CLIMATE CHANGE IMPACTS ON CROP YIELD, ARABLE LAND AND CHANGES IN WETLAND AREA IN RAJSHAHI DISTRICT, BANGLADESH

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ABSTRACT
Today climate change is an issue of great concern for the world. This paper explores the effect of climate change on water resources and agriculture in greater Rajshahi district of Bangladesh and deals with the effect of climate change on crop yield, long-term effect of drought over cropland and changes of wetland. For these purposes, rice, Wheat, and Potato crop has been selected. The effect of climate change on crop yield is shown by developing a relationship among maximum temperature, minimum temperature and rainfall. The change in the wetland area is shown by analysing Landsat satellite images using GIS and Remote Sensing technology. Results revealed that maximum temperature positively influenced Aus, Aman, potato yield and negatively affected yield of Boro and wheat. Minimum temperature adversely affected all crops except Aman and Boro. Rainfall showed less prominent influence for increase in yield. Rice, sugarcane, maize had decreasing trend in cropland area whereas increasing trend of cropland area was noticeable for potato, wheat, pulse etc. From 2006-2011, Rajshahi lost about 17% of its wetland and about 7% wetland lost from 2011-2016. All these information prove that Rajshahi district is very vulnerable in face of food security and existing water resources in this region.

Keywords: Climate change; agriculture; wetland; remote sensing; GIS; Bangladesh

INTRODUCTION
The problem of climate change is extensive, broad, and a threat to human civilization. The factors, which influence climate change, also affect the agricultural production. So it is natural that climate change will affect the agriculture. Agriculture in Bangladesh is mostly influenced by temperature and rainfall. Due to impact of climate change there may result a change in property and yield of crop. So food security will face a great risk. A study found that 1°C increase in maximum temperature at vegetative, reproductive and ripening stages there was decrease in *Amman* (Nvember and December harvest) rice production by 2.94, 53.06, and 17.28 tons respectively and with the change in temperature (by 2°C and 4°C), the prospect of growing Wheat and Potato would be severely impaired (Baten et al., 2008). It is predicted that yield of rice and Wheat will decrease 8% and 32% respectively in Bangladesh within 2050 and by the end of 21st century overall crop production will decrease 30% *(IPCC*, 2007). Rajshahi, a district of northwestern part of Bangladesh is mostly affected by climate change where two seasons are seen to be appeared among six seasons in a year, summer, and rainy season. Other seasons can be realized very little. In this district, there is almost no rainfall in rainy season (Ashar and Sravon month). In the month of October (Ashwin), there occurs so intense rainfall that creates waterlogging. So rain fed crops face a great problem and their growing season also hampers. Due to this, agricultural lands are used for another crop production, which can withstand this weather. Rice, Wheat and Potato are the crops, which are very sensitive to temperature and rainfall. They need different temperature and rainfall for their different growth stages. Due to increased temperature, ponds, canals are drying out. Also for earning more benefit, farmers are more interested to make cropland into water-body to cultivate fish. So the area of wetlands is not constant but changing day by day. Several papers have shown temperature and rainfall change effect on crop yield and their risk assessment in northwestern part of Bangladesh but no paper, to my best of my knowledge, have shown temperature and rainfall effect on cropland and crop yield simultaneously in

Rajshahi district. Shopan and Islam (2013) have shown changes in wetland area in northwestern area of Bangladesh but this paper focuses only changes in wetland area in most climate change prone district Rajshahi. The objectives of this study are i) to investigate the effect on crop yield due to change in temperature and rainfall in the area for three main cereal species i.e. rice, Wheat, Potato ii) to evaluate changing pattern of cropland for these crops due to cultivation of alternative crops which are more sustainable in changed weather iii) to estimate the changes of wetland.

METHODOLOGY

In order to investigate the effect of climate change on crop yield, data of last 12 years (2004-2015) of rice, Wheat, Potato of different upozilla in Rajshahi district are collected from Department of Agricultural Extension, Rajshahi. Data includes yield of the crops mentioned above, amount of cropland and average crop yield and last 12 years temperature and rainfall data. Here, ArcGis 10.1® has been used for analyzing satellite image to estimate wetland area.

Satellite Image

To estimate the wetland area, GIS and remote sensing technology is applied. Shopon and Islam (ICWFM 2013) have shown this method before. The difference is that here Landsat scenes of 2006, 2011 and 2016 are used. Images represent dry season of Bangladesh as they have been captured in Late January to Late February on different images. It is assumed that temporal changes of water bodies remain insignificant over this period. Properties of the images are presented in Table 1.

