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Effect of salinity on food security in the context of interior coast of Bangladesh

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ABSTRACT

The Southwest (SW) region of Bangladesh is facing salinity intrusion both environmentally and anthropogenically. In that circumstance, the dominating livelihood agriculture is affected severely including soil and ground water degradation, health problems and long term effect on ecosystem. Study from the Soil Resource Development Institute (SRDI) found that, from 2000 to 2009, saline water intrusion increased up to 15 km north of the coast and in the dry season reached up to 160 km inland, entering into other interior coastal districts as well due to low flow from upstream rivers. In line with that, this article explored local people's experience with salinity intrusion in interior coast of SW region. Along with semi-structured & open ended questionnaire five focus group discussions and eight interviews were conducted to outlines the relationship between food security and salinity intrusion in regards of crop production and examines the impact of salinity on the crop production. The analysis found salinity in both soil and water is favorable for rice cultivation, although yield loss in every year has increased. Community shifted from native to high yield rice varieties to increase production and cope with soil salinity, in turn, the activity increase fertilizer and pesticides usage. Additionally, oilseed, sugarcane and jute cultivation has discontinued for twelve years due to inability to cope with current salinity level. Some other reasons put forward for saline intrusion includes lack of fresh water in the dry season, and saline encroachment from sea through downstream rivers. Through identification of salinity in the study area, the study suggests to measure impacts rigorously and imply necessary adaptation even though the saline level is favorable for rice, to protect interior coast from suffering like exterior coastal districts.

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1. Introduction

Sea level rise (SLR) is considered one of the major reasons of salinity intrusion into soil and ground water which is the result of both natural and human induced climate change. Considering other forms of lands, deltas are easy victim of SLR. For instance, several study found that Mekong delta (Wassmann et al., 2004), Nile delta (Frihy, 2003) and Ganges floodplain (Sarwar, 2005) are facing constant inundation and saline intrusion due to exposure to the sea. As part of Ganges floodplain, Bangladesh is also experiencing similar consequences particularly the southwest part. The southwest region of Bangladesh is two meters above sea level, and the population density is approximately 743 km,^{2} a bit lower than national population density at 839 km^2 (Chowdhury, 2009; Ahmed, 2008). A study from South Asian Association for Regional Corporation Meteorological Research Centre found that the tidal level at *Hiron* Point, *Char Changa* and Cox's Bazar rose by 4.0 mm/year, 6.0 mm/year and 7.8 mm/year, respectively based on the tidal gauge record of the period 1977–1998 (Alam, 2003; cited in Sarwar and Khan, 2007). The World Bank (2000) predicted that sea level rise (SLR) due to climate change will submerge a lot of low lying lands by 2050, and salinity intrusion will be more severe. According to other prediction on SLR, about 13% more land will be inundated in the monsoon season due to a 62 cm sea level rise because of increased rainfall and prolonged dry season, 62 cm sea level rise will claim about 364,200 ha (10%) more land inundated in the year 2080 (IWM and CEGIS, 2007). Depending on a study of the Soil Resources Development Institute (SRDI, 2010) an average increase of salinity is about 0.74% per year. Evidently, soil salinity has increased from 0.833 million hectares to 1.056 million hectors in between 1973 and 2009 where only in nine years (2000–2009) it's affected 3.5 percentage of coastal land (SRDI, 2010, Fig. 1). Interior coastal districts have been newly salinized about last four decades

