SUSTAINABLE TECHNOLOGIES FOR CROP PRODUCTION UNDER SALT-AFFECTED SOIL IN INDIA

Dinesh K. Sharma

Central Soil Salinity Research Institute, Karnal, India

....

Dinesh Kumar Sharma holds a doctorate degree in Agriculture with specialiazation in Agronomy from G.B.Pant Uviversity of Agriculture and Technology, Pantnagar, and he is a Director of Central Soil Salinity Research Institute, Karnal. His expertise in the area of management of salt-affected soils and use of poor quality water for crop production. He has published 172 research papers including 42 in International journals.

ABSTRACT

Salt-affected soils adversely affect the livelihood security of people in more than 100 countries, as they occupy about 831 million ha (Mha) all over the world. Out of this area, 397 Mha (47.8%) are saline, while 434 Mha (52.2%) are sodic. On the regional scale, Asia, the Pacific and Australia together have the largest area (30%) under salt-affected. The area under salt-affected soils in India is estimated to be 6.73 Mha spread over a number of states across the country. Similarly, 25% of the ground water resources in the country are saline and brackish. Certain states like Rajasthan and Haryana located in the western part of the country are endowed with 84 and 62% of poor quality ground waters, respectively. Continuous use of such waters for irrigation to agricultural crops is bound to increase the problem of salinity and sodicity in India. Introduction of irrigation without making proper provision for drainage is the major cause for the development of salinity in canal commands. The projections indicate that the country will have 11.7 Mha area affected by salinity and sodicity by 2025. From reclamation and management point of view, the salt-affected soils in India are broadly placed into two categories: (i) sodic soils, and (ii) saline soils. The alkali soils in general are characterized by high soil pH up to 10.8, high exchangeable sodium per cent (ESP) up to 90, low organic carbon, poor infiltration and poor fertility status. These soils are dominated by sodium carbonate and sodium bi-carbonate salts. On the other hand, the saline soils have higher electrical conductivity (>4 dS m^{-1}), low ESP < 15%) and low pH < 8.5). The dominant salts in saline soils include chlorides and sulphates of Na, Ca and Mg (Abrol *et.al.*1988).

Central Soil Salinity Research Institute, Karnal, has developed and standardized several location-specific technologies for reclamation and management of saline and sodic soils. This paper provides a brief insight into some of the technologies, which involve intervention of farming system approach in Canal command and its effects on reducing the negative impact of water logging and sodicity, development of strategies for crop production through efficient, balanced and integrated use of inputs including amendments and fertilizers and minimization of the cost of reclamation (Sharma and Chaudhari 2012); resource conservation strategies in sodic land agriculture; improvement in crop production through the use of salt-tolerant varieties and carbon sequestration. In recent past, the fruit crops and agro-forestry systems have been identified as alternate land use systems for reclamation and management of sodic soils. Cultivation of identified halophytes, salt tolerant crop varieties and grasses with no or reduced doses of amendments are other attractive biological reclamation options.

Sodic soil land reclamation technology through chemical amendments developed by the institute has become quite popular and about 2.0 million ha area has been reclaimed with the adoption of this technology. The reclaimed area alone is contributing approximately 17 million tonnes of paddy and wheat annually. Besides, sodic land reclamation activity in the last 42 years generated one time employment of about 26 million person-days in the first year of reclamation. The reclaimed lands now generate an annual employment of 76 million person-days each year for rice-wheat cultivation.

KEYWORDS

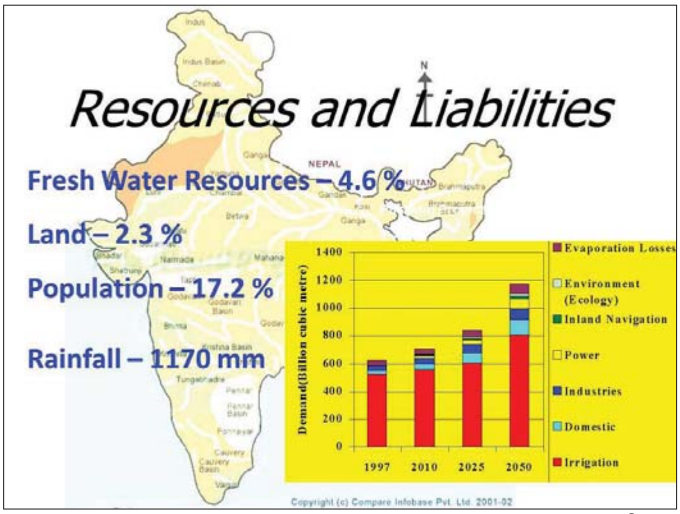
Salt-affected soils, land reclamation, saline soils, sodic soils, crop production.