Table 1: Properties of downloaded satellite images

Image No.	Acquisition Date	Satellite Sensor
1	February 27, 2006	Landsat 4-5 TM
2	February 17, 2011	Landsat7ETM+SLC-off
3	January 06, 2016	Landsat8 OLI/TIRS

Image Processing

ArcGIS® 10.1 has been used to process Landsat images Satellite data as mentioned earlier are geocoded with topographical maps using ground control points. Conversion of image from digital number to At-sensor and radiance to top-of-atmosphere (TOA) reflectance is done according to the equation given in Landsat handbook of NASA. In order to determine wetland area, in Rajshahi district of Bangladesh, the Normalized different water index (NDWI) (described in details in section 2.3) maps are prepared from satellite images. Then the map is reclassified into different NDWI values using “Reclassify” in spatial analyst toolbox of ArcGis. NDWI with positive values are taken into consideration as water features have positive values while soil and terrestrial vegetation features have zero for negative values (McFeeters, S.K, 1996). Then this raster map is converted to vector map (the summation of many polygons). Area of polygon, corresponding to water-body is calculated in square-metre. Then this area is converted to hectare. Wetland area obtained from three different satellite images for different time interval is used to find out the changes.

Using NDWI to delineate water body feature

Normalized different water index (NDWI) is a method developed primarily to delineate open water features and to enhance their presence in remotely sensed digital imagery while simultaneously eliminating soil and terrestrial vegetation features (McFeeters, S.K, 1996). The NDWI is calculated as follows:

$$NDWI = \frac{GREEN - NIR}{GREEN + NIR} \qquad (1)$$

Where, green is band that encompasses reflected green light and NIR represents reflected near infrared radiation.

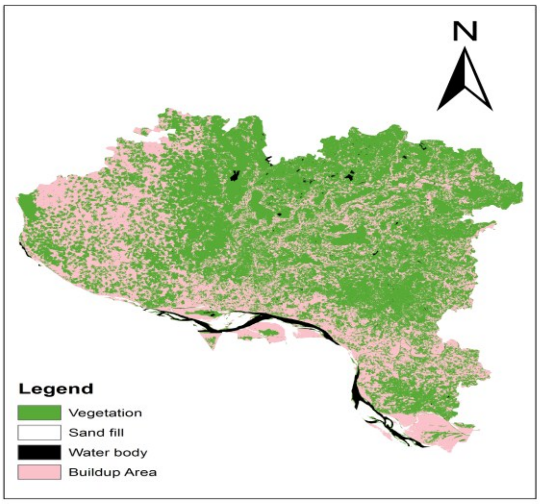

Fig. 1: Supervised classified image of Rajshahi district showing different land use.

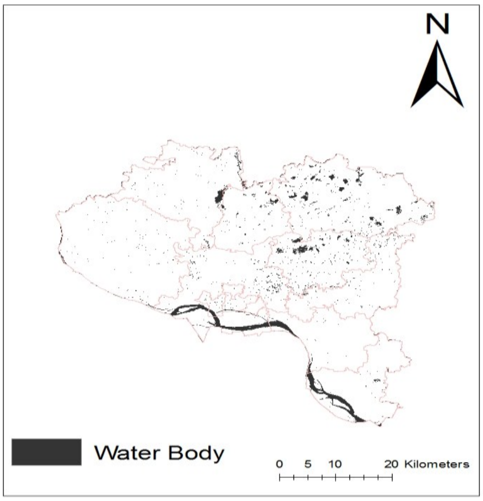

Fig. 2: Map of wetland area in Rajshai district on 06 January 2016.

NIR is observed strong by water and is reflected strongly by vegetation and dry soil. NIR data shows vegetated surfaces as being white, white water surfaces appear dark. The selection of green and NIR band was done to 1) maximize the typical reflectance of water features by using green light wavelength 2) minimize the low reflectance of NIR by water features and 3) take advantage of the high reflectance of NIR by terrestrial vegetation and soil features. Image processing software can easily be configured to delete negative values. This effectively eliminates the terrestrial vegetation and soil information and retains the open water information for analysis. The range of NDWI is then from zero to one. Multiplying equation (1) by a scale factor (e.g., 255) enhances the resultant image for visual interpretation.

