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CLIMATE CHANGE AND LAND USE CHANGE IN THE EASTERN COASTAL BELT OF BANGLADESH, ELUCIDATED BY ANALYZING RICE PRODUCTION AREA IN THE PAST AND FUTURE

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Abstract: Climate change is an important issue now-a-days. Global warming i.e. climate change causes sea level rise and that affect the coastal agricultural areas of Bangladesh. The net-cropped area of eastern coastal zone in Bangladesh has been decreasing over the years due to various purposes and the most common one is the land inundation and salinity intrusion by tidal water. The main aims of the study is to assess the change in climatic conditions particularly temperature, rainfall and agricultural land use change in the past and future. Past rainfall, temperature and salinity data have been used to assess the climatic and salinity conditions of the area under investigation. Normalized difference vegetation Index (NDVI) and False Color Composite (FCC) of digital Land sat images have been used to identify land use pattern and Boro rice coverage area. During last 31 years (1978 -2009) 31% rice production land has converted to shrimp culture and salt farming. Salinity intrusion is one of the major causes of agricultural land use change. Salinity level has increased dramatically in dry season during last decade due to increase of temperature, low rainfall pattern, high evaporation rate and low water discharge to the river systems. Future landuse has been projected for 2039 by Markov Model. Result shows that rice production area will decrease rapidly due to salinity intrusion as well as climate change which may threat for food security of Bangladesh. Hereafter, the Government of Bangladesh, national and international institutions will have to work together for minimizing the effect of climate change for food security.

Keywords: Land use change, Climate change, Sea Level Rise, Salinity intrusion and Shrimp culture.

সারাংশঃ জলবায়ু পরিবর্তন বর্তমানে একটি গুরুত্বপূর্ণ বিষয়। বিশ্ব উষ্ণায়ন যেমন জলবায়ু পরিবর্তন সমুদ্রপৃষ্ঠের উচ্চতা বৃদ্ধির কারণ যা বাংলাদেশের উপকূলীয় কৃষি এলাকাকে প্রভাবিত করে। বাংলাদেশের পূর্ব উপকূলীয় অঞ্চলে প্রকৃত চাষকৃত এলাকা বিভিন্ন উদ্দেশ্য বছরে বছরে কমছে এবং সবচেয়ে সাধারণ হলো জোয়ারের পানি দ্বারা জমিতে প্লাবন ও লবণাক্ততার অনুপ্রবেশ। এই গবেষণার প্রধান উদ্দেশ্য হলো জলবায়ুগত অবস্থার, বিশেষ করে তাপমাত্রা ও বৃষ্টিপাতের পরিবর্তন এবং কৃষিজ ভূমি ব্যবহার পরিবর্তনের অতীত ও ভবিষ্যত মূল্যায়ন করা। জলবায়ু গত ও লবণাক্ততার অবস্থা মূল্যায়নের জন্য গবেষণা এলাকার অতীত তাপমাত্রা, বৃষ্টিপাত ও লবণাক্ততার তথ্য ব্যবহৃত হয়েছে। ভূমি ব্যবহারের ধরণ ও বোরোধান উৎপাদন এলাকা নির্ণয়ের জন্য ডিজিটাল Land Sat ছবির Normalized difference vegetation Index (NDVI) and False Color Composite (FCC) ব্যবহৃত হয়েছে। গত ৩১ বছরে (১৯৭৮-২০০৯) ৩১% ধান উৎপাদনশীল জমি চিংড়ি ও লবণ চাষের জমিতে রূপান্তরিত হয়েছে। কৃষিজ ভূমি ব্যবহার পরিবর্তনের জন্য লবণাক্ততা অনুপ্রবেশ একটি অন্যতম কারণ। তাপমাত্রা বৃদ্ধি, অল্প বৃষ্টিপাতের ধরণ, উচ্চ হারে বাষ্পীভবন ও নদী ব্যবস্থায় অল্প পানি প্রবাহের কারণে গত দশকে শুষ্ক মৌসুমে লবণাক্ততা নাটকীয় ভাবে বৃদ্ধি পেয়েছে। ভবিষ্যৎ ভূমি ব্যবহার মারকোভ মডেলের সাহায্যে ২০৩৯ সালের জন্য অভিক্ষেপিত হয়েছে। ফলাফল প্রদর্শন করে যে, লবণাক্ততা অনুপ্রবেশ ও জলবায়ু পরিবর্তনের জন্য ধান উৎপাদন এলাকা দ্রুত কমবে যা খাদ্য নিরাপত্তার জন্য হুমকি হতে পারে। ভবিষ্যতে, খাদ্য নিরাপত্তার জন্য জলবায়ু পরিবর্তনে প্রভাব কমানোর ক্ষেত্রে বাংলাদেশ সরকার, জাতীয় ও আর্ন্তজাতিক প্রতিষ্ঠানসমূহকে একত্রে কাজ করতে হবে।

Introduction

Bangladesh is the most vulnerable country of the world for climate change scenario. Climate change accelerated the intensity and frequency of occurrences of salinity, storms, drought, irregular rainfall, increase of temperature, flash floods, etc. that resulted from global warming, Climate Change and its associated hazards like sea level rise, cyclone and storm surge have been increasing the salinity intrusion problem in many folds (Seal and Baten, 2012). Climate change in combination with sea level rise would aggravate the soil salinity in the coastal region of the country. The average increase in temperature in Bangladesh would be 1.3°C and 2.6°C by the year 2030 and 2075 respectively with respect to the base year 1990 (Ahmed and Alam, 1998). Two estimates of potential future SLR for Bangladesh are 0.30-1.5 m and 0.30-0.50 m for 2050 (DoE, 1993). Analysis of meteorological data of 1977 and 1998 clearly shows annual sea level rise at the rate of 7.88 mm, 6 mm and 4 mm respectively in Cox's Bazar, Chardanga at Hatiya and Hiron point in Sundarban (Shamsuddoha and Chowdhury, 2007)

