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Assessing the Impacts of Pre-monsoon Extreme Weather Events and Associated Factors on Rice Yield: A Study on Tahirpur Upazila of Sunamganj District, Bangladesh

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ABSTRACT: Bangladesh, being a geographically vulnerable country experiences a variety of severe weather phenomena and most of them occur during the pre-monsoon season (March-May). This study investigates the occurrence of the pre-monsoon extreme weather events in Sunamganj and their impacts on the rice yield. Sunamganj is one of most vulnerable areas of Bangladesh that experiences almost all types of extreme weather phenomena during pre-monsoon and therefore the assessment of the effect of these hazards on rice yield have been conducted in Dakshin Sreepur union, Tahirpur upazila, Sunamganj. This study has been accomplished by blending the findings of climate data analysis with field investigation. About 13 extreme climate indices related to temperature and rainfall created by the Expert Team on Climate Change Detection Indices (ETCCDI) were considered to evaluate the correlation between rice yield and extreme weather events in the particular region. The correlation shows that extreme events are not the only factor influencing the rice yields; rather, a few related factors such as socio-economic context, physiographic settings, river bed siltation, construction and management of dams are also affecting the rice production in the study area. As a result, the solutions derived from farmers are important in reducing the detrimental impact of extreme events on rice yield for effective food production.

Keywords: Extreme Weather Events; Climate Indices; Extreme Summer Days; Extreme Heavy Rainy Days; HYV Rice

INTRODUCTION

The relation between climate and agriculture is one that has been present from the inception of agriculture. To access the impact of extreme climate on agriculture, a broad and clear understanding of both is very crucial. The general changes in climate extremes and the intensities of local weather have a significant impact on the production of the agriculture. There have been noticeable changes in each year's yield in the agriculture due to the impact of different extreme weather event. Extreme weather events can be defined with the aberrant behavior of the value of any climate variable that can be above or below a threshold value considering a range of variables of observed values (Balasubramanian, 2018). Extreme climatic events are driving disaster risk in the whole world, including Bangladesh. Being a geographically hazardous country with more than 160 million people Bangladesh placed among top 5 countries that are vulnerable towards climatic phenomena, according to Global Climate Risk Index (Harmeling and Eckstein, 2012). Bangladesh is an agriculture-based country which is situated in the tropical monsoon climatic region. However, the geographical location, land characteristics, multiplicity of rivers and the monsoon climate render Bangladesh highly vulnerable to natural hazards that have been evident by the occurrence of about 219 natural disaster events between 1980 to 2008 (ADRC, 2019). Agriculture of Bangladesh is highly affected by these disasters in different ways. The impacts of climate change and extreme weather events on agricultural production represent a particular threat to food security in Bangladesh (Huda, 2015). The prediction of the Intergovernmental Panel on Climate Change (IPCC) suggests the projected rise in temperature and sea-level change will result in losing the rice and wheat production by 8% and 32% respectively by the year 2100 (IPCC, 2007). In the backdrop of limited cultivable land and the influence of climate change, Bangladesh has recently faced a severe problem in rice production to feed its growing population (Hossain, et.al. 2019). Recent years have seen a

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significant increase in interest in climate change studies and its effects on rice production. (Rahman et. al. 2009). Boro rice contributes about 56 percent of total food grains and has the highest productivity (3.965 MT per hectare) among the three major rice varieties compared to Aus rice and Aman rice (BBS, 2015). Local or HYV Boro rice contribution is the highest in Bangladesh's agriculture in the pre-monsoon season. So, pre-monsoon rice has been taken under consideration to analyse the relationship with extreme climate events.

The South Asian region encounters the hottest season of the year during pre-monsoon (March to May) along with frequent natural disasters and hot weather extremes including heat waves.(Kothawale et al. 2010). Additionally, most rainfall stations are experiencing an increase in the intensity of pre-monsoon and post-monsoon rainfall. (Bari et al. 2016). Furthermore, unpredictable changes in seasonal rainfall have also been observed across the country, particularly during the pre-monsoon season, which resulted in a devastating flash flood in Bangladesh's southeastern region in 2017 (Sumiya et al. 2019). Sunamganj district was one of the highlighted districts affected by flash flood 2017. The first objective of the research aimed to find out the long term climatic condition in Sunamganj district during pre-monsoon. The investigation of extreme weather phenomena during the pre-monsoon season is because this season frequently experiences unexpected rainfall or drought conditions mentioned earlier, and the intriguing factors indicate a substantial susceptibility in this season. Extreme temperature and rainfall events also mark their impacts on Boro rice. As temperature, rainfall, humidity, and solar radiation are all climatic factors that influence agricultural production (Masutomi et al. 2009). Consequently, the second objective is to explore the impacts of extreme climate events on Boro rice yields in Sunamganj with 13 extreme climate indices on temperature and rainfall developed by ETCCDI (Expert Team on Climate Change Detection and Indices). The purpose is to find out the real scenario and to what extent these events are actually affecting the production. Overall, the pre-monsoon period is significantly hazard prone on account of climate change that can better explain the Boro rice production condition as April-May is the harvesting period of this rice. In order to determine the extreme climatic conditions in various areas of Bangladesh as well as the effects of climate on agriculture, various analyses have been conducted. Many researches (Ara, Lewis, & Ostendorf, 2016; Badshah et al. 2016; Gow, 2019; Hossain et al. 2019; Karmakar, Quadir, and Mannan, 2015; Mojid, Kader, & Karim, 2016; Roy, Biswas, and Ghosh, 2015; Rahman et al., 2009) have shown the trend analysis of the climatic events and few of the researches have (Ara et al. 2016; Rahman et al. 2009; Gow, 2019; Hossain et al. 2019) correlated the results with agriculture. However, the objectives of the present study have not been addressed by the existing research. First of all, the present study emphasizes the Boro rice production condition for ensuring food security. While the Ministry's concern about food security threats is understandable, the adaptation measure's long-term viability remains in doubt (Misra, 2017). Not only the climatic factors impact on the production but also few associated factors are responsible too. The third objective of the research is to perceive the relative factors associated with Boro rice production from farmers' point of view as well as their suggestions for alternative solutions. Few studies (Gow, 2019; Misra, 2017; Asada & Matsumoto, 2009; Bhatta & Aggarwal, 2016) have been conducted on sustainable measures by sociological analysis or by farmers' opinions that originated mostly from questionnaire surveys. The present study differs from the existing one as substantial FGD surveys have been conducted and the factors identified from the field are analyzed through network analysis that is a novel method to illustrate farmers' perception.

Moreover, research tends to identify the relationship between extreme weather events and rice yields along with observation on associated factors that have an impact on the production as well as determination of possible solutions.

MATERIALS AND METHODS

Study Area

Selection of Sunamganj

To identify the effects of extreme weather events of the pre monsoon season on rice yield in Bangladesh, the hotspots for the occurrence of pre monsoon extreme weather events were first identified by analyzing the climatic parameters. The analyses revealed Sunamganj to be one of the most vulnerable areas in terms of occurrence of extreme weather events during pre-monsoon season. Therefore, to attain the ultimate goal of this study, Sunamganj has been selected as the study area.

Selection of Dakshin Sreepur

Sunamganj district is situated in the north-eastern side of Bangladesh under Sylhet division. Surrounded by Netrokona on the west, Sylhet on the east, Meghalaya state of India on the north, Habiganj and Kishoreganj district on the south. Due to the geographical settings of Sunamganj it is susceptible to floods every year. This region is downstream of four transboundary rivers namely Surma, Kushiyara, Dhamalia and Jadukata. This region is a comparatively flat basin from the upstream Meghalaya that is why sediments flow decreases and consequently the height of the riverbeds increases day by day. Moreover, due to heavy rainfall of the upstream region, waters from swollen rivers have been running out very speedily and causing flash floods in the downstream region. Shuvo et al. (2021) aptly described the topographic and geomorphological settings of this region; and also, their roles in making this region vulnerable to floods. Again, this region is close to the Meghalayan plateau. So, the region is prone to severe convective events; such as – thunderstorms and lightning. The reasons are somewhat described in the research of Islam et al. (2021). The characteristic wind pattern regularly gets disturbed by the presence of higher elevations. Therefore, the wind at the lower level make a return into the Sylhet region, where it again collides with the warmer wind flowing towards the north and northeast. This collision and counter-collision between warm wind, cold wind, and topography make the region a great place for severe convection. Hence, Sunamganj has recorded a significant number of deaths due to lightning events. To accumulate the perception and suggestions of the farmers and experts Dakshin Sreepur Union has been taken into consideration. Dakshin Sreepur is a union of Tahirpur Upazila, Sunamganj District. Surrounded by Uttar Sreepur on the North, Behehi union of Jamalganj upazila on south, Tahirpur Sadar upazila on the east and Bongshikunda union of Dharmapasha upazila. Dakshin Sreepur union is fully dependent on a single crop, that is rice (BRRI 28, BRRI 29) which is hereafter HYV rice. Being flooded under water for almost 6 months, rice cultivation takes place for the remaining 6 months. Compared to other unions of Tahirpur Upazila, Dakshin Sreepur has a comparatively higher amount of rice production. Badaghat and Borodol unions are comparatively highland with minimum amount of rice cultivation. They cultivate fruits and vegetables instead. Uttar Sreepur also has a lower level of rice production. So, Dakshin Sreepur can be highlighted in the case of rice cultivation.

