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Review

Impact of salinity intrusion on agriculture of Southwest Bangladesh- A review

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Bangladesh, a deltaic plain covers more than 30% of the cultivable land is in the coastal area. Out of about 1.689 million hectares of coastal land 1.056 million hectares are affected by various degrees of soil salinity. Agricultural land use in these areas is much lower than the country's average cropping intensity owing to salinity resulting from the accumulation of excess soluble salts. Consequently normal crop production is hampered due to inadequate irrigation water source, unavailability of salt tolerant crop varieties, habited to cultivation local variety, increase climate change related natural disaster, insufficient locally adaptable technologies for mitigating salinity problem. Additionally, decrease cropping intensity with increased salinity environmental hazards in this area specially during rabi season is common phenomenon. As a result, salinity intrusion not only destructs crop yield but also causes a loss of total crop production on highly salt concentrated soil. Thus saline-prone coastal region had a drastic yield loss i.e. approximately average 20-40% in major crops (cereals, potato, pulses, oil seeds, vegetable, species and fruit crops). The dominant cropping pattern of the saline prone areas of southwest Bangladesh is local transplanted Aman followed by HYV Boro rice. Further rice based farming systems are being converted into prawn/shrimp/crab based farming due to salinity accompanied with the disappearance of native fish species both in open and fresh water bodies encompassing decrease livestock production leading to food insecurity. So key impacts of salinization on extent, land feature and crop production along with its credible causes and pathways in south-west Bangladesh are discussed with the recommendations needed.

Keywords: Salinization, cropping intensity, food security, Southwest Bangladesh, Agriculture.

INTRODUCTION

Bangladesh has a total area of 147,570 km^2 including 29,000 km^2 of coastal region. However, more than 30% of the cultivable land is covered by coastal and offshore area (Haque, 2006). About 50% of the coastal lands face different degrees of inundation, thus limiting their effective use. This situation is expected to become worse further because of the effects of climate change (Islam, 2006). Additionally, Sundarbans- the world's largest mangrove forest covers nearly 4500 km^2. So the rest of the coastal area is under agricultural use. Again, salinity intrusion affects cultivable land of coastal areas to a great extent. Salinity conquered land furthermore increase many folds due to climate change and its driven catastrophic hazards like sea level rise, cyclone (eg. recent past super cyclone

Sidr, Aila) and storm surge (Anik and Khan, 2012). Salt-water invasion along the coastlines accelerates water and soil salinity that might be enforced adverse effects on agriculture, forestry and fisheries (Hoa et al., 2014). Further, agricultural land use in the salinity-intruded area is nearly 53% of the country's average (Petersen and Shireen, 2001). In general, salinity intrusion hampers crop production throughout the year particularly in rabi season due to unfavorable environment. Salient factors responsible for remarkable salinity intrusion are tidal flooding and inundation etc. Additionally, salinity intrusion causes land desertification and scarcity in irrigation water (Shaheed, 2010). As a result, increasing level of salinity and salt effect largely restricts normal crop production. Even salinity intrusion impacts on the availability of water required for drinking, irrigation and industrial usability (Unnayan Onnesha, 2012). Therefore, salinity intrusion in southwest Bangladesh not only affects plant growth, development and yield to a great extent, even it brings vast agricultural land under fallowing along with the introduction of prawn/shrimp/crab based farming. Thus coastal agriculture and livelihood patterns are closely interlinked with the degree of salinity intrusion**.** Relevantly, a comprehensive number articles have been published so far (Unnayan Onnesha, 2012; Haque, 2006; Karim et al., 1990; Petersen and Shireen 2001; Rahman and Ahsan, 2001; Singavaral et al.,1996; CARE, 2000; Habibullah, 1986; Huq and Iqbal, 1995; Jahan et al., 1998; Khan et al., 1998; Mazid, 1998; Wilson et al., 1996; SRDI 2010; Kalam et al., 2001; Miah et al., 2004; Miah and Mia, 2012; Alam et al., 2002; BARCIK, 2004; BARI, 2008; Cardon et al., 2007; Franzen, 2009; Hossain and Uddin, 2011; Islam et al., 2006; Miah et al., 2010; Miah et al., 2008; Munns and Tester, 2008; Naher et al., 2011; Parida and Das, 2005; Paul, 2004; Querishi et al., 2008; Razzaque et al. 2010b and Sudharani et al., 2010).

