ISSN: 2224-0616
Int. J. Agril. Res. Innov. Tech. 12(2): 18-26, Dec 2022
DOI: https://doi.org/10.3329/ijarit.v12i2.64023

OPEN ACCESS
Available online at https://ijarit.webs.com
https://www.banglajol.info/index.php/IJARIT

Crop production amid climate change and river water level fluctuation at northeastern region of Bangladesh: A time series analysis

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Received 23 June 2022, Revised 26 October 2022, Accepted 22 December 2022, Published online 31 December 2022

A B S T R A C T

The overall goal of this study was to examine the effects of climate change on the yield of four distinct crops (Aus, Aman, Boro and Wheat) in Sylhet by using secondary climate data from 1970 to 2020. The study's other goal is to assess the impact of river water levels on crop productivity in Sylhet over time. Data on crop productivity, weather variability and river water levels were gathered from the various fields. Yield vs. climatic correlation was discovered in the study, and this correlation varied according to season. To estimate the impact of climate change on rice yield, a multiple regression model is used. Climate variables in the model were found to account for 11% of the overall variation in Aus rice yield. The relationship between relative humidity and maximum temperature is positive and statistically significant. Other variables had no effect on yield because they were not significant. Furthermore, Regression results indicated that climate variables account for 60.6 percent of the overall variation in Aman rice output. Relative humidity, on the other hand, can undermine the yield. Climate variables account for 53.5 percent of the overall variation in Boro rice output, according to the findings. As a result, an increase in rainfall may have a negative impact on Boro rice yield. Maximum and minimum temperatures might have a favorable impact on Boro rice yield. Increases in maximum temperature, on the other hand, can considerably boost Wheat yield while decreases in minimum temperature can diminish Wheat yield. On the other side, the results of the regression analysis suggest that river water level has a minor impact on Aus, Aman, and Boro yield. However, as the model demonstrates, the river water level can have an impact on wheat yield. The impact of temperature and rainfall on water level was also investigated in this study because the regression model failed to produce positive results. Surprisingly, the model performs well, despite the fact that maximum temperatures have a negative impact on water levels in the Aus and Aman seasons. This shows that if warmer temperatures aid raises Aus and Aman yields, then the water level cannot sabotage the yield rise. Rainfall has a favorable impact on the water levels in the Aus, Aman, and Boro seasons, but has a negative impact on the water levels in the Wheat season.

Keywords: Climate change, Crop yield, River water, Impact analysis

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Cite this article as: Uddin, G.T., Mishu, M.A., Hasan, M.T. and Choudhury, D. 2022. Crop production amid climate change and river water level fluctuation at northeastern region of Bangladesh: A time series analysis. *Int. J. Agril. Res. Innov. Tech.* 12(2): 18-26. https://doi.org/10.3329/ijarit.v12i2.64023

Introduction

Bangladesh is regarded as one of the world's most vulnerable countries to climate change and natural disasters. The country is situated in low-lying floodplains at the confluence of three powerful Asian rivers, the Brahmaputra, Ganges, and Meghna, as well as their countless tributaries (World Bank, 2010). Bangladesh's climate is shifting, and it is becoming more unpredictable every year. Temperature and rainfall variations caused by global warming are already visible in many places of the world, including our own country. Climate change has an impact on agriculture by having a biological effect on crop yield, which has an impact on costs, production, consumption and ultimately per capita calorie consumption and malnutrition.

Agriculture, the largest sector, is already under strain due to rising food demand and issues with agricultural land and water depletion (Amin *et al.*, 2015). However, due to limited cultivable land and the influence of climate change, Bangladesh is currently experiencing a significant difficulty in rice production to feed its growing population. Changes in temperature and rainfall caused by global warming are becoming visible on a worldwide scale, as well as in our own country. Temperature, rainfall, humidity and sun radiation are among climatic elements that influence agricultural production. Due to changing climatic circumstances, a decrease in rice productivity is expected to be a serious problem in the next years.

In Bangladesh, climate change has had a significant impact on the yield and cropping area of four important crops: Aus rice, Aman rice, Boro rice and Wheat (Amin *et al.*, 2015). Amin *et al.* (2015) discovered that maximum temperature had a substantial impact on all food crops as well as cropping area. Although the minimum temperature harmed Aman rice, it boosted the yield and cropping area of the other three crops. Australia's farming area benefited from the rain. Humidity has a role in the Aus and Aman rice yields. One of the most important climatic conditions for agricultural production is rainfall (Karim *et al.*, 1999).