REFERENCES

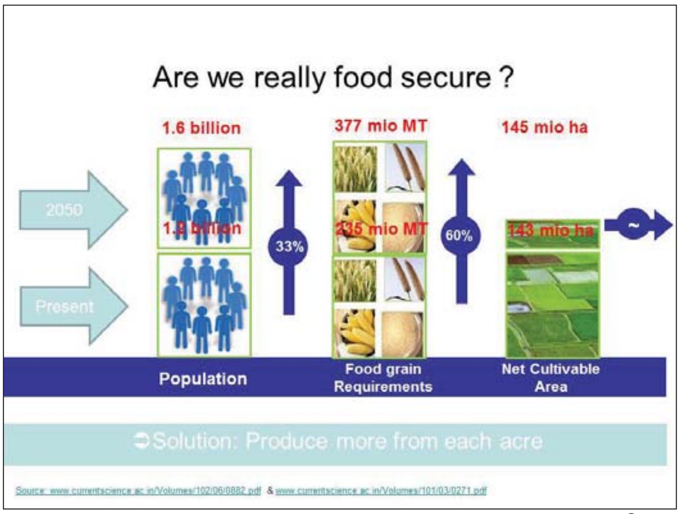
Abrol, I.P., J.S.P. Yadav and F.I. Massoud, 1988: Salt-affected soils and their management, Soil Bulletin No. 35, FAO, Rome, 131p.

Sharma, D.K. and S.K. Chaudhari, 2012: Agronomic research in salt-affected soils of India: An Overview. Indian Journal of Agronomy, 57,175-185.

1



2



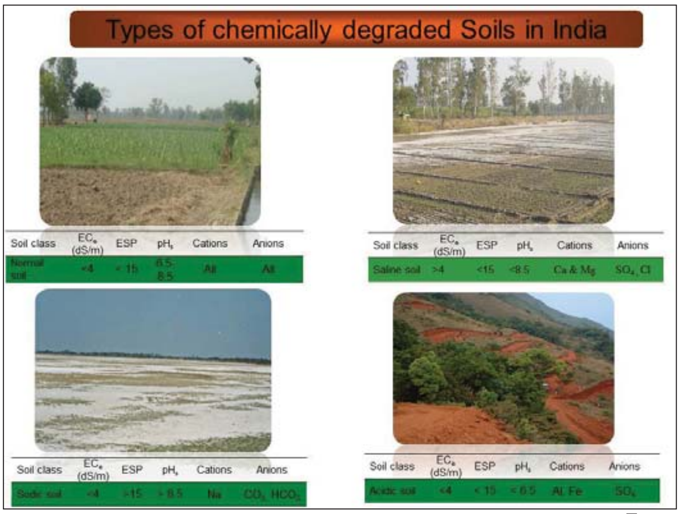
3

Regional distribution of salt affected soils, (Mha)

Regions	Total Area	Saline soil		Sodic soil	
Africa	1899	39	2.0	34	1.8
Asia, the Pacific and Australia	3107	195	6.3	249	8.0
Europe	2011	7	0.3	73	3.6
Latin America	2039	61	3.0	51	2.5
Near East	1802	92	5.1	14	0.8
North America	1924	5	0.2	15	0.8
Total	**12781**	**397**	**3.1%**	**434**	**3.4%**

Source: FAO Land and Plant Nutrition Management Service

4



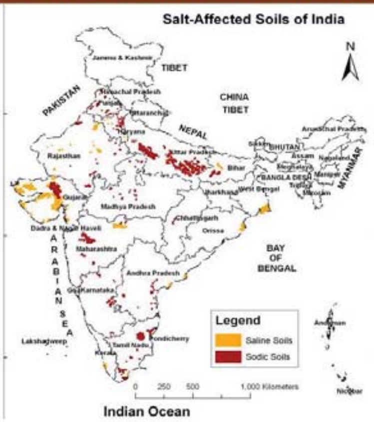
5

State wise Area (ha) of Salt-Affected Soils in India

States	Saline	Sodic	Total
Andhra Pradesh	77598	196609	274207
Andaman & Nicobar Island	77000	0	77000
Bihar	47301	105852	153153
Gujarat	1680570	541430	2222000
Haryana	49157	183399	232556
Karnataka	1893	148136	150029
Kerala	20000	0	20000
Madhya Pradesh	0	139720	139720
Maharashtra	184089	422670	606759
Orissa	147138	0	147138
Punjab	0	151717	151717
Rajasthan	195571	179371	374942
Tamil Nadu	13231	354784	368015
Uttar Pradesh	21989	1346971	1368960
West Bengal	441272	0	441272
Total	**2956809**	**3770659**	**6727468**

