21 Putting Saline Agriculture into Practice

A Case Study from Bangladesh

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CONTENTS

21.1 INTRODUCTION

Coastal Bangladesh is severely affected by salinity. In 2010, over 1 million hectares of land were salt-affected. This is a 26.7% increase since 1973. The Soil Resource Development Institute estimates that an additional 36,440 hectares of new land have become affected by salinity during the past nine years (SRDI, 2010). In Bangladesh, there are three distinct seasons: a hot, humid but dry summer (March-June), a cool, wet monsoon season (June–October) and a cool, dry winter (October–March). Salinity issues mostly occur during the two dry seasons (October–March and March–June). A recent publication (Chen and Mueller, 2018) shows that soil salinity is one of the main forces driving migration in coastal Bangladesh. It is estimated that this could affect up to 27 million people by 2050. At present, around 44% of the salt-affected area is moderately saline (EC_e values between 4 and 12 dS/m – SRDI, 2010).

The Dutch social enterprise "Salt Farm Texel" has worked on salt-tolerant crops for the past 13 years and has identified salt-tolerant varieties of common crops

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including, among others, potato, cabbage, cauliflower, carrot and beets that can be cultivated successfully under these moderately saline conditions (De Vos et al. 2016; Van Straten et al. 2020). These crops have now been introduced to coastal Bangladesh as part of the Salt Solution project. The first implementation focused on the October–March cropping season.

Here, we describe a project on saline agriculture aimed at improving the livelihoods of farmers living in salt-affected areas. We present the current situation of the project in terms of soil salinity levels and which types of cultivation strategies have been recommended. Additionally, the impact of this project is discussed according to the Sustainable Development Goals (SDGs), to assess how effective (or not) the introduction of saline farming practices can be in farming communities in coastal Bangladesh. The improvements to the livelihoods realized by the project have been quantified through the independent evaluation by a third party, Grameen Bikash Foundation (GBF), Bangladesh (commissioned by ICCO), using the SDGs as an overarching theme, and these results are also reported here.

21.2 THE PROJECT

The Salt Solution project was funded by the Dutch Postcode Lottery and implemented by a consortium led by the ICCO Group BV; ICCO is a leading non-governmental organisation with headquarters in the Netherlands and regional offices in several countries, such as Bangladesh. Salt Farm Texel (specializing in saline agriculture in the Netherlands), CODEC (a Community Development Centre from Bangladesh), Acacia Water (specializing in water in the Netherlands) and Lal Teer Seed (a seed company from Bangladesh) were also part of the consortium. The Salt Solution project was an innovative climate-smart agriculture-based project and throughout its 3-year duration, it trained 5,000 farmers directly on saline agriculture in four coastal districts (Khulna, Bagerhat, Barguna and Patuakhali). This indirectly benefited 25,000 household members and some aspects of the project continue to this day, increasing the number of people reached. The project had four main outputs:

- salt-tolerant crop production on salt-affected land
- increased nutritious food consumption
- increased participation and decision-making by women in crop production and water management
- creation of a network of farmers, extension officers, policy makers and scientists to create solutions aimed at adapting to salinity

The project involved government personnel with the project intervention designed to sensitize them towards the intended project production technologies of salt-tolerant crop varieties. Key interventions of the project were: setting up a field station and the development of best practices, demonstration and promotion, scaling up, linking with input suppliers and with markets for the sale of produce, research, water management and the influencing of government policies.

The project aimed to ensure that farmers in the salt-affected area in coastal Bangladesh were empowered to improve their yields and livelihoods. At present, the majority of the farmers in the coastal area grows only one crop per year commercially (rice during the monsoon season); while in the north of the country, three crop cycles per year are standard. By making use of salt-tolerant crops and smart soil and water management, it became possible to introduce two additional crop cycles per year to the coastal area. By growing different high yielding, nutritious crops with good market value, smallholder farmers were able to adapt to the increasing salinities and improve their livelihoods, so that ultimately migration out of the area could be stopped. However, before this climate-smart, resilient form of agriculture could be introduced on a large scale, several limiting factors had to be addressed.