Estimation of wetland area

NDWI values which have positive value indicate water feature if the digital number of NIR band of a pixel is less than digital number of red band and the green band the NDWI is ≥ 0.44, then it is classified as water, otherwise not. So wetland=NDWI≥0.44 (Goel et al., 2009). Figure 2 shows a NDWI map of water body of Rajshahi district on o6 january 2016.

DESCRIPTION OF THE STUDY AREA

Location and topography

Rajshahi district is a district in north western Bangladesh and bounded by Naogaon district to the north, Natore district to the east and Chapai Nababganj district and the river Padma to the south. There are different types of land found in Rajshahi district. Among these lands, high lands 37.97%, medium high land 23.38%, medium low land 23.36%, low land 8.43% and very low land 6.86% covers the total land area.

Rainfall

Rajshahi has a tropical wet and dry climate. The climate of Rajshahi district is marked with moderate rainfall. Between driest and wettest months, the difference in precipitation is 299 mm. The annual rainfall in the district is about 1448 mm (57 in).

Temperature

The climate of Rajsahi district is marked with high temperature. The hot season commences early in March and continues till the middle of July. The maximum mean temperature observed is about 32 to

36°C. During the month of April, May, June and July and the minimum temperature recorded in January is about 7 to 16°C.

Major crops

There are three cropping seasons Rabi, Kharif-I and Kharif-II in Rajshahi district. Important crops in Kharif season are Aman, Sugarcane, Jute, Maize, Cotton etc. In the Rabi season, crops need cool climate during growth period but warm climate during the germination period of seed and maturation. The major crops are Wheat, linseed, mustard, Potato etc.

RESULTS AND DISCUSSIONS

Temperature and rainfall variation

Maximum temperature is statistically significant for all rice yields with positive effects on Aus and Aman rice. The influence of maximum temperature and minimum temperature compared with that rainfall (Sarker et al., 2012). Optimum Temperature for maximum photosynthesis ranges from 25°C to 30°C for rice under the climatic condition of Bangladesh (Basak, 2010).

In figure 3, the trend of change in temperature shows that highest maximum temperature was in 2014 and deviates 1.62°C from mean temperature 40.83°C. Lowest minimum temperature was found in 2013 and deviates 1.03°C from mean 6.42°C. In figure 4, the trend of change in rainfall shows a decreasing trend over the period 2004-2015. Lowest rainfall was in 2010 and deviates 237mm from mean 1263mm.

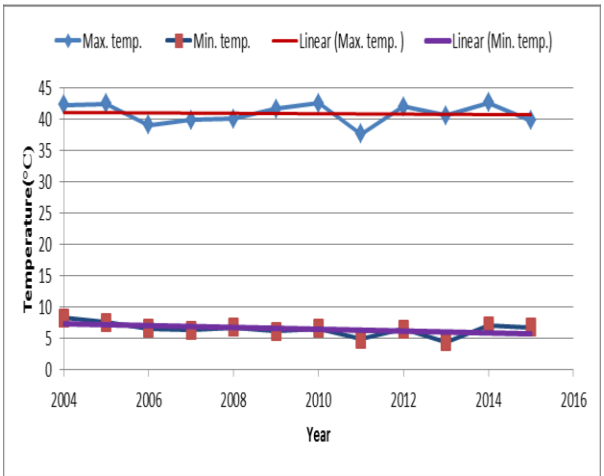

Fig. 3: Variation in average maximum and minimum temperature, 2004-2015.

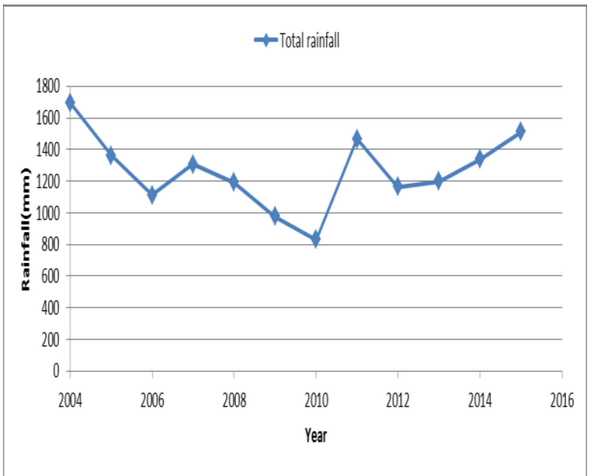

Fig. 4: Graphs showing variation in total rainfall, 2004-2015.