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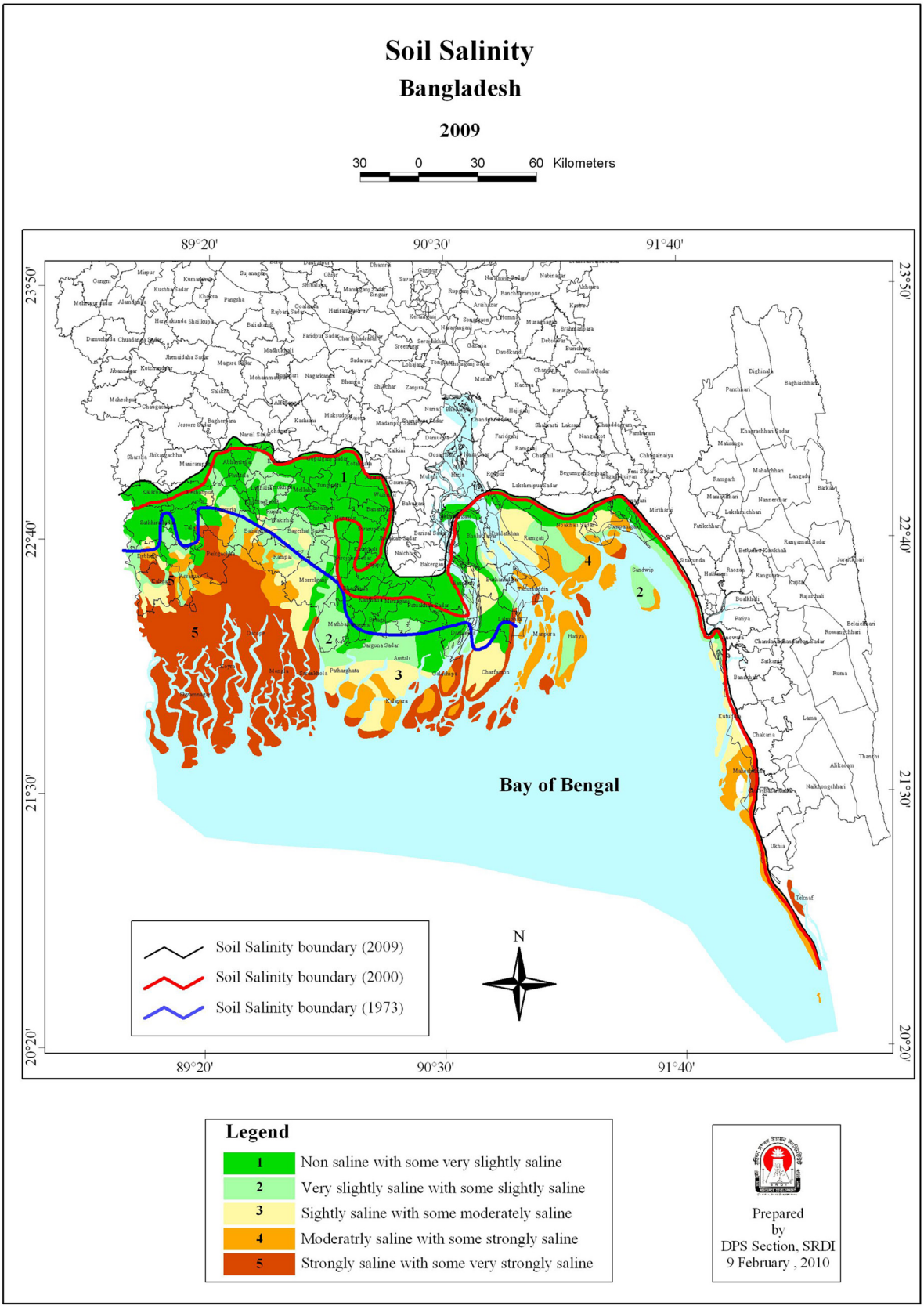


Fig. 1. Soil salinity line (source, BARC 2009).

and has increased significantly to 3.76 mha in 2007 from 2.96 mha in 2000 (Ahsan and Sattar, 2010). Therefore, Bangladesh has 12.5 decimals arable lands per capita due to dense population and the newly climatic changes has increased threat on shrinking lands too (Quasem, 2011).

To reduce salinity in the arable land farmers become dependent more on fertilizer. In Bangladesh subsidies are provided for chemical fertilizers, pesticides and irrigation equipment to enable farmers to accept these technologies for increasing crop yields (Hossain, 1988). Traditional cropping practices, such as mixed cropping, crop rotation, and inter-cropping are gradually being replaced by conventional farming (Hossain and Kashem, 1997). This has led to the increased practice of mono-cropping and a higher dependency on irrigation, inorganic fertilizers, and pesticides. Mono-cropping along with the inappropriate application of inorganic fertilizers, pesticides, and intensification of land use without usage of organic fertilizers has given rise to deterioration in soil quality and fertility (Hossain and Kashem, 1997; Rahman and Thapa, 1999). Increasing High Yield Varieties (HYV) crop requires chemical fertilizer to intensify its productions; studies found that fertilizer usage increased 12464.80 metric ton per kiloliter from 11354.44 in between 1996 and 2010 (CCC, 2009; BBS, 2011).