21.3 APPROACH AND LIMITING FACTORS

Part of the approach of the project is summarized in Figure 21.1. First of all, the project should be embedded at an institutional level. Extension programs have to be developed as well as "best practices" for crop cultivation that includes crop, soil and water management and an agro-service for farmers need to be established to assist farmers upon request. Salt Farm Texel has tested the yield potential of several salt-tolerant vegetable crops and crop varieties (including potato, cabbage, cauliflower, carrot, beetroot and kohlrabi) at the Salt Farm Texel Research and Training Centre in the Netherlands (for crop species and varieties see Bruning et al. 2015; de Vos et al. 2016). Given the evidence from these field experiments, Salt Farm Texel had begun to pilot the feasibility of introducing some varieties into the production portfolios of lead farmers in coastal Bangladesh. A Saline Agriculture Research and Training Centre (referred to as the Training Centre in the rest of this chapter) has been set up in coastal Bangladesh in collaboration with Lal Teer Seeds, as part of the ongoing project. At the start, the project focused on the validation of the crop performance under local conditions and the development of the "best practices" for crop

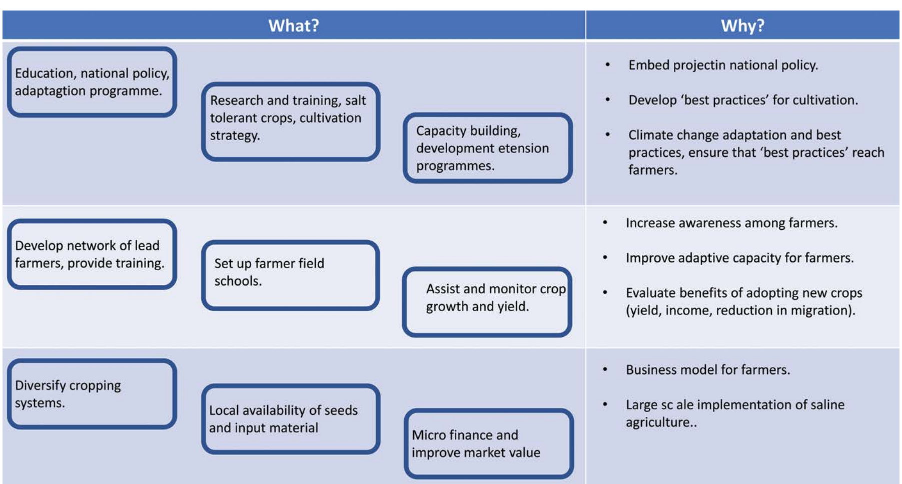

FIGURE 21.1 Overview of the approach of the Salt Solution project to ensure large-scale implementation of saline agriculture in coastal Bangladesh.

cultivation under saline conditions in coastal Bangladesh during the dry seasons. In total, six different crops have been introduced at the farm level so far: cabbage, cauliflower, kohlrabi, carrot, beetroot and potato.

21.4 ROLE OF THE TRAINING CENTER

A cultivation strategy for the year-round production of rice, potato and other vegetables under saline conditions was developed in the Training Center during the Salt Solution project. Smart soil and water management strategies were developed and tested at the Training Center. The introduction of new technologies such as (underground) rainwater harvesting (in partnership with Acacia Water) and drip irrigation was implemented. Soil monitoring (soil analysis and frequent salinity measurements) and management focused on crop rotation, raised bed cultivation, mulching and the use of organic inputs to improve the structure and fertility of the soil are conventional practices that might play an important role in fighting salinization. An additional added value of the training center is that the Bangladesh Agricultural Research Institute is performing important work in developing and selecting suitable varieties of crops such as rice to be cultivated under saline conditions. All these crops and varieties continue to be tested and demonstrated at the Training Centre developed in The Salt Solution Project.