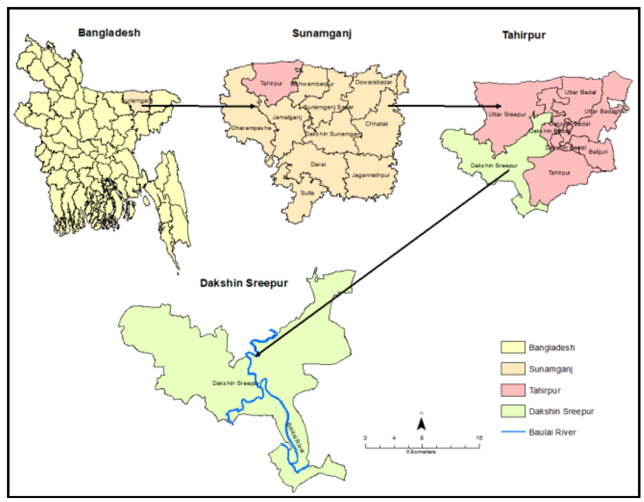


Figure 1: Map of the Study Area

Data Sources

Both primary and secondary data is used for this study. Secondary data that is climate data more specifically temperature and rainfall were collected from Bangladesh Meteorological Department (BMD) from the year 1981-2021 and HYV rice production data from “45 years agricultural statistics of major crops”, and “Yearbook of Agricultural Statistics” by Bangladesh Bureau of Statistics (BBS) of the year 2018 and 2020.

Primary data were collected from FGD survey to incorporate farmer's perception on identifying the impacts of extreme weather events and related factors on rice yields. Two extensive Focused Group Discussions (FGDs) were conducted in Dakshin Sreepur Union. The participants of those FGDs were local stakeholders (farmers, fishermen, local agricultural land owners and Union chairman). Total number of participants for each FGDs was 25.

Data Processing and Analysis

The quantitative data (temperature and rainfall) collected from BMD has been cured, processed and analyzed on Microsoft Excel through filtering, sorting, using an auto-sum (Sum, Average, Max, Min) tool, and different formulas (Countif, Countifs). To represent the spatial distribution of extreme climate events, ArcGIS geo-processing tool IDW (Inverse Distance Weighted) has been used on Arcmap 10.8. The HYV rice distribution analysis has also been processed in Arcmap 10.8. The correlation of about 13 extreme climate indices created by Expert Team on Climate Change Detection Indices (ETCCDI) and the indices were considered to evaluate the correlation between rice yield and extreme weather events in the particular region. The climate variables used in this study are temperature and rainfall to evaluate the summer days and extreme precipitation events. HYV rice is computed with correlation analysis in SPSS with Pearson correlation with significance level at 0.05 with two tailed graphs. To extract the perception of the farmers, the graph has been created with Gephi software to visualize their thinking on associated factors related to rice yield as well as the weight of one factor related to another.

Methodology and Approach

The climate condition of Sunamganj has been investigated with the help of nearby weather station data. In this case, the spatial analysis of Sunamganj district through 4 different years i.e. 1991, 2001, 2011 and 2021 is analyzed along with the rainfall and temperature trend of Sunamganj during from 1980-2021 to bring out the actual scenario in Sunamganj climate scenario throughout the years. The spatial analysis has been done with two extreme climate indices among the 13 (Table 1) to identify the extreme events (Rainfall, temperature) which has a direct impact on rice as one of the objectives is to explore the relationship between extreme events and rice. The normal growth of rice happens between a temperature range of 20°C and 35°C (Yoshida, 1981). So when temperature rises above 35 °C, normal growth may hamper. In this case, one of the temperature indices named Summer days (Temperature greater than 35°C) has been chosen. Rainfall is good for rice but if the rainfall is much higher than the regular rainfall amount, it has a significant chance of damaging the standing crops. During the pre-monsoon season, the average rainfall was 4.66 mm/day, with a standard deviation (SD) of 1.50 mm/day and a coefficient of variation (CV) of 32.25 percent (Reza, 2018). So, when the daily amount of rain ranges between 44-88mm (termed heavy rainy days), it has a strong possibility of flood occurrence or water logged condition that is harmful to the crops. So among rainfall indices, heavy rainy days have been selected to find out the geographical condition of climate in Sunamganj.

Besides, 13 extreme climatic indices out of 27 developed by ETCCDI (Expert Team on Climate Change Detection and Indices) have been considered to identify the relationship between extreme climate indices and rice yields in a statistical manner. The indices are described below:

Table 1: Extreme Climatic Indices (ETCCDI) Taken under Consideration in the Present Study

Indicators	Definition
Temperature	
Summer days (days)	Annual count when daily max. temp > 35 ^{0}C
Tropical nights (days)	Annual count when daily min. temp > 25 ^{0}C
Max T_{max} (^{0}C)	Monthly max. value of daily max. temp (^{0}C)
Min T_{min} (^{0}C)	Monthly min. value of daily min. temp (^{0}C)
Min T_{max} (^{0}C)	Monthly min. value of daily max. temp (^{0}C)
Max T_{min} (^{0}C)	Monthly max. value of daily min. temp (^{0}C)
Cool night (days)	Percentage of days when min. temp < 10th percentile
Cool days (days)	Percentage of days when max. temp < 10th percentile
Warm days (days)	Percentage of days when max. temp > 90th percentile
Rainfall	
Moderate rainy days	No. of days with daily precipitation ranging from 23 mm to 43mm

Heavy rainy days	No. of days with daily precipitation in between 44-88 mm
Very heavy rainy days	No. of days with daily precipitation above 88 mm
Annual total wet-day precipitation (days)	Annual total precipitation in wet days (daily precipitation≥1 mm)

According to climatic indices by ETCCDI summer days are annual counts when daily maximum temperature > 35 ^{0}C. For better understanding we classified into five categories like: (i) Extreme summer days (17-20 days) (ii) Upper moderate summer days (13-16 days) (iii) Moderate summer days (9-12 days) (iv) Lower moderate summer days (5-8 days) (v) Summer days (1-4 days).

Likewise daily precipitation ranging between 44-88mm termed as heavy rainy days For better understanding we classified into five categories like i) Extreme heavy rainy days (9-10 days) (ii) Upper moderate heavy rainy days (7-8 days) (iii) Moderate heavy rainy days (6-7 days) (iv) Lower moderate heavy rainy days (3-4 days) and (v) Heavy rainy days (1-2 days)

The climate indices of Sunamganj and the 14-year HYV rice yields of the Sunamganj district have been correlated. Due to the unavailability of union level rice yields data, the study area Dakshin Sreepur agriculture data cannot be correlated. Likewise the spatial distribution, climate data in this correlation has also been extracted from the nearby weather station located at Sylhet.

The reason for excluding local Rice yields from this analysis is that it has been experiencing a considerable decline (Chart 3) since 2006-07. This shows that the local Boro has lost popularity over time, and its production is insignificant when it comes to correlating with extreme climate indices.

The third objective is the identification of associated factors with the help of farmers that impact the Rice yields in Dakshin Sreepur. Through a FGD survey, field-level information about farmers' perceptions was gathered. Two FGDs were conducted with a total of two groups at two different union locations. Landowners and farmers on lease composed both groups. There were 25 individuals in both groups. Discussion topics included the overall condition of Boro cultivation in the union, agricultural tools and methods, the effects of extreme events, various issues they are having with Boro production, and recommendations for how to deal with climatic and associated challenges in the future. All of these field notes were visualized by network analysis through Gephi software.

RESULT AND DISCUSSION

Condition of Long-term Temperature in Sunamganj During Pre-monsoon

The long term (1981-2020) temperature of Sunamganj helps in depicting the trend of summer days variability of the upazila. The 40 years variation has shown in decadal terms that is 1981-1990 (Fig. 2), 1991-2000 (Fig. 3), 2001-2010 (Fig. 4), and 2011-2020 (Fig. 5).