As a result, agricultural and natural resources are being used without judicious considerations on near and far future impact of salinity intrusion. Naturally there could be severe consequences both on environment and economy with particular focus on agriculture. Under these circumstances, it is essential to ensure the best use of resources relevant to salinity intrusion problems with particular reference to south west Bangladesh to secure the livelihood and over all betterment of the people of the region concerned focusing on thorough review based collective information despite reviews mentioned above.

In different parts of the southwest Bangladesh, salinity problem started in different times. In parts of Khulna district namely Dumuria and Batiaghata upazillas, this problem began since 1980's. However, most agricultural scientists opine that intruded salinity has been accelerated in many folds by increasing salinity in river water, unplanned construction of embankments and polders. As a result, farmers of southwest coastal Bangladesh have shifted their rice farming system to Bagda farming owing to entrance of saline water in rice field. In turn, salinity intrusion has made the soil saline and unfavorable for crop cultivation. Additionally, expansion of Bagda cultivation in new areas is a threat for the life and livelihood of the local people of southwest Bangladesh in particular and it is a great threat to the food safety and overall economy of Bangladesh in general (Miah, 2014).

Even to our knowledge, no review report update showed an over-all feature on cultivation processes accompanied with cropping strategies in the saline prone southwest Bangladesh so far. This article narrates an over view on crop cultivation status along with salinity intruded problems of crop production, environment and locally available as well adaptable technologies for mitigation of the salinity problems involved therein. However, this review article could not be anticipated for covering all the problems related with salinity intrusion and its effect on overall agriculture of southwest Bangladesh. So efforts were made to keep the relevant sections independent of each other. Therefore, readers would be interested to go through this article to employ generate more technical knowledge for using the potentials of salinity intruded land(s) for better agricultural production.

MATERIALS AND METHODS

All the databases and reports used in this review article were collected from available secondary sources. The resources were gathered from online publications, books, government reports, international reports, scientific journals, news articles by searching Google and Google Scholar etc. including socio-economic and statistical data relevant to the impacts of salinization on agriculture of southwest Bangladesh.

RESULTS AND DISCUSSIONS

Salinity development: Reasons and pathways

Causes of salinity intrusion

Causes of salinity intrusion in Bangladesh are well documented (Alam et al., 2017; Clarke et al., 2015; Mahmuduzzaman et al., 2014; Miah, 2014; Haque, 2006 and Unnayan Onnesha, 2012). Of the reasons, vital ones are natural, socio-economic and political. Natural systems include geographical location, sedimentation, sea level rise, cyclone, storm surge and tidal surge etc (Coleman et al., 1969; Milliman and Meade, 1983 and Ali., 1996). Whilst socio-economic systems comprise shrimp farming (Flaherty et al., 2000 and Karim, 2000), infra structure (Shaw, 2006) and climatic variables (Rajan, 2007) encompassed with political systems (Rounak and Rahman, 2013; Khan, 1993; Mirza, 1998). However, the alluvium from the upward stream deposition in the coastal areas of Bangladesh becomes saline as it comes in contact with the sea water and continues to inundate during the high tides and ingress sea water through the creeks. So major causes responsible for salinity intrusion is tidal flooding during

Table 1. Major causes for increasing salinity

Major causes of increasing salinity	Respondent No.	Respondent (%)
Unplanned gher expansion	70	63
Increasing salinity in river water	25	23
Unplanned embankment construction	5	5
Influence of powerful manforbagda cultivation	4	4
Water logging	3	3
Natural saline soil	1	1
Blockage of canal/river	1	1

