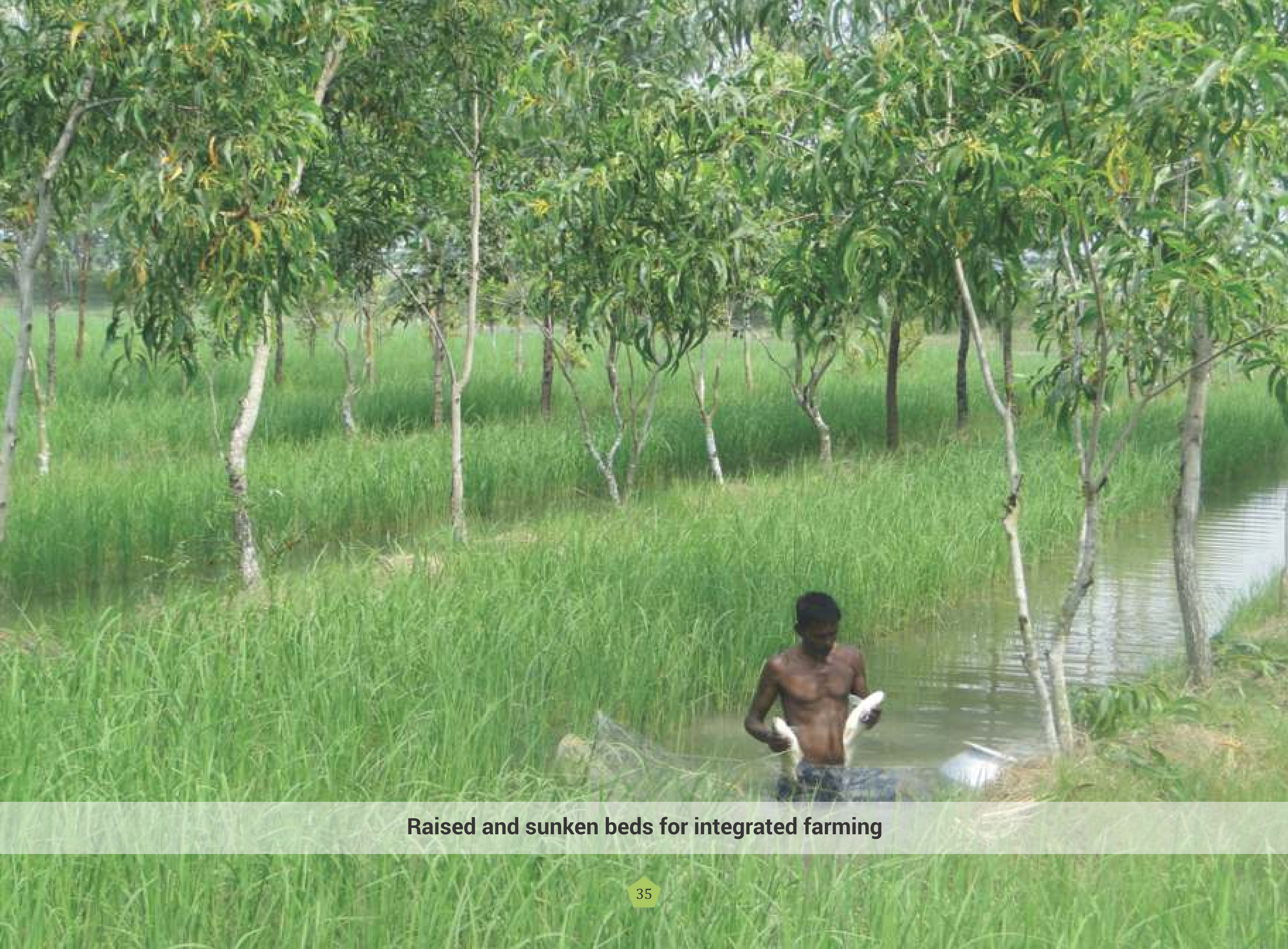
High ridge and deep furrow technique for coastal areas

The farmland is shaped into alternate ridges (1.5 m top width ×1.0 m height × 3m bottom width) and furrows (3m top width × 1.5 m bottom width × 1.0 m depth). These ridges remain free of waterlogging during *Kharif* with less soil salinity build up in dry seasons (due to higher elevation and presence of fresh rain water in furrows). Remaining portion of the farmland including the furrows is used for growing more profitable paddy-cum-fish cultivation in Kharif. The rainwater harvested in furrows is used for irrigation. The remaining portion of farmland (non-furrow and non-ridge area) is used for low water requiring crops during dry (rabi/summer) seasons. The rain water stored in furrows is used for initial irrigations during rabi. The water stored in furrows is also used for fish cultivation and supplementary irrigation in Kharif. The ridges are used for cultivation of vegetables and other horticultural crops round the year instead of monocropping with rice in Kharif. The rain water stored in furrows keep the root zone soil relatively saturated with fresh water during the initial dry months after *Kharif*, thus reduces upward capillary flow of brackish water from shallow subsurface layer and thereby reducing the salinity build up in soil. The furrows provide better drainage and protect the crops from damages due to occasional heavy rains in rabi/ summer due to climatic disturbances. Water harvested in furrows from such rains also provides additional source of irrigation. This technology can be adopted in areas where farm pond technology cannot be adopted due to presence of acid sulphate soil at shallow soil depth.