Water is required at vital periods in the growth and development of all crops. Furthermore, excessive rainfall can result in flooding and waterlogging, which can result in crop loss (World Bank, 2000). Climate change has affected the yield and cropping area of four main crops in Bangladesh: Aus rice, Aman rice, Boro rice and Wheat (Amin *et al.*, 2015). According to Amin *et al.* (2015), maximum temperature has a significant impact on all food crops as well as cropping area. Despite the fact that the minimum temperature damaged Aman rice, it increased yield and cropping area for the other three crops. Rainfall is one of the most important climatic factors for agricultural production (Karim *et al.*, 1999). All crops require water at critical times during their growth and development. Furthermore, heavy rains may cause flooding and water logging, which can lead to a slew of other issues. A 1 mm increase in rainfall will reduce Aman rice yield at the vegetative, reproductive and ripening stages (Amin *et al.*, 2015). Agriculture is a particularly vulnerable sector to climate change; for example, in Africa, over two-thirds of arable land will be lost by 2025 as a result of climate change, and agricultural production would fall from 21% to 9% by 2080 (Masipa, 2017; Liliana, 2005).

The consequences of climate change, as well as the vulnerability of small and medium farms to these changes, present a challenge for institutions and policymakers. Moderate weather fluctuations during critical periods of crop development can also have a significant impact on production. While cost of inputs, types of tools used, irrigation water availability, rainfall and commodity prices are some of the additional elements that can affect output; they are not the only ones. Besides, crop yield is being harmed because of the climate change, posing food and livelihood security concerns (Tripathi, 2017).

Climate change, along with rising poverty and food scarcity, has resulted in a slew of food security issues, posing a threat to the entire country. According to Ahmed (2006), agricultural product production was dropped by 45 percent during the terrible storm of 1988 and more than 2 million hectares of crop area were flooded again in 1998. According to a research by (Dasgupta *et al.*, 2010) the 2007 flood swamped 42 percent of the country's land, drowned 2.1 million hectares of agricultural land and affected 14 million people. For the livelihoods, most of the people in Bangladesh depend on its natural resources. Global warming has contributed more frequent, severe and vast extent of the recent droughts (Dash *et al.*, 2012; Paul, 1995). It threats to food security in many regions worldwide including Bangladesh (Dash *et al.*, 2012; Rahman *et al.*, 2007).

Sylhet is located in the active monsoon areas of Bangladesh with an annual rainfall of roughly 3963 mm (Bari *et al.*, 2015). The rainfall distribution has not been steady so far. The rainy season, which runs from April to October, is hot and humid with heavy showers and thunderstorms practically every day, whereas the short dry season, which runs from November to February is mild and clear (Wikipedia, 2009). Rainfall is a continuous random variable that varies not only with time but also with geographical region and height in space (Ali *et al.*, 1994). It is the free supply of water that is directly and most consistently supplied to a crop and vegetation. However, it may be used most effectively by limiting its destructive effects while enhancing favorable outcomes, which requires agricultural activities to be planned in such a way that the beneficial effects of rainfall are maximized while the dangerous effects are reduced (Khan *et al.*, 1991).

Almost all-earlier research was limited to climatic impacts on specific food crops. To date, no research has been done in Bangladesh to assess the economic effects of climate change on overall crop production. Some research on the economic implications of climate change on agriculture has already been done in neighboring countries. All of the studies found that climate change has a major impact on agriculture; however, there was a wide range of loss and gain in different places. This emphasizes the importance of assessing the effects of climate change on agricultural growing in the Sylhet region. Sylhet, on the other hand, has already been identified as a possible center of large-scale production. However, these places are behind in terms of socio-economic development and are vulnerable to natural disasters and environmental degradation. Because of the challenges posed by climate change, Sylhet is one of Bangladesh's most afflicted areas. Thus, the following objective is to determine the impact of climate change and river water level fluctuations on agricultural production.

Materials and Methods

Selection of study area

The Jaintia, Khasi and Tripura hills surround Sylhet, which is located on the banks of the Surma River (SCC, 2015). Sylhet is located at 24.8917°N, 91.8833°E in Bangladesh's northeastern area. The climate in this area is generally mild, warm and temperate. Summers in this area see a lot of rain but winters see very little. In Sylhet, the average annual temperature is 23.6°C (74.5°F). The average annual rainfall is 5048 millimeters.

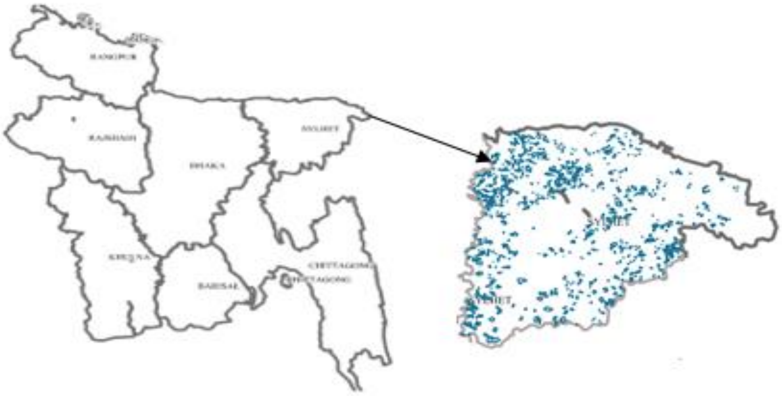

Fig. 1. Map of the study area.

