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Comparison the Drought Probability at Different Decade from Northwestern Area of Bangladesh

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Abstract: ***The study area is the northwestern region (24˚.30´-26˚.40´N, 88˚.01´-89˚.90´ E) part of Bangladesh is selected for drought analysis. We consider Rajshahi, Rangpur and Dinajpur district for the total time period 1980 to 2015. The daily rainfall data were converted into 5, 7 and 10 days rainfall data for different decade such as 1980-1989, 1990-1999, 2000-2009, 2010-2015. The choice of threshold value for Markov chain model is very important especially when it is used for agricultural purpose. The measurement unit of rainfall is millimeter (mm) with measurement instrument is standard rain gauge. After collecting the data for analysis we calculated them in decade-wise by using Microsoft Excel. After cleaning the daily rainfall data set we calculated them into different time interval like 5, 7 and 10 days by using Microsoft Excel then we use R program to analyze drought index under Markov Chain Model for threshold value 3 mm of rainfall. From empirical analysis we observed that the decades of different time scale in Rajshahi, Rangpur and Dinajpur are stable in different stages. Finally we conclude that Rajshahi and Rangpur districts were more drought prone than Dinajpur district. Among these three districts Rajshahi was the highest drought prone area and Dinajpur was the lowest drought prone area during the study period 1980 to 2015.***

Keywords: Drought index, Markov Chain, Higher Transition Probability Matrix, Northwestern region, Bangladesh

1. Introduction

Bangladesh is one of the most disaster-prone countries in the world because almost every year the country faces different kind of natural disasters such as tropical cyclones, storm surges, coastal erosion, floods, and droughts, causing heavy loss of life and property and jeopardizing the development activities [1]. Despite the recurrent and devastating nature of droughts it has concerned far less scientific attention than floods or cyclones ([26], [27], [18], [24], [20], [10]). According to the World Bank Report [29], in Bangladesh the losses from drought are likely to be more severe than from floods. Rice production losses in the drought of 1982 were 50 percent more than the losses occur due to the flood in the same year. In the perspective of global warming, most of the climatic models project a decrease in precipitation in dry season and an increase during monsoon in south Asia. This will cause a cruel combination of more extreme floods and droughts in the region. Karim et al [11] prepared the first agricultural drought risk map by considering the effect of dry days, higher temperature and soil moisture. After that several studies had been done to investigate the impact of drought on agricultural in case of Bangladesh (for example, [7], [8], [25], [12], [17], [21]). On economy [5] and on society ([5], [18]) in Bangladesh, due to the land use changes within the country and in neighboring country. Therefore, it is necessary to identify different kinds of drought for taking proper management plan. Moreover, Drought is a highly misused word because there is no universally accepted definition of drought. Several authors defined drought on the basis of meteorological, agricultural, hydrological and socio economic impact and also tries to linking up the various types of drought. Meteorological drought is directly related to the weather parameter rainfall, but agricultural drought in is the consequence of meteorological drought. Agricultural drought is mainly caused by the soil water deficiency which is occurred because of meteorological derivation. Standard precipitation index (SPI) ([15], [16]) is the most widely used meteorological drought index. The advantages of SPI are that it can be calculated for a variety of time scales. This versatility allows SPI to monitor short-term water supplies, such as soil moisture which is important for agricultural production, and long-term water resources, such as groundwater supplies, stream flow, and lake and reservoir levels. On the other hand Markov chain model is a widely used agricultural drought index in the Indian subcontinent. It has been used for determining drought proneness, Analyzing rainfall drought correlation Analyzing agricultural drought and predicting critical wet and dry spell. Markov chain model is found to be promising in simulating the length of the longest dry and wet spells and largest rainfall amount during monsoon. The drought measuring parameters are not linearly related to one another, these drought indices often have little correlation among themselves. Therefore it is quite common when one drought index identifies drought at a particular place, another drought index indicates normal condition at the same time and place. The aim of this paper is to find out the drought index of the Northwestern region of Bangladesh by using Markov Chain model with different time decade. The rest of the paper is organized as follows: section 2 present the description of the study area, section 3 present the methodology, section 4 present the result and discussion and finally section 5 present the conclusion.