21.5 STRUCTURE OF THE PROJECT

As the Salt Solution project matured, the structure was such that once the best strategy had been determined in the Training Center, this was implemented by a network of lead farmers who had been trained and assisted closely. According to the "train-the-trainer" principle, the knowledge and know-how of "Salt Farm Texel" were passed on to the staff of ICCO and CODEC, who subsequently trained the lead farmers. The training focused on pre-sowing activities (formation of raised beds, fertilizer, compost and gypsum application, improvement of the seedling nurseries), soil, crop and water management and monitoring and data collection. Protocols and illustrations, animations, videos, community theater and farmer field days were all used to inform and instruct farmers. The lead farmers became trainers themselves and trained the farmers in their community (group farmers), spreading the awareness of tolerant crop cultivation as a way to adapt to increasing salinity levels. All input materials were made available locally, such as appropriate seeds as well as a toolkit to monitor soil and water salinity levels.

For farmers, "seeing is believing". By setting up a network of lead farmers that act as farmer field schools for the local community, all farmers could experience saline agriculture close up. Also, through crop diversification, the farmers were able to produce different crops to ensure good market value throughout the year. The diverse crops were also selected for their nutritional value to improve nutritious food consumption since around 20% of the yield is used for household consumption.

Soil salinity was closely monitored at the Training Center and at an additional 50 different farms across the whole project. Lead farmers and, subsequently, the farmers' groups were trained in determining the salinity of their soil using various methods, as well as the salinity of the irrigation water. Results of these measurements were converted to the international standard of EC_e values to be able to link crop performance to soil salinity values.

The best way to convince a farmer to change their way of farming is by showing the financial return on investment. For this reason, special attention was focused on farm business models, also aimed at Shifting traditional agriculture to a commercial basis. Close monitoring took place by ICCO and CODEC, collecting data of the different crops at a minimum of 30 different farms per crop.

21.6 RESULTS

21.6.1 Soil Characteristics

For 11 locations, soil samples were collected and analyzed in detail. The majority of the analyzed soils were silt loam and silt clay loam soils. The pH and organic matter percentage ranged from 6.2 to 7.5 and 1.1 to 2.5%, respectively. The saturation of the Cation Exchange Capacity (CEC) was, on average, 81, 13, 4.8 and 1.1% for Ca, Mg, K and Na, respectively. These results indicate that few problems occur with soil structural issues in relation to salinity, and soils appear to be non-sodic (low Na saturation in CEC, pH<8). As mentioned above, the soil salinity was monitored at 50 different locations distributed over 4 coastal districts where the project implementation took place. The average soil salinity level (EC_e) of all 50 locations was 3.6 ± 2.0 (s.d.) dS/m at the first sampling event and 5.6±3.3 (s.d.) dS/m at the last sampling event, with a seasonal average of 4.7 dS/m. Of the 50 locations, 5 locations were in the 0–2 dS/m range, 21 locations in the 2–4 dS/m range, 18 locations in the 4–8 dS/m range, 4 locations in the 8–12 dS/m range and 2 were in the >12 dS/m range (based on the seasonal average EC_e).

21.6.2 Cost Effectiveness

Data were collected and analyzed regarding the input costs (costs for fertilizer use, crop protection, labor, seeds, irrigation equipment) as well as the yield and market value. Although the analyzes are ongoing, and the second year of data will be required to obtain a robust and reliable data set, the first trends do show some interesting results. The introduced crop varieties showed no yield reductions even at the higher salinity levels; however, there was considerable variation in crop yield within salinity classes suggesting that other factors besides salinity have a great effect on crop yield, i.e. greater than the effect of salinity. This effect was also observed under controlled field conditions (Van Straten et al. 2020), and additional research is needed to determine which other factors affect the yield in which manner and how this can be improved.