Source: Miah et al., 2004

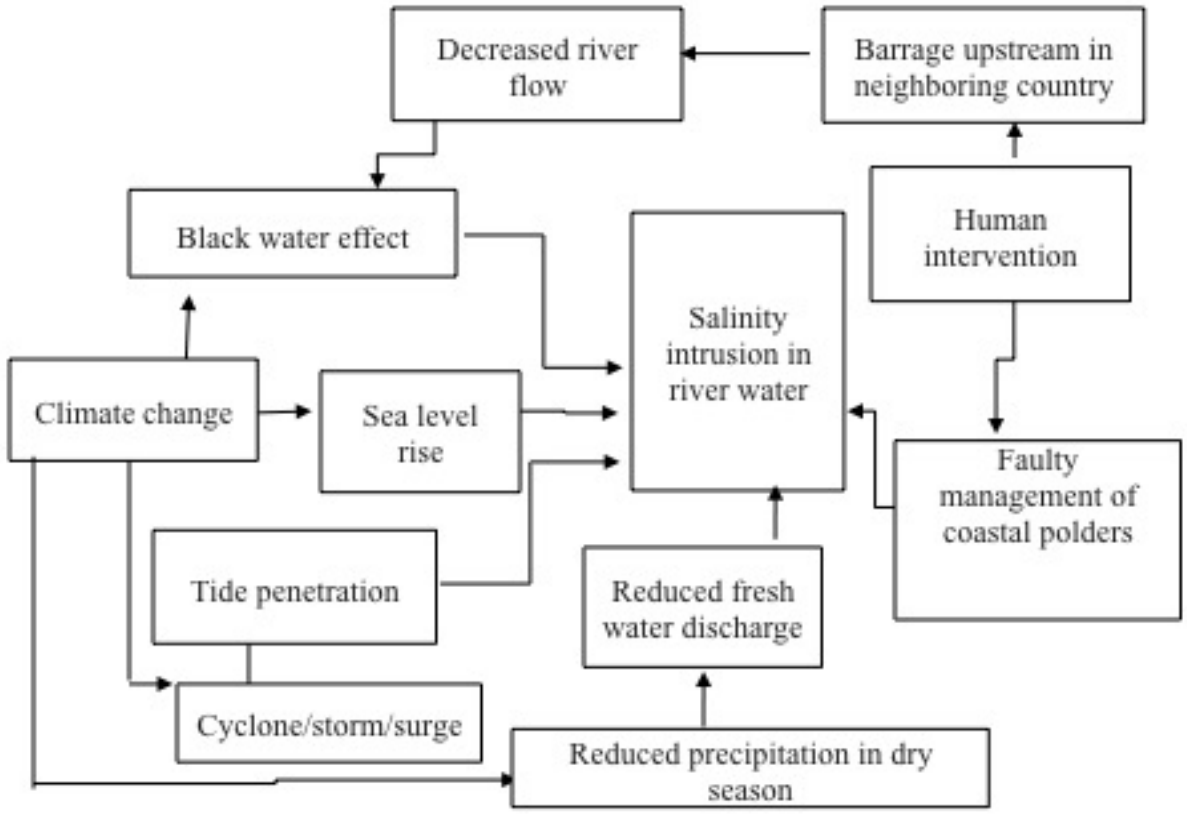

Figure 1: Causal diagram of salinity intrusion in river water (Adopted from Unnayan Onnesha, 2012)

wet season (June-October), lack of rainfall during dry season (November-March) followed by upward or lateral movement of saline ground water. A part from this, seasonal variations in rain fall, faulty irrigation or inadequate vegetables coverage in the saline areas are the additional causes for salinity intrusion (Miah et al., 2004). Moreover, inundation of arable land by saline water for shrimp cultivation is also a dominant pathway for salinity intrusion (Mazid, 1998). Even there are reports that withdrawal of the Ganges water at the Farakka barrage beyond the border of Bangladesh has reduced the discharge of fresh water leading to the salinity intrusion in the main land (Chowdhury, 1993). So the major concern left in the salinity intrusion studies is the data based documentation. In this regard, detailed evidential findings on salinity intrusion affected agricultural production (Table 1) in southwest coastal Bangladesh have been reported (Miah et., al 2004) coupling a schematic diagram (Figure 1) adopted from (Unnayan Onnesha, 2012).