2. Study Area Descriptions

The western part Bangladesh, which is divided into two regions: northwestern region (24°.30′–26°40′ N, 88°.01′–89°.90′ E) and southwestern region (22°.52′–23°.90′ N, 88°.20′ –90°.30′ E) ([3]). These two regions are considered as the main *Boro* paddy rice growing areas of Bangladesh by

which country's food security can be ensured to a significant level. Three kinds of rice cropping patterns such as winter (*Boro*), summer (*Aus*), and monsoon (*Aman*) are usually practiced in the study area. Out of these three, high yield variety (HYV) *Boro* rice is the main contributor of total rice production in Bangladesh. This study considers only the *Boro* paddy fields that have been severely threatened by drought events in the last several decades. We selected Rajshahi, Rangpur and Dinajpur ditrict from northwestern region of Bangladesh.

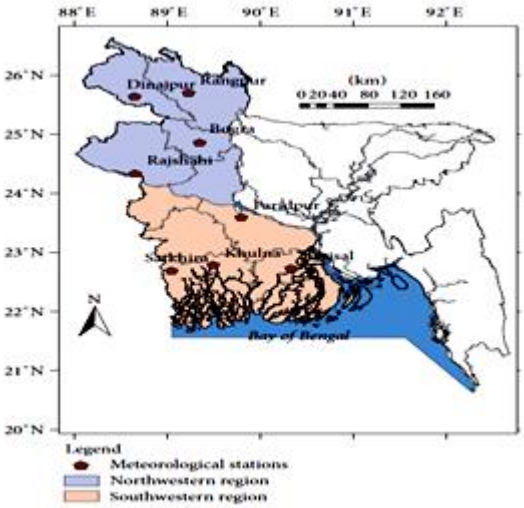

Figure 1: Western part of Bangladesh ([3])

3. Methodology

Different indexes have been used to detect drought (for example, [4], [28]). Palmer Drought Severity Index (PDSI) widely used in the United States ([19], [6]). Mo and Chelliah [13] made some modifications to improve the PDSI. Standardized Precipitation Index (SPI) proposed by McKeeet et. al. ([15], [16]), which measured meteorological flood and drought by using only precipitation. Kamaruzzaman et al. [9], Rahman ([22], [23]) and other authors used Markov chain based index for identifying drought for different stations. In our study we use Markov chain model to create drought index based on rainfall data.

3.1 Markov Chain Model

Markov chain probability model is based on the assumption that the state of any day depends only on the state of the preceding day. A two state Markov chain model involves the calculations of two conditional probabilities (1) α, the probability of a wet week following dry week and (2) ᵝ, the probability of a dry week. The two state Markov chain for the conditional probabilities are as follows:

		Dry	Wet
Present state	Dry	1- α	α
	Wet	ß	1- ß

Let us consider the conditional probabilities
$P_0 =$
Pr$\{W/D\}$
$P_1 =$
Pr$\{W/W\}$

The above sequence is considering as is irreducible Markov chain with two argotic states. Its stationary probability distribution has a probability of success
$P = p_{01}/(1 - (p_{11} - p_{01}))$.

3.2 Markov Chain Model of Order M

A Markov Chain is a Markov process where the state and parameter spaces are considered to be discrete and the dependence of the state is called Markovian dependence [14].. The m order Markov chain is a sequence of trails of the outcome if each trail depends on the outcome of the directly preceding trails and depends only on that. According to the sequence of random variables $\{X_n\}$ forms a Markov chain of order m, if given a fixed m, for all possible values of the variables $X_n (n = 0,1,2, \dots)$ it is true that
Pr$[X_n$
$= j|X_0$
$= i_0, X_1$
$= i_1, \dots, X_{n-m}]$
Pr$[X_n$
$= j|X_{n-m}$
$= i_{n-m}]$