Methodology

This research was carried out using secondary data from the Bangladesh Meteorological Department (BMD). Sylhet station is one of the hydro-meteorological stations of BMD. Daily observed rainfall and temperature data for the Sylhet station were gathered over the period 1970–2020 since climate variables with at least daily temporal resolution from long-term high quality and reliable records are important to account for variations in extremes (Tank *et al.*, 2009).

Data collection and analysis of collected data

The Yearbook of Agricultural Statistics of Bangladesh, issued by the Bangladesh Bureau of Statistics (BBS), Department of Agricultural Extension (DAE) and the Bangladesh Rice Research Institute (BRRI) were used to compile data on Aus, Aman, Boro and Wheat Season for the period 1970–2020. On the other hand, Bangladesh Water Development Board (BWDB) collected daily river water level data reported in (m) of several stations in the research region that encompasses important rivers from 1996 to 2020. The data was then translated into seasonal average statistics based on the growing seasons of the four crops studied.

The analysis was done in three steps. Then, a correlation analysis was performed to find the correlation coefficient (r) between yield data and all other available variables to find if they positively or negatively correlated with each other. Lastly, a multiple linear regression analysis was performed to find the R^2 (Regression Coefficient) value.

Results and Discussion

Correlation coefficients between crop yield and climatic parameters

Aus rice

The line traced through the parameters in Fig. 2 (a, b, c, d) has a mixed slope, indicating that this scatter plot demonstrates a mixed linear connection. The yield, temperature, and cloud cover all have a negative connection, according to the correlation study. On the other side, yield, rainfall and relative humidity all have a positive association. The R^2 value for all parameters suggested that the co-relation between the variables was inadequate. For all parameters except maximum temperature and relative humidity, the slope of the line is quite low, indicating that yield is more dependent on maximum temperature and relative humidity than other characteristics.

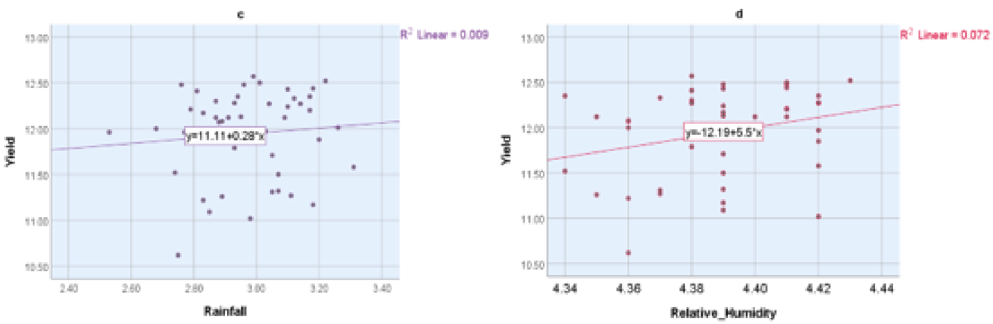

Fig. 2. Aus (a) Yield vs TempMax, (b) Yield vs TempMin, (c) Yield vs RF and (d) Yield vs RH.

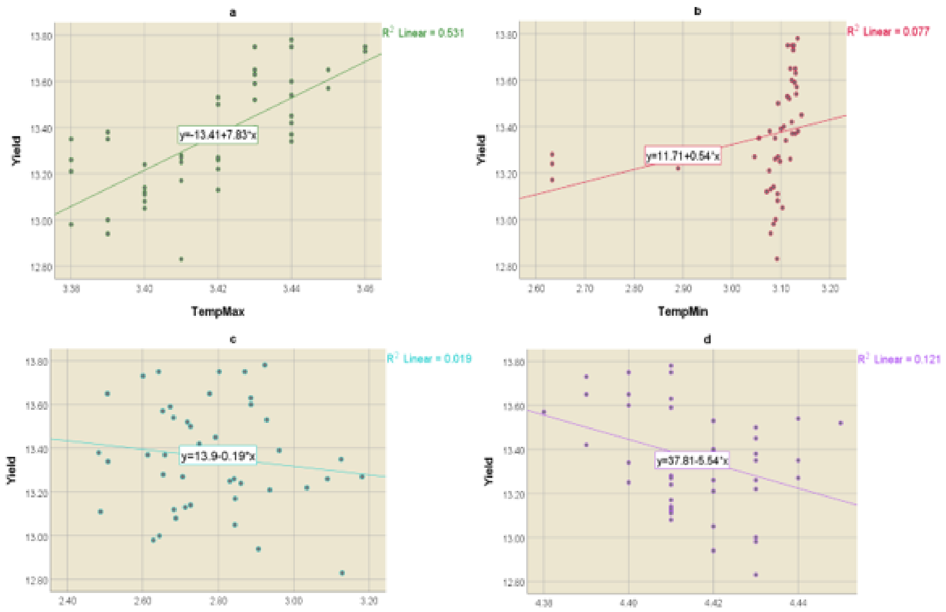

Fig. 3. Aman (a) Yield vs TempMax, (b) Yield vs TempMin, (c) Yield vs RF and (d) Yield vs RH.