Paddy cum fish cultivation

Raised sunken bed technique for integrated agriculture production

Raised and sunken beds are constructed alternatively by digging soil from one strip and putting it on the other. A minimum width of raised bed is taken as 2.0 m with the height of sunken bed being kept at 1.0 m from ground surface. The average depth of sunken bed remains 0.50 m below ground surface with side slope of 1:1. Vegetable crops like tomato, brinjal, bottle gourd, bitter gourd, ridge gourd, sponge gourd, okra, chilly, tinda, pumpkin, cucumber, etc, can be be grown on the beds during kharif, rabi and summer seasons. Tissue culture banana plantlets were also taken on the raised beds. The entire water requirement of the banana plants was met from the water from sunken beds and also through seepage. Up to 22.5 kg of banana can be obtained from 140 plants taken on two beds. Deep water rice and water chestnut have been found successful in the sunken beds. The model also proved helpful in minimizing the negative impact of the seepage water on ecological system of the canal command areas.



Raised and sunken beds for integrated farming

GAP for managing the excess rainfall - artificial groundwater recharge

In North-West India, the total rainfall is unchanged but heavy rain storm events have been increasing over the years. This phenomenon is likely to further increase the dependence on groundwater for meeting water requirements of crops as well as there is a need for drainage for dispose of heavy storm runoff water. Decline in water table can be reduced to some extent by enhancing artificial recharge of groundwater using rain and excess canal water through surface spreading and well injection techniques. It helps in utilizing flood water, which otherwise goes waste or causes damage to property and standing crops, for improving groundwater quality as well as act as drainage outlet during heavy storm events. Individual farmer based groundwater recharge structures have been developed and implemented at 52 sites in farmers' fields in Haryana, Punjab, Uttar Pradesh and Gujarat during 2008- 2011. The structures involve passing of excess rain and canal water under gravity through a bore well to subsurface sandy zones coupled to a recharge filter consisting of layers of coarse sand, small gravel and boulders in a small brick masonry chamber. The recharge capacity of recharge shafts and cavities (4 inch dia. pipe) has been estimated @ 4-6 litre sec^{-1} or 2500- 3500 m^3 per week. The life of recharge structures, with periodic cleaning of clogged sediments in subsurface layers, is expected to be 15- 20 years. The recharge structures can be installed at any low lying location prone to surface water flooding. Being individual farmer oriented and of small size, these structures have relatively better chances of success due to ease of cleaning the clogged recharge filters by farmers themselves. The estimated cost for 9 inch diameter bore of 100 feet is Rs. 1-1.5 lakh. With this technique farmer is getting additional income of about Rs. ~25000-50000 yr^{-1} depending on the severity of submergence by saving his crop from submergence during extreme rain in addition to augmenting groundwater resources and improving its quality.

Artificial ground water recharge structure in rice crop

Good agricultural practices for saline vertisols

Among field crops; cotton, sorghum, pigeon pea, wheat, safflower and sunflower are suitable for cultivation in moderate saline (4-5 dS m^{-1}) vertisols. While Dill, a medicinal crop can also be grown successfully in saline vertisols with salinity level of 4-6 dS m^{-1}. Salt tolerant grasses like *Aeluropus lagopoides, Eragrostis spp*., *Dichanthium annulatum, Leptochloa fusca*) could give satisfactory production in salinity up to 15.0 dS m^{-1}. Whereas in highly saline vertisols of 20 - 30 dS m^{-1}, industrial oil yielding economic crop like Salvadora persica may be grown. Crop varieties like KRL-210 and KRL-213 of wheat and G COT-23 and G COT-25 of desi cotton are relatively more tolerant suitable.

Tillage and crop establishment: Alternate ridge (75-100cm) and furrow system of crop cultivation is the most suited practice for saline vertisols for maintain suitable moisture regimes and better crop establishment. For reducing salinity build up, the primary tillage should be done in dry season. In the area of shallow saline groundwater, deep summer ploughing during rabi season is better in breaking the capillaries to minimize the ground flux to the surface. Pre-sowing irrigation with good quality water enhances germination and stand establishment of cotton. Application of 25% higher seed rate is recommended for good seedling establishment in saline vertisol.

Fertilizer and irrigation management: Cotton-fallow and cotton-sorghum-wheat cropping systems are suitable in moderate saline soils (4.0-6.0 dS m^{-1}). The yields of these systems can be enhanced by integrated nutrient management (INM) with 50% RDF+ 50% supply through municipal solid waste compost + azotobacter + soil application of Zn. Conjunctive use of saline ground water with stored good quality surface wateris recommended for crops like wheat, dill, safflower, mustard. Saline ground water can also be utilized in cyclic mode along with surface water in 1:1 ratio by drip irrigation in wheat crop without much yield penalty.