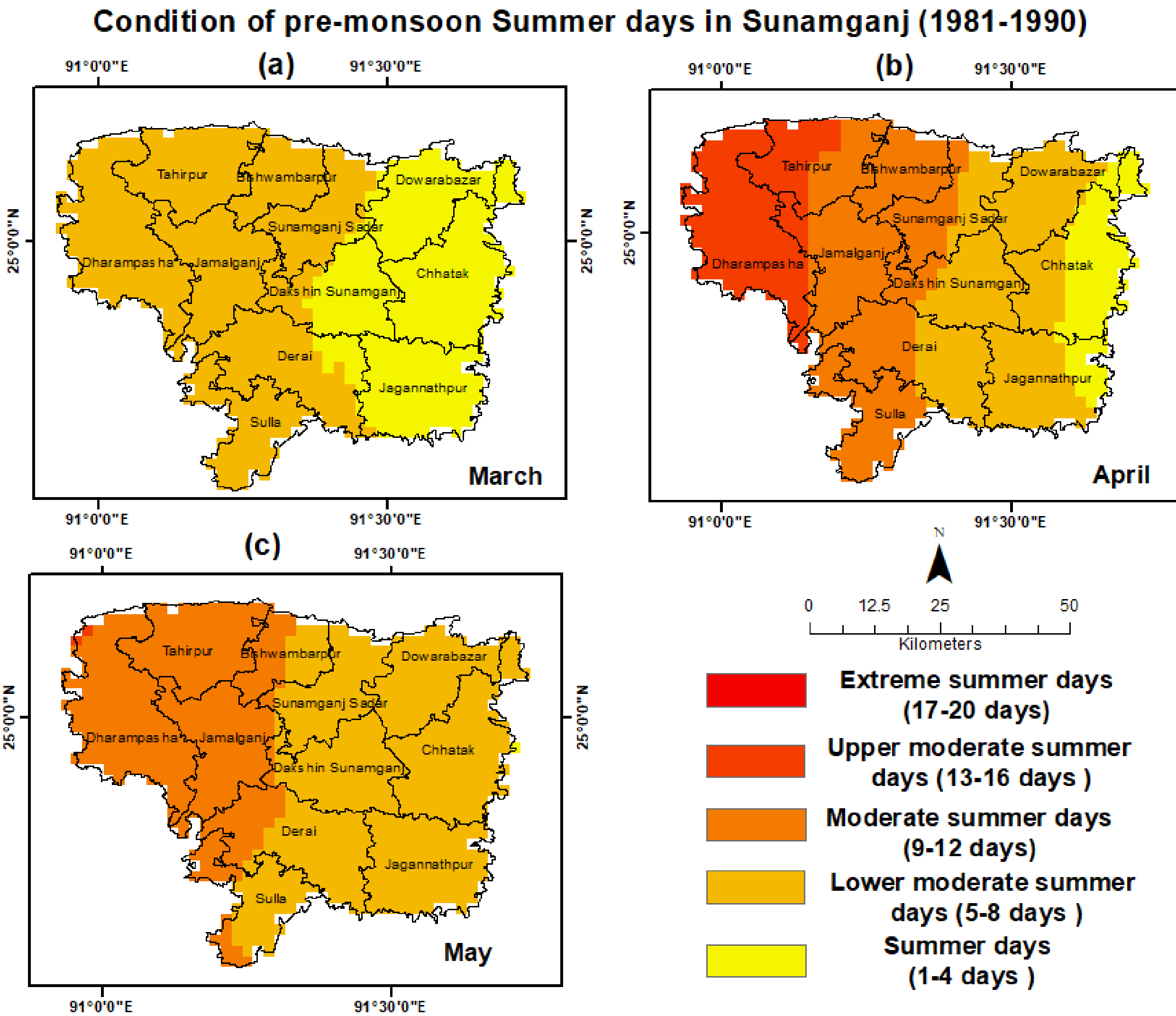


Figure 2: Pre-monsoon Summer Days in Sunamganj (1981-1990)

Figure 2 represents the summer days (annual count when daily max. temp > 35 °C) condition during pre-monsoon that is March (a), April (b), May (c). The maximum days with temperature above than 35 °C is observed in April that is up to 17 to 20 days. The temperature ranges between 36 °C-38 °C. Other two months settle between summer days to moderate summer days range having 1 to 12 days that has faced temperature beyond 35°C. During these two months temperature was between 35.5 °C-37 °C.

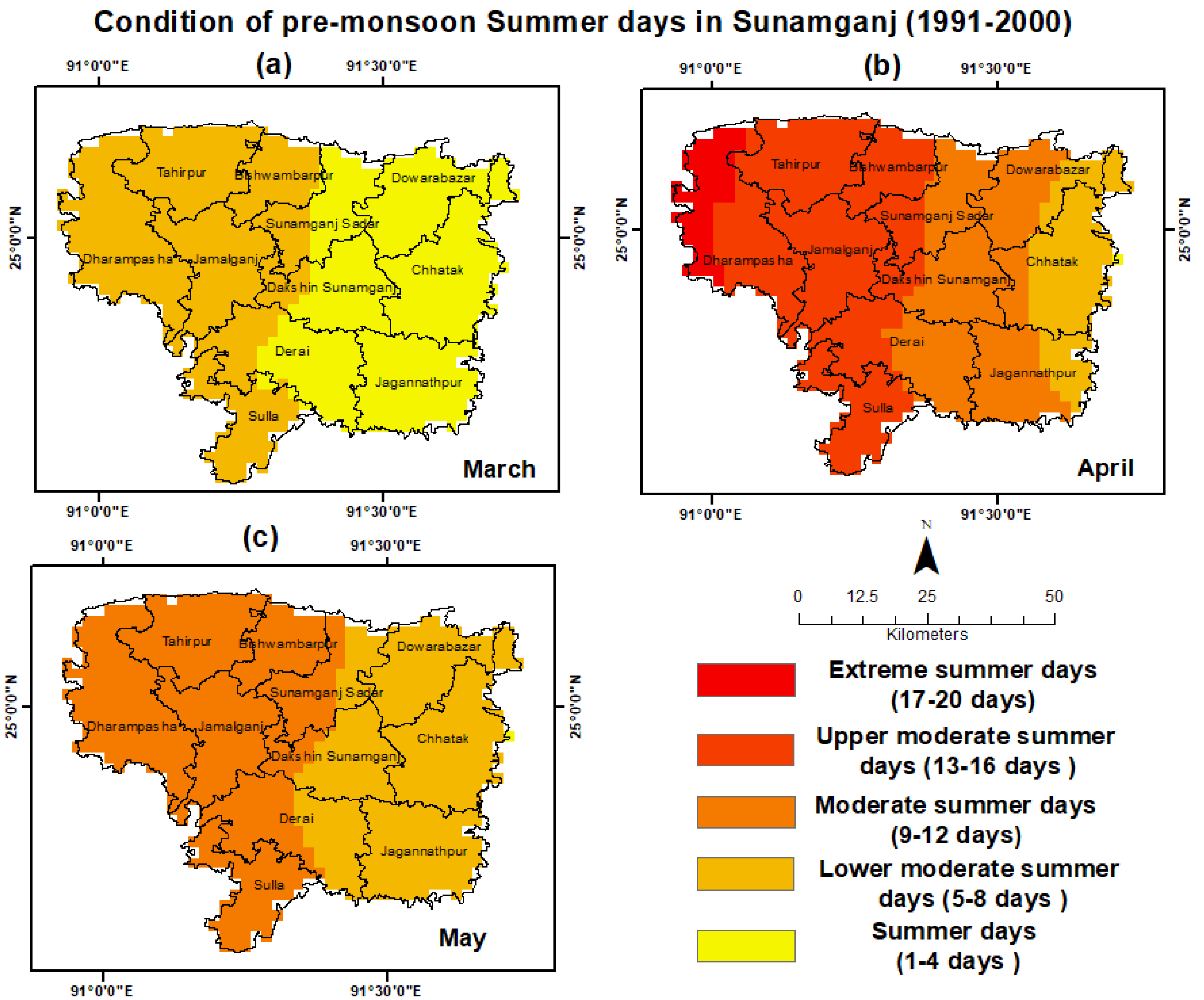


Figure 3: Pre-monsoon Summer Days in Sunamganj (1991-2000)

Figure 3 represents a similar outcome as earlier portraying highest count of summer days up to 20 days in April with maximum temperature 37.5 °C. March and May show less intensity in summer days than April. March ranged between summer days to lower moderate summer days with maximum temperature 38 °C. Whereas May ranged from lower moderate to moderate summer days that means may has experience highest 12 days and the maximum temperature during this month is 37°C