A substantial area of coastal land in Bangladesh has already eroded. It has been found that the sea level rise of 0.5 meter over the last 100 years has eroded approximately 162 sq. km. of Kutubdia, 147 sq. km. of Bhola and 117 sq. km. of Sandwip (CCC, 2009). However, the net-cropped area of coastal zone in Bangladesh has been decreasing over the years due to various purposes and the most common one is the land inundation and salinity intrusion towards the main land by tidal water. Fresh water reduction along with intrusion of saline water is perhaps the most devastating consequence of climate change in the coastal areas of Bangladesh. Already, 830,000 million hectares of land have been identified which are affected by soil salinity at different degrees (CCC, 2009). It is estimated that a net reduction of 0.5 million metric tons of rice production will take place due to a 0.3 meter sea level rise in coastal areas of Bangladesh (World bank, 2000). Due to climate change, land use of south-eastern coastal belt is changing rapidly. During last 31 years (1978 - 2009) 31% rice production land has converted to shrimp and salt farming area which is respectively

9715.38 hectares. Salinity intrusion is one of the main causes of reduction of agricultural land use. Salinity level has increased dramatically in dry season during last 31 years due to increase of temperature, low rainfall pattern, high evaporation rate and low discharge of water in river. Based on land use pattern of 2009 future landuse projection shows that rice and shrimp-salt production will be 16546.96 and 56370.36 hectares respectively. For food security, adaptation and mitigation are two options for Bangladesh. Of which, the first one is country specific, or even local specific, but mitigation demands collective efforts of global communities. Development of adaptation policies for agricultural sectors will help Bangladesh to face the crucial hazards of climate change and sea level rise. Lobby in the international communities will be helpful to mitigate CO_2 emissions by developing countries, which is responsible for global warming and sea level rise. Proper mitigation plan and formulating adaptation policies are emerging need to minimize climate change and sea level rise impacts on the country.

Research Objectives

The main objectives of the present research have been set as follows:

1. To assess the change in climatic conditions particularly temperature and rainfall.
2. To analyze agricultural land use change in the past and future.

Study Area

The coastal areas located in southern part of Bangladesh. The area is the most extended plain landmass located between 20°45′N to 23°20′N latitude and 88°57′E to 92°10′E longitude (Figure 1). The climate and rainfall distribution of the area is of tropical nature dominated by the southwest monsoon of the Indian Ocean. Tidal and estuarine floodplains cover almost 98% of the coastal area. Small areas (2%) with river and peat basins are found in the northern part of the coastal area. Tidal floodplains occur in Satkhira, Khulna, Bagerhat, Pirozpur, Jhalukhati, Barisal, Patuakhali, Chittagong and Cox’s Bazar districts. Above mentioned areas cover a total of 18,65,000 ha which is 65% of the coastal area. Estuarine floodplains occur in Noakhali, Bhola and Patuakhali districts and in the north-western part of Chittagong district. They cover about 9,37,000 ha or about 33% of the coastal area (Haque, 2006)

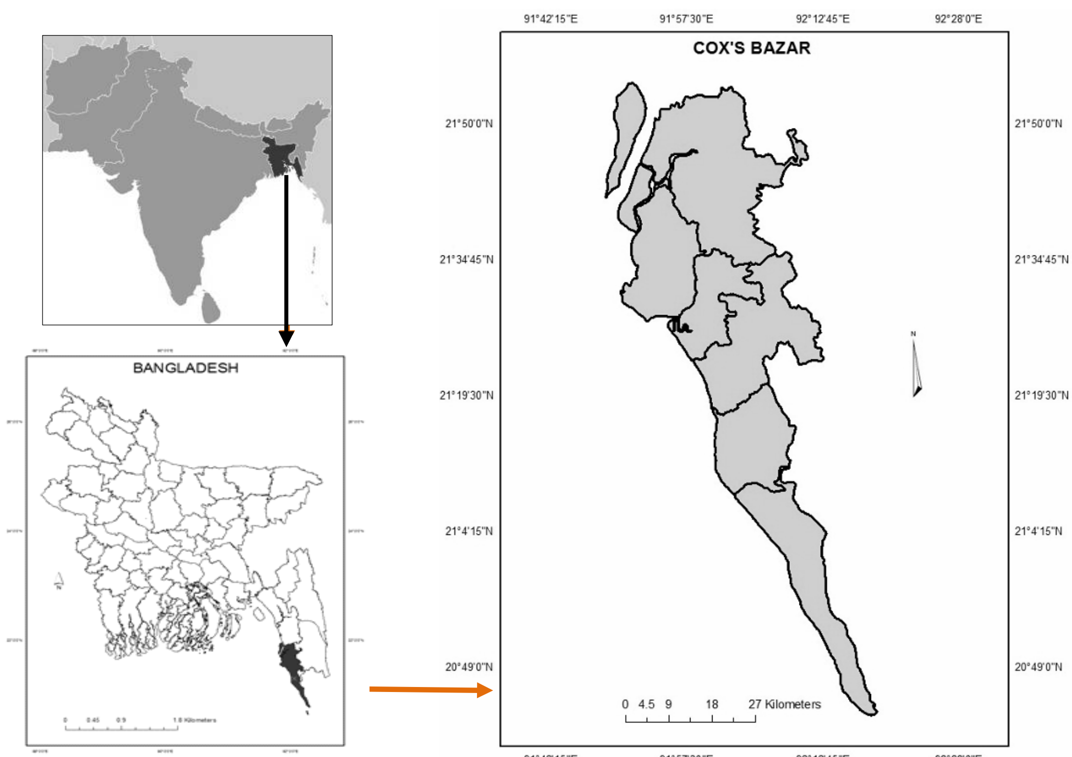


Fig. 1: Study area
Source: LGED, 2009

Data and Methodology

The main theme of the present study is the evaluation of climate change with respect to major food crop area under production. With a view to achieving and fulfilling the objectives, data have been collected from the primary and secondary source. In this study past temperature, rainfall, Sea level rise, evaporation, water discharge and salinity data have been used to analyze climate change and salinity intrusion. Simultaneously Landsat Digital Imagery of four different years (1978, 1989, 2001 and 2009) have been used to analyze and future projection of agricultural landuse change.