Pathways of salinity

Salinity in agricultural soils is the salt accumulation owing to water salinity, drainage and evaporation (Clarke et al., 2015). As for Bangladesh, salient methods of salt accumulation have been well narrated (Brammer, 2014;

Table 2. Extend of soil salinity during the last four decades (1973-2009) in coastal areas

Salt affected area (000'ha)			Salinity class and area (000'ha)												
			S_1			S_2			S_3+S_4			S_5			
1973	2000	2009	1973	2000	2009	1973	2000	2009	1973	2000	2009	1973	2000	2009	
833.45	1020.75	1056.26	287.37	289.76	328.43	426.43	307.20	274.22	79.75	336.58	351.69	39.90	87.14	101.92	

Legend
S_1= 2.0−4.0; S_2 = 4.1−8.0; S_3= 8.1−12.0 dS/m; S_4 = 12.1−16.0 dS/m; S_5 =>16.0
Source: SRDI, 2010

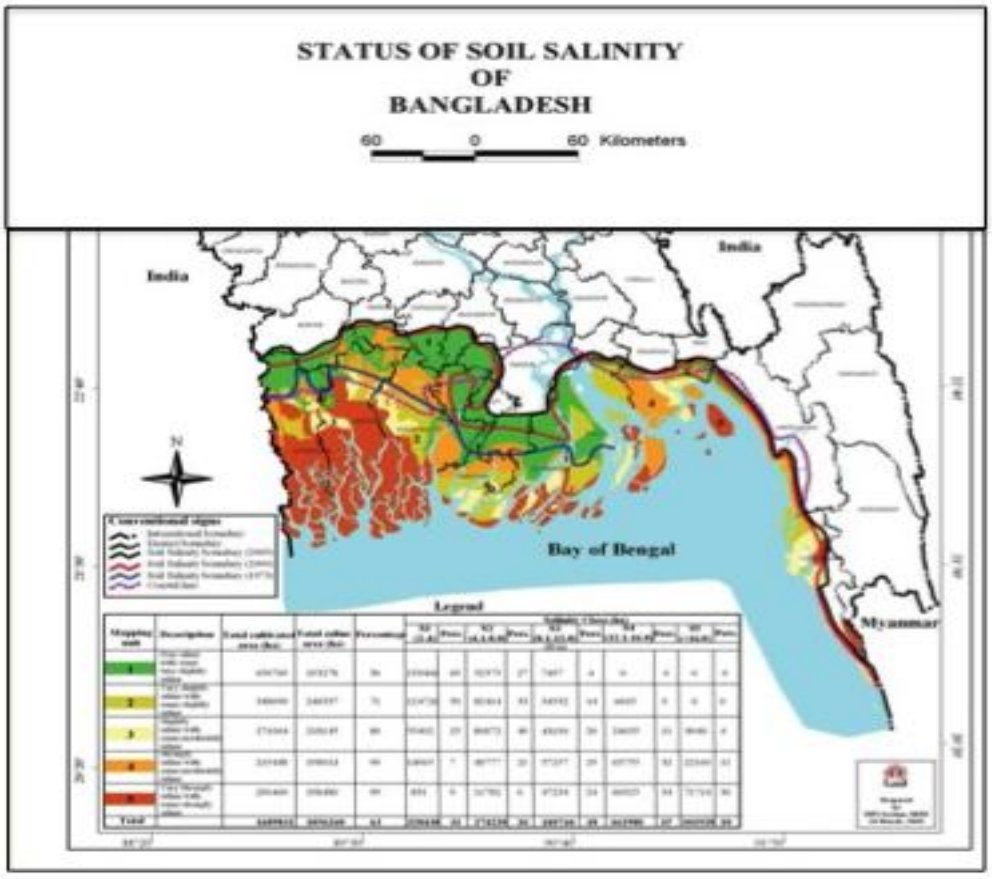

Figure 2: Soil salinity affected area of Bangladesh (Source: SRDI, 2010)

Haque, 2006). Recognition of primary and secondary causes responsible for salinization in agricultural land are crucially discussed (Beltran, 1999). However, developing reason with regard to salinity in south west Bangladesh is the inland salt entrance through rivers and channels during winter season followed by flooding with river saline water or seepage associated with salt concentration in the surface layers resulting from evaporation. Secondary salinization in this region is the use of coastal ground water for shrimp cultivation (Begum and Alam, 2002; Hossain et al., 2004).