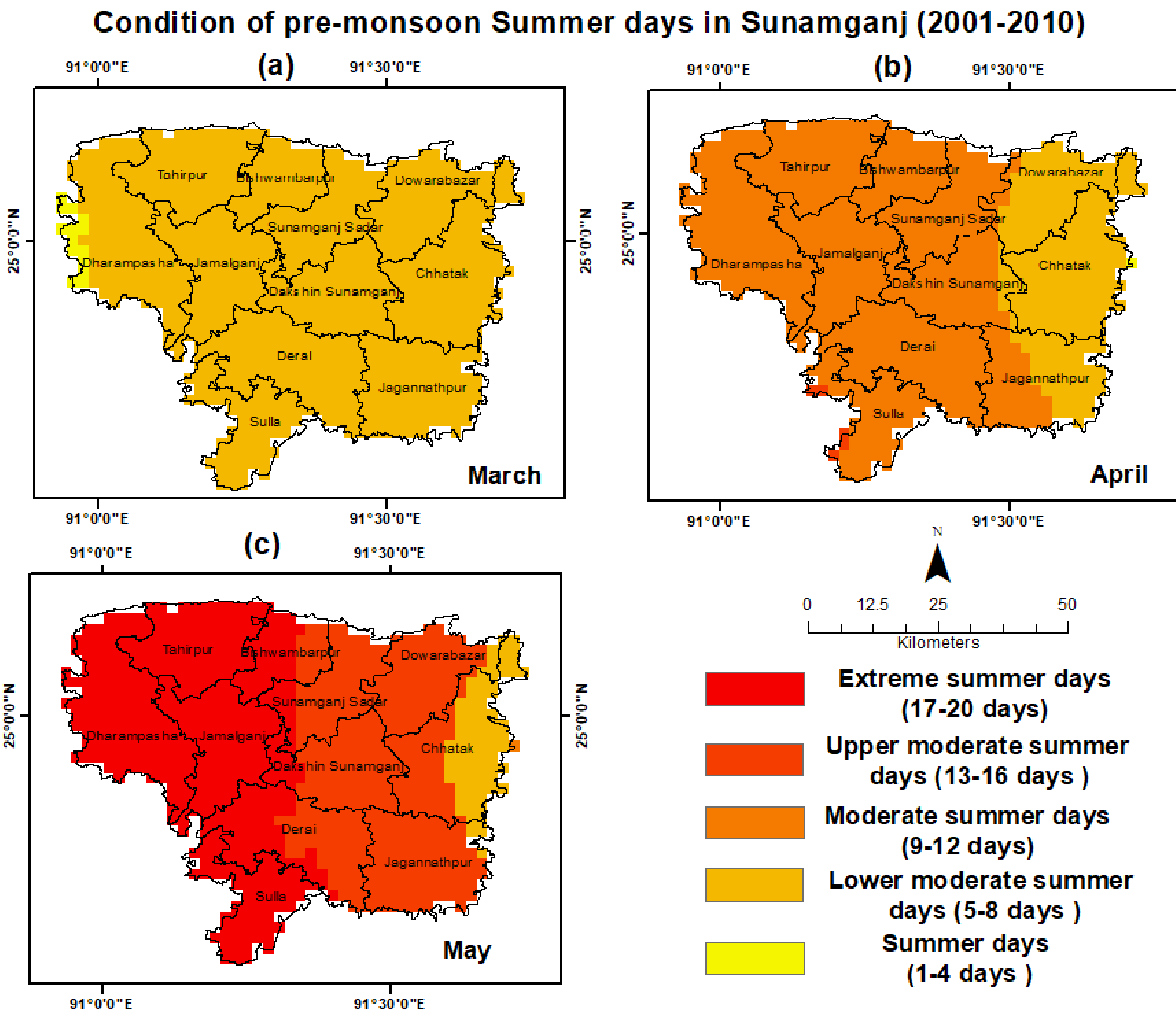


Figure 4: Pre-monsoon Summer Days in Sunamganj (2001-2010)

Whereas figure 4 exhibits a different situation compared to the past figures. It shows the highest amount of days having temperature greater than 35 ◦C during the month of May. Temperature during this month 36 ◦C-38 ◦C. The month mostly ranged between upper moderate to extreme summer days scale that is also the highest intensity among the three figures. Lower moderate summer days has been noticed during March explaining this month has witnessed 5 to 8 days experiencing temperature higher than 35 ◦C. These particular days has temperature between 36 ◦C-37◦C. Moderate summer days (9-12 days) cover a very large majority of April and the rest shows lower moderate summer days. Temperature rises to 36 ◦C highest during April.

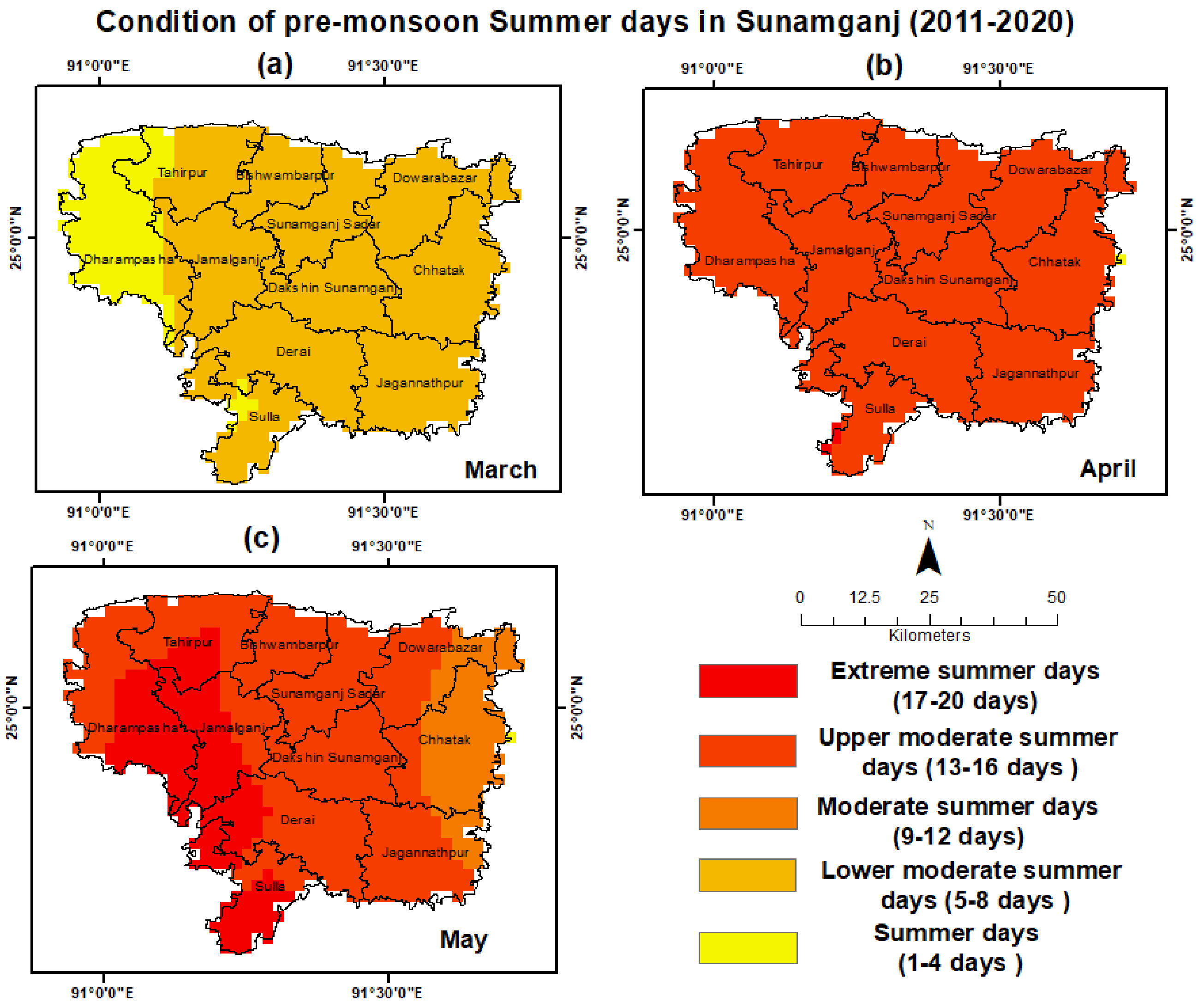


Figure 5: Pre-monsoon Summer Days in Sunamganj (2011-2020)

Figure 5 differs from previous as it shows higher summer days in two months unlike previous years. Both April and May consist of an intensified summer days range. April shows homogeneous scale exhibiting 13 to 16 days with above 35^{0}C which is upper moderate summer days. Highest temperature during this month is recorded up to 38^{0}C. While May ranges between moderate to extreme summer days with temperature ranges between 35.5 ^{0}C- 37.5 ^{0}C. On the other hand, over three quarters of March has experienced lower moderate summer days (5-8 days) with 35.5 ^{0}C- 37^{0}C.

40 years scenario indicates the number of summer days has increased overall but undergo an inconsistent pattern. Furthermore, April has been the hottest month through these years during pre-monsoon.

Spatial distribution of summer days (Fig. 2-5) shows an erratic pattern with April being the month exhibiting highest days with temperature greater than 35 ^{0}C. But the 40 years of summer day's data shown in chart 1 suggest a gradual growth in summer days during pre-monsoon period in Sunamganj. Similar to the spatial distribution, the trend chart also shows a higher trend of rise in temperature during April.

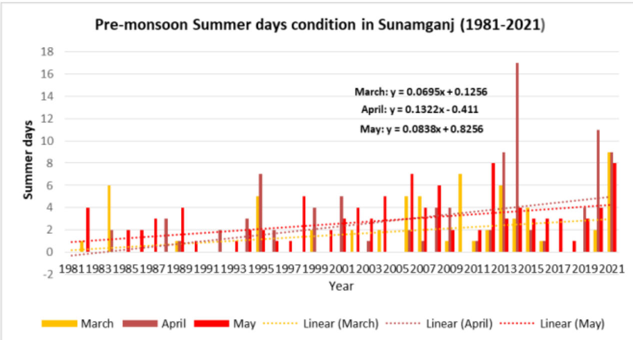


Chart 1 Summer Days (Daily Max. Temp > 35 ^{0}C) Trend (1980-2021) in Sunamganj during Pre-monsoon.