Adoption of salt tolerant wheat KRL-210 in saline (ECe 4.0 dS m^{-1}) gives higher productivity (~3.0 t ha^{-1}) and net returns (Rs. ~30922 ha^{-1}) than traditional cultivars. Similarly, cultivation of desi cotton G COT-23 is more profitable in saline vertisols with gross returns of about Rs. 34,00 ha^{-1} in rainfed and Rs. 75,000 in irrigated situations.

Cotton crop under saline vertisols

GAP for residue management in rice-wheat system

Rice-wheat system is generally adopted after reclamation of sodic soils but rice being transplanted after wet puddling of soils degenerates soil physical conditions. The turnaround time between rice harvesting and wheat sowing is very limited (hardly 10-15 days) that results in open-field burning of rice residue and causes increased concerns of public and soil health and environmental problems. In NW India, management of ~20 million tonnes of rice residues within 15 days is very difficult to manage. Management of 8-10 t/ha residues (anchored + loose) with ZT machine is not feasible. The happy seeder, a key innovative planter is capable of direct drilling of wheat after rice harvest with surface retention of residues as mulch and without any preparatory tillage. For uniform spread of loose residues, a Super Straw Management System (Super SMS) is attached at rear of the combine harvesters to help uniform crop establishment. Crop residue at the soil surface reduces evaporative water losses, thereby limiting the upward movement of salt (from sub-surface soil and saline ground water) into the crop root zone. Cultivation of cereal crops under ZT with residue retention improves system resilience against abiotic stresses like salinization and resodification. Coverage of fields with 30 percent to 50 percent residue significantly reduces evaporation losses and salt injury to crop plants. Under crop residue, soils remain wetter, allowing fall or winter precipitation to be more effective in leaching salts, particularly from the surface soil layers where damage to crop seedlings is most likely to occur. Happy Seeder technology for in-situ crop residue management improves the wheat productivity to the tune of 0.1-0.6 t ha^{-1} and reduces the input cost by ~Rs 5000 ha^{-1} through saving in tillage and nutrients. Crop residues are the pre-cursor of soil organic carbon and by retaining crop residue in rice-wheat system the SOC can be increased by 100% from its initial (0.4%) after 5 years with recycling of ~12 t of crop residues every year. It improves the soil quality by improving soil physical, chemical and biological properties and reduces the N requirement by 20-30%, and K by 50% after 5 years of continuous cultivation. Zero-tillage layered with residue retention in conservation agriculture (CA) based cereal systems has potential to improve the wheat protein by 10-15% and maize carbohydrate by ~5% and fragrance in rice after 4-5 years of continuous cultivation.

Harvesting of rice using SMS and sowing on wheat using Happy Seeder

Laser land leveling (LLL) to achieve more crop per drop

Unevenness of the soil surface induces adverse effects on seedling emergence, crop stand, crop uniformity and crop yield through salt-water-nutrient interactions under normal as well as salt affected soils. Laser land leveling is a precursor to good agronomic, soil and crop management practices. LLL is a process of leveling (± 2 cm) of the land surface from its average elevation using laser-equipped drag buckets. This practice uses tractors and soil movers that are equipped with global positioning systems (GPS) and/or laser-guided instruments so that the soil can be moved either by cutting or filling to create the desired slope/level. Traditional methods of land leveling are cumbersome, time consuming and expensive. Therefore, modern methods to level the cultivated land through Laser land leveler at zero gradient is getting popular all across the RW system and it cover ~80% of the total cultivated area of NW India. The LLL can be implemented in both irrigated and un-irrigated ecosystems across the region, cropping system, soil type and environmental conditions. This practice saves 11 and 6% irrigation water under puddled transplanted rice (PTR) and directed seeded rice (DSR) respectively compared to traditional method of leveling/irrigation. Effective land leveling optimizes water-use efficiency by saving irrigation water irrigation (20-30%), improved crop establishment, increased cultivable area (by 3 to 5% approximately) and reduces the irrigation and farm machinery time. It helps in uniform leaching of salts from the surface soil to eliminate the patchy crop growth on salt affected soils. It also improves the fertilizer use and weed control efficiency, and reduces the greenhouse gas (GHGs) emission due to lesser and efficient use of water and nitrogen in reclaimed soils and in normal soils. Laser land leveling accompanied by 100% retention of previous crop residues on saline vertisols (7.9-8.66 pH and 4.04- 9.04 dS m^{-1}) results in saving of 20-25% irrigation water with higher and better quality grain yield of zero-tilled wheat.