Secondary data collection

Climatic study is a long term study. It usually requires the observations and collection of data for a period of about two to three decades for measuring actually what is going on in the climate condition. Hence, it is very difficult to use primary data for any scientific inference. In the present study, the secondary data has been extensively used to investigate the ongoing changes (although very infinitesimal) of the climate. The secondary sources from where the information regarding climatic phenomena have been collected are; Bangladesh Meteorological Department (BMD), Bangladesh Agricultural Research Institute (BARI), reports/ maps from relevant organizations such as Soil Resource Development Institute (SRDI) , Coast and Equity Trust, books, journals, national and international publications, articles, newspapers and internet surfing.

Method of analysis

Various sorts of softwares have been used for processing spatial and non-spatial data set like i) Idrisi Selva 17.0 ii) Arc GIS 9.3 iii) Cartalinx and iv**)** MS Excel (for simple statistical analysis). It is well known that using satellite image is most common and easiest method of identify major food crop land of an area. In this research, Remote sensing landsat digital data of different years have been selected for land use mapping like Landsat TM on 10 March 2009, Landsat ETM on 19 March 1999, Land sat TM on 22 March 1989 and Landsat MSS on 07 March 1978. As the images are not upplied in usable format in research, so those will have been processed though some techniques like geometric and radiometric correction to make them usable. Later those images have been geo referenced using software Idrisi Selva.

Normalized difference vegetation Index (NDVI) and False Color Composite (FCC) images have been used to categorize the vegetation and identify land use pattern. To make the images workable the data needed to be transformed in to a uniform ground co-ordinate system a proper map projection was chosen. Geometric correction for the Landsat-TM image has been done using a set of ground control points (GCP) generated from orbital parameters. The image reference system was converted in to Bangladesh Transverse Mercator (BTM) system. Based on the variations in reflectance patterns found in the FCC images 22 terrain areas have been selected. Later the terrain areas have been located using GPS and land use patterns have been detected. Finally supervised classification is used to identify the land use pattern. NDVI is suitable for vegetation identification but not suitable for general land use classification. Therefore, FCC is used to identify general land use pattern such as shrimp farm, salt bed, Hill area. Using the DN value range from the curve different land use type in the image has been detected. GIS techniques are used for mapping.

To monitor climate change, climatic data like temperature, rainfall and evaporation is analyzed by MS-Excel software. Soil and water salinity intrusion has also been monitored by time series analysis. Finally an attempt has been made to predict the future major food crop production area through analyzing the satellite image using Markov model. Landsat satellite images of the corresponding years were used as the input of the model. Then the model will have been simulated to generate several future major food crop production maps for several time intervals. Acceptable accuracy will have been achieved through comparing short time simulated map and available major food crop production map of the corresponding time.

Trend of Climate Change in Cox’s Bazar

Bangladesh is a subtropical monsoon climate characterized by wide seasonal variations in rainfall, moderately warm temperatures, and high humidity. The climatic parameter i.e. rainfall and temperature of cox’s bazar district has changed rapidly during last 31 years.

Annual Temperature:

Temperature trends during last 31 years (1978-2009) based on observed data of BMD, annual minimum and maximum both have a tendency to increase. Maximum and minimum temperature both have increase 1.44 °C and 1.18 °C respectively during last 31 years (1978-2009) which has been shown in the Figure – 2 given bellow.

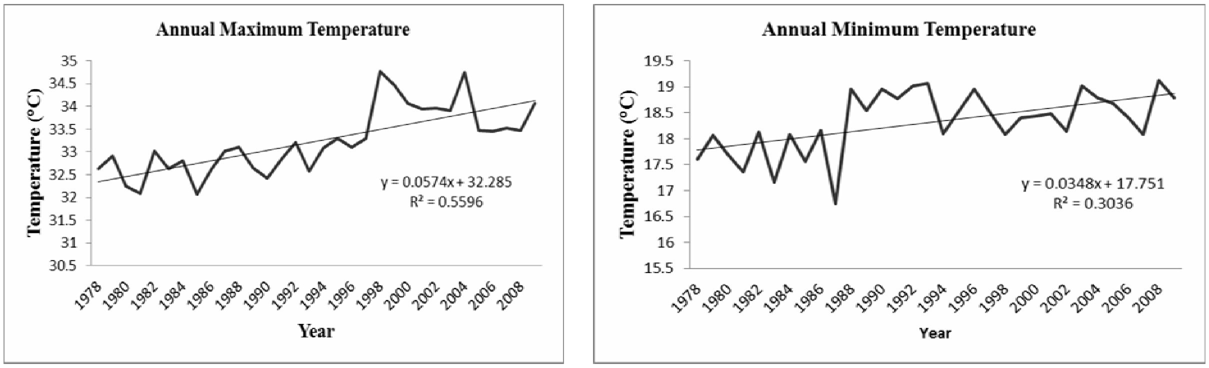


Fig. 2 Temporal variation of annual maximum and minimum temperature of Cox's bazar during 1978-2009
Source: BMD

Decadal and Seasonal variation of Temperature:

In winter, maximum temperature was highest (30.46°C) in 2000s and lowest (29.92) in 1950s, whereas, minimum temperature was highest (16.96°C) in 2000s and lowest (15.33°C) in 1950s. In case of pre-monsoon, highest (32.37°C) and lowest (31.28°C) maximum temperature was recorded in 2000s and 1960s respectively, while highest (23.80°C) and lowest (23.08°C) minimum temperature was in 2000s and in 1950s respectively.