Damming of rivers, on the other hand also intensifies the effects of salinity and SLR. The Farrakha barrage is one example of the uneven distribution of water that is affecting the freshwater flow inside Bangladesh (Khalequzzaman, 2012). Tipaimukhi Dam, which would be constructed on the Tipaimukhi hydroelectric project of India, includes 226 big dams above the Borak River which is capable of producing 99,000 MW electricity (Khan, 2007). Low pressure on the upstream gives space to go up in saline tidal water further north and make surface water irrigation more difficult for crop agriculture (Roy et al., 2009). It has already been discovered that approximately 19 districts in the coastal zone are salinized, 30% of these are cultivable lands (located in southwest) and 53% has been severely salinized (Haque, 2006). Another study stated that salinity decreased the germination rate of some plants (Ashraf et al., 2002; Rashid et al., 2004). Construction of roads, industries and houses on the other hand are reducing 220 ha arable land daily, which is quite alarming (Islam et al.,2004).

The tidal effect is perceptible due to regular fluctuation of the rise and fall of the water level of sea and the tidal channels and creeks. The flow repeatedly inundates the soils and covers them with soluble salt that causes salinity in both soil and subsoil. Southwest zone is flooded every day twice at high tide in about 24 h. Daily inequality of tides is equally significant and generally ranges between 0.55 m and 0.15 m (Islam, 2004). This regular occurrence helps deposit silt as well as salt in inner land naturally.

A study from World Bank (2000) suggests that increased salinity alone will give rise to sea level by 0.3 m causing a net reduction of 0.5 million metric tons of rice production. It has also been predicted that long term floods and restriction in irrigation would reduce *Aman* and *Boro* rice area; as a result, it might decline rice production nationally in the future (World Bank, 2000). Drainage congestion and resultant water logging are another important factor hampering crop agriculture in the southwest region (Roy, 2004). A study from National Adaptation Program Action (NAPA, 2005) indicates that a rise of 1–2° Celsius in combination with lower solar radiation causes sterility in rice spikelet. Studies showed evidence of reduced yield in HYVs (*Aus*, *Aman* and *Boro* rice) in all seasons in a warmer (by 4 °C) climatic scenario (NAPA, 2005). CROPWAT[1] outputs suggest Soil Moisture Deficit (SMD) would increase negligibly in the local *Boro* period, leaving the crop no added vulnerability while HYV *Boro* would show a climb in yield loss though SMD won't show any increase by 2030 and 2075 (Roy et al., 2009). CEGIS (2006) has predicted that, in southwestern coastal region the HYV of *Aman* rice would start losing land for cropping due to SLR. According to Jahiruddin and Satter (2010), depletion of soil fertility has arisen mainly due to the increased amount of cropping and the use of Modern Varieties (MVs), soil erosion, sandy soils, and higher decomposition of organic matter due to sub-tropical humid climate. In the southwest, communities are turning their crop land into shrimp farm which is provisionally profitable due to salinity. As a result almost 138, 600 ha of agricultural lands have been transformed in shrimp farms (Bala and Hossain, 2009). However, the establishment of such farms is decreasing crop land and increasing soil salinity through brackish water intrusion, in turn, reducing rice production (Bala and Hossain, 2009; Karim, 2006). Impact of saline intrusion on food security is a major concern for agriculture based countries such as Alexandria region in Egypt, Moroccan coast and Vietnam, were reducing crop production (Frihy, 2003; Wassmann et al., 2004; Snoussi et al., 2008).

This article aims to explore- a) local people's perception on salinity intrusion, b) its impact on food security in the context of interior coast of Bangladesh and c) how local people has adapted to it. To investigate, the article studied the possible reasons of the salinity encroachment in the study area including other districts and its impact on the crop production. Finally, by identifying the consequences of salinity on crop production along with influencing reasons, the article draws attention on the involvement of experts and development bodies to improve current scenario by further research.

