Changing Rainfall Pattern Effects on Water Requirement of T.Aman Cultivation in Bangladesh

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ABSTRACT

Variability in the amount and distribution of rainfall is one of the most important factors for limiting yield of rainfed crop like T.Aman rice in Bangladesh. The changing pattern of rainfall in T. Aman growing (June to October) has been assessed through analysis of data on rainfall for the period 1972-2008 for 12 major rice growing locations. The continuous rainless days (CRDs) and total rainless days (TRDs) are considered as those occurring between one or more consecutive rainy days yielding below 3.00 mm rainfall. The study shows, CRDs and TRDs both increased in 37 years for all rice growing locations and the significant change has been found for the months of July, August and October for CRDs and July, August and September for TRDs. Similar result has also been found for TRDs for different spells which are considered in this study. Some regional variation of CRDs and TRDs has been observed, with higher somewhat probability level calculated for Northwestern region in Bangladesh. This changing pattern of CRDs and TRDs may have a considerable negative effect on T.Aman cultivation in future which can be minimized by providing supplemental irrigation during this period to get better yield.

Keywords: CRDs, Rainless days, Rice yield, TRDs, T.Aman

1. INTRODUCTION

Any kind of agriculture crop is strongly influenced by the availability of water. Different forms of water have been modified rainfall, evaporation, run-off and soil moisture storage. Changes in total seasonal rainfall or in its pattern of variability are both important. Water is indispensable to plant life. A plant's water content varies by species and within various plant structures and also diurnally during the entire growth period. The formative water for the plant is obtained mainly from soil through absorption by the plant roots. The plant uses only less than 5% of the absorbed water. The rest is lost to the atmosphere through transpiration from the plant leaves. An adequate water supply is one of the most important factors in rice production. In many parts in Bangladesh, rice plants suffer from deficit water because of irregular rainfall and soil type. Variability of rainfall affects rice crop at different times. If the variability is associated with the onset of the rain, stand establishment and the growth duration of rice are affected. If variability is associated with an untimely cessation at the reproductive or ripening stage of the rice crop, yield reduction is severe (Moomaw and Vergara, 1965).

The rice-growing environment is classified into three major ecosystems based on physiography and land types: irrigated, rainfed, and floating or deepwater. [1]The cultivation of

[1] (World Food Programme, http://foodsecurityatlas.org/bgd/country/availability/agricultural-production)

rainfed Aus rice covers with an area of only 10 percent, the rainfed Aman crop with about 51 percent and the increasingly important irrigated Boro crop with about 39 percent. Therefore, rainfall is playing a vital role to crop production especially rainfed Aus and Aman rice during April to October when 61 percent of the total rice area depends on rainfall. About 90 percent of the total rainfall occurs during April to October. Despite the high rainfall in monsoon month of May to September, there is considerable degree of the year to year variability of rainfall at the drought affects Aus rice adversely and abrupt ending of monsoon in September can create severe water stress of T.Aman (up to maximum tillering stage) and rainfall may meet the crop water demand of rice. After October, rainfall is not sufficient for potential yield of rice and most of the Aman rice remains at the flowering and grain filling stage. If water is not supplied on those farms rice yield will be reduced drastically (Sattar and Parvin, 2009).

A number of studies have been carried out on crop water requirement of T.Aman rice associated with rainfall pattern in Bangaldesh (Arvind et al., 2006; Islam et al., 2004; Amin et al., 2004; Talukder et al., 1994; Karim et al., 1990; and Elias, 1986). Karim et al. (1990) mentioned that due to uncertain rain and its uneven distribution in Bangladesh, drought of different intensities occurs during growing of transplanted Aman. Amin et al. (2004) conducted a study on rainfall pattern and probability analysis and reported that the characteristics of the rainfall of the different locations of Bangladesh as depicted by analysis might be very useful in planning cropping practices in rainfed agriculture and also where conjunctive use of rainfall and irrigation water is made. Islam et al. (2004) reported that analysis of rainfall showed the evidence of a changing pattern of yearly and monsoon rainfall at comilla region; but did not show any changing pattern for both yearly and monthly rainfall for other regions. Investigation on rainfall trend for other locations of the country is necessary to observe the pattern. In order to aid crop planning and water management practices analysis, of rainless days is an important issue. With a view to this, the present study has been undertaken to quantify rainless days particularly in T.Aman growing season for planning supplemental irrigation in Bangladesh. It also investigates the nature, extent and frequency of rainless days from long term rainfall data for the improvement of drought and crop water management.