3.3 Method of Markov Chain Model

Several authors have found that the sequences in daily rainfall occurrences can be described by a simple Markov chain model. Additional evidence to indicate the feasibility of using a Markov chain model has been presented by Rahman ([22], [23]) and Banik et al. [2]. The theory of Markov chain is described below:
Let $X_0, X_1, X_2, \dots, X_n$ be random variables distributed identically and taking only two values, namely 0 and 1, with probability one, i.e.

$$X_n = \begin{cases} 0 \text{ if the n-th week is dry} \\ \\ 1 \text{ if the n-th week is wet} \end{cases}$$

Firstly, it may be assume that,

$$P(X_n + 1 = x_n + 1, X_n = x_n, X_n - 1 = x_n - 1, \dots, X_0 = x_0) = P(X_n + 1 = x_n + 1, X_n = x_n)$$

Where $X_0, X_1, \dots, X_n + 1 \in \{0,1\}$
In other words, it is assumed that probability of wetness of any week depends only on whether the previous week was wet or dry. Given the event on previous week, the probability of wetness is assumed independent of further preceding weeks. So, the stochastic process {X_n, n = 0, 1, 2…….} is a Markov chain.
Considering the transition matrix as:

$$P_{ij} = \begin{bmatrix} P_{00} & P_{01} \\ P_{10} & P_{11} \end{bmatrix}$$

Where $P_{ij} = P(X_1 = j|X_0 = i) i, j = 0,1$ note that $P_{00} + P_{01} = 1$ and $P_{10} + P_{11} = 1$
For higher order transition probability matrix we have,

$$P_{ij}^{(m+1)} = \sum_r p_{ir} p_{rj}^{(m)}$$

Finally, we get the stable point at $T^i \cong T^{i+1}$
Where, i = 1, 2, 3, 4, ..., n

3.4 Index of Drought Proneness

P_{11} gives the probability of a week to be wet given that previous week was also wet. When P_{11} is large, the chance of wet weeks is also large. But only a small value of P_{11} may not indicate high drought proneness. In this case, large value of P_{01} implies a large number of short wet spells which can prevent occurrence of drought. Hence, an index of drought proneness may be defined as $DI = P_{11} * P_{01}$

The index of drought proneness is bounded by zero and one. Higher the value of DI, lower will be the degree of drought proneness. The extent of drought proneness is given in Table 1.

Table 1: The index of drought proneness

Criteria	Degree of drought proneness
0.000≤DI≤0.125	Chronic
0.125≤DI≤0.180	Severe
0.180≤DI≤0.235	Moderate
0.235≤DI≤0.310	Mild
0.310≤DI≤1.000	Occasional

Source: Banik, et al. [2]

4. Result and Discussion

Markov Chain Model had been used to evaluate Drought Index using Higher Transition Probability Matrix. An index based on the parameters of this model has been suggested for agriculture drought measurement in Rajshahi district. For calculating Drought Index we consider threshold value 3 mm.

4.1 Drought Index for the decade 1980-1989

The drought index based on rainfall for the decade from 1980-1989 at 5 days, 7 days and 10 days are reported in Table 2 and Figure 2.

Table 2: Drought index for the decade 1980-1989

5 days						
	Rajshahi		**Rangpur**		**Dinajpur**	
	First TPM	Higher TPM	First TPM	Higher TPM	First TPM	Higher TPM
DI	0.066	0.259	0.053	0.257	0.056	0.233
Comment	Chronic	Mild	Chronic	Mild	Chronic	Moderate
7 days						
DI	0.050	0.326	0.048	0.320	0.048	0.293
Comment	Chronic	Occasional	Chronic	Occasional	Chronic	Mild
10 days						
DI	0.045	0.397	0.039	0.388	0.038	.0358
Comment	Chronic	Occasional	Chronic	Occasional	Chronic	Occasional