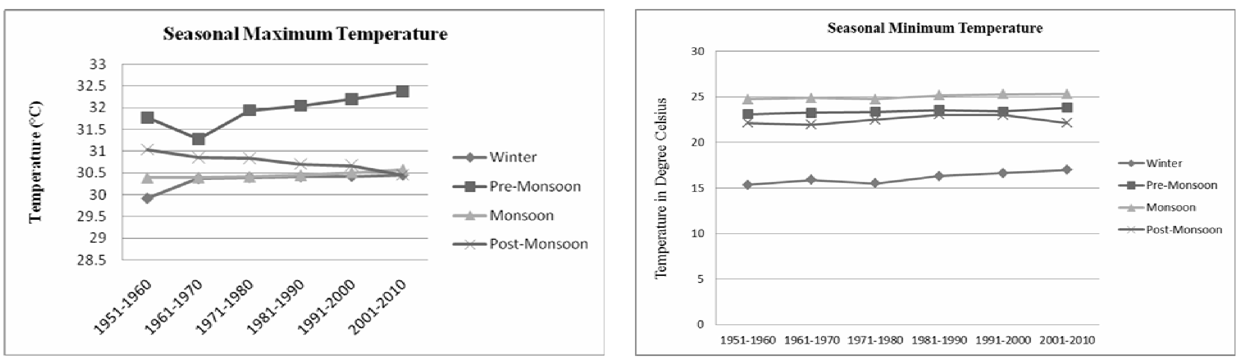


Fig. 3 Seasonal variation of maximum and minimum temperature during last 60 years
Source: BMD

In monsoon, highest (30.58°C) and lowest (30.39 °C) Maximum temperature was recorded in 2000s and 1950s respectively, in contrast, minimum temperature was highest (25.32 °C) and lowest (24.73 °C) in 2000s and 1970s respectively. However, maximum temperature in post-monsoon was highest (31.03 °C) in 1950s and lowest (30.45 °C) in 2010 respectively, whereas, highest (23.02 °C) and lowest (21.94°C) minimum temperature was in 1980s and in 1960 s respectively. Considering four seasons, it is clear that maximum temperature was highest in pre-monsoon, while minimum temperature was highest in monsoon which has been shown in the Figure – 3.

Rainfall

Average rainfall during last 31 years (1978-2009) has a positive trend with a slight decrease in monsoon season (Figure 4). Highest average (17 mm) amount of rainfall was recorded in winter season in year 2000s, while in 1980s lowest average (4.00 mm) rainfall was occurred. In case of pre-monsoon season, heighest average (158 mm) rainfall was recorded in the last decade (2000-2010), whereas, minimum (79 mm) was in 1950-1960 decade. Recent last decade (2000-2010) has received the highest average rainfall than previous decade in pre-monsoon season. So, from this analysis it is clear that trend in rainfall increment was Positive in pre-monsoon. Highest average (808 mm) and lowest (693 mm) rainfall in monsoon was recorded in 1950-60 and in 2000-2010 respectively. In case of post monsoon Maximum average (207 mm) and minimum average (88 mm) amount of rainfall was recorded in 1950-60 and 2000-2010 respectively. Considering four seasons, it is found that at Cox's Bazar, monsoon was the highest rainfall occurring season during last three decades which has been shown in the Figure – 4 given bellow.

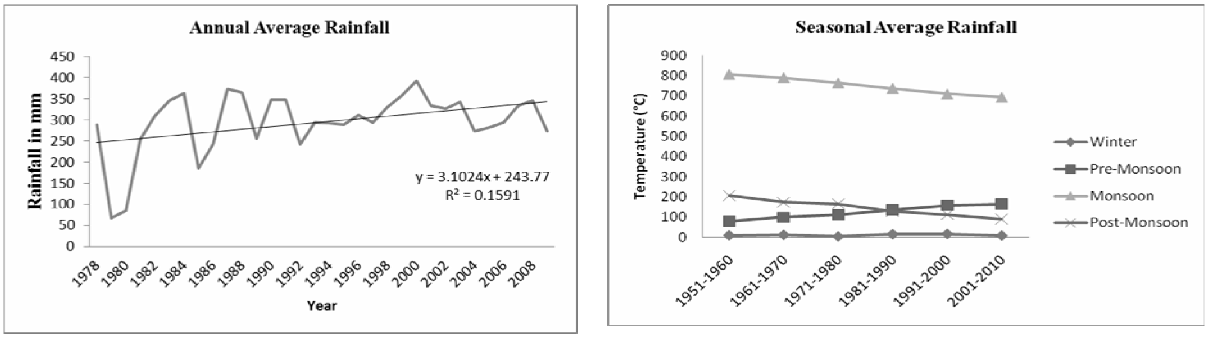


Fig. 4 Temporal variation of annual average and seasonal rainfall of Cox's Bazar during 1978-2009.
Source: BMD

Change of Coastal Shore Line

The SLR will inflict its impacts on Bangladesh in the coastal area and through the coastal area, on the whole of Bangladesh. About 2,500, 8,000 and 14,000 sq km of land (with a corresponding percentage of 2%, 5% and 10% with respect to the total land area of the country) will be lost due to SLR of 0.1m, 0.3m and 1.0m respectively (Ali, 2000). The potential land loss estimated by IPCC (2001) is even worse. It reports 29,846 sq km area of land will be lost and 14.8 million people will be landless by 1 m SLR. Due to Sea Level Rise (SLR) Coastal shore line is changing rapidly at Cox'sbazar. During last 31 years 0.63 sq Km coastal land has submerged which has been shown in the Figure – 5 given bellow. Most changes occurred in the south part of Moheshkhali Island and Teknaf.