The study conducted in five villages named *Joynagar*, *Panipara*, *khasial*, *Putimari* and *Dewli* under Khasial and Joynagar union[2] of Kalia upazila (sub-district) in the district of Narail. Kalia upzila, situated beside the Madhumati River, mostly depends on agriculture. 72.51% out of 151,052 ha farming land produces high yield varieties paddy including wheat, vegetable, sugarcane and other minor cereals (BBS, 2008). The area has extremely flat topography and is located within 1–5 m from the mean sea level (DHV-WARPO, 2000; Ahmed, 2008). Annual average temperature of the area varies from maximum 37.1 °C, minimum 11.2 °C; annual rainfall 1467 mm (BBS, 2013). Kalia upzila is 301.32 km^2; including 9.20 km^2 riverine area (BBS, 2013). Study areas have been newly salinized along with other interior districts such as Shariatpur, Jessore and Gopalgonj (Seal and Baten, 2012) but Narail has not been given any attention (Fig. 1) till date. Intrusion of salinity will lead to irregular production of food. What is more alarming is that salinity encroachment is already visible in some of the inland districts. It is one of the major reasons to select the study area including the agricultural importance in gross crop production and emerging threat on food security of the country.

2. Methodology

The primary data was collected during May to September in 2012 by five Focus Group Discussions (FGD) and eight in-depth interviews. Also transect walk was conducted to get an overview of demography of the study area. Secondary data was collected through existing research papers, articles and relevant organization in Bangladesh.

[1] CROPWAT model developed by the FAO was used to predict the soil moisture deficit (SMD) for the projected climate scenarios to assess crop water requirement (CWR) and variation in yield of the main rain fed crops in the said region.

[2] Small administrative unit of government.

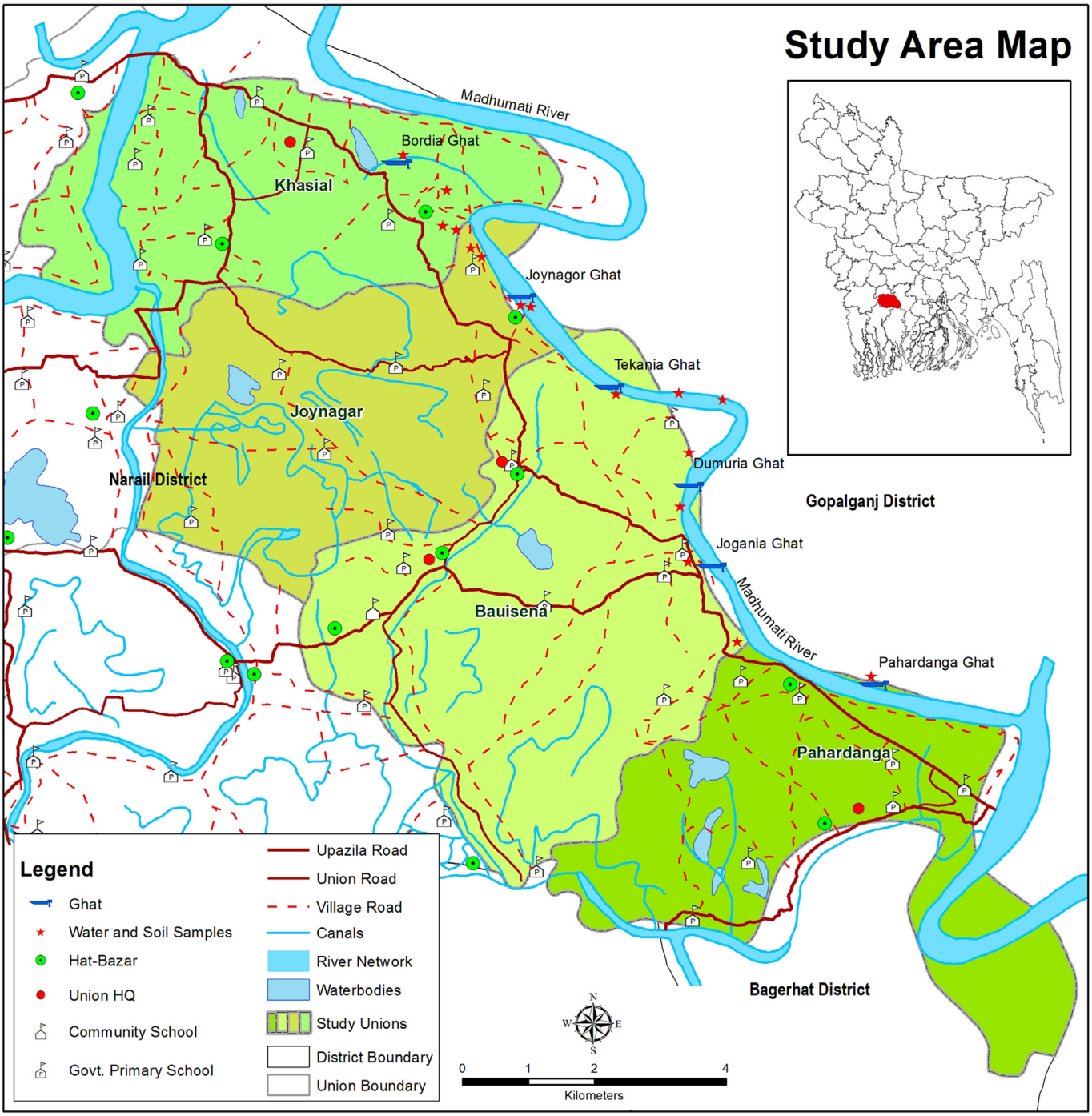
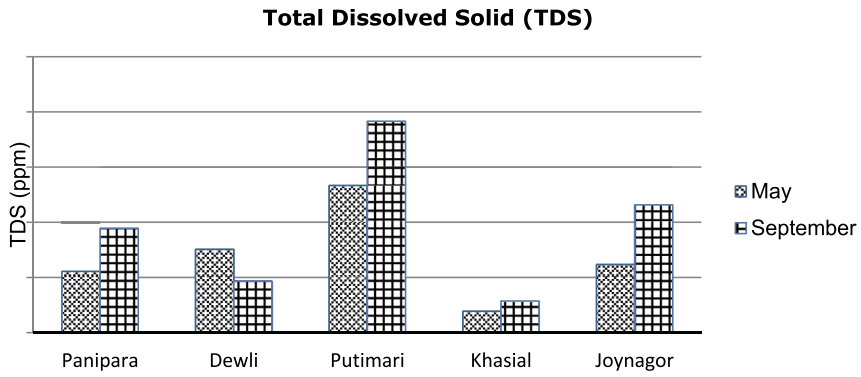