Laser land leveler for uniform land slope

GAP for precise water management : Sub-surface drip irrigation

On-farm water management technology consists of proper land leveling and shaping, efficient design and layout of irrigation methods, scientific scheduling of irrigation under both adequate and deficient water supply, and high shallow water table conditions. In saline soils, crop evapo-transpiration and in sodic conditions soil infiltration are critical. Light and frequent irrigations are needed to keep the soil-water potential at less negative levels in salt affected soils. In surface drip irrigation water is delivered directly through emitters to the base of the plant on soil surface; while in sub-surface drip irrigation (SDI), water is delivered in the sub-surface root zone at ~15 cm below the soil surface). Micro-irrigation (SDI) systems apply only required amounts of water and nutrients (in our case N) as and when required directly to the plant root zone thus maintain favorable moisture conditions and nutrient availability in the root zone and pushes salts to the edge of the soil wetting front, reducing harmful effects on seedlings and plant roots. Care must be taken in plant placement relative to the drip line position to avoid these high-salinity zones. Leaching of the salinity zone above the dripline is often necessary. Sodic soils can be reclaimed fast under SDI by leaching the displaced Na salts arising with use of gypsum. In reclaimed soils of NW India, SDI is one of the best practices for maintaining the sustainability of groundwater aquifers in rice-wheat system. In addition, SDI facilitates fertigation and saves 20-25% of nitrogenous fertilizer by increasing N use efficiency due to improvement in uptake and minimizing losses via leaching and volatilization. SDI saves the irrigation water by ~50% in cereal (rice, wheat and maize) crops and improves water use efficiency by many folds compared to flood irrigation. It helps in increasing the productivity by 5-15% in rice/maize-wheat system and profitability by Rs 7000-10500 ha^{-1} in rice-wheat and 3500-7000 ha^{-1} in maize-wheat system for water saving in SDI. Dry soil surface reduces the occurrences of soil borne diseases and helps to control weed infestations also. Use of plastic mulches surface residue retention with drip irrigation further effectively reduces the salt concentration arises from evaporation.

Sub-surface drip irrigation in wheat crop

GAP for precise nutrient management: GreenSeeker and Nutrient Expert decision support tool

In India, fertilizer recommendations in crops are based upon crop response averaged over large geographic areas without considering indigenous nutrient supplying capacity of site specific soils. Such blanket fertilizer application results in either under or over-fertilization leading to low nutrient use efficiencies and profit and increased environmental problems. Precise nutrient management approach aims to supplement plant nutrients optimally to match their inherent spatial and temporal needs. Managing the 4R stewardship (right amount, right dose, right time and right fertilizer) is best accomplished with the right tools for crop-location, site specific nutrient management practices. Among various technologies/tools GreenSeeker and Nutrient Expert® (NE) software are used for precise management of N and other nutrients, respectively. In salt affected soils, plant nutrient availability is altered by increasing losses during leaching and volatilization losses of nitrogen, reduced solubility of micronutrients at higher pH and antagonistic effects of Na on Ca and K.

GreenSeeker is an affordable integrated optical sensing and application system. It offers an efficient and precise estimate of instant N application based on heath or vigor of a crop. Urea Calculator android app (available in English, Hindi and Punjabi language) on a smartphone or tablet is used to calculate N fertilizer application rates from crop readings (NDVI) taken with the GreenSeeker. Green Seeker based N application improves profitability by 5-10% in cereal based systems of IGP by reducing the excessive fertilizer dose. It also helps in reducing the N dose by 5-15% depending on the crops, cropping systems, weather conditions and crop year etc.

Nutrient Expert® is an easy-to-use, interactive computer based decision support tool. It provides nutrient recommendation for individual farmers' given fields with or without soil test data. NE takes into account the most important factors affecting nutrient management recommendations and uses a systematic approach of capturing information, which is important for enabling the farmers to rapidly implement site specific nutrient management (SSNM).

The software can estimate the nutrient requirement for attainable yield of crops (rice, wheat, maize etc.) based on farmers' own experiences about expected N, P and K responses in target fields. NE based SSNM increases cereal systems productivity by 5-15% and net returns by 10-15% compared to farmers' fertilizer practice. It also helps in lowering global warming potential (GWP) by about 2.5% in rice and between 12-20% in wheat.