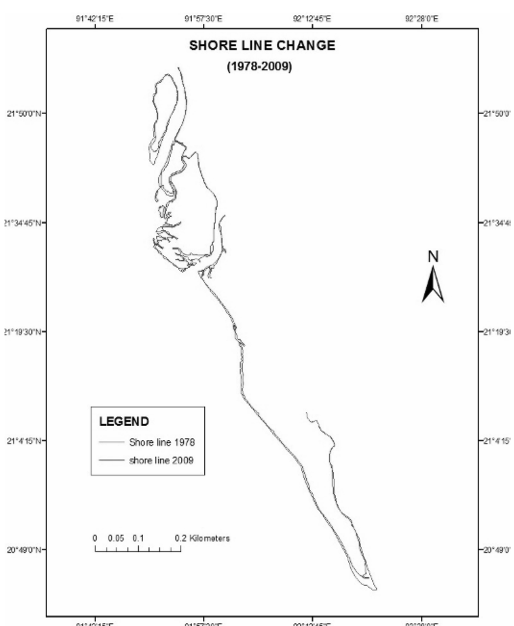


Fig. 5 Changes of coastal shore line in Cox's Bazar
Source: prepared based on the Landsat MSS-1978, TM-2009 and the result obtained by the author

Land Salinization in Cox's Bazar

Soil salinity of the study area varied from location to location and season to season. From the findings it can be said that soil salinity depend on annual rainfall, maximum temperature, evaporation and discharge. In monsoon, soil gets enough water and soil salinity decreases as rain water dilutes the concentration of salt in the soil. In post-monsoon, soil salinity starts to increase because of lower rainfall and higher evaporation of moisture from soil surface. Increasing soil salinity continues up to pre-monsoon when soil becomes water stress condition. Maximum soil salinity was observed in pre-monsoon, whereas, minimum was in monsoon. It was observed that soil salinity starts increasing from post-monsoon and continued to increase pre-monsoon when it reached the highest level. Highest (1.14 dS/cm) soil salinity was measured in pre-monsoon at Shahporir Dwip (Teknaf) of Cox's Bazar. Highest average soil salinity in winter (1.09 dS/cm) and in pre-monsoon (1.12 dS/cm) was measured at Cox's Bazar which has been shown in the Figure – 6 given bellow. Salinity is closely related to climatic variable like rainfall, temperature, evaporation and hydraulic variable like fresh water discharge.