Aman rice

A mixed linear correlation may be seen in Fig. 3 (a, b, c, d). The yields, rainfall, and relative humidity all have a negative link, according to the correlation study (Yield vs RF, Yield vs RH). On the other side, yields, maximum temperature, and minimum temperature all show a strong positive association (Yield vs TempMax, Yield vs TempMin). The R^2 result suggested that the relationship between the variables yield, maximum temperature and relative humidity is adequate. In addition, the R^2 value of other parameters suggests a low correlation. The slope of the line is moderate for maximum temperature and relative humidity, indicating that yield has a modest dependence on these variables compared to other variables.

Boro rice

From Fig.4 (a, b, c, d) found that the correlation analysis indicates a negative correlation between yield and rainfall (Yield vs RF) whereas a strong positive correlation displays between yield, maximum temperature, minimum temperature and relative humidity (Yield vs TempMax, Yield vs TempMin, Yield vs RH). The value of R^2 indicated that the co-relation between the variables yield, maximum temperature, minimum temperature are well enough. On the other hand, other parameters R^2 value indicates low correlation between climatic parameters except sunshine. The slope of the line is good for maximum temperature and minimum temperature, which indicated that yield, has a good dependency on those parameters than other parameters. The lines also provide lower rainfall and relative humidity related to the Boro rice.

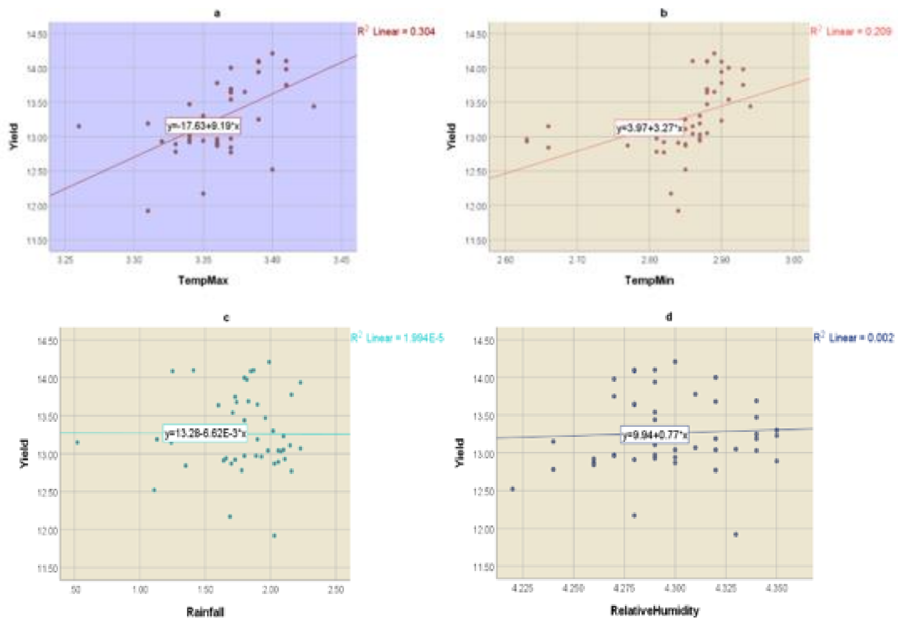

Fig. 4. Boro (a) Yield vs TempMax, (b) Yield vs TempMin, (c) Yield vs RF and (d) Yield vs RH.