Extent of salinity intrusion

Established fact is that salinity intrusion is a growing problem of southwest Bangladesh. Simultaneously, it has also attracted the scientists across the glove as a major problem of agricultural production in coastal areas. The spatial distribution of saline soils (Table 2; Figure 2) with different degrees of salinity has been well classified (SRDI, 2010). The coastal region of southwest Bangladesh comprises Bagerhat, Khlna, Sathkhira and Jessore districts. World's biggest mangrove- the Sundarbans also belongs to this region. The greater part of the region has a smooth relief and general pattern of river banks and extensive basins. It has also been reported that saline aquifer has penetrated about 151 km from the coast towards the Khulna region (Habubullah, 1986). Meanwhile elaborated categories and extent of saline soils of Bangladesh are also

Table 3. Land types in southwest coastal zone (Adapted from SRDI, 2010)

District	Land types				
	High land	Medium High land	Medium lowland	Lowland	Very lowland
	Area in percentage				
Satkhira	17	62	3	0	0
Khulna	4	62	9	2	0
Bagerhat	5	61	7	2	0
Jessore	31	33	11	3	0

available (Huq and Iqbal, 1995).

Land features

With its flat and low topography, the coastal areas of deltaic Bangladesh lie about 1.5 to 11.8 meters above the mean sea level. It includes tidal, estuarine and meander floodplains. The coastal saline zones of the south-west Bangladesh covers an area of almost 5704 ha land (Kabir et., al 2004) with various categories of land (Table 3). Additionally, peat basins located at the western part of Khulna are subject to flooding in the monsoon season and waterlogging in the dry season (Haque, 2006). Normal crop production is hampered throughout the year specially in rabi season owing to special environmental and hydrological situations derived from salinity intrusion. Further most of the land of these areas remains fallow because of salinity intrusion, lack of good quality irrigation water and late draining condition (SRDI, 2010).

Overall impact of salinity intrusion

Soil fertility

High soil pH (6.0-8.4) induces deficiency of micronutrients in soils of southwest coastal region of Bangladesh (Haque, 2006). The general fertility level is high with medium to high organic matter content coupling high cation exchange capacity (CEC). Moreover, he suggested that high Ca and K contents in these soils are responsible for deterioration of soil physical properties followed by offset plant nutrition. Moreover, phenomena like synergism derived from high Mg content induced Na uptake encompassing antagonism with simultaneous reduction in Ca and K uptake also occur. Along with notable P deficiencies, these soils are even deficient in Zn and Cu too (Karim et al., 1990).

Farming practices

First of all, year round crop production along with diversified crop cultivation is hampered by salinity intrusion as most of the crops loss their yield capacity due to their intolerance to salinity. However, different farmers follow different farming practices to reduce salinity effect on the land and to increase crop production. Based on crop type, some of them adopted special type of farming practices like mulching with water hyacinth, straw and ash etc. accompanied with the use of compost to mitigate the salinity induced soil problems and to keep the evaporation at minimum level as well. However, presented below are current major cropping patterns (Kalam et al., 2001).

Fallow-Fallow-Tranplanted Aman
Fallow/rabi crops-Mixed aus and aman
Fallow-Broadcast aus-Transplanted aman
Boro-Fallow-Shrimp/prawn/crab

Cropping system

The dominant cropping pattern practiced in coastal areas is Fallow-Fallow-Taman rice. Late harvesting of T-aman rice and delay tidal floodwater recession triggers about 40-45% and 30-35% of fallow land during rabi and Kharif-1 season (Rafiquzzaman et al., 2010). The major field crop of southwest coastal Bangladesh is rice (Aman/Boro). However, farmers of this region do not cultivate Aus as the intensity of salinity becomes higher during Aus growing season. Farmers cultivate both local and HYV varieties in aman and boro season, respectively. Of the rice varieties, BRRI 28 is the most popular HYV rice variety compared with other HYV ones like BRRI 29 or so. But in aman season, cultivation of local rice varieties is popular compared with those of HYV ones. Widely cultivated local aman rice varieties are Jati, Gunshi, Hogla, Hoglapata, Chapal, Moynamoti etc. Actually farmers like to cultivate local varieties in aman season because of their indigenous characters like taller plant height accompanied with insect, disease, waterlogging and salt tolerance capacity and better taste despite their low yield performance (2.6 ton/ha) compared with higher yields of YHV (4.4 ton/ha) (Table 4). Further crops like jute, sesame, groundnut, mustard, and vegetables specially the winter ones are also being cultivated in limited scale.