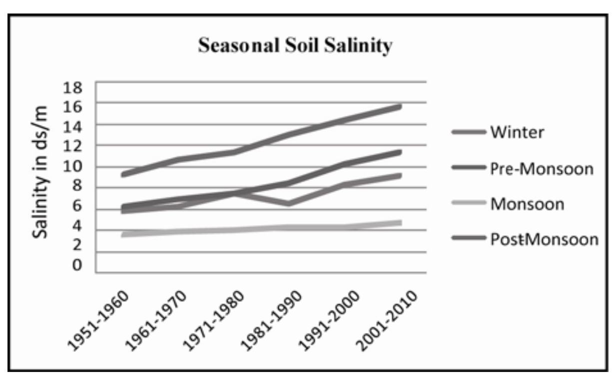


Fig. 6 Seasonal and Decadal Soil Salinity at Cox'sbaza
Source: SRDI

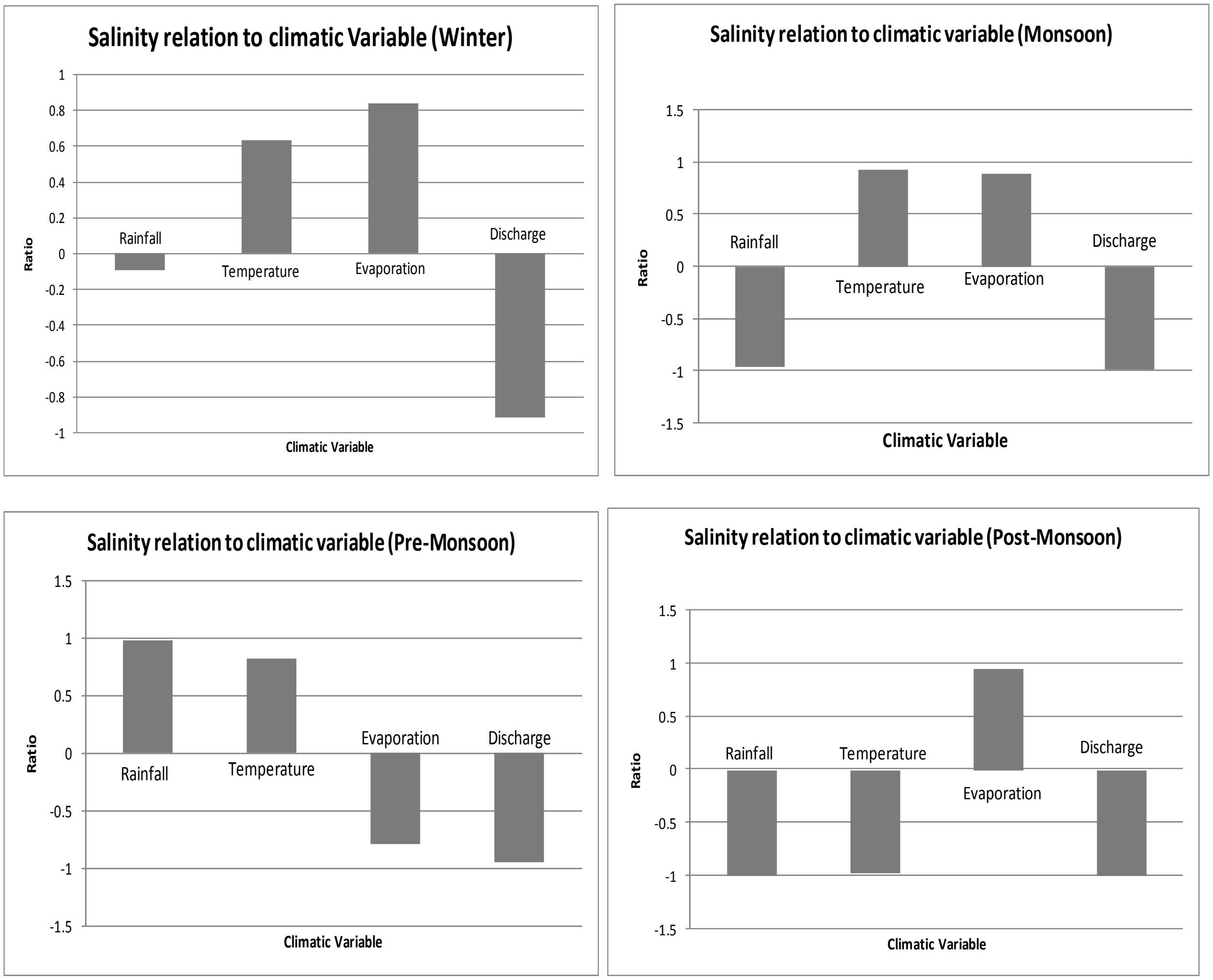


Fig. 7 Salinity relationship with climatic and hydrological variables
Source: Author

The correlation analysis which has been shown in the Figure –7 shows that there is seasonally positive and negative impact of climatic variable on soil salinity. Temperature and evporation are positively; on the other hand rainfall and discharge are negatively related to soil salinity level in both winter and monsoon season. In Pre-Monsoon, rainfall and temperature are positively; as opposed to evaporation and discharge are negatively related to soil salinity. Rainfall, temperature and discharge are negatively related to soil salinity, only discharge is positively related in post-monsoon season.

Landuse of Cox'sBazar:

Landuse of the study area is changing rapidly due to climate change. Most of changes occur in agricultural land during last 31 years which has been shown in the Figure – 8 given bellow.

Salinity intrusion under climate change and sea level rise is one of the main factors for land degradation and land use change. In 1978, forest including mangrove was the major land cover type which accounted 65945.20 hectares. Shrimp and salt farm cover area was 22627.20 hectares (11%). Rice cover area was 9% which accounted 15561.47 hectares; the second largest land cover type was hill and bare soil type including which accounted 58580.63 hectares (30%) respectively. In 2009, main land use type was hill and bare soil which accounted 67341.76 hectares (34%) respectively. Third and fourth largest land use type was shrimp and salt, rice field which accounted 21% and 13% area of total land.

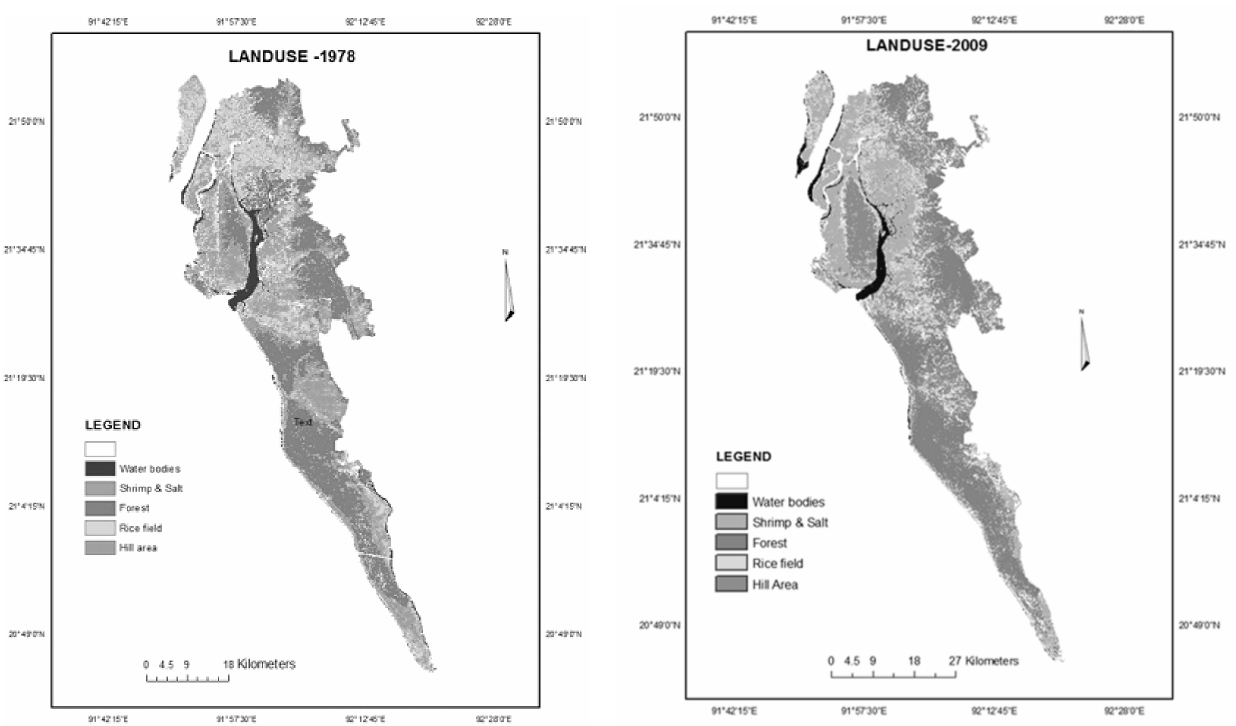


Fig. 8 Showing the result of Landuse in 1978 and 2009.
Source: prepared based on the Landsat MSS-1978, TM-2009 and the result obtained by the author