2. METHODS

2.1 Site Selection

An analysis of continuous rainless days (CRDs) and total rainless days (TRDs) within the T.Aman growing period (June to October) have been made to investigate the requirement of supplement irrigation. For this study, 12 districts were selected from the major rice growing areas in different regions of Bangladesh. Among them, Rajshahi, Bogra and Dinajpur were selected from northwestern region; Mymensingh and Tangail from central region; Jessore and Satkhira from southwestern region; Barisal and Madaripur from southern region; Chandpur and Comilla from southeastern region; and Sylhet district from eastern region.

2.2 Data collection and data range

In this study, daily rainfall data for the selected 12 rice growing locations in Bangladesh were collected from the Bangladesh Meteorological Department (BMD). Daily rainfall data has been included for the period of January 1948 to December 2008. As between 1948 and 1971, Bangladesh was going through a transitional period of political unrest and war of independence, data of the period was not recovered form the archive of the respective authority. However, data for the 37-year period from 1972 to 2008 for Barisal, Bogra, Comilla, Dinajpur, Jessore, Rajshahi, Satkhira and Sylhet locations and 32-year (1977 to 2008) for Chandpur, Madaripur and Mymensingh locations and 21-year (1988 to 2008) for Tangail have been used in the present study, because data for the period 1948-1971 were not considered reliable.

2.3 Data Analysis

T.Aman growing period was divided into five months from June to October. The

Continuous Rainless Days (CRDs) and Total Rainless Days (TRDs) were reckoned as those occurring between one or more consecutive rainy days yielding below 3.00 mm rainfall. The number of such CRDs and TRDs were counted for the all months separately for each year of daily rainfall recorded for trend line and probability analysis both.

2.4 Probability Analysis

The values of CRDs and TRDs were arranged in descending order and rank was given as well. If two or more observations have the same value, assuming them different consecutive values and they have been assigned each a unique rank and the first position of each observation in descending order was considered of its ranking place. Missing value for any data was filled by taking average of the values for the same data of the previous and the following years. 4CRD, 6CRD, 8CRD have been considered for the months of June, July, August and September and 14CRD, 16CRD, 18CRD for October month only for probability analysis of CRDs. Likewise, 12TRD, 14TRD, 16TRD were considered for June, July and August month and 14TRD, 16TRD, 18TRD for September and 22TRD, 24TRD, 26TRD for October. The data were analyzed for probability distribution through Weibull's method which is given below

$$P = \frac{m}{n+1}$$

Where,
P is the exceedance probability
n is the number of values in the recorded
m is the rank of the event in order of magnitude

3. RESULT AND DISCUSSION

3.1 Trend line analysis of CRD and TRD

The trend of CRDs and TRDs was analyzed for each of the 12 locations in Bangladesh and the result is summarized in Table 1 and Table 2. Table 1 demonstrates that CRDs in maximum locations show increasing trend during the T.Aman growing period in Bangladesh. Out of 12 locations, 6 locations follow increasing trend in June month, 10 locations in July, 8 locations in August, 6 locations in September and 11 locations in the month of October. It indicates the number of interval between two consecutive rainy days (equal or above 3 mm rainfall in a day) increased within the last 37 years (1972 to 2008). Besides, the change of CRDs was significant for the months of July, August and October during this time period.

The vegetative phase of T.Aman rice starts at the end of July and continue up to the middle of the September, when requirement of water is high. Water requirement of T.Aman rice for its total growing period is 1000-1100 mm whereas 600 to 650 mm is required during vegetative phase only (Rashid, 2010). Therefore, the changing pattern of CRDs must play a considerable negative role on T.Aman production and might have an effect on water requirement in near future during this period.