Fig. 2. Study area map.

The Geographic Positioning System (GPS) device was used to outline the study area (Fig. 2) along with to indicate water sample collection point in the Madhumati River. Laboratory test has been done on soil and water sample to measure salinity of sample that collected from deep tube-well and river from the study area. The examined deep tube-wells were 350 ft–440 ft deep. Electrical Conductivity (EC) and Total Dissolved Solid (TDS) process was applied to examine inorganic salts, particularly chlorides dissolved in water. TDS and EC one (Graph 1 & Table 2) was collected in May (the beginning of the monsoon) and TDS and EC two both were collected on September (beginning of dry season). The salinity measure tool, provided data in micro-Siemens format which had to be converted in deci-Siemens following this method (μS/cm × 0.1 = mS/m × 0.01 = dS/m). Saline problems may become evident when EC escalate 2 to 4 deci-Siemens per meter; otherwise the problems are usually minor for crops (Maas, 1985). When the EC extent from 4 to 8 deci-Siemens per meter, problems become more evident but crops with moderate salt tolerance usually show signs of reduced growth, foliage burn or chlorosis when its more than 8 (Maas, 1985). The sample was examined in 27 °C in the Environmental Science Laboratory, of Independent University Bangladesh (IUB).



Graph 1. Total Dissolved Solid in the deep tube well of the study area May & September 2012.

FGDs were carried out in groups for both men and women, but in some communities it was necessary to separate the groups into men and women. FGD and interviews were focused on local experiences on agriculture and how salinity intrusion has affected their lives. FGD sampling was done by stratified sampling consisted of 5–9 participants. This technique was used to find the specified group's problem in the actual term, despite of the presence of irreverent group and some groups selected as a snowball sampling. The group consisted with landowners, local businessmen, subsistence farmer or small fisherman. Semi-structured questionnaire was used to conduct interviews and open-ended questions were applied to conduct group discussion. In-depth interviewee participants were selected based on a simple random sampling technique. Both qualitative and quantitative approaches were applied to collect and analyze data. Based on both traditional and current perspective of the participants, two crop calendars were prepared to understand the changes.

3. Result and discussion

3.1. Result

From the local perception, the study area has experienced salinity for 10–12 years. The community has observed decline in soil cohesiveness and fertility distinctly. These changes have affected both crop production and construction of clay house. For instance, community produces 7–8 Mon[3] rice instead of ten to twelve Mon rice after a decade. Moreover, sugarcane, jute and varieties of oilseed cultivation have stopped due to reduced production. To prevent soil salinity, the community has increased usage of fertilizer that has also increased agricultural cost. As a result, many farmers prefer to cultivate one crop in a year instead of two or three crops.