Trend of Land use Change:

Main landuse change occurred in rice and shrimp-salt sector. Shrimp-salt farms has increased and conversrely rice field has increased during 31 years (1978-2009). Simultaniously hill and baresoil cover area has increased respectively. Water bodies, Shrimp-salt and Hill-bare soil has increased to 3076.73 hectares (1.50%), 18956.63 hectares (9.46%) and 8761.12 hectares (4.08%) respectively. Conversely, due to salinity intrusion forest and rice field has decreased to 15446.77 hectares (8.23%) and 12996.76 hectares (6.82%) respectively. On the other hand due to lack of sustainable government planning total mangrove forest has vanished today.

Trend of Boro Rice field:

Boro rice coverage area has changed dramatically. The following graph (Figure 9) has been prepared based on Landsat MSS-1978, TM-2009 shows the decreasing trend. Boro rice cover areas have decreased (-33.78%) to 25456.52 76 hectares in 2009 from 38453.256 76 hectares in 1978.

Most changes occurred in during 1978-1989 because that time shrimp culture expanded rapidly. Unplanned landuse policy and climate change are the main causes of winter rice covere area change during 1978-1978.

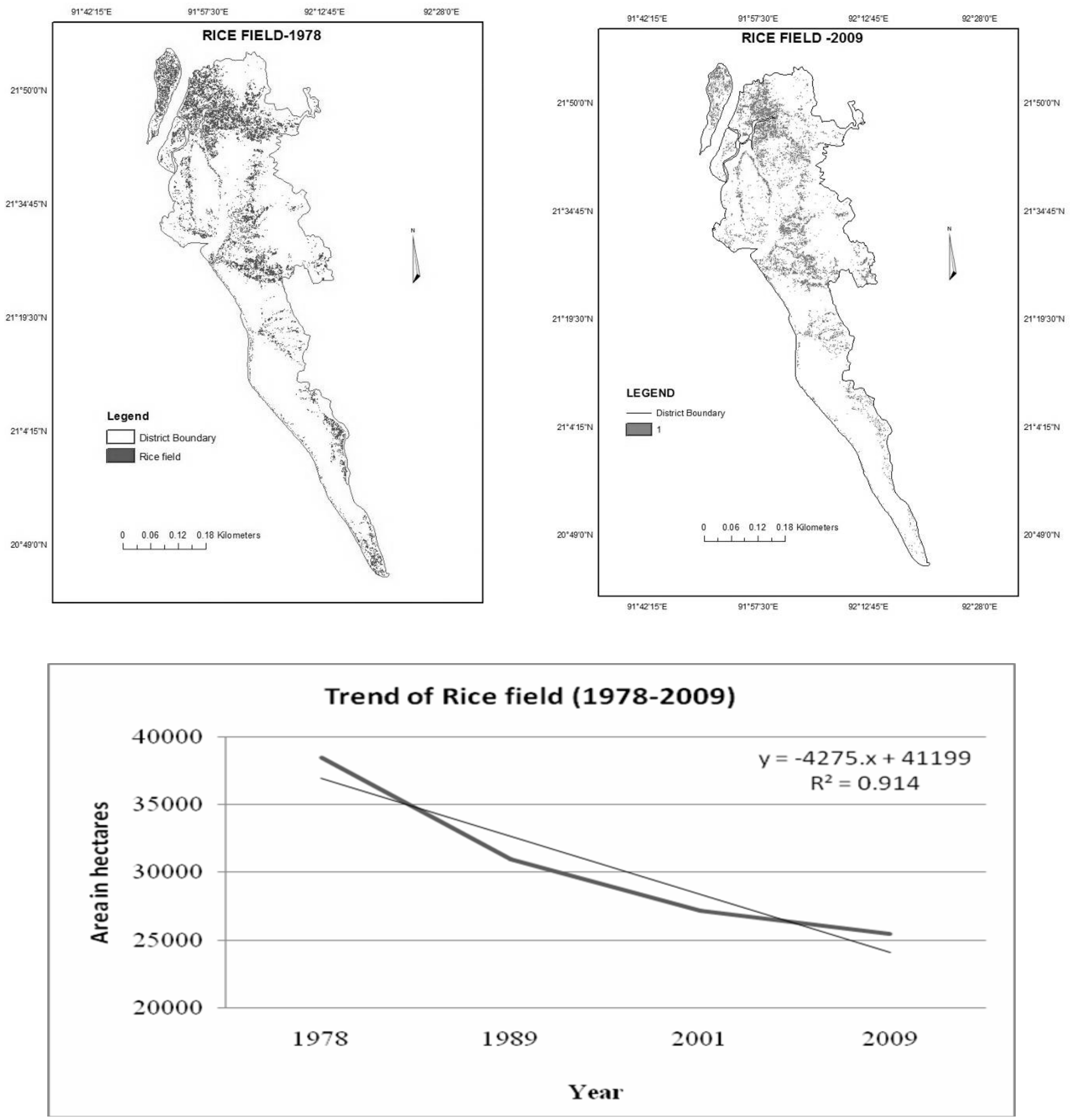


Fig. 9 Trend of rice field

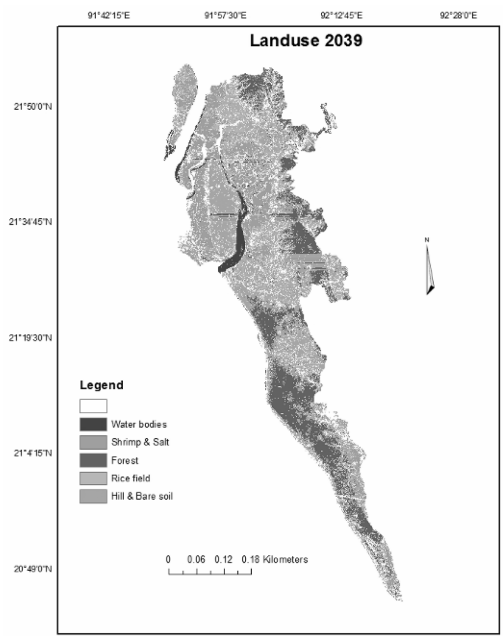
Land use projection by Markov Model

The Probability matrix (Table 1) shows that, 30% of rice field and 33% of forest land will be convert to Shrimp and Salt field and hill and bare soil respectively. Based on land use pattern of 2009, salt affected areas will increase (36.27%) to 56370.38 hectares in 2039. *Boro* rice cover areas will decrease (35.16%) to 16546.96 hectares in 2039 due to salt salinization and shrimp cultivation.

Table 1 Probability matrix of land use change to

Landuse \ Landuse	Water Bodies	Shrimp and Salt	Forest	Rice field	Hill and bare soil
Water Bodies	0.6573	0.2862	0.0018	0.0158	0.0387
Shrimp and Salt	0.0182	0.7928	0	0.1243	0.0646
Forest	0.0007	0.0538	0.5975	0.0098	0.3382
Rice field	0.0072	0.309	0.0027	0.3983	0.2828
Hill and bare soil	0.0017	0.0751	0.0744	0.1038	0.745

Source : Landsat MSS-1978, TM-2009



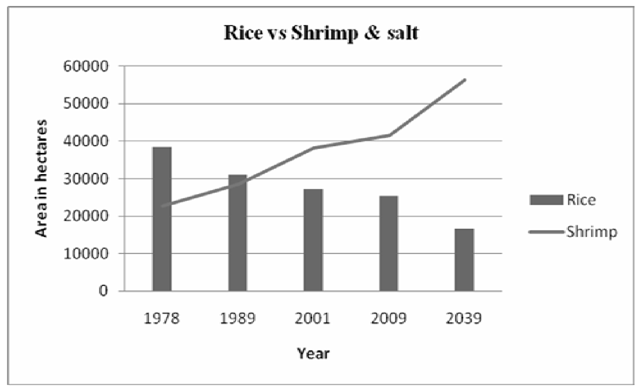


Fig. 10 Landuse projection

Key findings

i) Maximum & minimum temperatures show an increasing trend annually 0.05°C and 0.04°C respectively ii) Annual average precipitation has decreased (8.51%) during last 31 years, whereas pre-monsoon rainfall increased (3.04%). Max. temperature is increasing compared to min. temperature affecting boro rice production. Iii) Sea level rise trend is high in cox'sbazar (7.8 mm/year) during last 31 years iv) Due to sea level rise 0.63 sq. km area submerged during last 31 years v) Salt affected areas have remarkably increased (83.78 % increase) to 41583.84 hectares in 2009 from 22627.21 