Long-term Condition of Rainfall in Sunamganj during Premonsoon (1980-2021)

The severity of heavy rainfall events is examined according to decadal distribution 1981-1990 (Fig. 6), 1991-2000 (Fig. 7), 2001-2010 (Fig. 8), and 2011-2020 (Fig. 9). The long term observation helps in depicting the rainfall tendency in Sunamganj.

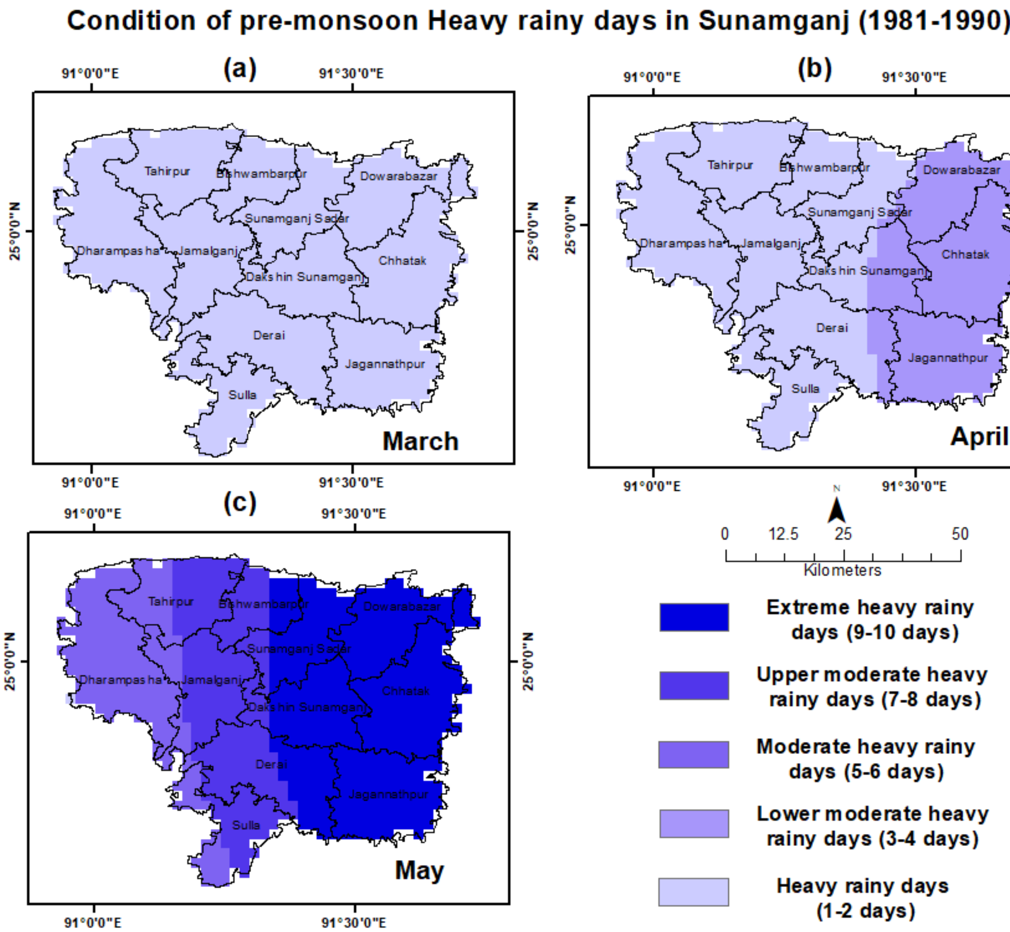


Figure 6: Pre-monsoon Rainy Days Condition in Sunamganj (1981-1990)

Figure 6 represents the heavy rainy days (No. of days with daily precipitation in between 44-88 mm) situation in March (a), April (b) and May (c) that is the pre-monsoon season. Among the 3 months, highest amount of rainy days are counted during May. This month experience heavy rainy days from moderate to extreme scale that is from 5 days up to 10 days. Whereas during 1981-1990, March shows the scenario of heavy rainy days with 1-2 days. April experiences 1-4 days of heavy rain. The rainfall ranges from 44-88 mm throughout the three months.

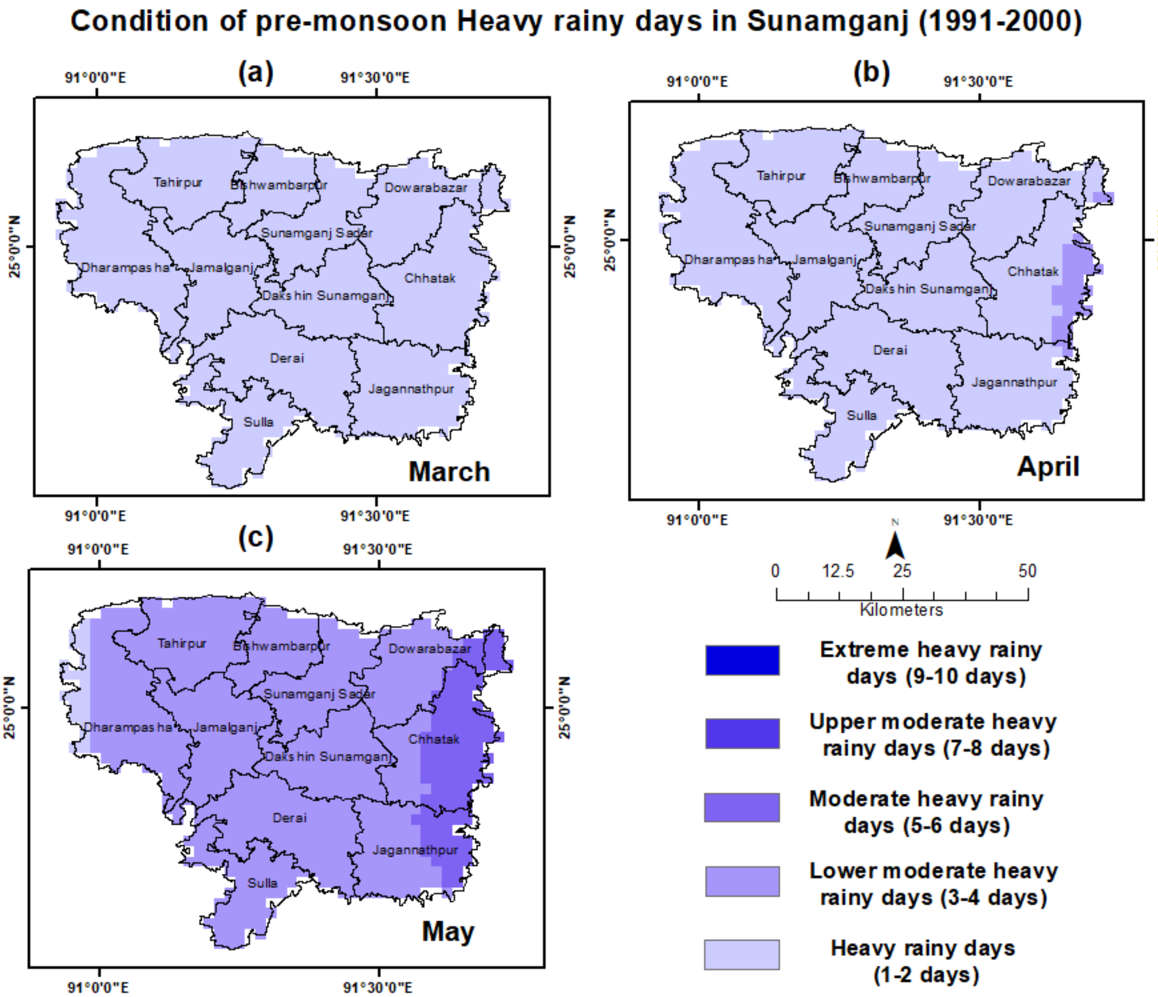


Figure 7: Pre-monsoon Rainy Days Condition in Sunamganj (1991-2000)

Similarity in pattern is observed in figure 7 as the number of rainy days is higher in May. Both March and April shows heavy rainy days (1-2 days) in two months during 1991-2000. The amount of heavy rainfall during March is 44-88mm. April has heavy rainfall of 52-88mm. Heavy rainy days to moderate heavy rainy days are seen during May that indicates of having heavy rainfall up to 6 days in that month. The amount of rainfall in May is 44-72mm.