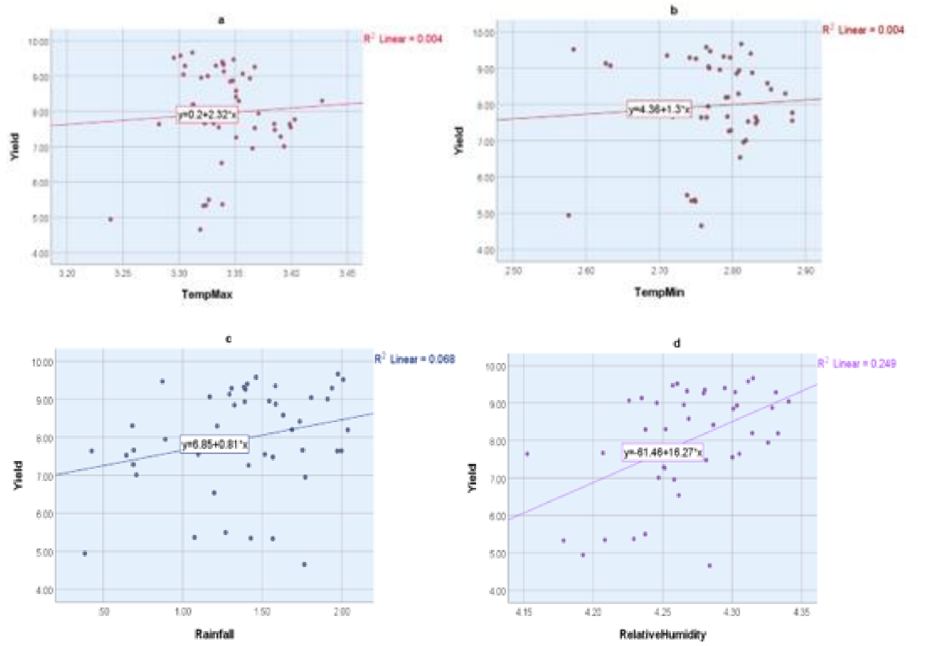

Fig. 5. Wheat (a) Yield vs TempMax, (b) Yield vs TempMin, (c) Yield vs RF and (d) Yield vs RH.

Wheat

The line traced through the parameters in Fig. 5 (a, b, c, d) has a mixed slope; hence, this scatter plot reveals a mixed linear connection. The yield, maximum temperature, rainfall, and relative humidity all have a moderately favorable connection according to the correlation study (Yield vs TempMax, Yield vs TempMin, Yield vs RF, Yield vs RH). However, yield, wind speed and sun shining hour all have a negative association (Yield vs WS, Yield vs SS). The R^2 value indicates that the variables yield, relative humidity, wind speed, and sunshine have a good association. Other parameters R^2 values, on the other hand, suggest a low correlation between climatic variables. The slope of the line is good for relative humidity, which indicated that yield has a good dependency on relative humidity than other parameters. The lines also provide lower maximum and minimum temperature related to the Wheat yield.

Yield with River water level

The correlation study indicates a favorable relationship between Aus yield, Aman yield, and Wheat yield as shown in Figure 6 (a, b, c, d). The correlation result for Boro yield, on the other hand, shows a modest relation between yield and water level. Except for Wheat yield, the R^2 value for other factors suggested that the correlation between the variables was insufficient. The line's slope is quite low, indicating that yield is only slightly affected by climate variables.

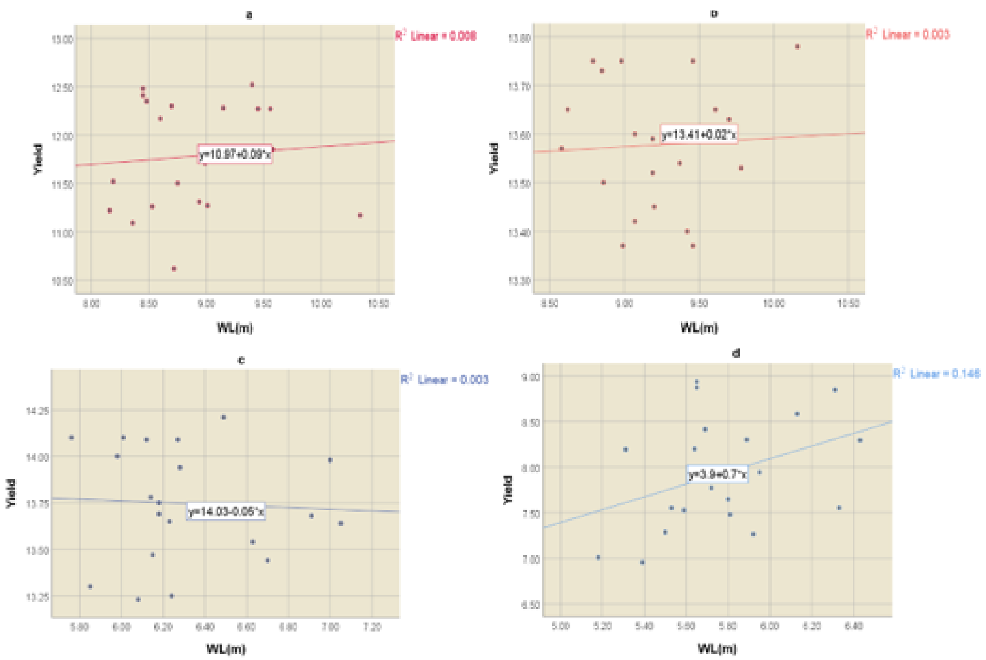

Fig. 6. (a) Aus yield vs WL, (b) Aman yield vs WL, (c) Boro yield vs WL and (d) Wheat yield vs WL.