Effect on Crop Production

From figure 5, it is found that, maximum temperature shows a positive trend on yield of Aus rice. From 2010 to 2011, increase in maximum temperature of 1.69°C increased yield from 2.3 to 2.76 metric ton/ha. On the other hand, decrease in minimum temperature increases the yield. From figure 6, it can be shown that, rainfall trend doesn't play any dominant role on yield of Aus rice.

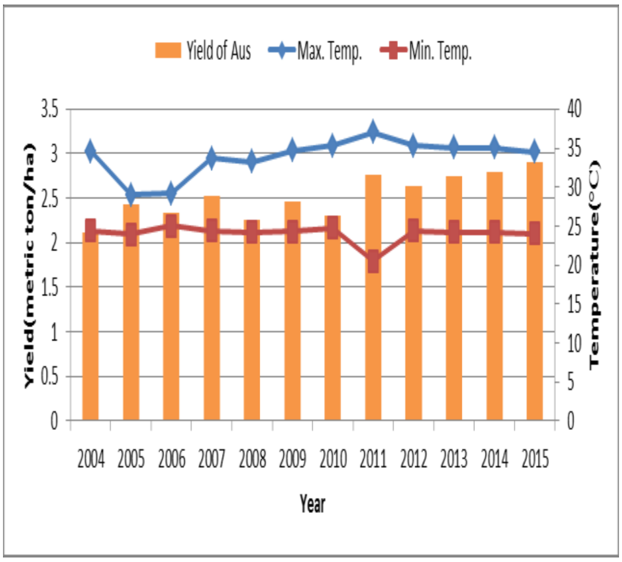

Fig. 5: Combined graph for Aus rice yield and temperature, 2004-2015

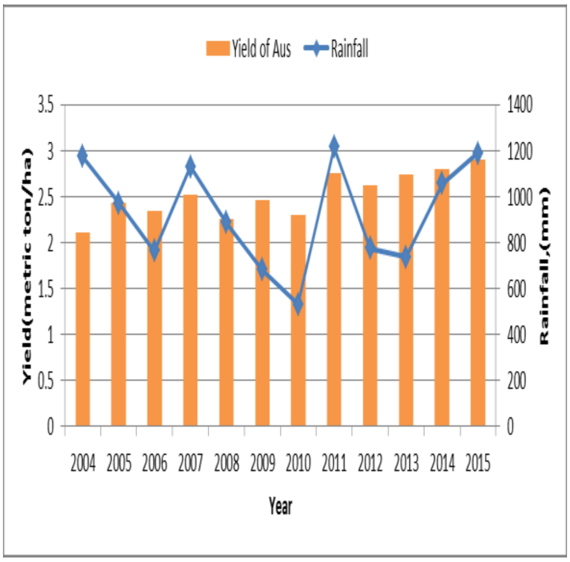

Fig. 6: Combined graph for Aus rice yield and rainfall, 2004-2015

In case of Aman rice, both maximum and minimum temperature shows positive influence on yield of Aman rice (Figure 7). Effect of rainfall is not much prominent for yield of Aman rice (Figure 8).