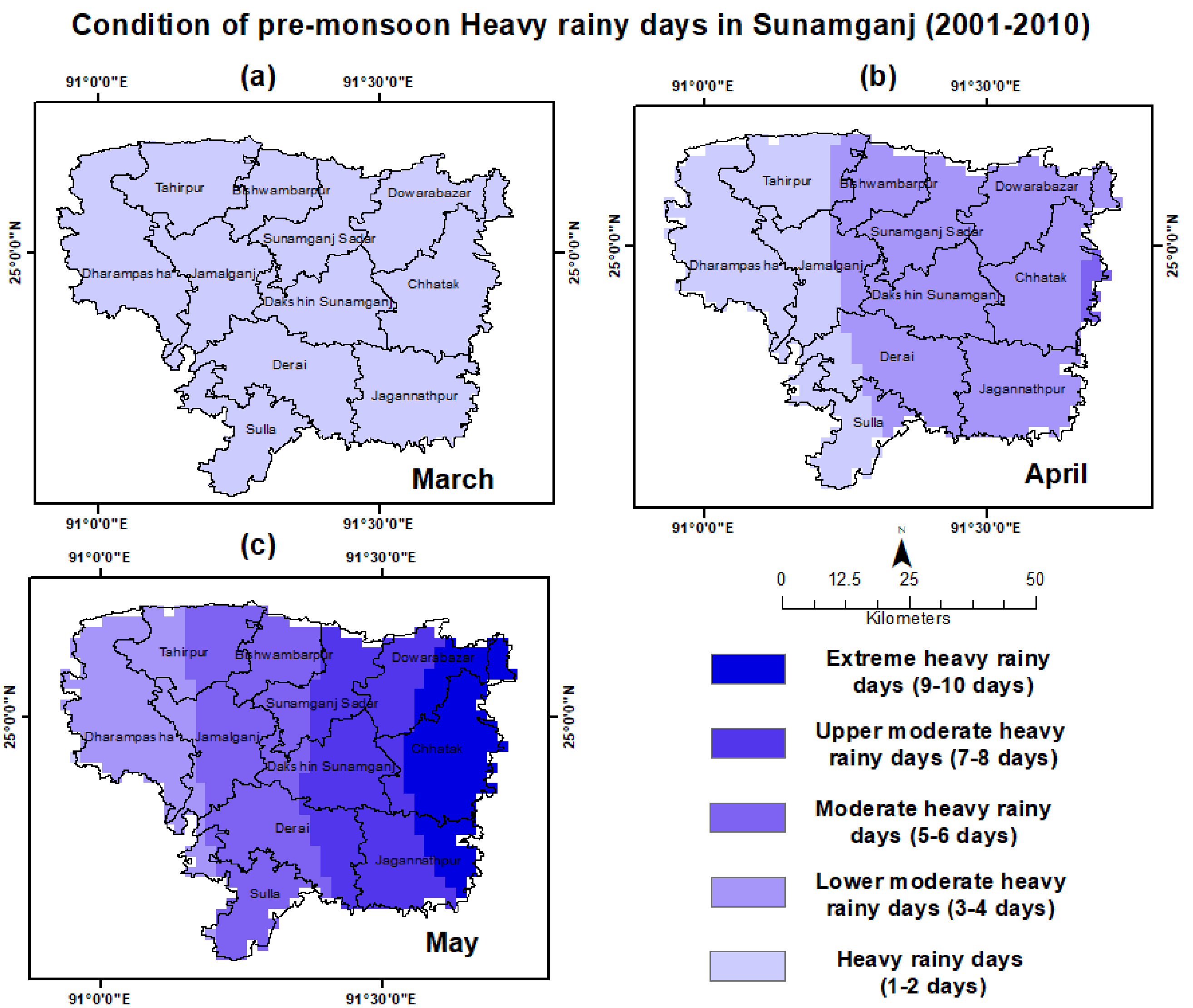


Figure 8: Pre-monsoon Rainy Days Condition in Sunamganj (2001-2010)

A gradual increase in heavy rainy days has been observed in figure 8 March exhibits only heavy rainy days (1-2 days) with 44-70 mm of rainfall. Whereas April ranges from heavy rainy days to lower moderate heavy rainy days and rainfall is 44-79 mm. May ranges from moderate to extreme heavy rainy days with rainfall amount similar to April.

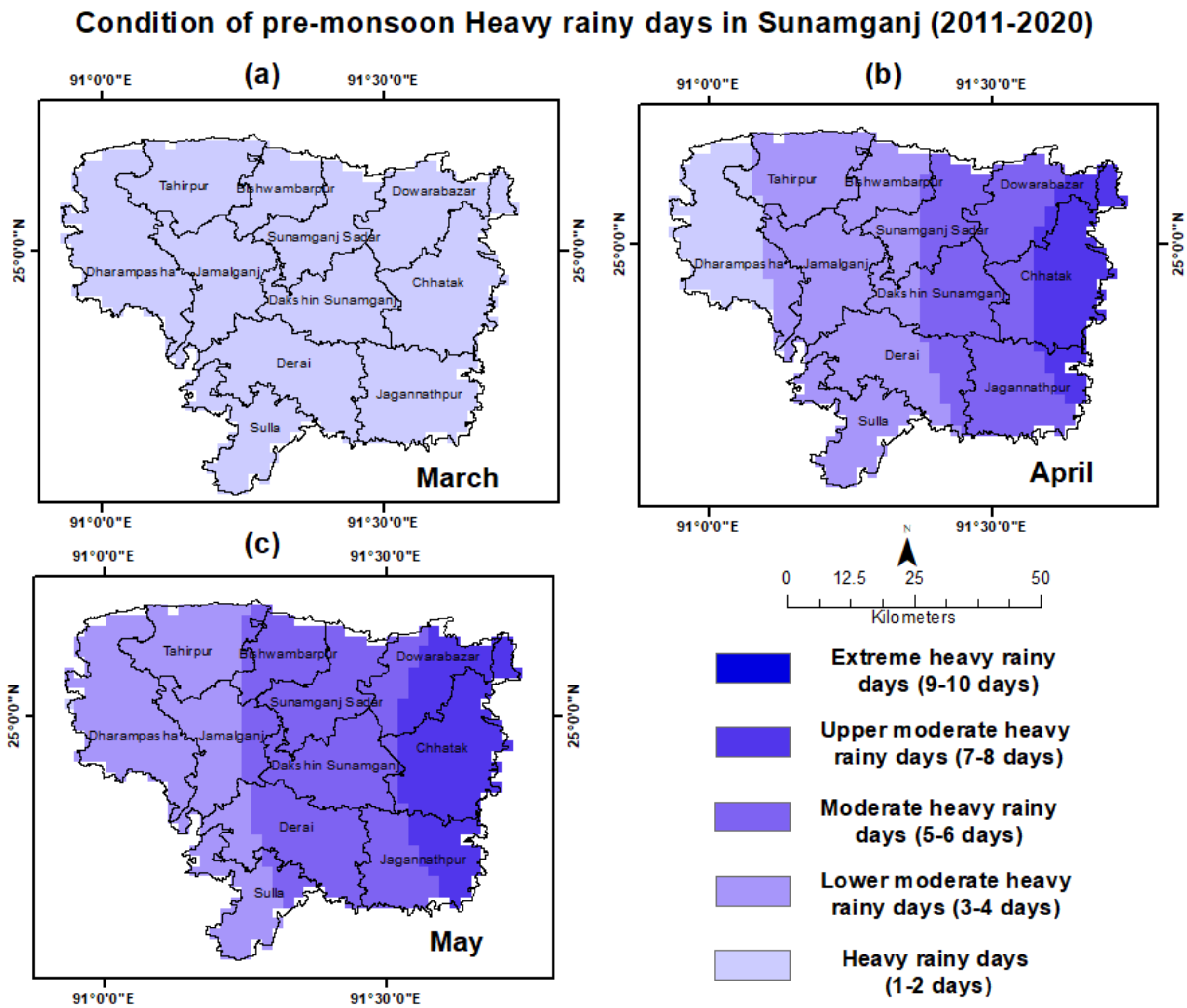


Figure 9: Pre-monsoon Rainy Days Condition in Sunamganj (2011-2020)

The amount of heavy rainy days shows similar pattern only in March like previous figure having 1-2 days of heavy rainfall, but the amount is 61-70 mm unlike figure 8. The intensity of heavy rainy days has increased during the rest of the two months. Both April and May experience heavy rainfall up to extreme heavy rainy days along with 44-88 mm rainfall.

In general, the amount of heavy rainy days has increased through last 40 years the growth is not gradual which represents an erratic pattern similar to temperature. Additionally, May experience the highest amount of heavy rainy days during the pre-monsoon.

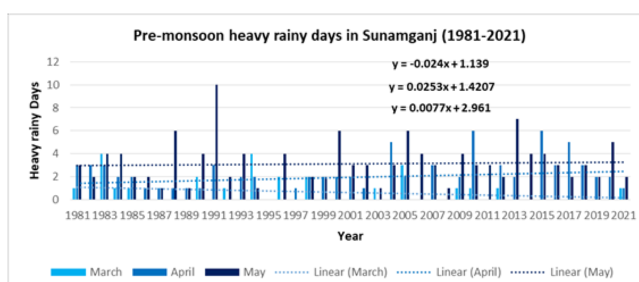


Chart 2 Heavy Rainy Days Trend (1980-2021) in Sunamganj during Premonsoon

The chart 2 shows the trend of heavy rainy days variability in Sunamganj from 1981-2021. Though Sunamganj can be categorized as one of the higher rainfall receiving districts compared to other districts in the country, this particular district trend shows decreasing pattern during the months of March whereas April and May manifests an increasing pattern similar to the spatial distribution.