6

Distribution of Salt-affected soils in the country



7

Background

1.	Waterlogged saline/sodic soil	2.2 million ha
2.	Coastal saline soils	3.1 million ha
3.	Poor quality water	35 % ground water
4.	Sewage generation	75 % untreated
5.	Fluoride pollution in India	25 states
6.	Poor socio-economic base	Saline and sodic farmers
7.	Climate change	Projected

8

Canal water loss (%)

Sources of losses	Seepage	Evaporation	Total
Main canal and Branches	13.6	3.4	17.0
Distributaries	6.4	1.6	8.0
Field and Water Courses	16.0	4.0	20.0

9

Rehabilitation of Irrigation System

10

Use of Amendments

Phosphogypsum precipitates when apatite (or sedimentary phosphate) is treated with sulphuric acid according to the reaction :

$$\underbrace{Ca_{10}(PO_4)_6F_2}_{\text{apatite (phosphate) rock}} + 10H_2SO_4 + 20H_2O \rightarrow \underbrace{10CaSO_4 \cdot 2H_2O}_{\text{phosphogypsum}} + 6H_3PO_4 + 2HF$$

As a general rule, 4.5 to 5.5 tonnes of phosphogypsum are generated for every ton of phosphoric acid produced.

4.5 million tonnes is generated per year in India. Over 10 million tonnes has accumulated at factory sites.

11

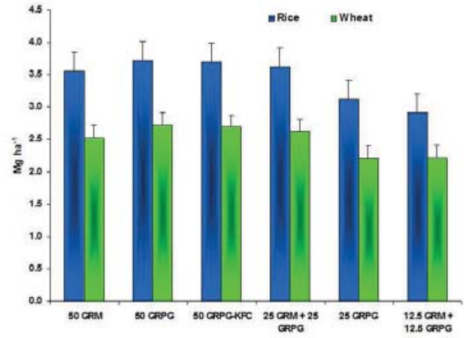
Field Experiments

Treatments:

T1 - 50 % GR (Gypsum requirement 12.5 t/ha)
T2 - Phosphogypsum equivalent to 50 % GR
T3 -T2 with first crop as karnal grass
T4 - 25% T1 + 25 % T2
T5 - 25%T2
T6 - 12.5% T1 + 12.5 %T2

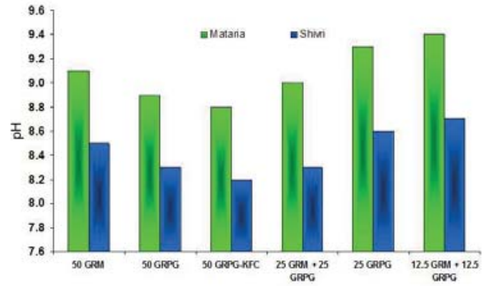
Number of replications	= Four
Plot size	= 40 sq. m
Design	= RBD
Cropping system	= Rice-Wheat
Number of sites	= Two

12



Comparative effect of phosphogypsum on the rice and wheat yields

13



Comparative effect of phosphogypsum on the soil pH after two cycles of rice-wheat at Shivri (initial pH 9.7) and Mataria (initial pH10.3)

14

Alternative land use system

1. **More than 2 tones ha-1 of fruit yield was obtained by growing aonla after 6 years and karonda after 12 years of plantation**

Banana is a promising crop after 5-6 years of reclamation of sodic soils.

Basil and matricaria are the promising crops in reclaimed sodic soils.

15

Direct seeded rice followed by zero tillage in wheat with 30 % crop residue not only produced at par yield to conventional practice but also significantly increased organic carbon build up, soil physico chemical properties and also saved Rs 7300 /ha /year through reduction in tillage, irrigation and nutrients cost.