Tree production

Salinity intrusion also hinders the production of both fruit and forest trees. Fruit trees like Mango, Betel nut, Date palm, Giant taro, Jackfruit, Black berry, Wax jumbo etc. is disappearing to a great extent. Drastic reduction growth of Betel nut, Papaya and Banana is also noticed. However, some exotic quick growing trees like Babla, Rain tree, Eucalyptus, Chamble, raj koroi etc. grow satisfactorily

Table 4. Variety wise rice cultivation in different rice season

Sl. No.	Participant No.	Season	Variety	Total Cultivated variety	Average Yield (ton/ha)
1	68 (Local) 47 (HYV)	Aman	BR-10, BR-11, BR-21, BR-22, BR-23, BR-26, BR-28, BR-29BR-30, Jotai, Gunsi, Chapal, Hoglapata, Hogla, Chiniatap, Mohini, Chaplash, Jotaieu, Ghute salute, Bamonbalam, Moynamoti, Patibalam, Badampatni.	9 (HYV) 18 (Local)	1.9 (Local) 2.5 (HYV)
2	5 (Local) 16(HYV)	Boro	IT, BR-11, BR-23, BR-26, BR-28, BR-29, BR-1, Vajan, Bare ratna, Chinease	7 (HYV) 3(Local)	2.6 (Local) 4.4 (HYV)

Source: Monalisa et al., 2002

although plant growth varies from area to area depending on the degree of salinity. Generalized observation is that growth of trees is satisfactory at the beginning but once the taproots reach at saline layer, the trees start to dye owing to shortage of pure soil water via nutrient depletion and physiological disturbance (Monalisa et al., 2002).

Food safety

Well-recognized fact is that food safety is the main pillar for the economic growth and over all development of Agrarian Bangladesh. But various factors like limited cultivable land, scarcity of irrigation water and unfavorable climatic conditions are leading the food safety of Bangladesh towards a great threat. Among the various reasons, salinity intrusion in southwest Bangladesh is the key factor for induction of food insecurity as it brings much more salt concentration in soil at the root region of crop plants. As a result, drastic crop yield reduction occurs due to the osmotic process induced large-scale hindrance in plant growth and development. Furthermore, severe scale salinity intrusion may cause zero crop yields leading to a food crisis affected food epidemic (Miah, 2014). BCAS (2010) has reported that climate change driven salinity intrusion had caused a drastic yield reduction of major crops (cereals, potato, pulses, oilseeds, vegetables, species and fruits) approximately 14.05 lakh tons per annum in the coastal districts, summarized a total of 20-40% yield loss. Therefore, under these circumstances, one might predict that long-term effect of salinity intrusion would certainly break the food security ring.

Environmental adversities

As for environment, major impact of salinity intrusion is the rapid change in physiographic structure of the saline areas. Besides, declining tree species production, reducing soil fertility, increasing disease and pest infestation in field crops and increasing human and animal diseases are the vital adversities. Even native fish species both in open and fresh water bodies are also decreasing gradually due to salinity effect. For short term, salinity intrusion destroys green belt of coastal zones in one hand and accelerates increase in temperature, heavy showers, drought etc. on the other. In addition, it is responsible for the gradual decrease in grazing lands leading to the decrease in the number of livestock owing to shortage of feed, forage, straw etc. accompanied with the shortage of both fresh and irrigation water. So salinity intrusion will be a major hazardous issue for the future generation of the southwest region of Bangladesh.

Conclusion and recommendation

In inference, long-term effects of salinity intrusion must be taken into accounts to cope up with the current farming system, changes in environment and sustainable agriculture. To uplift the overall socio-economic conditions, farmers could be recommended to change their rice farming system to prawn farming as it creates opportunity for the cultivation of rice and vegetables in the same field. Finally, there is a broad-spectrum research opportunity to develop the salinity tolerant crop varieties encompassing farming practices relevant to salinity intrusion mitigation. To preserve the biodiversity and produce new rice varieties, salinity adapted local varieties must be conserved. It is also important to build up awareness on saline reclamation modern cultivation techniques like, proper soil management, fertilizer usages, raising cultivation, Shorjan cultivation, stress tolerant crop varieties and alternative cropping system to boost up agriculture in such saline-prone areas. Moreover encourage substitute of dominant livelihood system like social forestation, homestead gardening and pond fishing etc. for coastal community development. Furthermore intensive research should be reinforcing to assist in finding alternative strategies to ensure food security in coastal saline prone area.

Conflict of interests

The authors declare that they have no conflicting interests.

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