Collection of NDVI readings using Green Seeker in wheat crop

GAP for good crop establishment - permanent bed planting

In raised bed cultivation, salts tend to progressively accumulate towards the surface of the raised beds or ridges where water flows converge and evaporates in salt affected areas. This problem is magnified when a single row of seeds is planted in the central position of the raised bed/ridge, and the saline water is used for irrigation. Excessive salt accumulation damage the seed germination and seedling establishment. The seedbed shape, seed location, residue retention (mulching) and irrigation methods along with appropriate field grading should be managed to minimize or prevent excessive localized accumulation of salts. The bed planting technique is used for modification of the raised beds of ridges into double row flat- topped beds with shoulders on both sides (bed width 67.5 cm and top width 37.5 cm). The seeds can be safely planted using bed planter on either side shoulders of the bed to avoid the zone of high salt accumulation. The north-east side direction of the beds is good to avoid salt injury to crops when tops are bare, if it is mulched than direction does not plays a critical role in salt movements. The sowing on raised beds is done with the help of the multi crop bed planter fitted with inclined seed metering mechanism and adjustable blades for making raised beds of different widths and heights. Under rainfed ecologies of south India, wider beds of >100cm are used for cultivation of crops in vertisols and alfisols. The permanent (ZT) beds with only superficial reshaping in the furrows between the raised beds is needed before planting of each succeeding crop. Moreover, it controls machine traffic, limiting compaction to furrow bottoms, allows the use of lower seeding rates than with conventional planting systems and reduces crop lodging. It reduces the effect of salts on the crop growth and development by sowing at the right place and in the right direction. Bed planting reduces the cultivation cost by saving on seed (25%) fertilizer (25%) and irrigation water (35%). It improves the productivity and profitability on any system to the tune of 10-20%. Bed planting of crops are able to harvest the positive border effect thereby it improves the grain quality of crops.

Permanent bed planting in wheat crop

Multi-enterprise agriculture for sustainable management of resources

ICAR-Central Soil Salinity Research Institute, Karnal, developed a diversified multi-enterprise agriculture model for a parcel of 2.0 ha area of reclaimed sodic lands. The model aims to improve the agricultural productivity and profitability per unit area and reduce the risks associated with specialized crops/cropping system of small farmers. It integrates synergies of different components by judicious, multiple and synergistic use of farm inputs, resources and byproducts for generating regular income and employment. For semi-arid eastern zone of Haryana, optimally suitable portions of total land holding are allocated to different agricultural enterprises such as grain crops (0.8 ha), fodder(0.2 ha), vegetables (0.2 ha), horticulture(0.2 ha), floriculture(0.2 ha), mushroom cultivation, fish pond (0.2 ha) and livestock+ poultry with biogas plant and compost pits (0.2 ha). In comparison to prevalent rice-wheat system, The average total productivity and net income from crop and subsidiary components of multi-enterprise agriculture model remain 18-22 and 12-18% higher, respectively in comparison to prevalent conventional rice-wheat system. This model generates higher and regular round the year income and annual employment (875 man-days) than rice-wheat system. Availability of on farm production and availability of cereals, vegetables, fruits, milk, eggs, fish etc. enhance the consumption of these products by farm family and thus ensures food and nutritional security of small farmers.

With multiple use of water in fisheries, horticulture and vegetable crops on pond dykes; multi enterprise agriculture used 19 and 7% lesser water and specific energy, respectively than rice-wheat system. Adoption of this system also helps in improving soil health leading better water and nutrient use efficiency. This system improves the food and nutritional security of the households.

Multi-enterprise model for farmers' livelihood security

Management practices for improving the oil quality of mustard

Adequate and timely nutrient supply increases the seed and oil yields of mustard by improving the nutrient availability in a optimum proportion. Recommended dose of fertilizers (RDF) for mustard in irrigated and timely sown salt affected areas is 80:40:0 kg N:P:K kg ha^{-1}. The diammonium phosphate (DA) in being used by the farmers to meet the P requirement of crops. Replacing of DAP with single super phosphate (SSP) resulting in better availability of sulphur. Split application of total nitrogen in two equal doses one-each as basal, second at the time of first irrigation resulted in maximum increase in yield attributes and yield of *Brassica juncea*. Top dressing of nitrogen fertilizers should be done at first irrigation and second irrigation to increase the N use efficiency. Delaying of first irrigation, results in yield reduction of mustard crop. Among the oilseed crops, mustard has the highest requirement of sulphur. Sulphur promotes oil synthesis. In terms of agronomic efficiency, each kilogram of sulphur increases the seed yield of mustard by 7.7 kgha^{-1} and oil content by 3-5%, if applied up to the recommended level i.e. 40 kg ha^{-1} at first irrigation (35-40 days after sowing). A lower level of nitrogen reduces erucic acid content by 3% with a concomitant increase in oleic acid. Higher doses of sulphur along with low doses of nitrogen affect the chain elongation enzyme system thereby leading to reduction in erucic synthesis i.e. better oil quality and higher oil content.

Bumper crop of mustard

Suitable cultivars to support good agriculture practices in salt affected area

A large extent of salt affected land in India and world (India: 6.73 M ha and World: 932 M ha) presents an opportunity for bolstering food security via use of salt tolerant varieties for rice, wheat and mustard that can play both the roles i.e. vertical expansion with increasing in production as well as horizontal expansion by converting salt affected area into cultivated area. Hence, problematic areas are no more problematic and becomes profitable with cultivation of salt tolerant crop varieties. Following are the suitable cultivars for harnessing profitability from salt affected area:

Rice varieties

Variety	Description
CSR 10	It has a plant height of about 85 cm and matures in 120 days. It has short bold grains. It is recommended for the area having highly deteriorated sodic and inland saline soils. It can tolerate sodicity up to pH_2 ~10.0 and salinity up to 11 dS m^{-1}. It's grain yield in normal soils is 6.0 tons ha^{-1} and in salt affected soils is 3.0 tons ha^{-1}.
CSR 13	It has a plant height of about 115 cm and matures in 145 days. It has long slender grains. It is highly acceptable and excellent under normal and moderately deteriorated salt affected soils. It can tolerate sodicity up to pH_2 ~10.0 and salinity up to 9 dS m^{-1}. It is suitable for sodic and inland saline soils of U.P., Haryana, Gujarat and Maharashtra. Its grain yield in normal soils is 6.0 tons ha^{-1} and in salt affected soils is 3.0 tons ha^{-1}.
CSR 23	It has a plant height of about 115 cm. It matures in 130 days. It has long slender grains. It can tolerate sodicity up to pH_2 ~9.9 and salinity up to 10.0 dS $m.^{-1}$ It is suitable for sodic soils of Uttar Pradesh, Haryana, and coastal saline areas of Gujarat, Maharashtra, Tamil Nadu, Kerala and West Bengal. It's grain yield in normal soils is 6.5 tons ha^{-1} and in salt affected soils is 4.0 tons ha^{-1}.
CSR 27	It has a plant height of about 115 cm. It matures in 125 days. It has long slender grains. It can tolerate sodicity up to pH_2~9.9 and salinity up to 10.0 dS m^{-1}. It is suitable for sodic and coastal saline areas of India. It's grain yield in normal soils is 6.5 tons ha^{-1} and in salt affected soils is 4.0 tons ha^{-1}.

Basmati CSR 30	It has a plant height of about 155 cm. and matures in 155 days. It has extra long slender grains. It can tolerate sodicity up to pH2 ~9.5 and salinity up to 7.0 dS m^{-1}. It is the first salt tolerant basmati variety, developed by ICAR-CSSRI and is recommended for sodic areas of UP, Haryana and Punjab. It performs very well in normal soils also. Its grain average yield in normal soils is 3.0 tons ha^{-1} and in salt affected soils is 2.0 tons ha^{-1}.
CSR 36	It has a plant height of about 110 cm. and matures in 140 days. It has long slender grains. It can tolerate sodicity up to pH2 ~9..9 and salinity up to 11.0 dS m^{-1}. It is suitable for sodic soils of Uttar Pradesh, Haryana and Pondicherry. Its grain yield in normal soils in 6.5 tons ha^{-1} and in salt affected soils is 4.0 tons ha^{-1}.
CSR 43	It has a plant height of about 95 cm and matures in 110 days. It has short bold grains. It can tolerate sodicity up to pH2 ~10.0 and salinity up to 7.0 dS m^{-1}. It is recommended for salt affected soils including sodic soils of Uttar Pradesh. Its grain yield in normal soils is 6 tons/ ha and in salt affected soils: 3.5 tons ha^{-1}.
CSR 46	It is a medium duration (125-135 days), semi dwarf culture (110 cm), with green foliage, erect flag leaf, compact panicle, long slender grains and complete panicle exertion. This variety yields 6.5 t ha^{-1} under normal and 4.0 t ha^{-1} under salt affected conditions.
CSR 56	It matures in 125 days and have 100 cm plant height. This variety has long bold grain and higher tolerance than CSR 36. This variety yields 7.0 t ha^{-1} under normal and 4.3 t ha^{-1} under salt stress situation.
CSR 60	It matures in 120 days and of 105 cm in plant height. This variety has long slender grain types and higher tolerance and higher head rice recovery than CSR 36. This variety yields 7.0 t ha^{-1} under normal and 4.5 t ha^{-1} under salt affected condition.

Wheat varieties

Variety	**Description**
KRL 1-4	It also tolerates the salinity stress up to ECe 7.0 dSm^{-1}. The yield potential in normal soils is 4.0 tonnes ha^{-1} and in sodic soils (having pH_2 up to 9.3) is 3.0 tonnes ha^{-1}.