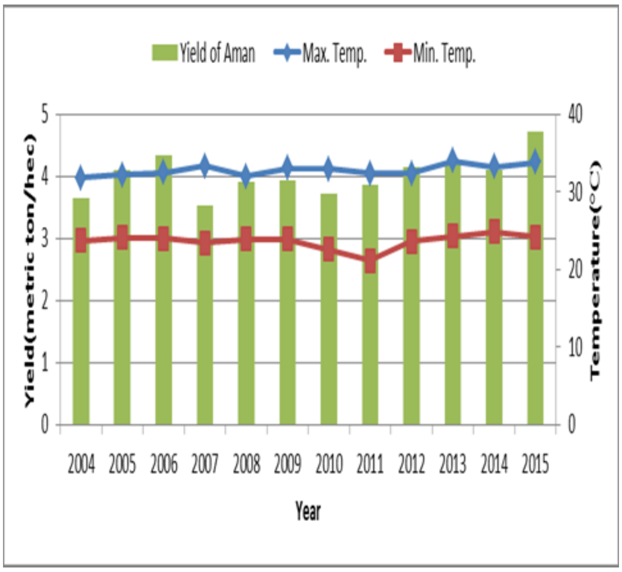

Fig. 7: Combined graph for Aman rice yield and temperature, 2004-2015

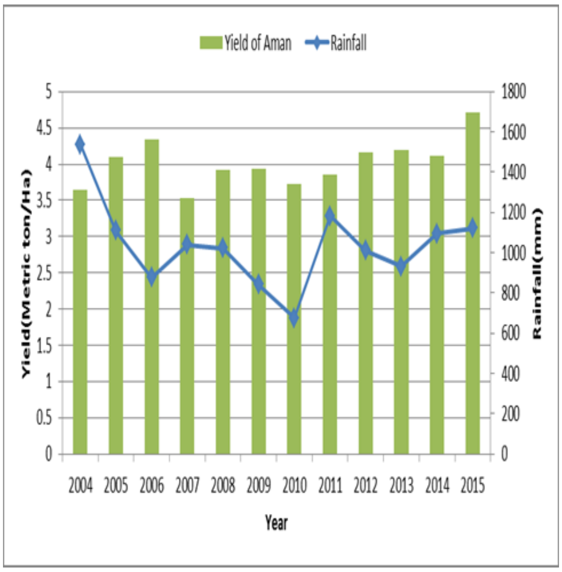

Fig. 8: Combined graph for Aman rice yield and rainfall, 2004-2015

In case of Boro rice, maximum temperature shows adverse effect on yield of Boro rice while minimum temperature benefited the yield (figure 9). Rainfall shows positive influence on yield of Boro rice with some exception (figure 10).
In case of wheat, both maximum temperature and minimum temperature adversely affected yield of wheat (figure 11). Rainfall shows positive influence with some exception (figure 12).
In case of potato, maximum temperature shows a positive effect on yield of potato and minimum temperature shows opposite relation with yield (figure 13). Here, influence of rainfall adversely affected yield of potato (figure 14).

Fig. 9: Combined graph for Boro rice yield and temperature, 2004-2015.

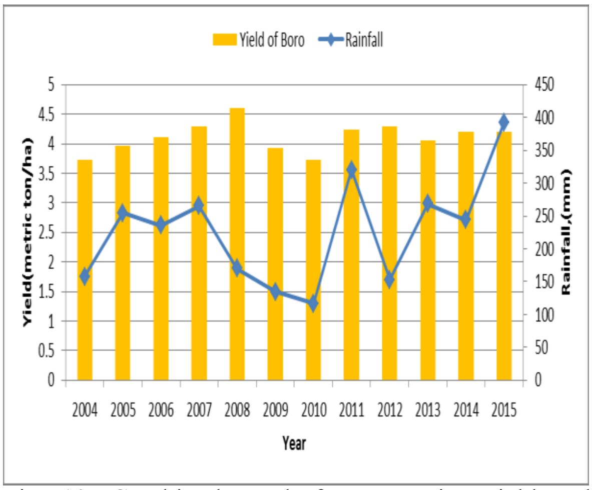

Fig. 10: Combined graph for Boro rice yield and rainfall, 2004-2015.

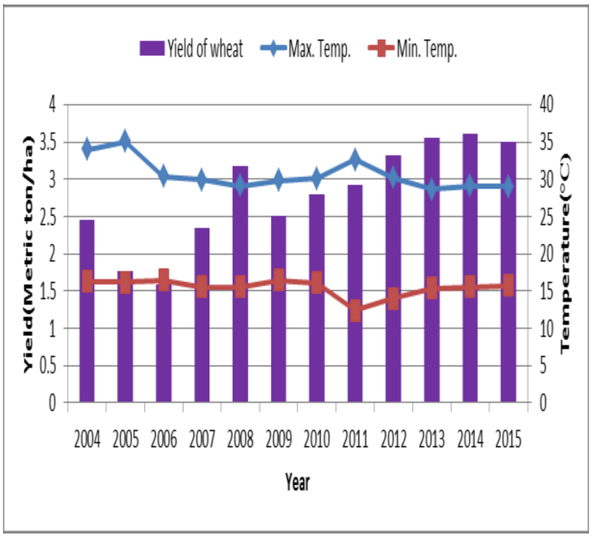

Fig. 11: Combined graph for wheat yield and temperature, 2004-2015.