Some regional variations are also being observed in the trend line analysis of rainfall data. In region-wise analysis, a closer look shows that CRDs in Northwestern region changed at a significant rate during the period of July to October (except August in Dinajpur location) and the significant level of these changes of CRDs are comparatively higher than the other regions in Bangladesh. It states that the increasing rate of continuous rainless day have occurred more rapidly in Northwestern region in the last 37 years. Moreover, Northwestern part represents drought pone region in Bangladesh. Therefore, supplemental irrigation must be made available for T.Aman cultivation for all locations in this region to reduce water stress in future.

Similar to CRDs, the analysis shows increasing trend of TRDs for the most rice growing locations in Bangladesh. Out of 12 locations, 6 locations follow increasing trend in June, 8 locations in July, 9 locations in August, 10 locations in September and 6 locations in the month of October. It indicates the number of rainless days (below 3 mm rainfall in a day) increased within the last 37 years (1972 to 2008). Besides, the change of TRDs has been found significant for the months of July, August and September during the same period.

Mymensingh, located in Central region and Jessore and Satkhira in Southwestern region follow a comparatively better situation compared to the other regions for both CRDs and TRDs. In addition, these three locations do not cover the maximum area of rice cultivation in Bangladesh. Therefore, the changing pattern of rainfall (CRDs and TRDs) must play a considerable negative impact on yield of T.Aman in upcoming years which can be minimized by providing supplemental irrigation during its growing period.

In addition, IPCC third assessment report, projection of changes in precipitation in different Asian regions has been made (under IS92a emission scenarios). The projection shows increases in summer precipitation for projected years, 2020s (2010-2029), the 2050s (2040-2069), and the 2080s (2070-2099), especially under the influence of GHGs alone. On the other hand, it shows a reduction in winter precipitation (especially with consideration of sulfate aerosols) over south Asia (with or without direct aerosol forcing). Huq et al. (1999) predicted that winter precipitation would decrease at a negligible rate in 2030, while in 2075 there would not be any appreciable rainfall in winter. On the other hand, monsoon precipitation would increase at a rate of 11 percent and 28 percent for the years 2030 and 2075, respectively. Basak et al., (2009) analyzed in 30 years data from 1976 to 2005 and found that out of 34 weather stations, 30 stations follow increasing trend during Monsoon season (June to September) and 32 stations during Post-Monsoon season (October-November) in Bangladesh which cover the total growing of T.Aman cultivation. But from this study, it is found that both continuous rainless days (CRDs) and total rainless days (TRDs) increased during June to October. Therefore, it is clear that intensity of rainfall in growing period of T.Aman increased but frequency and distribution pattern changed which might occur to ensure the fulfillment of water requirement demand for a certain time but not for a definite time interval which is very essential to harvest good yield for any type of agriculture crop.

Table 1: Trend line equations of CRDs for the most rice growing areas in Bangladesh during T.Aman season

Locations	June	July	August	September	October
Northwest reg.					
Rajshahi	y = -0.0702x + 8.603	y = 0.0066x + 5.2252	y = 0.0073x + 5.563	Y = 0.0256x + 6.756	y = 0.005x + 15.716
Bogra	y = -0.0697x + 7.162	y = 0.0076x + 5.5045	y = 0.004x + 6.9234	Y = 0.0012x + 7.301	y = 0.0081x + 14.063
Dinajpur	y = -0.0413x + 6.014	y = 0.0571x + 4.8317	y = -0.0456x + 8.23	Y = 0.0574x + 5.493	y = 0.0613x + 14.256
Central region					
Mymensingh	y = -0.04x + 5.2843	y = -0.0495x + 5.3165	y = 0.0035x + 5.16	Y = 0.0062x + 5.897	y = 0.0101x + 14.427
Tangail	y = 0.013x + 5.5238	y = 0.0026x + 5.8286	y = -0.2065x + 9.03	Y = 0.0169x + 6.909	y = 0.0182x + 13.657
Southwest reg.					
Jessore	y = -0.032x + 6.7162	y = 0.0078x + 4.5811	y = 0.0002x + 5.18	Y = -0.0327x + 7.837	y = -0.093x + 15.797
Satkhira	y = 0.0006x + 6.5714	y = 0.0256x + 3.9984	y = -0.0476x + 5.82	Y = -0.0539x + 7.525	y = 0.0488x + 12.625
Southern reg.					
Barisal	y = -0.0377x + 6.337	y = 0.0256x + 3.7027	y = 0.0097x + 4.166	Y = -0.0778x + 7.423	y = 0.0028x + 13.459
Madaripur	y = 0.0092x + 5.4738	y = 0.0242x + 3.9133	y = 0.0367x + 3.707	Y = -0.0609x + 8.004	y = 0.0568x + 12
Southeast reg.					
Chandpur	y = 0.0058x + 5.6437	y = 0.0036x + 4.6115	y = 0.1152x + 3.013	Y = -0.1486x + 9.103	y = 0.0013x + 14.179
Comilla	y = 0.0078x + 5.2568	y = -0.0588x + 6.6577	y = 0.0175x + 15.58	Y = -0.1494x + 10.67	y = 0.0045x + 14.158
Eastern region					
Sylhet	y = 0.0005x + 3.4505	y = 0.0055x + 2.3288	y = -0.0422x + 4.04	Y = 0.0052x + 5.441	y = 0.119x + 11.631