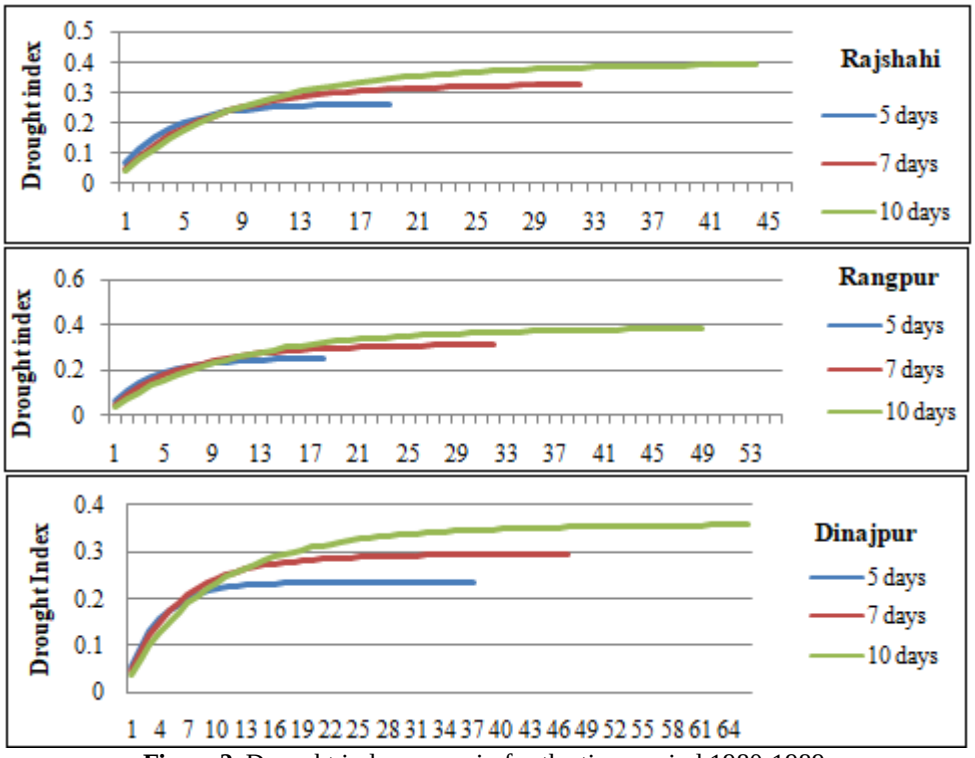

Figure 2: Drought index scenario for the time period 1980-1989

From the above Table 2 we observed that at the first TPM the drought prone is chronic drought for each periods (5 days, 7 days, 10 days) and at higher TPM the drought prone are converted into mild, occasional and occasional respectively in case of Rajshahi district for the decade 1980-1989. For Rangpur district the first TPM indicate the drought are Chronic at each of three periods and it also converted into mild, occasional and occasional

respectively at higher TPM. The Table 2 also showed that at the first TPM the drought prone are chronic for each of three periods in case of Dinajpur district and these index converted into moderate, mild and occasional respectively for these three period at higher TPM. From the figure 2 during the period 1980 to 1989 we found that for 5, 7 and 10 days drought are chronic in the starting stage for threshold value 3 mm and finally due to climate change it showed that the drought is being stable at specific stage (20th, 33th and 45th) for 5, 7 and 10 days and it turns into mild, occasional and occasional drought respectively in case of Rajshahi district. For Rangpur district the drought are starting from chronic and it is being stable at (19th, 33th and 50th) stage and turned into mild, occasional and occasional respectively. From the above figure we also found that all of these three drought index starting from chronic for 5 days, 7 days and 10 days and after 36th, 46th and 65th stage the index were stable and converted into moderate, mild and occasional respectively in case of Dinajpur district.

4.2 Drought Index for the decade 1990-1999

The drought index based on rainfall for the decade from 1990-1999 at 5 days, 7 days and 10 days are reported in Table 3 and Figure 3.