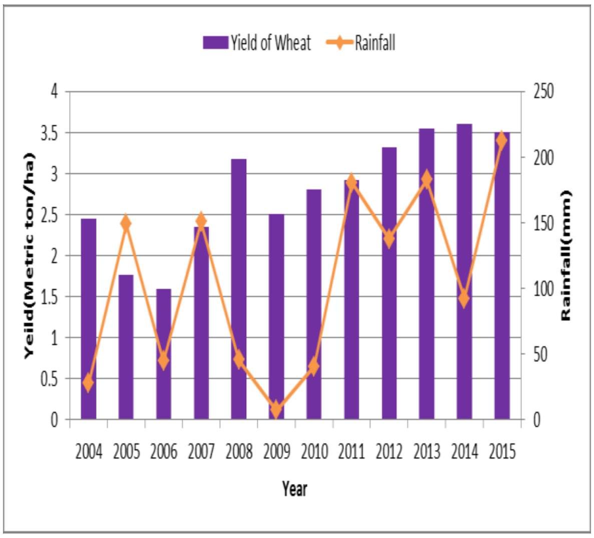

Fig. 12: Combined graph for wheat yield and rainfall, 2004-2015

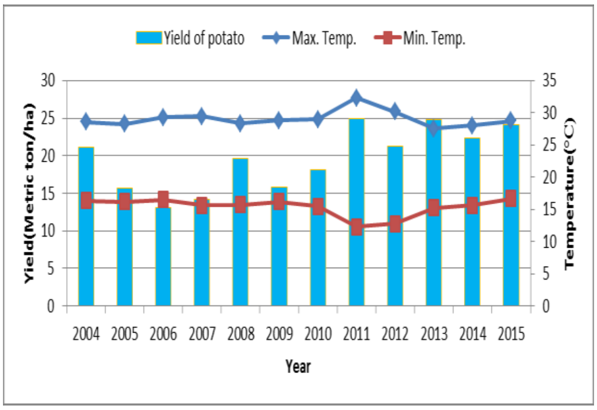

Fig. 13: Combined graph for potato yield and temperature, 2004-2015.

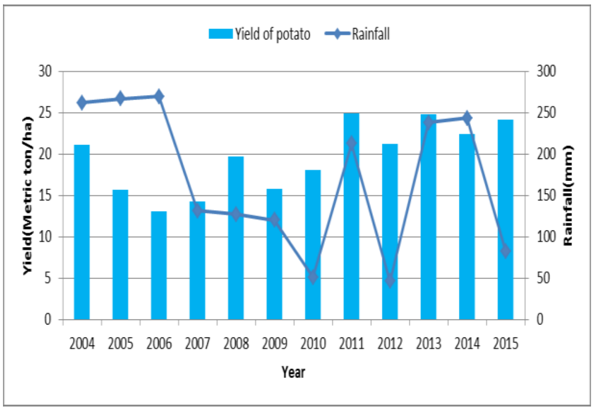

Fig. 14: Combined graph for potato yield and rainfall, 2004-2015.

Effect on Cropland

From the graph, it is clear that there is decreasing trend of cropland area for rice, sugarcane, maize, jute. On the other hand, it shows an increasing trend of cropping area for vegetable, Pulse, mustard, onion, Potato and Wheat.