16

Management of Waterlogged Saline Soils

- **Large scale adoption of technology in Haryana, Rajasthan, Maharashtra, AP**

Average increase in productivity: 45% (Paddy), 111% (Wheat), 215% (Cotton)

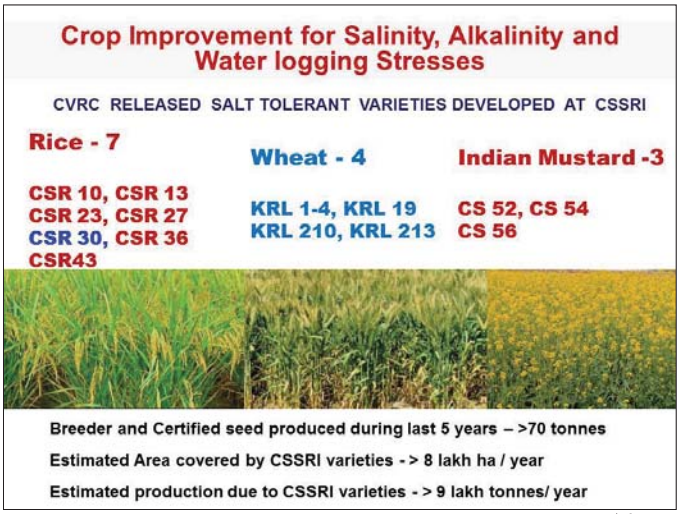
- **Generation of additional mandays -128 man-days/ha/yr**

17

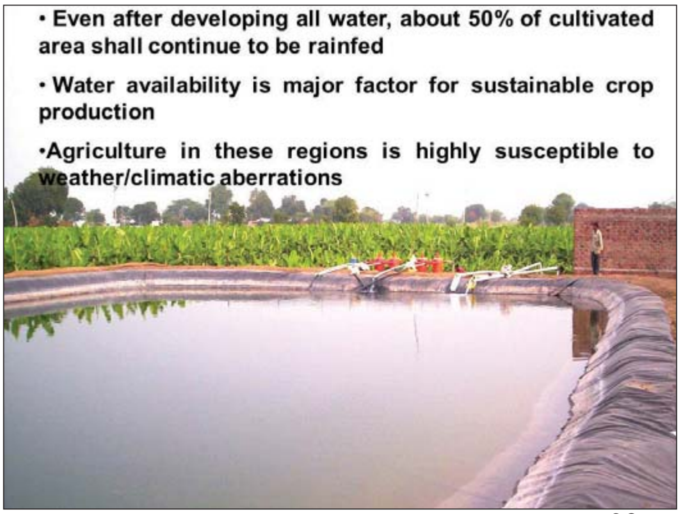
Change in Cropping Intensity

Place	Before drainage	After drainage	Increase (%)
Sampla	0	200	-
Ismaila	73	148	103
Gohana	117	175	50
Konanaki	70	90	29
Uppugunduru	130	165	27
Islampur (Karnataka)			
ORP	0	200	-
Phase II	88	156	77