Table 2: Trend line equations of TRDs for the most rice growing locations in Bangladesh during T.Aman season

Locations	June	July	August	September	October
Northwest reg					
Rajshahi	y = -0.057x + 19.581	y = 0.0119x + 15.505	y = 0.0441x + 16.973	y = 0.0145x + 17.617	y = 0.0187x + 24.806
Bogra	y = -0.0934x + 17.64	y = 0.0009x + 14.523	y = 0.0028x + 17.108	y = 0.0073x + 17.104	y = 0.0052x + 24.144
Dinajpur	y = -0.035x + 15.259	y = 0.092x + 12.548	y = 0.0828x + 14.719	y = 0.0828x + 14.719	y = 0.019x + 24.703
Central reg.					
Mymensingh	y = -0.138x + 15.558	y = 0.0073x + 11.754	y = -0.049x + 15.254	y = 0.0638x + 14.26	y = -0.0751x + 25.80
Tangail	y = 0.0481x + 15.662	y = 0.0091x + 15.614	y = -0.106x + 18.457	y = 0.0065x + 17.738	y = 0.0195x + 24.548
Southwest reg.					
Jessore	y = -0.046x + 16.586	y = -0.0991x + 15.91	y = 0.0066x + 15.685	y = -0.1131x + 19.554	y = -0.06x + 26.086
Satkhira	y = 0.0039x + 16.595	y = 0.0537x + 11.868	y = -0.063x + 15.525	y = 0.0003x + 16.162	y = -0.0429x + 25.32
Southern reg					
Barisal	y = 0.0059x + 14.32	y = -0.0695x + 12.32	y = 0.0588x + 11.369	y = 0.0019x + 16.18	y = -0.0228x + 24.35
Madaripur	y = 0.0284x + 14.938	y = 0.0015x + 12.726	y = 0.0563x + 12.79	y = 0.0328x + 16.615	y = -0.0389x + 25.14
Southeast reg.					
Chandpur	y = 0.0158x + 14.722	y = 0.0145x + 11.743	y = 0.1853x + 10.828	y = 0.008x + 16.476	y = 0.008x + 16.476
Comilla	y = 0.0081x + 14.658	y = -0.052x + 14.829	y = 0.0152x + 15.604	y = -0.0628x + 18.869	y = -0.0771x + 25.78
Eastern region					
Sylhet	y = -0.0583x + 9.081	y = 0.0168x + 5.4099	y = -0.053x + 9.8468	y = 0.0178x + 12.122	y = 0.0083x + 23.113