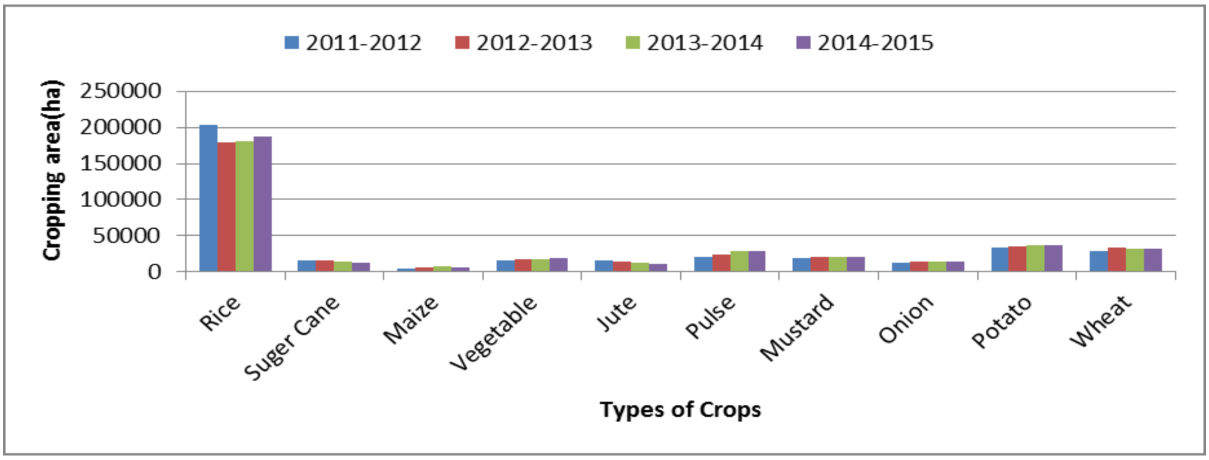

Fig. 15: Graph showing variation in changing pattern of cropping area for different crops

Effect on Wetland Area

Table 2: Changes in wetland areas in Rajshahi district during the dry period

Time Period			Change in wetland area(Ha)	Percentage Change (%)	Change in Wetland area per year(Ha)	Percentage Change per year (%)
From	To	Year Interval				
2006	2011	5	-1114.58	-17.82	-222.92	-3.56
2011	2016	5	-390.87	-7.6	-78.17	-1.52

From the above table, it is found that, there is a decreasing trend in wetland since 2006. During 2006-2011 and 2011-2016, Rajshahi district has lost more than 17% and 7% of its wetland.

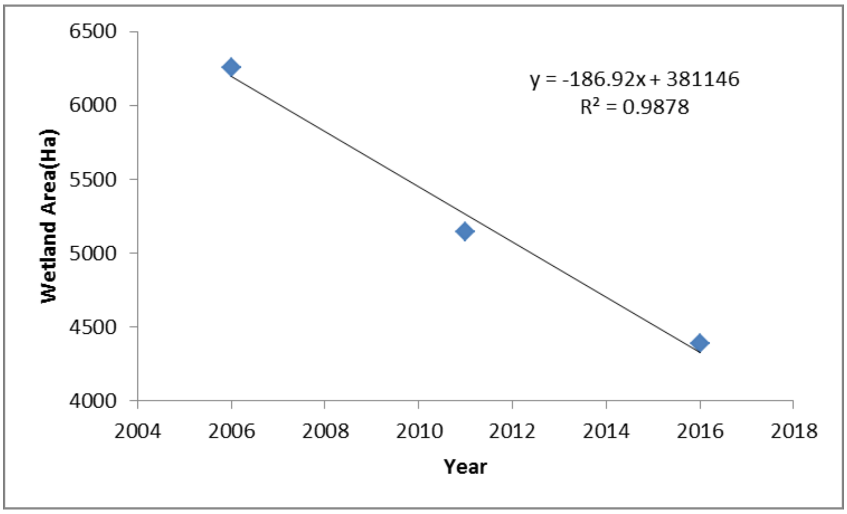

Fig. 16: Change in wetland area in Rajshahi district during the dry period

CONCLUSIONS AND RECOMMENDATION

To investigate the impact of climate change in Rajshahi district, change in crop yield due to temperature and rainfall variation, changing pattern of cropland area and changes in wetland area are the prime concern of this study. In case of Aus and Aman rice, maximum temperature shows positive influence on yield. Boro, wheat and potato are negatively affected by maximum temperature. According to (Sarker et al., 2012), maximum temperature is statistically significant for all rice yields with positive effects on Aus and Aman rice and negative effects on Boro rice. Minimum temperature inversely related to Aus, wheat, and potato yield and positively related with Aman and Boro. According to (Kabir, 2015), an increase in minimum temperature is likely to decrease the yield variability for Aus and Aman rice production while the yield variability for Boro rice is increased. On the other hand, rainfall shows very little on yield of major crops in this region. According to (Sarker et al., 2012), the influence of maximum and minimum temperature is more pronounced with that of rainfall. In case of cropland area, rice, sugarcane, maize have decreasing trend whereas pulse, wheat, potato are becoming more popular as they are more sustainable in changed weather. Sharp decreasing trend in wetland area are observed in Rajshahi district. During 2006 to 2011, about 17% of wetlands have been lost and 2011 to 2016, about 7% wetlands are converted into other types of land. Shopan and Islam (2013) have shown about 15% and 22% of wetland had been lost from 1989 to 2000 and 2000 to 2010 respectively in Rajshahi district. This indicates future desertification in this region. For future study, there also needs consideration for technology development, groundwater, humidity, sunshine, soil property in this region.

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