Community besides the Madhumati River keep crop lands uncultivated most of the time of year due to soil salinity. As the dry season lasts longer (five to six months) than monsoon, farmer needs deep tube-well irrigation to continue agriculture since both river and surface water carries salt. Moreover, study communities perceived changes in traditional crop calendar, as *Kharif*-I[4] starts in April and ends in May instead of April-June span and *Kharif-II*[5] have also shifted from June-October to July-October. Study also revealed that winter crops grow only during November-February, which previously grew till mid-April. In the study area, there are other stressors that are affecting agriculture and intensifying salinity severely (Table 1).

Findings revealed that, salinity encroachment is not only affecting agriculture but also labor cost, fertilizer and pesticide expenses. Moreover land loss due to riverbank erosion is affecting rice cultivation negatively. As a result, rice cultivation is discouraged in the study area. Furthermore, it could not be identified whether the alternative crops or other rice varieties were able to adapt to salinity.

The study also discovered that the income of respondents ranges from 5000 to 6500 BDT (62.37–81.087 USD[6]) per month. This amount of income cannot afford agricultural cost along with family expenditure, claimed respondents. Farmers' cultivation expense is 1160 BDT (14.47 USD) for each Mon, while they sell crops on 800 BDT (9.98 USD). It was mentioned in the group discussion that during harvest, farmers have to pay 200–300 BDT (2.49–3.74 USD) for each worker. Because of that, young generation is more interested in alternative income sources like rickshaw pulling, *votvoti* (local taxi) driver or shopkeeper instead of being a farmer. To bare additional family cost, people tend to move to Khulna, Jessore and Dhaka region for non-farm jobs i.e. temporary works in shipyards and readymade garments factories in Khulna district. However, social forestation encouraged by the Bangladesh Forest Department (BFD) has become an alternative income source and there are thousands of wood trees planted along both side of the roads. There were existence of NGOs identified, like BRAC, ASA and Grameen bank mostly concentrated on the micro-credit program. While community expects assistance on livelihood and riverbank erosion problem, these two has been given least priority by development workers.

Laboratory investigation also discovered salinity in the soil and water sample of the study area. Both total dissolved solid (TDS) and electric conductivity (EC) method showed chloride presence in the sample collected from study areas (Graph 1& Table 2). In the dry season both TDS and EC has shown higher presence of chloride than monsoon season (Graph 1& Table 2). However, the Madhumati River water has not shown chloride presence significantly due to examine in monsoon season (Graph 2). Chloride as solvent and conductivity found at *Putimari* village higher than other study sites (Graph 1& Table 2), both in May and September where at *Khasial* village was lowest. TDS in *Joynagor* in September also shows a closer salinity range with the *Putimari*.

The level of soil salinity in the study area is less than 2 dS/m except in *Putimari*. However, the TDS of water sample is higher than expected drinking water quality.[7]

[3] One Mon is equivalent to 40 kg.
[4] Aus rice season.
[5] Aman rice season.
[6] One USD = 76.82 BDT (as of March 2016).
[7] TDS concentrations below 1000 mg/L is usually acceptable to consumers due to World Health Organization.

Table 1
Existing stressors and their impact in the study area.

Stress	Impacts on environment and agriculture
Salinity intrusion	Contaminating ground water and fresh water
	Increase soil salinity
	Lessening soil cohesiveness
	Decline soil fertility
	Intensification of fertilizer and pesticide usages
	Reduce rice production
	Cash crops like jute, sugarcane are not growing anymore
Water logging/flood	Decreasing soil fertility
	Increase diarrhea, skin itching and vector-borne diseases
	Fresh water contamination
	Delay cultivation period
Riverbank erosion	Land loss both arable and homestead
Increasing population	Lack of arable land
	Land loss due to new habitation