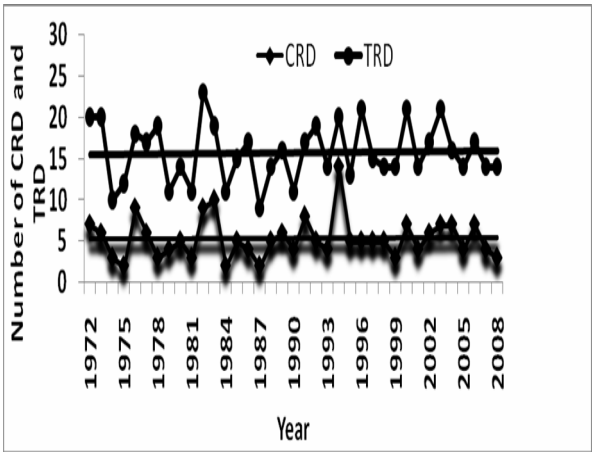

Figure 1: Variation of CRDs and TRDs in July at Rajshahi location

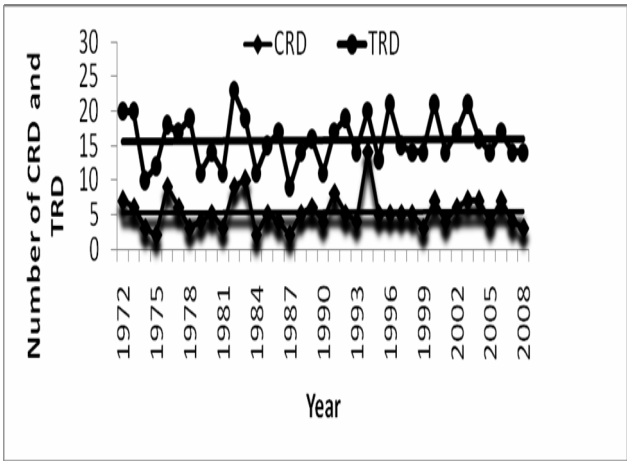

Figure 2: Variation of CRDs and TRDs in August at Jessore location

3.2 Probability analysis of Continuous rainless days and Total rainless days

The probability analysis of CRDs and TRDs for 12 rice growing locations is shown in Table 3 and Table 4 for the period of June to October. For the probability analysis of CRDs, 4CRD, 6CRD and 8CRD are considered for the months of June, July, August and September and 14CRD, 16CRD and 18CRD for October only, because the amount of rainfall in October is less than compared to the other four months. Therefore, the spell of CRDs is considered to be high level.

Table 3 shows the probability of occurrence of 4CRD and 6CRD are high during June, August and September for all 12 rice growing locations. The probability level of 5.26 in June at Sylhet to 94.74 in September at Bogra for 4CRD and 2.63 in July at Sylhet to 63.16 in September at Bogra for 6CRD has been found from the analyses. It reveals that less difference in the four continuous rainless days of these months are observed. For

example, the probability of occurrence 4CRD spell is 94.74 at Bogra which implies that 4CRD spell is expected every year in September during T.Aman growing season at Bogra. On the other hand, 5.26 probability in June at Sylhet which indicates that there is very low probability (only 5.26) to occur 4CRD spell in every year in June. For 8CRD, the probability level is 3.30 in July at Madaripur to 38.78 in August at Tangail. It indicates that there is very low probability to occur 8CRD compared to 4CRD and 6CRD during June to September. However, the probability level for October month gradually increased and the level of probability is 34.22 at Barisal to 57.89 at Rajshahi for 14CRD and 12.12 at Madaripur to 32.43 at Dinajpur for 18CRD. Some regional variations are also being observed from the probability analysis. A closer look shows that the probability of occurrence of 4CRD, 6CRD and 8CRD during June to September and 14CRD, 16CRD and 18CRD during October are high in Northwestern region and low in Eastern region in Bangladesh. It could be expected that there is a high risk of availability of rainwater during T.Aman growing season in Northwestern part.