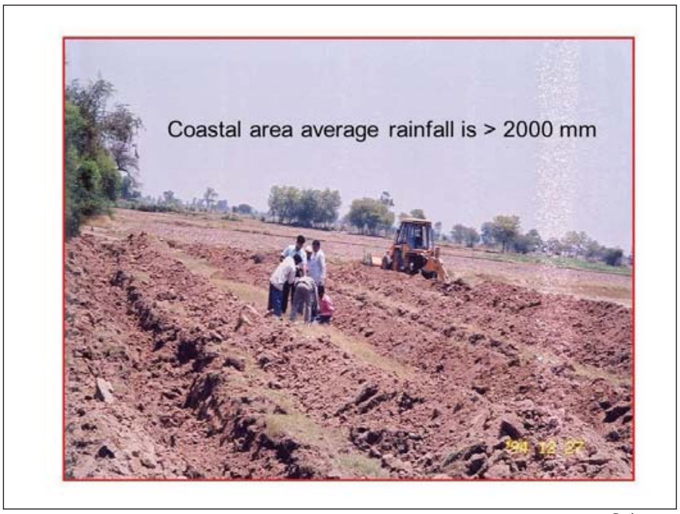
18



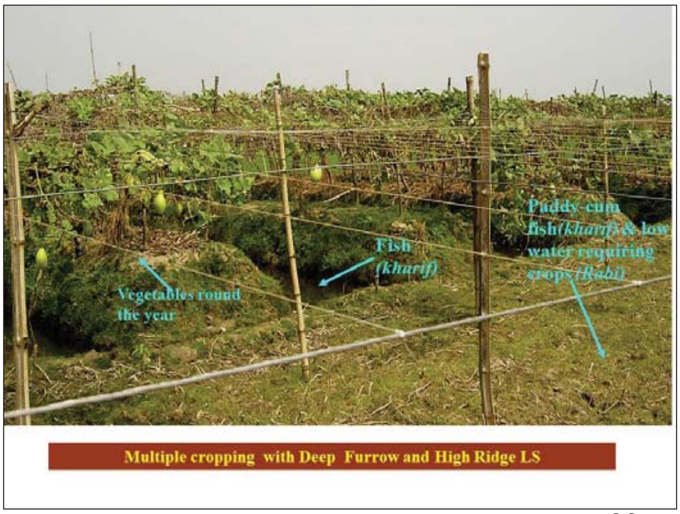
19



20



21

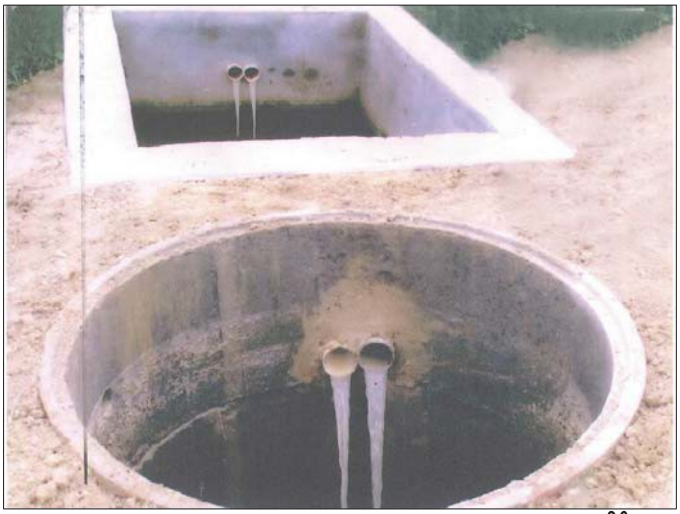


22

23

24

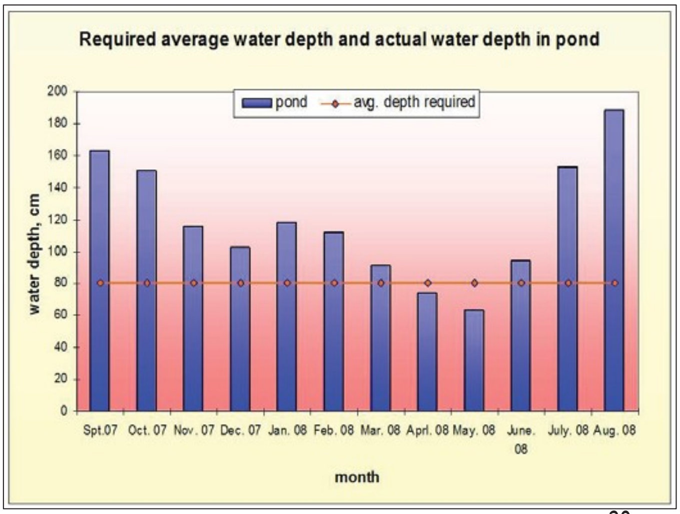
25



26

27

28

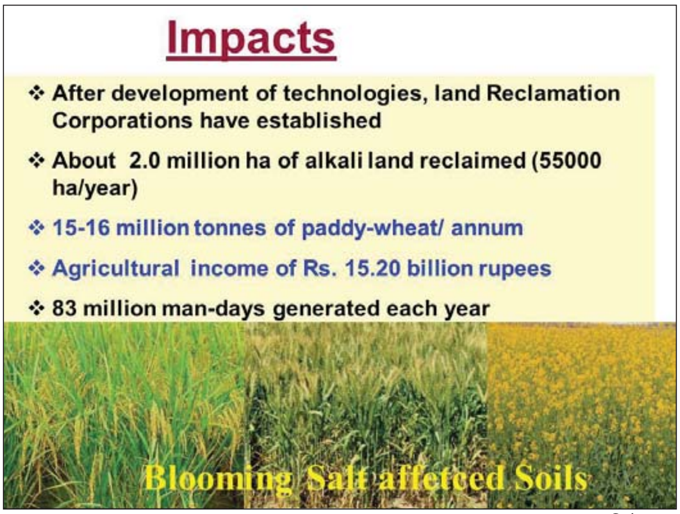


29

Economics of the system

System	Cost of Cultivation (Rs)	Gross Income (Rs)	Net return (Rs)	B:C Ratio
Fish	8500	40970	32470	4.82
Cereals	6540	11240	4700	1.71
Vegetables	4235	10456	6221	2.46
Forage	1480	3218	1738	2.17
Total	20755	65884	45129	3.17