Regression analysis between the crop yield and climatic variables

The Regression Results for the four-crop model between the climatic variables. The multiple regression method is employed to identify the impacts of climatic variables and river water level (i.e., LnYield, LnTempMax, LnTempMin, LnRF, LnRH) on the yield of Aus rice, Aman rice, Boro rice and Wheat.

Table 1. Estimated Results of the Aus rice model.

Dependent Variable	Independent Variable	Coefficient	Std. Error	t-Statistic	P-value	R^2	Adjusted R^2	F-Statistic	Sig.
Yield	TempMax	0.004	4.558	0.015	0.988	0.249	0.110	1.796	**
	TempMin	-0.043	0.570	-0.281	0.780				
	Rainfall	-0.001	0.463	-0.007	0.994				
	RH	0.554	5.384	2.105	0.042				

*Note: *, ** and *** represents the 1%, 5% and 10% level of significance respectively.*

The findings of the experiment (Table 1) revealed that climate variables can explain part of the variability in Aus rice output. Climate factors included in the model can explain 11 percent of the entire variation in Aus rice yield, according to the corrected R^2 value. The results also showed that at a 5% level, (seasonal average) relative humidity is statistically significant. The results also showed that relative humidity and maximum temperature have a positive relationship with Aus rice yield, whereas minimum temperature and rainfall have a negative relationship with Aus yield. Relative humidity, on the other hand, is beneficial to Aus yield. Finally, maximum and minimum temperature and rainfall could not influence that much to the yield of Aus rice since the coefficient of maximum and minimum temperature, rainfall is statistically insignificant.

Table 2. Estimated Results of the Aman rice model.

Dependent Variable	Independent Variable	Co-efficient	Std. Error	t-Statistic	P-value	R^2	Adjusted R^2	F-Statistic	Sig.
Yield	TempMax	0.481	1.552	3.332	0.002	0.667	0.606	10.868	*
	TempMin	0.076	0.203	0.727	0.472				
	Rainfall	0.056	0.161	0.486	0.630				
	RH	-0.272	2.056	-2.101	0.042				**

*Note: *, ** and *** represents the 1%, 5% and 10% level of significance respectively.*

According to the regression results (Table 2), Aman rice is an almost entirely rain-fed crop that is grown throughout the monsoon season. The findings of the experiment revealed that climate variables could explain part of the variability in Aman rice output. The corrected R^2 value indicated that climate variables in the model could explain 60.6 percent of the total variation in Aman rice yield. At the 1% and 5% levels, the seasonal average maximum temperature and relative humidity were significant and had a positive and negative connection. As a result, relative humidity has the potential to sabotage the yield rate. Minimum temperature and rainfall, on the other hand, have a positive association and are statistically negligible; therefore, they have no effect on Aman rice yield.

Table 3. Estimated Results of the Boro rice model.

Dependent Variable	Independent Variable	Co efficient	Std. Error	t-Statistic	P-value	R^2	Adjusted R^2	F-Statistic	**Sig.**
Yield	TempMax	0.223	2.385	1.558	0.128	0.607	0.535	8.393	**
	TempMin	0.318	1.019	2.230	0.032				**
	Rainfall	-0.201	0.175	-1.648	0.100				***
	RH	-0.172	2.395	-1.183	0.244				

*Note: *, ** and *** represents the 1%, 5% and 10% level of significance respectively.*

Seasonal average rainfall is adversely connected to Boro rice yield, according to the regression approach and is highly significant at the 10% significance level. This means that an increase in rainfall may have a negative impact on Boro rice productivity. However, average maximum and minimum temperatures have an impact on Boro rice yield and are statistically significant at the 5% level. Although relative humidity is adversely associated, the effect on yield is statistically insignificant. The corrected R^2 value indicated that climate variables in the model could explain 53.5 percent of the overall variation in Boro rice yield.

Table 4. Estimated Results of the Wheat model

Dependent Variable	Independent Variable	Coefficient	Std. Error	t-Statistic	P-value	R^2	Adjusted R^2	F-Statistic	Sig.
Yield	TempMax	0.300	6.886	1.679	0.100	0.489	0.395	5.199	***
	TempMin	-0.397	3.448	-2.318	0.026				**
	Rainfall	0.166	0.457	1.121	0.269				
	RH	0.482	5.861	2.681	0.011				**

*Note: *, ** and *** represents the 1%, 5% and 10% level of significance respectively.*

The seasonal average maximum temperature is strongly associated and highly significant at a 10% level of significance, according to the calculated result (Table 4). At a 5% significance level, the minimum temperature is negatively linked but still significant. Additionally, there is a positive association and statistical significance for relative humidity at a level of 5%. That suggests that a rise in the maximum temperature may have led to an increase in wheat output. Although favorably associated with rainfall, it is statistically insignificant. According to the corrected R^2 value, the climate variables in the model can account for 39.5% of the overall variation in wheat production.