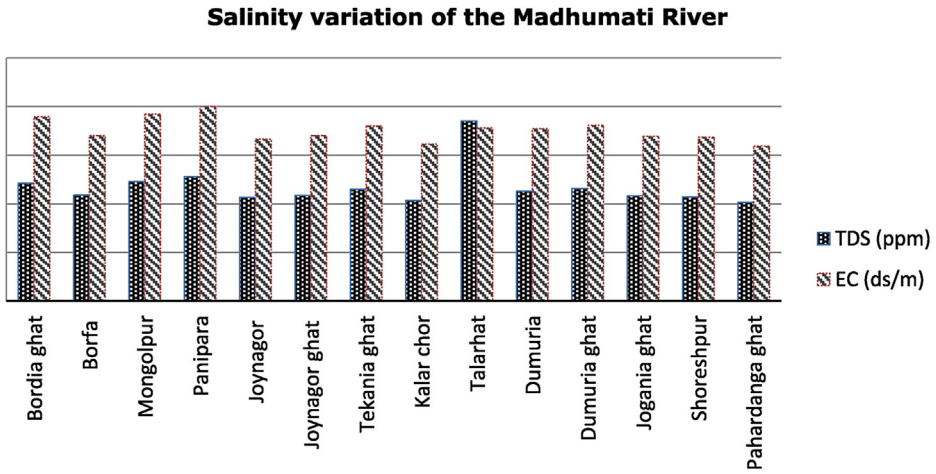
(Source, field study, 2012)

Table 2
Level of salinity (EC) in the study area of deep tube-well.

Study sites	May 2012 (dS/m)	September 2012 (dS/m)
Panipara	1.03	1.33
Dewli	0.326	0.659
Putimari	2.42	2.69
Khasial	0.367	0.404
Joynagar	0.264	1.629

(Source, field study 2012)

and southwest zone provides 5.04% of food in national production where rice alone is 4.37% (ASS, 2005). In the study area, cultivation of High Yield Varieties of rice (*Aus*, *Aman* and *Boro*) has increased (BBS, 2008) due to yield loss of native rice varieties, stated the respondents. To increase rice production, study area has amplified usage of fertilizer (urea, gypsum and sulphur). This could be another reason for salt deposition in soil. However, using excessive fertilizer not only increase salt in the soil but have other health impacts also on health (Darwish et al., 2005; Khan et al., 2011 cited



Graph 2. Salinity variation of Madhumati River in September 2012.

3.2. Discussion

Farming community is producing less rice than before and they are afraid it might decline more in the future. Saline tolerance is varied to different crops adopting capacity (Habibullah et al., 1999; CCC, 2009), regarding that, the study area is losing oilseed, jute and sugarcane due to salinity in soil. However, it is still favorable (Table 2) to rice cultivation. Unfortunately some other areas close to coast like Khulna, Shatkhira, Bagherhat districts are facing changes in native crops and biodiversity (Haque, 2006; SRDI, 2010). Previous studies show that salinity intrusion is one of the main reasons for decreasing crop yield and directly affects the yield of the most preferred crops, which was observed in the coastal zone (Karim et al., 1990; Sarwar, 2005). Coastal regions are contributing about 16% of the total rice production of the country (Mia and Islam 2005) in Shameem et al., 2014). This statement is applicable for the study area as the respondents mentioned – they are suffering from both water borne diseases and skin disease (itching of skin). On the other hand, increased usage of fertilizer is raising agriculture expenses, which the farmer communities find hard to cope with due to poverty. In Bangladesh most of the farmers are involved with crop sharing agriculture, in that case, famer shares their crop with land owners (Majumder et al., 2009). Historically, Bangladesh has more landless farmers than land owners, and the owners owns most part of the cultivable land and distribute them among the marginal or poor farmers (Majumder et al., 2009; Paprocki and Cons, 2014).

The whole situation becomes more complicated with arable land loss due to the Madhumati riverbank erosion. This makes farming difficult and in the process affects community's livelihood system. According to Bangladesh Water and Development Board

(BWDB, 2011), the Madhumati river system has trend to show two types chloride caring tendency in the month of May to September (BWDB, 2011). Presence of chloride is high before monsoon and salinity reduce after monsoon in the Madhumati River is evident in both field data (graph 2) and study from Institute of Water and Flood Management (IWFM, 2012). By characteristics Madhumati River like any other river in Bangladesh is prone to change channels frequently (Alam, 1996). From the field experience, the community mentioned that soil cohesiveness has decreased drastically and increased frequency of riverbank erosion could be a result of intensification of saline intrusion in soil as well. The study area, is facing land loss both arable and homestead (riverbank erosion and salinity intrusion), soil infertility (salinity), water contamination (saline and arsenic) and yield loss, which leading them for easy solution like migration or non-farm activities to improve lifestyle.