hectares in 1978 in cox's bazar. Land use projection (Figure 10) has been prepared based on Landsat MSS-1978, TM-2009 shows that salt affected areas will increase (36.27%) to 56370.38 hectares in 2039. vi) Boro rice cover areas have decreased (-33.78%) to 25456.52 hectares in 2009 from 38453.25 hectares in 1978. Based on Markov model Boro rice cover areas will decrease (35.16%) to 16546.96 hectares in 2039 due to salt salinization and shrimp cultivation.

Conclusion

Coastal Agriculture of Bangladesh is highly vulnerable due to climate change and Sea Level Rise. The intensity of disasters like sea level rise, tidal surge, soil salinity, salt water intrusion and cyclone in coastal belt are being increased. Consequently, the crop area is reducing. The study shows that Maximum & minimum temperatures have an increasing trend annually 0.05 °C and 0.04°C respectively. Annual average precipitation has decreased (8.51%) during last 31 years, whereas pre-monsoon rainfall increased (3.04%). Annual average precipitation has decreased (8.51%) during last 31 years, whereas pre-monsoon rainfall has increased (3.04%).Sea level rise trend is high in Cox's Bazar (7.8 mm/year) and 0.63 sq. km area submerged due to sea level rise during last 31 years. Sea Level will rise 14cm and 32 cm respectively by 2030 and 2050(World Bank 2000). Average increasing rate of maximum water level at Baghkhali river is 0.415 m during 31 years. Salt affected areas have remarkably increased (83.78 % increase) to 41583.84 hectares in 2009 from 22627.21 hectares in 1978 in Cox's Bazar. As per Markov model salt affected areas will increase (36.27%) to 56370.378 hectares in 2039. Simultiniously, Boro rice cover areas have decreased (-33.78%) to 25456.52 hectares in 2009 from 38453.26 hectares in 1978. Based on Markov model Boro rice cover areas will decrease (35.16%) to 16546.96 hectares in 2039 due to salinization and shrimp cultivation. Salt affected areas have significantly increased (26.71 % increase) to 950,780 hectares in 2009 from 750,350 hectares in 1973 in the western, central and eastern coastal region of Bangladesh. Average yield level of HYV *Boro* is being affected (30-40 % yield loss) by high temperature (causing sterility) and salinity intrusion (Miah, 2010).

Adaptation and mitigation are two options for Bangladesh. Of which, the first one is country specific, or even local specific, but mitigation demands collective efforts of global communities. Development of adaptation policies for different sectors will help Bangladesh to face the crucial natural and anthropogenic hazards. Proper mitigation plan and formulating adaptation policies are emerging need to minimize the impacts of climate change and sea level rise in the country.

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