Regression analysis between the crop yield and river water level

Table 5. Estimated Results of water level impact on yield model.

Dependent Variable	Independent Variable	Coefficient	Std. Error	t-Statistic	P-value	Significance
Aus yield	WL	0.087	0.244	0.372	0.714	
Aman yield		0.055	0.077	0.234	0.234	
Boro yield		-0.054	0.197	-0.229	0.821	
Wheat yield		0.382	0.399	1.752	0.097	***

*Note: *, ** and *** represents the 1%, 5% and 10% level of significance respectively.*

Variable	Regression Statistics	
Aus yield	R^2	0.008
	Adjusted R^2	-0.048
	F-Statistic	0.138
Aman yield	R^2	0.003
	Adjusted R^2	-0.052
	F-Statistic	0.055
Boro yield	R^2	0.003
	Adjusted R^2	-0.052
	F-Statistic	0.053
Wheat yield	R^2	0.146
	Adjusted R^2	0.098
	F-Statistic	3.069

According to the estimated results (Table 5), there is a strong positive relationship between seasonal average wheat growing season and water level at the 10% level of significance. The test shows a statistically negligible positive association during the Aus and aman crop growing seasons with no influence on yield. There is a negative association that is likewise statistically insignificant during the Boro growing season, therefore the yield is unaffected. The corrected R^2 values of Aus, aman and Boro rice yield provides very poor explanation by water level. The modified R^2 value for wheat, however, indicated that water level could account for 9.8% of the entire variation in wheat output.

Regression analysis of river water level with temperature and rainfall

Water level is greatly changing with temperature and rainfall. In order to understand the impact of crop yield due to river water level, it is necessary to evaluate the effect of temperature and rainfall into water level.

Table 6. Estimated Results of temperature and rainfall impact on river water level model.

Dependent Variable	Independent Variable	Coefficient	Std. Error	t-Statistic	P-value	Significance
Aus Season WL	TempMax	-0.515	0.224	-2.007	0.062	***
	TempMin	0.320	0.366	0.062	0.141	
	Rainfall	0.515	0.037	1.548	0.017	**
Aman Season WL	TempMax	-0.521	0.211	0.141	0.016	**
	TempMin	0.368	0.280	2.651	0.041	**
	Rainfall	0.478	0.038	0.017	0.013	**
Boro Season WL	TempMax	0.015	0.162	-2.686	0.959	
	TempMin	0.379	0.257	0.016	0.200	
	Rainfall	-0.243	0.061	2.227	0.361	
Wheat Season WL	TempMax	-0.089	0.138	0.041	0.802	
	TempMin	0.252	0.200	2.809	0.432	
	Rainfall	-0.104	0.057	0.013	0.725	

*Note: *, ** and *** represents the 1%, 5% and 10% level of significance respectively.*

Variable	Regression Statistics	
Aus Season WL	R^2	0.676
	Adjusted R^2	0.615
	F-Statistic	11.122
Aman Season WL	R^2	0.686
	Adjusted R^2	0.627
	F-Statistic	11.666
Boro Season WL	R^2	0.172
	Adjusted R^2	0.017
	F-Statistic	1.107
Wheat Season WL	R^2	0.049
	Adjusted R^2	-0.130
	F-Statistic	0.273

From the result (Table 6), it was clear that the water level of Aus and Aman growing season greatly influenced by temperature and rainfall. For both Aus and Aman season, strong statistically significant negative correlation was found in case of maximum temperature at 10% and 5 % level, respectively. This suggests that a rise in the maximum temperature may cause the water table in Aus and Aman to drop throughout the growing season. While the minimum temperature and rainfall both show a statistically significant positive relationship at the 5% level, this suggests that an increase in those parameters can also cause an increase in water level. The water level in Sylhet is strongly influenced by temperature and rainfall during the Aus and Aman seasons, according to adjusted R^2 values of 61.5 and 62.7 percent. Now since the model does not produce statistically significant results for the Boro and Wheat seasons, a positive or negative connection between water level and those meteorological factors can have a negligible effect that is easily overlooked.

Conclusion

Agriculture productivity is directly correlated with climatic variables such as temperature, precipitation, relative humidity, etc. The study found that temperature and relative humidity could have a positive impact on Aus crop yield. Relative humidity, on the other hand, can ruin the yield. Rainfall can reduce the yield of boro rice. In the case of wheat production, a rise in the maximum temperature can significantly boost yield while a decrease in the minimum temperature can lower it. While river levels can affect wheat output, they have little direct impact on Aus, Aman, and Boro rice. However, meteorological factors like temperature and precipitation have a big impact on water level, therefore it can be said that river water level has an indirect impact on agricultural productivity. The following criteria have been highlighted as limits and recommendations for future research projects based on the results of the current study. The study largely relied on secondary data and certain missing data were discovered and minimized in order to do the analysis. As a result, the analysis was occasionally hindered, which weakened it. Additionally, there was no field-level data included in the study; we hope to integrate it soon. Other approaches to assessing the influence of climatic variables on agricultural output should be used in future research. The data on water levels that were gathered for evaluation were not accurate enough; hence, the outcomes did not meet expectations. That limitation needs to be addressed and will be resolved in future research hopefully. In future, other climatic parameters like evaporation rate, wind, cloud cover, sunshine hour, solar radiation and soil moisture may be considered. For further research should give priority on other area and other crop variety of Sylhet region in order to identify the impact on crop production due to climate change.