Costly and laborious farming leading the young generation to be rickshaw pullers, shopkeepers or migrates to nearest city for a day laborer job. Migration is a continuous process to improve livelihood i.e. seasonal migration (agriculture) or temporary migration (brickfield, garments, construction work) in the nearest cities (Mohit, 1990; Tacoli, 2009). In Bangladesh migration depends on availability of agricultural activities- when there is less farming activities the labor force seek alternative income sources (Shameem et al., 2014). Studied community reported, they prefer to migrate in the city to do construction work in shipyard, infrastructure and employment in readymade garments and now a days it is becoming recurrent. It is also a growing concern for the city to accommodate new comers and provide them city services, which may create another hassle for the community as well (Mohit, 1990; Kartiki, 2011). As the study aims to explore the relation among salinity intrusion and food security in the context of interior coast of Bangladesh, other emerging issues (migration, riverbank erosion, water logging) will be discussed vaguely to understand their relation with salinity. In Bangladesh coastal zone are already under saline line and approaching inside gradually (Alam, 1996; SRDI, 2010), although the study area has not any significant report on transformation of crop land into shrimp farm but there is a case of land loss due to riverbank erosion and soil infertility due to salinity. The selected area is a slightly saline prone zone (Fig. 1), but SLR and continuous low flow from the upstream water sources (Alam, 1996; Islam & Gnauck, 2011) will change the saline curve and sedimentation scenario in the interior coast of Bangladesh.

In the study area there is lack of initiative for adaptation regarding rice cultivation reported in the field investigation. But some coping strategies like salt tolerant rice, rain water harvesting or three F (fish, fruit, and farm) approaches are perceived in other coastal districts to minimize the impact of climate change induced phenomena (Gain et al., 2004). It should be mentioned that existing NGOs has less concentration on the mentioned issues in the studied area, although the community expected their presence more in the community in regards of agriculture and livelihood system. Some other major problems that are also inhibiting rice production are: long lasting water logging, late monsoon and riverbank erosion this is another indicator of climate change, that people are facing - late monsoon and long summer which is affecting crop production (Haque, 2006).

More than 100 countries are affected in varying degree of saline in different landform, irrigation regions and agricultural land (Shahid et al., 2013). Salinity intrusions due to sea level rise and human activities are well-known facts in the central Asia, arid or semiarid and even Russian federation (Shahid et al., 2013). Northern Thailand, Egypt, Syrdarya river basin in central Asia, who are dominant by agriculture are facing similar problem of reducing crop production and increase of unfertile lands due to saline encroachment (Shahid et al., 2013). A projection has been made by fourth assessment report of IPCC (2007) *Boro* rice and wheat production will be declined approximately 15354.38 MT and 355.50 MT respectively in 2100 against the base year 2010, projected under A2 scenario (IPCC, 2007; AR4). Furthermore, only salinity intrusion due to sea level rise will reduce 0.2 million metric ton of rice production (World Bank, 2000). It's a growing concern for those countries that are dependent on agriculture for food production for food security.

4. Conclusion

Five study areas under Kalia upzila has reported yield loss, and identify soil salinity as the main reason. This article documented people's experience along with scientific data regarding salinity intrusion and its impact on agriculture; including other push-factors (i.e. riverbank erosion, new habitation and land filling). Both climate change factors (i.e. sea level rise, tropical cyclones) and human activities (i.e. upstream damming and excessive usages fertilizer and pesticides) are amplifying salinity encroachment in interior coast. This has resulted into a costly but unprofitable and laborious farming system. At the same time it has diverted young generation to either non-farm activities or migration (seasonal and permanent) to another part of the country. Existing stakeholder and constitutional management worker are not emphasizing on salinity problem even though the situation is becoming more severe in the context of crop production.

To have a stable food production, it is necessary to increase crop yield in Bangladesh. Since food aid is decreasing and price is getting higher in the international food market, it will change the scenario of food security of Bangladesh in future. It is important to create awareness on fertilizer usage, crop varieties, introduce salt tolerant crops and alternative cropping system to boost up agriculture. Additionally, social forestation, homestead gardening and pond fishing can be encouraged as a substitute for dominant livelihood system for the interior coastal community. Involvement of experts in the matter and further study may be assist in finding alternatives to ensure food security and possible adaptation strategy.

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