The Distribution of Boro in Sunamganj

According to the agriculture data collected from secondary sources, HYV rice production of Bangladesh from 2006-2020 is also divided into 5 groups:i) Highest Production (10137611-15904887 m.ton), ii) Upper moderate production (4881110-10137610 m.ton), iii) Moderate production (2165543-4881109 m.ton), iv) Lower moderate production (951571-2165542 m.ton), v) Lowest production. The data suggests that Sunamganj represents the second group that is upper moderate production.

Likewise, local Boro rice yields of Bangladesh are also divided into 5 groups. i) Highest Production (162722-522619 m.ton), ii) Upper moderate production (86343-162721 m.ton), iii) Moderate production (29465-86342 m.ton), iv) Lower moderate production (10114-29464 m.ton), v) Lowest production (0-10113 m.ton). Among the districts, Sunamganj is one of the highest Boro producing districts.

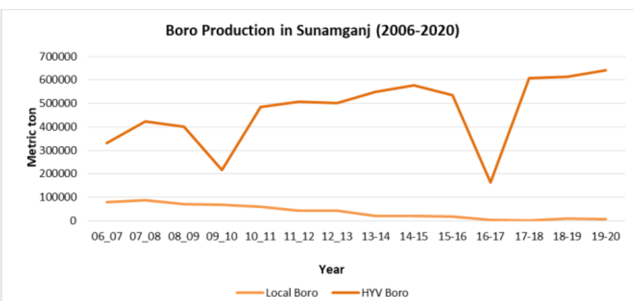


Chart 3 HYV and Local Rice Yields Trend (2006-2020)

The trend of HYV Boro and Local Boro yields in Sunamganj shows a significant difference between them. Over the years, HYV Boro has increased whereas local boro has a decreasing pattern in general. But the radical changes in the HYV Boro graph indicate an erratic phenomenon. The notable decrease in the production during 2009-10 and 2016-27 fiscal year is the result of flash floods in the Haor region. Maximum duration of the flash floods in Haor areas caused greater damages in crop production in 2000, 2002, 2004, and 2010 (Salauddin, 2010). Especially in 2009–10, there were a number of negative shocks that affected the production of Boro rice, including damage to seedlings from fog and cold at the start of the season and damage to paddy fields totaling 51,000 hectares (ha) in Haor regions from an early flash flood (CPD, 2010).

The year 2017 has the lowest production in Sunamganj since 2009-10 due to extreme weather events. With flash floods, hailstorms, tornadoes, and lightning, 2017 was dangerous. Huge croplands in Haor regions and low-lying areas of the northeast have been submerged as a result of heavy rainfall and the onrush of water from the upstream Meghalaya hills in India. The Sunamganj district has been most severely impacted by early-year flash flooding in 2017. While 91,690 hectares of standing crops in Boro fields have sustained damage, around 102,436 hectares of agricultural land have sustained complete devastation (Mondol et. al., 2021).

On the other hand, the green revolution and advancement of the technologies caused the local rice to have lower production. One of the study areas, Dakshin Sreepur has fully shifted to HYV rice which is BRRI 28 and BRRI 29 for the last 15-20 years. According to the locals of the study area, higher tolerance levels and shorter cultivation times for HYV Boro provide resilience from flash floods compared to local Boro. These factors have contributed to the local Boro's deteriorating popularity over time in this district.

Correlation between Extreme Climate Indices and HYV Rice

The correlation has been performed for the months of March, April and May of the Pre-monsoon season. The results are discussed below:

Table 2: Correlation of Extreme Climate Events and HYV Rice Production

HYV rice yields relationship with the indices	*March*		*April*		*May*	
	p value	Pearson r	p value	Pearson r	p value	Pearson r
MaxTmin	.425	.232	.856	.053	**.047**	**-.538**
MaxTmax	.377	.256	.140	.415	.864	-.050
Summer days	.392	-.248	.137	.418	.525	.186

Warm days	.383	.253	.210	.357	.785	.080
Cool days	.231	.342	.293	.303	.140	-.416
Tropical nights	.801	.074	.463	.-214	.713	-.113
Cool nights	.956	.016	.928	-.027	**.026**	**-.591**
MinTmin	.894	-.039	.357	.267	.647	.134
MinTmax	.976	-.009	388	-.250	.838	0.60
Heavy Rainy Days	**.023**	**-.600**	.322	-.286	.379	-.255
Annual total wet dry precipitation	.074	-.492	.299	-.299	.756	-.091
Very Heavy Rainy days	---	---	.585	-.160	.346	-.272
Moderate rainy days	.148	-.408	.193	-.370	.526	.185

** *Here, the correlation of very heavy rainy days could not be computed because one of the variables is constant*.

** *Correlation is significant at the 0.05 level (2-tailed)*

(Table 1 includes the description of every parameter associated with extreme climate events.)

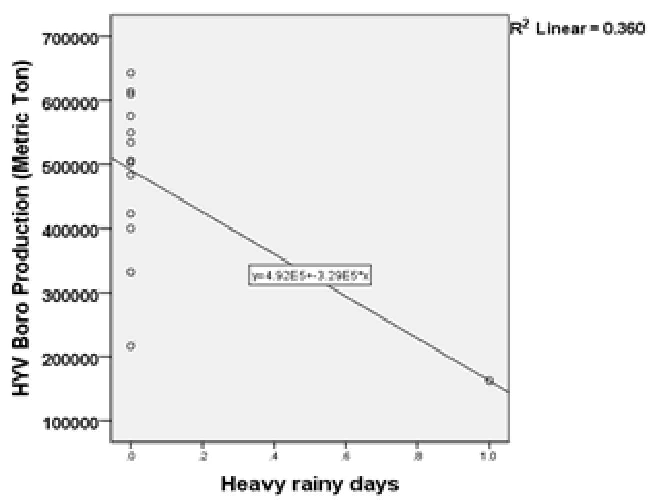
The combined scenario of the relationship between extreme climatic events and HYV Boro rice production in pre-monsoon is shown in Table 2.

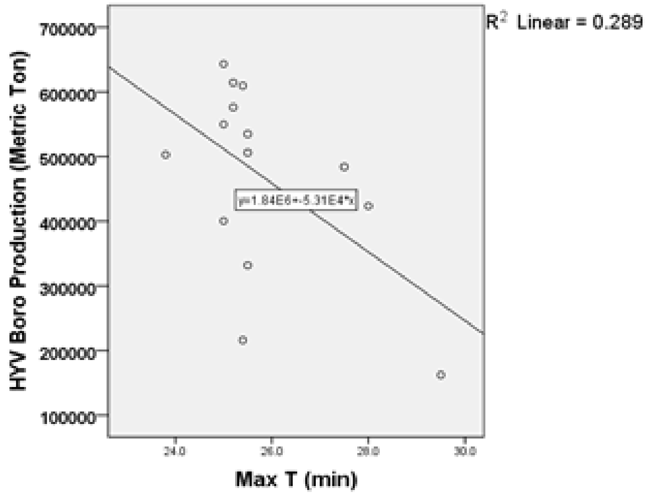
During March, 6 indices (MaxTmin, MaxTmax, Warm days Cool days, Tropical nights, and Cool nights) exhibit a positive relationship indicating that rice production will rise if one of the variables rises. However, none of the correlations are significant. While the remaining 6 variables (summer days, MinTmin, MinTmax, Heavy Rainy Days, Annual total wet dry precipitation, and Moderate rainy days) show negative. Any increase in these indicators will result in a drop in production. Among them, only Heavy rainy days exhibit significant correlation showing that this particular parameter has a notable contribution towards the Boro production.

The month of April shows positive relationships with 6 indices (MaxTmin, MaxTmax, Summer days, Warm days, Cool days). And rest of the 7 indices (MaxTmin, MaxTmax, Summer days, Warm days, Cool days, And Tropical nights, Cool nights, Heavy rainy days, Annual total wet dry, Very heavy rainy days, Moderate rainy days) have negative correlation. Although none of them represents any significant correlation. Although there is no significant correlation between any of them.

In May, only 5 indices (Warm days, Cool days, MinTmin, MinTmax, Moderate wet days) represents positive relation and other 8 (MaxTmin, MaxTmax, Cool days, Tropical nights, Cool nights, Heavy rainy days, and Annual total wet dry, and Very heavy rainy days are the variables showing negative relationship) indices have negative relation indicating majority of the indices impact the Boro production inversely. Most of the parameters has very low significance but Cool nights and MaxTmin exhibits significant relationship.

The statistical correlation portrays that Heavy rainy days (No. of days with daily precipitation above 88 mm), Cool nights (Percentage of days when min. temp < 10th percentile) and MaxTmin (Monthly max. value of daily min. temp (degree C) has significant negative relationship with the HYV Boro production in Sunamganj. As Sunamganj is a low lying haor region, heavy rainfall during pre-monsoon cause drastic waterlogged condition in the standing crops and reducing the production. Massive amount of silt and debris fall from the hills, results in riverbed filling and flooding.