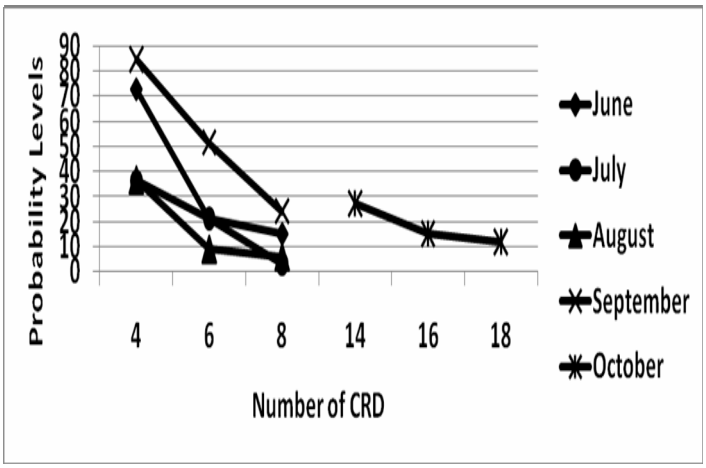

Figure 3: Probability analysis of CRDs at Dinajpur

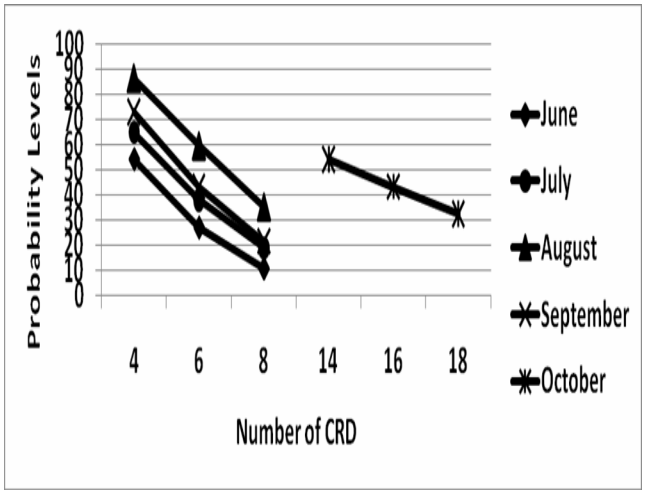

Figure 4: Probability analysis of CRDs at Madaripur

Likewise CRDs, the probability levels of TRDs are low in July during the total growing period. As well as, Northwestern region are also facing a more severe situation compared to the other regions for cultivating T.Aman due to changing the pattern of Rainfall of TRDs. However, the other regions in the country are lying more or less in the probability level for both CRDs and TRDs. Thereby, to ensure the fulfillment of water requirement demand, it is essential to provide additional water supply to get better yield of T.Aman in future.

Table 3: Probability analysis as percentage of CRDs for the most rice growing locations in Bangladesh during T.Aman season

Locations	June	July	August	September	October										
CRD	4	6	8	4	6	8	4	6	8	4	6	8	14	16	18
Northwest reg															
Rajshahi	78.95	50.00	34.21	60.53	28.95	13.16	73.68	26.32	15.79	78.95	52.63	26.32	57.89	34.21	23.68
Bogra	63.16	39.47	15.79	60.53	39.47	07.89	86.84	55.26	21.05	94.74	63.16	26.32	44.74	23.68	18.42
Dinajpur	54.05	27.03	10.81	64.86	37.84	18.92	86.49	59.46	35.14	72.97	43.24	21.62	54.05	43.24	32.43
Central region															
Mymensingh	48.48	21.21	06.06	42.42	18.18	06.06	45.45	30.30	15.15	60.61	33.33	18.18	42.42	36.36	24.24
Tangail	81.82	27.27	09.09	82.61	26.10	08.10	69.57	52.17	34.78	86.96	56.52	30.43	43.48	26.10	21.74
Southwest reg															
Jessore	63.16	36.84	23.68	44.74	18.42	07.89	68.42	15.79	10.53	84.21	55.26	39.47	50.00	26.32	23.68
Satkhira	83.78	54.05	16.22	29.73	13.51	10.81	48.65	27.03	08.11	72.97	37.84	21.62	37.84	27.03	24.32
Southern reg.															
Barisal	57.89	26.32	18.42	39.47	18.42	07.89	44.74	13.16	02.63	63.16	28.95	21.05	34.22	26.32	21.10
Madaripur	72.73	21.21	15.15	36.36	21.21	03.30	36.36	09.10	06.10	84.85	51.52	24.24	27.27	15.15	12.12
Southeast reg															
Chandpur	70.97	25.81	16.13	38.71	25.81	09.68	45.16	25.81	12.90	77.42	45.16	32.26	51.61	25.81	19.35
Comilla	60.52	28.95	13.16	65.79	26.32	10.52	65.79	34.21	07.89	89.47	50.00	23.68	47.37	31.58	18.42
Eastern region															
Sylhet	21.05	10.53	05.26	05.26	02.63	-	18.42	07.89	-	55.26	31.58	21.05	36.84	23.84	18.42