KRL 19	It is resistant to yellow and brown rusts as well as for Karnal bunt resistance. It has been specifically bred for salt tolerance to saline (EC_e 5-7 dSm^{-1}) as well as alkaline (pH_2 9.3 to 9.4) soil conditions. It also does well in areas, where the ground water is either brackish and/or saline (EC_{iw} 15-20 dSm^{-1}, RSC 12-14 $meql^{-1}$). The yield potential in normal soils is 4.5 tonnes/ha and in salt affected soils (having pH_2 up to 9.3 and EC up to 7.0 $dS\ m^{-1}$) is 3.0 tonnes ha^{-1}.
KRL 210	It is a semi dwarf variety. It takes about 143 days to mature. Its grains are amber in colour, bold in size and contain about 11% protein. It is resistant to yellow and brown rusts, loose smut, Karnal bunt and flag smut. It has also shown tolerance to shoot fly. The hectolitre weight of the grain is 77 Kg with sedimentation value of 39. It is recommended for salt affected soils of NWPZ and NEPZ. Its cultivation has environmental impacts as it reduces use of chemicals for soil amendment. The yield potential in normal soils is 5.2 tonnes ha^{-1} and in salt affected soils (having pH_2 up to 9.3 and EC up to 6 $dS\ m^{-1}$) is 3.5 tonnes ha^{-1}
KRL 213	It has been specifically bred for salt tolerance to saline (ECe 6.0 dSm^{-1}) as well as alkaline soils (up to pH2 9.2) conditions. It also does well in areas where the groundwater is either brackish and/or saline (ECiw 15 dSm^{-1}; RSC 12-14 $meql^{-1}$). The yield potential in normal soils is 5.1 tonnes ha^{-1} and in salt affected soils (having pH_2 up to 9.2 and EC up to 6.4 $dS\ m^{-1}$) is 3.3 tonnes ha^{-1}.
KRL 283	KRL 283 has been identified by UP state variety release committee for sodic soils of Uttar Pradesh in 2015 on the basis of good yielding ability and salt tolerance with superiority in grain yield. Under normal conditions its yield potential is 4.8-6.2 t ha^{-1} while in sodic soils (pH_2 9.0-9.3) it gave 45-48 q ha^{-1}. KRL 283 has shown multiple stress resistance (Abiotic Stresses- Sodicity/Alkalinity/Waterlogging/lodging /Biotic stresses- Stripe Rust/ Brown Rust/ Stem Rust/Karnal bunt/Aphid/Shoot fly).

Mustard varieties

Variety	Description
CS 52	It grows up to a height of 175-180 cm. It matures in about 135-145 days. Its seeds are brown in colour and medium in size with 1000 seed weight more than 4g. By growing in saline soils and even irrigating with saline water, 38% oil content has been determined from the seeds of this variety. It can grow economically in saline soils up to a soil salinity level (EC_e) 9.0 dS m^{-1} and in alkali soils up to pH_2 ~ 9.3. It is highly suitable for saline and sodic soil conditions. The yield potential in normal soils is 2 t ha^{-1} and in salt affected soils (having pH up to 9.3 and soil salinity upto 9.0 dS m^{-1}) is 15 quintal ha^{-1}.
CS 54	It grows up to a height of 155-160 cm. It takes about 45 days for 50% flowering and matures in about 121 days. Its seeds are brown and bold with 1000 seed weight more than 5.3g. Its main shoot length is around 65-70 cm and it has more than 14 seeds per siliqua. It yields around 40% oil content even under salt stress conditions. It is recommended for saline soils up to soil salinity level (EC_e) of 6-9 dS m^{-1} and in alkali soils up to pH_2 ~ 9.3. It is highly suitable for saline and sodic soil conditions. The yield potential in normal soils is 2.4 t ha^{-1} and in salt affected soils (having pH_2 up to 9.3 and soil salinity upto 9.0 dS m^{-1}) is 19 quintal ha^{-1}.
CS 56	It grows up to a height of 195-202 cm. It matures in about 132 days. It is moderately tolerant to Alternaria black spot, black leg (leaf, root and stem rot), white rust, Sclerotinia stem rot, mildew and aphids. Its oil content is 37%. It is suitable in late sown irrigated conditions and in Rice –Mustard cropping system. It is recommended for Haryana, Uttar Pradesh, Madhya Pradesh, Gujarat and Rajasthan. The yield potential in normal soils is 2.6 t ha^{-1} and in salt affected soils (having pH up to 9.3 and soil salinity upto 9.0 dS m^{-1}) is 1.9 t ha^{-1}.
CS 58	It grows up to a height of 180-185 cm. It matures in about 125-130 days and 1000 seed weight is 5.6-6.0g. It is recommended for saline soils up to soil salinity level (ECe) up to 12.0 dS m^{-1} and in alkali soils up to pH_2 ~ 9.4. It is highly suitable for saline and sodic soil conditions. It yields around 40% oil content even under salt stress conditions. The yield potential in normal soils is 26-28 quintal/ha and in salt affected soils (having pH up to 9.3 and soil salinity upto 9.0 dS m^{-1}) is 2.2-2.4 t ha^{-1}.
CS 60	It grows up to a height of 182-187 cm. It matures in about 125-132 days and 1000 seed weight is 5.0-5.5 g. It is recommended for saline soils up to soil salinity level (ECe) up to 12.0 dS m^{-1} and in alkali soils up to pH2 ~ 9.5. It is highly suitable for saline and sodic soil conditions. It yields around 41% oil content even under salt stress conditions. The yield potential in normal soils is 2.5-2.9 t ha^{-1} and in salt affected soils (having pH_2 up to 9.3 and soil salinity upto 9.0 dS m^{-1}) is 1.9-2.2 t ha^{-1}.