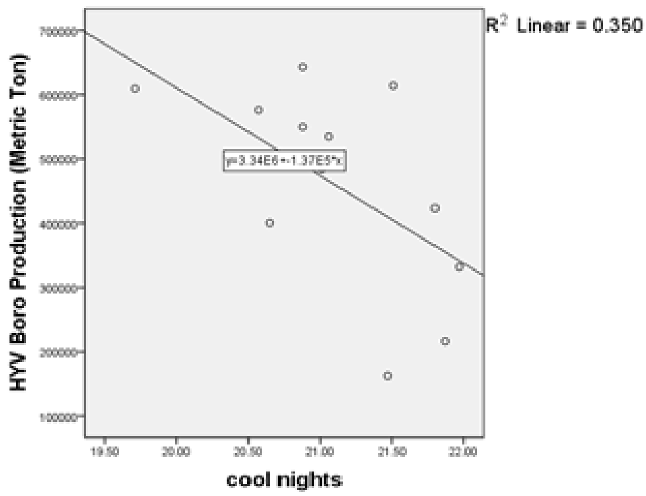


Chart 4 Significant Negative Relationship between Extreme Climate Indices and HYV Rice

Overall, the three months of the pre-monsoon season are correlated with low to moderate strength with HYV rice. For the past 14 years, no strong correlation has been found in this pre-monsoon. The relationship between climate and rice yield reveals that extreme climatic indices are not the only variable that affects rice yield; associated factors also have an impact which are described through the farmers' perception.

Farmers' Perception

The factors influencing the rice yield along with extreme climate events were identified through Focused Group Discussion (FGD) with the farmers of Dakshin Sreepur Union, Tahirpur. During the discussion, different factors have been highlighted. Among them, a total number of 6 factors are considered as highly influential for the yield of rice in Dakhshin Sreepur.. According to the farmers' perception, the six important factors from highest to lowest rank are: Economic, physiographic, climatic, flash flood, infrastructure, machinery. A total number of 14 associated variables of the six factors were also identified by the farmers.

Table 3: Associated Factors Impacting Boro Rice

Factors	Variables	Weight of the variables
Economic Factors	Subsidy	7
	Market place	5
	Low capital	5
	Labour cost	4
Physiographic factors	Low -lying area	9
	Flashflood	8
	Accumulation of Sediment debris	8
Climatic Factors	Flashflood	9
	Wind speed during thunderstorm	3
	Changed Flood Cycle	3
	Extreme heat	2
Other Factors	Absence of sluice gate	6
	Earthen dam	6
	Shortage of deep tubewell	8
	Single crop production	4

According to the farmers, Subsidy (weight: 7.0), market place (weight: 5.0), low capital (weight: 5.0), Labor cost (weight: 4.0) are the most relevant issues of the factor "economic". Another important factor "physiography" are comprise of important issues such as low-lying area (weight: 9.0), flashflood (weight: 8.0), sediment debris and accumulation (weight: 8.0), single crop production (weight: 4.0).Again, flashflood (weight: 09), sediment debris and accumulation (weight: 8.0), wind speed during thunderstorm (weight: 03), changed flood cycle (weight: 03), extreme heat (weight: 02) are considered significant issues for the factor "climatic". Climatic (weight: 9.0), sediment debris and accumulation (weight: 8.0), absence of sluice gate (weight: 6.0) are significant issues for the factor "Flashflood". Another important factor for Dakshin Sreepur is "infrastructure" that has important issues like absence of sluice gate (weight: 8.0), soil dams (weight: 6.0). "Machinery" factor mainly deals with single issue that is shortage of deep tube well (weight: 8.0).

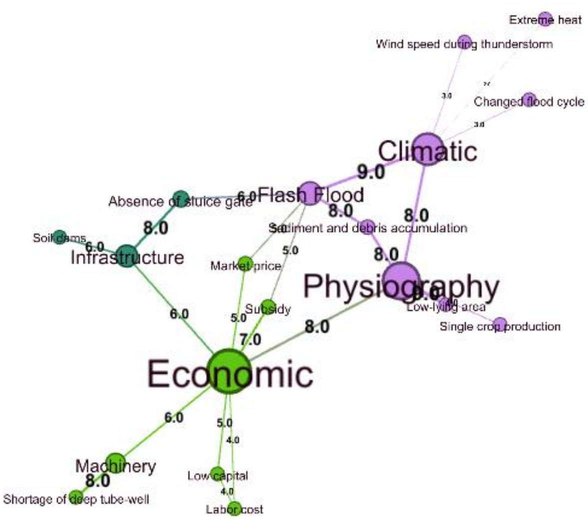


Figure 10: Ranking of the Factors Related to BRRI 28, BRRI 29 (HYV Boro) yield along with their associated issues. The circles with bold letters represent the major factors whereas non-bold factors are the associated issues of those major factors. The sizes of the circles show the rank and the width of the connecting lines indicate the weights of the associated issues.

The major factors affecting rice yield are depicted in figure 10 in which economic difficulties were identified as the key factor by the farmers of the study area. Low market price compared to production cost, low capital, which has an impact on labor costs, and inaccessibility/uneven distribution of subsidy all of which effect on yields. Decrease in yield is also caused by flash flood and thunderstorm events. Debris deposition on the riverbed has also been identified as an important of flash floods in areas with inadequate infrastructure. Farmers also discussed the lack of sufficient deep tube-well for irrigation.

Along with these major factors, a few minor factors such as social and transportation have also been identified from the farmers. Issues related to land fragmentation, syndicate regarding rice selling through dealers, low number of warehouse for rice preservation, and disputes with the fishermen community (since they hold water for fishing purposes causing delays in rice planting) were identified as social factors relevant to the yield. Furthermore, lack of transportation system in the haor region, resulting in an increase the production costs.

CONCLUSIONS AND RECOMMENDATIONS

The study reveals that the summer day and heavy rainy day trends are aberrant, with heavy rainfall being inconsistent and temperature increasing. Locals of the Dakshin Sreepur union have similarly described these traits. These could be signs of climate change, which would lead to more irregular extreme weather events. Only three of the thirteen extreme climate indicators (Heavy rainy days, MaxTmin, and Cool nights) exhibit a substantial negative connection with HYV rice yields. This suggests that other factors, in addition to climate variables, influence rice cultivation. Physiography has been regarded as the most crucial aspect by farmers. Being a low-lying region and affected with the sediment and debris coming though the hill slope that fills up the water body beds intensified the waterlogging. It is an important part of the Dakshin Sreepur union's rice yields. River dredging to keep water from overflowing during a flash flood is underlined as the best solution to this problem in the discussion.

Besides geographical location, Boro rice is impacted by a manifold of components. According to the farmers, the scarcity of deep tube-well for irrigation is also a highlighted factor impacting the total production. Most of the union depends on surface water for irrigation and the availability of this source of irrigation is gradually decreasing and they believe adequate deep tube-wells can increase the production. In addition for better irrigation suggestions for more canals among the haors also raised. Another factor is related to the infrastructure. The union has soil dams on both north and south side1s to prevent the union from excessive water from flash floods. The existing soil dams cannot provide sufficient protection. In this manner they have suggested the building of sluice gates on the site of existing soil dams in the north and south sides of the union will reduce flash floods in the first place. The farmers proposed a 200 feet Sluice gate on the north and 150-200 feet on the south to defend the union from excessive water. Economic and transportation factors have a mentionable impact together. Being a haor region the transportation system is quite inconvenient, raising the transportation cost. On the other hand, the market price of the rice is below expectation causing insufficient benefit. This situation leads to low capital for the next production accompanied with expensive labor cost and causing an undesirable cycle of challenges. Better transportation including "Jangal" (local word)/ roads among haor can solve the majority of these challenges. They shared about the deficiency related to a proper agricultural loan system for farmers. Also, the farmers of the Dakshin Sreepur union do not have proper training in seed preservation causing dependency on seed dealers and affecting the capital also. A standard loan system and seed preservation training can reduce their challenges. Apart from these, issues such as land fragmentation, conflict with the fishing community regarding the timeline of water holding in the land for fishing results in delaying the seedbed period, negligence in rice preservation also impacting the Boro production in the union.

Overall, Dakshin Sreepur is a remote and neglected union with a weak transportation system due to its location in a haor zone with high levels of fertility. However, the union can only survive on a single crop because the haor water remains non-stagnant for over 6-7 months, making alternative crop production impossible. Unfortunately, this union is unable to benefit from high fertility opportunities. The current disaster management scenario aids the union in protecting its crops in the event of an immediate emergency. However, a long-term solution is required. As a result, securing farming in a climatically sensitive union is essential. Farmers' solutions may be of use in this regard. Climate change cannot be prevented in a short amount of time; rather, it is a long process that can be improved by solutions developed at the local level by farmers and experts.

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