Table 4: Probability analysis as percentage of TRDs for the most rice growing locations in Bangladesh during T.Aman season

Locations	June	July	August	Septem ber	October										
TRD	12	14	16	12	14	16	12	14	16	14	16	18	22	24	26
Northwest re															
Rajshahi	97.37	86.84	76.32	81.58	55.26	44.74	97.37	92.11	71.05	84.21	57.89	47.37	78.95	63.16	44.74
Bogra	86.84	63.16	39.47	63.16	50.00	42.11	94.74	84.21	60.53	81.58	63.16	36.84	71.05	52.63	28.95
Dinajpur	75.68	48.65	29.73	67.57	48.65	32.43	94.59	86.49	67.57	72.97	45.95	24.32	89.19	59.46	35.14
Central reg.															
Mymensingh	54.55	39.39	27.27	45.45	18.18	09.09	75.76	51.52	30.30	66.67	42.42	24.24	78.79	57.58	21.21
Tangail	90.91	68.18	50.00	86.96	69.57	39.13	91.30	69.57	60.87	86.96	69.57	34.78	86.96	60.87	26.10
Southwest re															
Jessore	76.32	68.42	42.11	63.16	42.11	23.68	86.84	68.42	39.47	78.95	63.16	42.11	60.53	63.16	42.11
Satkhira	95.59	81.10	54.10	48.65	29.73	08.10	81.10	40.54	18.42	75.68	40.54	24.32	78.38	51.35	32.43
Southern reg.															
Barisal	71.05	50.00	28.95	34.21	21.05	07.89	57.89	34.21	10.53	68.42	52.63	31.58	76.32	42.10	18.42
Madaripur	81.82	63.64	36.36	54.55	30.30	12.12	60.61	45.45	30.30	78.79	54.55	39.40	81.82	45.55	24.24
Southeast reg															
Chandpur	80.65	51.61	22.58	45.16	19.35	09.68	61.29	38.71	22.58	80.65	58.06	19.35	80.65	54.84	35.48
Comilla	76.32	47.37	34.21	60.53	44.74	15.79	89.47	71.05	39.47	84.21	65.79	39.47	71.05	50.00	38.95
Eastern reg															
Sylhet	10.53	02.63	-	02.63	-	-	10.53	07.89	05.26	34.21	15.79	10.53	57.89	28.95	15.79

4. CONCLUSION

Rice crop is highly sensitive the to availability of water during its growing period. The study showed, CRDs and TRDs both increased within 1972 to 2008 for all rice growing locations and the significant change has been found for the months of July, August and October for CRDs. Out of 12 locations, 6 locations follow increasing trend in June, 10 locations in July, 8 locations in August, 6 locations in September and 11 locations in October. It indicates the number of interval between two consecutive rainy days (above 3 mm rainfall in a day) increased during this time period. Similar to CRDs, the analysis shows an increasing trend of TRDs for the most rice growing locations in Bangladesh. Out of 12 locations, 6 locations follow increasing trend in

June, 8 locations in July, 9 locations in August, 10 locations in September and 6 locations in October. It indicates the number of rainless day (below 3 mm rainfall in a day) increased and the change of TRDs has been found significant for the months of July, August and September. It is also observed that the probability level of 4CRD and 6CRD are significant during June, July, August and September in all selected locations except Sylhet. Similar result has also been found for TRDs for different spells which are considered in this study. Some regional variation of CRDs and TRDs has been observed, with higher somewhat probability level calculated for Northwestern region in Bangladesh. Mymensingh in Central region and Jessore and Satkhira in Southwestern region follow a comparatively better situation compared to the other regions for both CRDs and TRDs. However, these locations do not cover the much more rice growing area in Bangladesh. Therefore, the changing pattern of rainfall (CRDs and TRDs) must play a considerable negative impact on yield of T.Aman in upcoming years which can be minimized by providing supplemental irrigation during its growing period to boost a better yield.

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