30


Impacts
❖ After development of technologies, land Reclamation Corporations have established
❖ About 2.0 million ha of alkali land reclaimed (55000 ha/year)
❖ 15-16 million tonnes of paddy-wheat/ annum
❖ Agricultural income of Rs. 15.20 billion rupees
❖ 83 million man-days generated each year
Blooming Salt affetced Soils

31


Thank you

32

Chair Suenaga: Good afternoon. Now I'd like to start Session 2. My name is Kazuhiro Suenaga. I will chair this session together with Dr. Shono. First half, including two presentations, I will chair and later Dr. Shono will chair the second half.

In this session, we focus on salinity among other soil problems. We have three presentations from different viewpoints. First speaker, Dr. Sharma, will give a comprehensive talk about salinity. He will talk about various mitigation measures taken against salinity problems in India. The other two presentations are little bit more specific. Dr. Shimizu's presentation will be about the status and possible reasons of the salinity issues in Loess Plateau, China. Finally, Dr. Xu will talk about an innovative approach for utilization of tolerance genes in soybean.

Now I'd like to introduce the first speaker Dr. Sharma. He is Director General, Central Soil Salinity Research Institute, India. He holds a doctorate degree in Agriculture from G. B. Pant University of Agriculture and Technology, India, and his expertise is management of salt-affected soils and use of poor quality water for crop production. His topic today is "Sustainable Technologies for Crop Production under Salt-Affected Soil in India." Dr. Sharma, please.

Dr. Dinesh Sharma: Thank you, Mr. Chairman. First of all, I am thankful to organizer, particularly President of the JIRCAS, to provide me an opportunity to share my knowledge, not only the salt-affected soils but also on other aspects, and I got the opportunity to interact with scientists from all over the world.

At present you have seen the salt affected soil in India. It was the totally barren soil in 1970. Nothing was grown here. But after the reclamation, we are growing all types of the plants, crops, not only this but on other areas also.

Our population is increasing and it is now 1.25 billion. In 2050, it will increase to 1.6 billion. So, the increased percentage is 28 %, but now we will require 235 million tons of food grain, but we are producing 265 million tons of food grain. It is much above the requirement. But in 2050, we have to require 377 million tons of food grain. So, this increase is about 42 %. The net cultivated area now we have only 143 million hectares, and it will increase to 145 million hectares. The only marginal area will increase and we have to depend on this area for our food requirement. So, we have to produce more food from this limited available land.

The table is showing the regional distribution of the salt-affected soils. Out of 12,781 million hectares of total land area, saline soil is 397, and sodic soil is 434 million hectares. It is about 3.1% is the saline soil and 3.4% is the sodic soils in the world.

I want to draw your kind attention, what are the salt-affected soils and how it is different from the normal soils. The normal soil is having electric conductivity is less than 4 dS m-1, exchangeable sodium percentage is less than 15, pH on saturated paste is between 6.5 to 8.5, and equal proportion of anions and cations. But the saline soil have the electric conductivity is more than 4 dS m-1, exchangeable sodium percent is less than 15, and pH is less than 8.5, and mostly calcium and magnesium are the cations and the chloride and sulfate are the anions, now these are the soluble salts. And then third category soil is the sodic soil and this type of soil is having electric conductivity is less than 4 dsm-1 because this type of soil could not have the soluble salts, and the exchangeable sodium is more than 15, and pH is between 8.5 to 10.5, this is the range of pH we are working on, and mostly the sodium is the cation and that is more on the exchangeable complex, and mostly the anion are carbonate and bicarbonate. And then fourth category is the acidic soil, the pH ranging is less than 6.5, and no problem of the salts and soluble salts, and the cations are aluminum and iron and mostly the sulfate anion.

This presentation is showing the distribution of salt-affected soils in our country. The area is 6.73 million hectares of salt-affected soils, either saline or sodic. In the coastal salinity, we have 8,185 kilometers long coastal area situated in Western and Eastern Coast. So because of the salinity, it is increasing in both sides of the coastal area. In Gujarat, dry land area saline area is also increasing.