On average, the input costs for fertilizers and labor were more than twice as high as the costs for crop protection and irrigation (irrigation costs are mostly based on pump renting and fuel costs). The input cost for seeds vary greatly depending on the crop, and in the case of carrot, beetroot and potato, the input cost for the seeds was the largest investment for the farmer. However, the market value of beetroot and carrot was the highest (no market value for potato has been obtained so far) and in all cases (for all five crops that were evaluated) the cultivation was, on average, profitable for the farmers. The profit for the farmers varied, on average, between 70 and 240 euros per decimal (commonly used unit of area in Bangladesh, equals around 40 m^2), with beetroot, cabbage and cauliflower showing the highest profit. These results are based on data sets collected at around 30 farms for each crop. Again, these first results are only based on one dry season and should be validated in a second year, especially since these profits appear to be very high.

21.6.3 Project Accomplishments according to the SDGs

Two years after the start of the project, directly after the season in which the abovementioned inputs costs and potential profits were obtained, an independent third-party evaluation, executed by the GBF, took place to determine the effect of the project (mid-term results, see Table 21.1). The SDGs were used to determine the impact of the project.

First, results showed that 75% of the farmers now use the salt-affected land during both dry seasons as described in Section 21.1, which addresses SDG 2, Zero

TABLE 21.1
The Mid-Term Results of "The Salt Solution" Project, Based on an Independent Evaluation for Which 260 Farmers from a Group of 2,000 Farmers Were Interviewed. Project Outcomes Are Linked to the Relevant SDG

SDG Number	SDG Description	Accomplishment in the Project after 2 Years	Before Start of Project	2 Years after Start Project
1	No poverty	**Average household income increased**		34%
		Households with more than €100, - monthly increase:		
		- *Lead farmers*		55%
		- *Group farmers*		4%
		Employment increased		
		- *Lead Farmers*		10%
		- *Group farmers*		41%
2	Zero hunger	**Food security increased**[a]	15%	65%
		Use of salt affected fallow land increased[b]	0%	76%
3	Good health and well being	**Vegetable consumption increased**[c]	26%	74%
		Households improved dietary diversity	75%	100%
5	Gender equality	**Skills on sustainable food production in women increased**	9%	79%
		Access to land for women increased	4%	87%

[a] Food security is based on household food insecurity access scale-0 (full food security).
[b] During the first part of the dry season (December–February).
[c] Defined as the consumption of a minimum of 150 g/day, during at least 10 months/year.

Hunger. At the start of the project, none of the farmers used this land. Vegetable consumption increased from 26% to 74% which addresses SDG 3, Good Health and Well-Being, and food security increased from 15% to 65% also addressing SDG 3. Average household income increased by 34% which falls under SDG 1, No Poverty. The project also deals with gender inequality (SDG 5), providing training for women, resulting in an increase of the number of women with improved skills for sustainable food production from 9% to 79% and increasing access to land for women from 4% to 87%.

21.7 NEXT STEPS

The results shown in Table 21.1 are based on one year (one season). The second year of similar results would validate the possibilities and the profitability of crop cultivation under saline conditions. It is the ambition of the team to collect and analyze this second year of data but is beyond the scope of this case study.

21.7.1 Conditions for Further Testing and Training

The second crop cycle in the dry season (March–June) will be more challenging, as salinity levels increase until the next monsoon rains, in combination with high temperatures and low freshwater availability. Crops should be both salt and heat tolerant, and water availability should be ensured by (rain) water harvesting in times of surplus. Underground freshwater can be stored using novel methods in making optimal use of the existing soil profile. Rainwater is stored in coarse sand surrounded by natural clay layers that form a barrier. Later, this water can be pumped up and used for irrigation.

The newly built test facility has a special focus on the summer crops (such as okra, Indian spinach, bitter gourd and eggplant) and underground storage of water. More testing is needed to determine which varieties are most suitable for cultivation under saline conditions. Before new crop varieties can be introduced more broadly at the farm level, the proof of concept should expand, demonstrating a relatively low risk for the farmers involved. This can be centered around the Training Center in Bangladesh and the first pilots have begun. Breeding for salt tolerance to introduce even better varieties is also taking place at the Training Center but this is a time-consuming effort and is planned for the coming years. At present, the economic viability of underground water storage is being evaluated. This includes the price of equipment, installation costs and the amount of water that can be stored and the market value of the crops that can be cultivated off season.