Information and communication tools to support good agricultural practices (GAP)

Information and communication technologies (ICTs) are gaining rapid momentum and wider application with the convergence of computing and communication tools and development of user friendly softwares. Smart Mobile phone is helping the farmers in technology adoption with availability of expert software applications. The smart phone, now in the hands of every other farmer, has enabled the technology disseminators to reach a wider audience with minimum use of time and energy, and with high degree of fidelity. Keeping in view the versatility and availability of smart phones, the Central Soil Salinity Research Institute Karnal has developed two mobile based applications - 'GypCal' and 'Salinity Expert' which act as decision support system for farmers. These applications help in judicious use of amendments for soil reclamation and facilitate the adoption of good agricultural practices (GAP).

GypCal mobile app

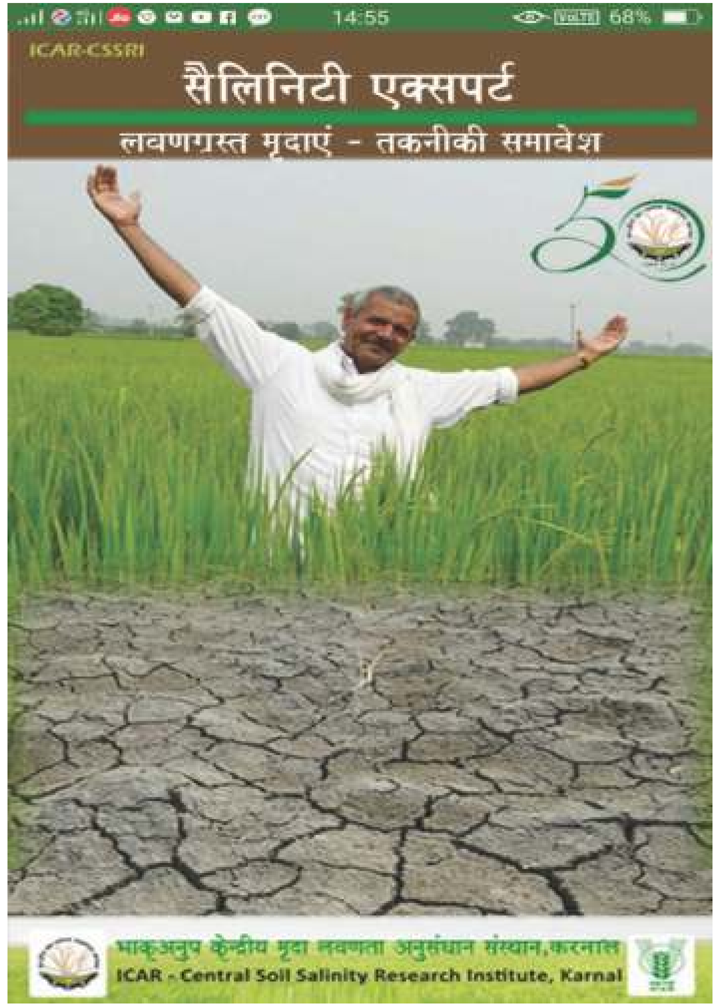
Gypsum Calculator App based on android smart phone has been developed by the scientists of ICAR-CSSRI. This App calculates the gypsum requirement in bags (of 45 kg), total depth of water required for leaching and the expected yields of salt tolerant as well as traditional varieties of rice and wheat after reclamation. Based on area, soil pH_2, soil type and soil depth data, this software calculates the gypsum requirement on the basis of mathematical equation obtained through curve fitting. It also estimates the exchangeable sodium percentage (ESP) of the sodic soil. This App is user friendly and is highly useful for researchers, field functionaries and farmers for chemical reclamation of sodic soil for optimizing crop production in the IGP. GypCal mobile App is compatible with all the smart phone handsets with Android operating system commonly available in Indian markets. Anyone can download on their Android Mobiles/Tabs/Smart Phones and use the application anywhere. The mobile application is now available at Google Play Store which can be accessed at the following link:

https://play.google.com/store/apps/details?id=gypcal.shyamsanginfosys.com&hl=en

Salinity Expert mobile app

Salinity Expert is a knowledge based digital compendium including management practices for rice, wheat and mustard crops under salty environments right from sowing to harvesting. This is also a user friendly App which enables the farmers to raise queries either as text messages or in graphic/recorded form. The queries are then attended by the administrator via message sorting, short message service, email etc. It provides Aadhar/Mobile number based Login ID through which information on farmers' background, soil fertility status and water quality can be accessed by the farmer at any time once linked to the App. This App provides methodology and precautionary measures for taking soil and irrigation water samples for analysis. Gypsum requirement is estimated considering inherent soil sodicity (pH) and residual alkalinity in irrigation water (RSC) and their concomitant effect on crop yields (yield predictions). This application also enables digitization of soil health cards (SHCs) and provides updated agro-advisories and information pertaining to training programmes and other important events planned to be oragnised by the institute. The mobile application can be freely downloaded from the Google play store mentioning 'Salinity Expert' or through link

https://play.google.com/store/apps/details?id=com.dev.cssri.farmerfirst&hl=en



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