This is some of the concerns how we can cope with the salt-affected soils and about 35% underground water in India is poor in quality either saline or sodic, therefore farmers are having poor resource base because they are having barren land and poor quality water so nothing was grown on these types of soils, and it is not support the livelihood security of farmers. In the coming years, it is the issue of climate change and temperature will increase then the salt accumulation will come on the surface and also due to ingress of seawater to the mainland, coastal salinity will also increase in the coming years.

We have two types of irrigation systems in our country. First is the groundwater and second is the canal water. From the dam to farmer fields, about 36 % of canal water loss mainly because of seepage. This excess seepage loss created secondary salinization. So, we have to check this type of problem.

This presentation is also showing another type of problem. We have the old irrigation system and only small renovation of old irrigation system; we can check the seepage from the main canal and the distributaries. This picture is before the renovation and another picture showing after the renovation of the channels and distributaries. We can reduce the seepage from the canal system by the renovation of old irrigation system .

We are using the mineral gypsum taken from Rajasthan mines during last 30 years, but the quality and amount of mineral gypsum is continuously decreasing. So, we will face the problem for the amendment in coming years. Phosphogypsum is the new byproduct for the phosphoric fertilizer factory. We can get this byproduct and about 4 to 5 million tons is generated every year and over 10 million tons has been accumulated nearby the factory. It will create the pollution problem. How best we can utilize this byproduct of phosphogypsum from the phosphoric factory for the reclamation of sodic soil.

We have conducted the experiment on sodic soil at two places one at farmers field and other was on experimental farm. You can see the comparative performance of the rice and wheat crop at two places. We can get more than 3.5 tons of rice and more than 2.5 tons of wheat with the application of 12 tons ha-1 of phosphogypsum as compared to same amount of mineral gypsum. This presentation is showing the reduction of the pH and initial pH at one site is 9.7 and another site at farmer field pH is 10.3. It was reduced to 9.2 and also 8.6 with the application of the phosphogypsum. So, this is another technology through which we can reduce the pH and growing of rice-wheat from sodic soil.

This slide is showing another technology. For growing transplanted rice, huge amount of water is required and also more labor is required. So direct seeding rice, we can reduce the labor and water. You will be surprised to know for produce 1 kg of rice, 3,000 liters of water is required. So, how to reduce this 3000 liters to 2,200 liters? Because of this direct seeding rice, we can reduce about 800 to 900 liters of water to produce 1 kg of rice. Land leveling and zero tillage technique also increased the yield and saved the water and other inputs.

This slide is showing another water logged area. Through subsurface drainage technology, we’re laying the percolated pipes 1.5 meters below the surface and then salty water moved from surface to sub-surface through these percolated pipes. It will reduce the salinity of the surface soil. And then we collected this salty water and this salty water we put in the drain. So, this process is continuing during first year. The second and third year also the concentration of salt in the water will reduce and after 4 or 5 years, this water we can use easily for irrigation.

Through land shaping technique, we can harvest excess rain water during monsoon season and utilized this water for next winter season to grow crops. This technique is changing of the cropping intensity from mono crop to double crops in coastal area where rainfall is more than 20000 mm. So through this technique we can increase the cropping intensity.

Our institute has also developed salt tolerant varieties of rice, wheat and mustard and chickpea. These seven varieties of rice, four varieties of wheat, three varieties of Indian mustard released by Central Variety Release Committee on all India basis. And we are also producing the breeder and certified seed during every year and total 70 tons of breeder and true level seed of these varieties, we have produced during last year. About 0.8 million tons of production increased due to salt tolerant varieties, and area of salt tolerant varieties is spreading about 0.9 million hectare per year.

This is another pond based land shaping technology through this, excess rain water we can harvest because the rainfall is too high. So, this high rainfall we can use for growing next season crops starting from November to March. And during the monsoon period from July to September, we can harvest the excess water through land shaping technique, through which we harvest in the more than 2,000 millimeters of water in the coastal area. For growing rice, only 1,000 millimeters of water is required. So, the additional amount of 1,000 millimeters we can store and then utilize for irrigation to next winter season crops. So, we can increase the cropping intensity as well as productivity per unit of land area, and also reduce the salinity of the system.

Ridge-furrow system is a different type of land shaping technique. Through this technique, we can harvest excess rain water during the monsoon season and utilized for irrigation during next winter season. We can also grow the fish and rice through rice-fish culture during monsoon season in the coastal area.

This is we can harvest about 4 tons of rice and 1.1 tons of fish. So, this is a good technology and farmers are taking this technology in the wide area.