Once the input materials are locally available and the farmers are able to acquire these materials and know-how to implement the best practice cultivation strategy, then large-scale implementation of saline agriculture is feasible. Currently, vegetable cultivation takes place on the land around the farmhouses; much greater impacts might be achieved when the rice paddies are used for vegetable cultivation in the dry season. This will also involve mechanization, large-scale water harvesting, improved market access and improved export potential.

TABLE 21.2
Overview of Limiting Factors for Agriculture during the Dry Season and the Proposed Solutions

Limiting Factor	Proposed Solution
Scarcity of quality irrigation water	Rainwater harvesting during monsoon, (underground) storage
Unstable rainfall	Rainwater harvesting during monsoon, (underground) storage
Limited salt-tolerant crop choices	Introduction of salt-tolerant varieties by Salt Farm Texel, Lal Teer Seed
Restricted sowing/planting time	Develop cultivation strategies to increase the window of planting
Polder structure of areas	Develop a strategy to shift from rice paddy to vegetable field and back
Soil salinity	Lowering soil salinity levels by making use of monsoon rains for leaching
Low soil fertility	Introduction of cultivation strategy with organic inputs, crop rotation
Shallow saline groundwater	Minimize capillary rise of saline groundwater into rootzone
Heavy soil that requires tillage	Cultivation strategy of raised beds with minimum tillage
Perennial water logging	Low tech drainage system, raised cultivation beds
Lack of extension programs	Capacity building of extensions services
Insufficient training for saline agriculture	Intensive training programs for (lead) farmers
Difficult communication, marketing	Develop a network of lead farmers, farmer field schools, training center, engage local communities
Availability of input materials	Ensure local availability seeds, (organic) fertilizers, irrigation equipment
Financial means	Availability of micro-finance
Proven minimum risk for farmers	Demonstration of crops and cultivation strategies, business model for farmers
Low market value	Diversify cropping systems, improve “going-to-market window”, improve farmer organization, improve market access, create more export opportunities
Limited success after the end of the project	Several social indicators will be identified and quantified to measure factors of success and these factors will be used to stimulate the continuation of the success after the project ends

21.7.2 Limiting Factors

Several limiting factors need to be addressed before scalable solutions for crop cultivation under saline conditions can be introduced successfully. The limiting factors, as presently identified, are listed in Table 21.2. The proposed solutions for the identified limiting factors are also listed.

21.8 CONCLUSION

Although most data presented in this case study are based on a single season, the results do indicate that crop cultivation under (moderate) saline conditions in coastal Bangladesh is possible and profitable. The vast majority of the farmers previously did use the salt-affected land in the dry season, but now with the help of this project, three out of four farmers in the local area are empowered to use salt-affected land. The results in Table 21.1 clearly show the cascading effect of this and the impact of the project in addressing the SDGs.

These accomplishments closely match some of the SDGs. Now, "new" land can be used for crop cultivation (SDG 2: Zero Hunger) which improves the vegetable consumption (SDG 3: Good Health and Well-Being) and diversifies the diet, increases the food security and the income for the households (SDG 1: No Poverty, 2: Zero Hunger and 3: Good Health and Well-Being). Since women were actively involved, their skills and participation increased greatly (SDG 5: Gender Equality). The project is a clear example of Climate Action (SDG 13) and setting up (public-private) partnerships (SDG 17) to reach the goals. Although this project is already training 5,000 farmers, many more farmers need to be reached in coastal Bangladesh and beyond. Most farmers started this project dedicating only a small piece of land for demonstration in the project but have turned their whole land into the tailor-made adaptive farming system developed at the Training Center. This shows that the chosen approach does work and farmers are willing to adopt the new farming strategies in order to better adapt to climate change.

Salt-affected lands are often considered to be unsuitable for crop production, but, in fact, the saline resources of the world have the potential to help improve the livelihoods of millions of farmers and contribute to global food security.

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