References

Ahmed, A.U. 2006. Bangladesh climate change impacts and vulnerability, a synthesis. Climate change cell. Department of Environment, Dhaka. 70p.

Ali, M.M., Talukder, M.S.U., Hossain, M.G. and Hye, M.A. 1994. Rainfall features and effect of extreme events on statistical parameters off rainfall at Mymensingh. *Bangladesh J. Agril. Sci.* 21(1): 157-165.

Amin, M.R., Zhang, J. and Yang, M. 2015. Effects of climate change on the yield and cropping area of major food crops: A case of Bangladesh. *Sustain.* 7(1): 898-915. https://doi.org/10.3390/su7010898

Bari, S.H., Rahman, M.T., Hussain, M.M. and Ray, S. 2015. Forecasting monthly precipitation in Sylhet city using ARIMA model. *Civil Environ. Res.* 7(1): 69-77.

Dasgupta, S., Huq, M., Khan, Z.H., Ahmed, M.M.Z., Mukherjee, N., Khan, M.F. and Pandey, K. 2010. Vulnerability of Bangladesh to cyclones in a changing climate, Potential damages and adaptation cost. Policy Research working paper; no. WPS 5280. World Bank. pp. 1-54. https://openknowledge.worldbank.org/handle/10986/3767

Dash, B.K., Rafiuddin, M., Khanam, F. and Islam, M.N. 2012. Characteristics of meteorological drought in Bangladesh. *Nat. Haz.* 64: 1461-1474. https://doi.org/10.1007/s11069-012-0307-1

Karim, Z., Hussain, S.G. and Ahmed, A.U. 1999. Climate change vulnerability of crop agriculture. In: Huq, S., Karim, Z., Asaduzzaman, M., Mahtab, F. (eds) Vulnerability and adaptation to climate change for Bangladesh. Springer, Dordrecht. pp. 39-54. https://doi.org/10.1007/978-94-015-9325-0_4

Khan, M.B.R., Moinuddin, M. and Sarker, P.K. 1991. Some probability aspects of rainfall in Gazipur. *Bangladesh J. Agric.* 16: 61-70.

Liliana, H. 2005. The food gaps, the impacts of climate change on food production: A 2020 perspective. Universal Ecological Fund, Alexandria, VA, USA.

Masipa, T.S. 2017. The impact of climate change on food security in South Africa, Current realities and challenges ahead. *Jàmbá: J. Disaster Risk Stud.* 9(1): 1-7. https://doi.org/10.4102/jamba.v9i1.411

Paul, B.K. 1995. Farmers' and public responses to the 1994-95 Drought in Bangladesh: A case study. FMHI Publications. 79p. https://digitalcommons.usf.edu/fmhi_pub/79

Rahman, A.A., Alam, M., Alam, S.S., Uzzaman, M.R., Rashid, M. and Rabbani, G. 2007. Risks, Vulnerability and Adaptation in Bangladesh Human Development Occasional Papers (1992-2007) HDOCPA-2007-13, Human Development Report Office (HDRO), United Nations Development Programme (UNDP).

SCC. 2015. Sylhet City Corporation. http://www.sylhetcitycorporationbd.org/index.php/cms/about_sylhet/#. Accessed on 25 June 2015

Tank, A.M.G.K., Zwiers, F.W. and Zhang, X. 2009. Guidelines on analysis of extremes in a changing climate in support of informed decisions for adaptation. Climate Data and Monitoring WCDMP-No. 72. pp. 1-55.

Tripathi, A. 2017. Socioeconomic backwardness and vulnerability to climate change: evidence from Uttar Pradesh state in India. *J. Environ. Plann. Manage.* 60(2): 328-350. https://doi.org/10.1080/09640568.2016.1157059

Wikipedia, 2009. Monthly Averages for Sylhet, BGD MSN Weather. https://en.wikipedia.org/wiki/Sylhet. Retrieved 25 May 2009.

World Bank. 2000. Bangladesh: Climate Change and Sustainable Development. Report No. 21104-BD Rural Development Unit, South Asia Region. The World Bank, Sher-e-Bangla Nagar, Agargaon, Dhaka. p. 95.

World Bank. 2010. Climate Change Risks and Food Security in Bangladesh, World Bank, Sher-e-Bangla Nagar, Agargaon, Dhaka-1207.