This is another problem of the salty water through which we can also have the dilution through monsoon rain. During the monsoon, we can dilute the water and intercept in 2 cubic meter size of structure and then some of the sedimentation will settle and then we utilize the same size of second structure and put this excess water in the cavity tube well. This diluted salinity water (EC is les than 4 dS m-1), saline water can utilized for irrigation to next winter season crops and it will not create the problem of salinity during germination of crop.

The secondary salinization is occurring in most of the irrigation command area in both sides of the canal. You can also see in the picture. It is because of the seepage from the canal. Salts and ground water also is reaching in the surface of soil. Before 30 years, it's very good soil and every crops were successfully grown by the farmers. But because of the introduction of the canal system, due to seepage from canal, this good land converted to this salty barren land.

We have the technology through which we can grow again any types of crops on same barren land through land shaping technology at farmer's field. We changed the land shaping and we dig out the soil up to 1.7 meter deep and 0.4 ha pond was made out of 1 hectare area, and then same soil was spreading on the remaining 0.6 hectare area. This 0.6 ha area is 1.5 meter height. Then this 0.6ha area, farmer is growing many types of crops and also fisheries in the pond.

Water level in the pond is more than 1.0 meter. This level is maintained by seepage from canal. The beauty of this system is we could not apply any amount of water for irrigating to crops outside the system. When we apply the water from this pond, then the next day water is coming in the pond through seepage of the canal. So, this water balance is maintaining throughout the year.

This is the economics benefit-cost ratio. You can see farmer can get 45,000 rupees (1 US dollar = 60 rupees) net income for 1 hectare of land through barren land to the productive land through this technology.

What is the impact of our research? This is an important issue and we are spending huge amount for conducting the research. What is the impact of that technology? So after development of that technology of land reclamation, different corporation has been formed in Haryana, Punjab and UP by the government. Till December 2013, we have reclaimed 2 million hectares of salt-affected soils and this land is producing about 15 to 16 million tons of additional food grain to the national basket, and the income of the farmers has been increasing in many folds. From this additional production of food crop, we also gain 15.2 billion rupees per year, and not only the reclamation we have also improved economic condition of farmers those are having salt affected land.

Thank you very much. I am also thankful to organizer for providing a very good hospitality for all of us. Thank you very much.

Chair Suenaga: Thank you very much, Dr. Sharma. He introduced background and current status of salinity problem in India and also he talked about successful management system. Do you have any question or comment to his presentation?

Mr. Junya Onishi Yes.

Chair Suenaga: Yes.

Mr. Junya Onishi: Thank you for interesting presentation. My name is Junya Onishi from JIRCAS. I have one question about zero tillage. I understand the benefit of cost and labor reducing. But if there is some good effect for mitigating salt accumulation, could you tell me?

Dr. Dinesh Sharma: Secondary salinization we have reclaimed because of our irrigation command area, most of the command because of the excess utilization of the water to either sugarcane or rice. This is because of the seepage from the canal and secondary salinization is also occurring. So, we have to reduce to the demand side of the application. In the sprinkler and drip irrigation, we can reduce the total demand of the water then the secondary salinization will also reduce and it will have more impact than the reclamation.

Dr. Kazuhiro Suenaga: Okay?

Mr. Junya Onishi: Thank you.

Chair Suenaga: Any other questions and comments? Yes, please.

Mr. Tete: Thank you very much for your nice presentation. I am Tete from Ghana. In your presentation, you made mention of the fact that you've been able to breed some tolerance rice varieties, wheat varieties and then mustard varieties. Have you been able to identify some of the traits which make those varieties tolerant from the sensitive ones?

Dr. Dinesh Sharma: Okay. Yeah.

Mr. Tete: Thank you.

Dr. Dinesh Sharma: For the salt tolerance of the rice we have identified genotypes from India and also with the IRRI and UC Davis. Then the Saltol gene is the major gene is controlling the tolerance of the limit of the salinity during the initial stage. But during the reproductive stage, till now we could not identify the gene. So in this direction we are doing research. Both types of genotypes (tolerant and sensitive) we are screening in the crop improvement programme. It is not a one gene tolerant to salinity, but is the multiple gene tolerance. So one gene is tolerant to initial stage, another reproductive stage, and another is total grain weight and also translocation of the product of photosynthesis from source to sink. The translocation and tolerance mechanism are governed by the gene. So this type of study is under progress.

Chair Suenaga: Thank you. Any other questions or comments? Okay, if no, thank you very much, Dr. Sharma.

Dr. Dinesh Sharma: Thank you.