Table 3: Drought index for the decade 1990-1999

5 days						
	Rajshahi		Rangpur		Dinajpur	
	First TPM	Higher TPM	First TPM	Higher TPM	First TPM	Higher TPM
DI	0.064	0.248	0.062	0.277	0.058	0.241
Comment	Chronic	Mild	Chronic	Mild	Chronic	Mild
7 days						
DI	0.050	0.314	0.040	0.461	0.051	0.301
Comment	Chronic	Occasional	Chronic	Occasional	Chronic	Mild
10 days						
DI	0.046	0.390	0.031	0.397	0.046	0.386
Comment	Chronic	Occasional	Chronic	Occasional	Chronic	Occasional

The chronic drought prone periods are found for each period at 1st TPM and at higher TPM the drought prone turned into the mild, occasional and occasional for the period 5days, 7 days and 10 respectively in case of Rajshahi district (Table 3). In Rangpur district, all of these three periods present chronic drought at first TPM but at higher TPM these three period drought changed into mild, occasional and occasional respectively. The Table 3 also showed that the data of the series 5 days, 7 days and 10 days present chronic drought at first TPM in Dinajpur district but at higher TPM these entire drought changed into mild, mild and occasional respectively

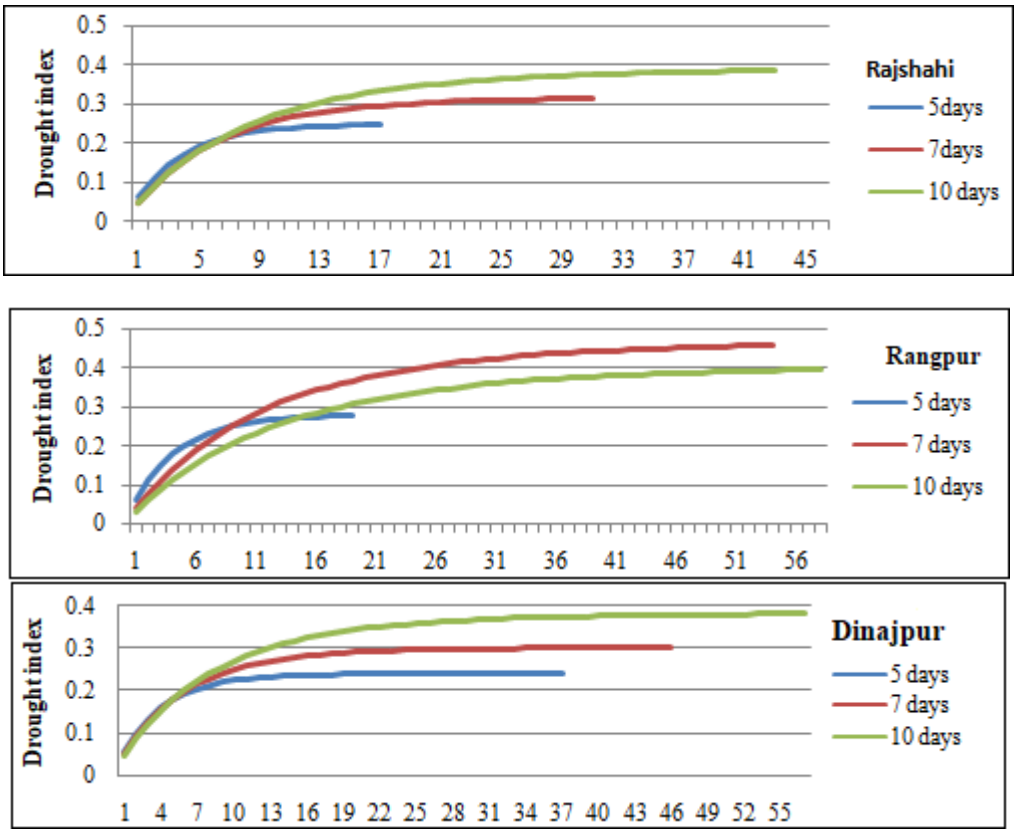

Figure 3: Drought index scenario for the time period 1990-1999

From the Figure 3 during the period 1990 to 1999 we saw that for 5, 7 and 10 days drought are chronic in the preliminary stage for threshold value 3 mm and finally due to climate change it shows that the drought is being stable at specific stage (18th, 33th and 44th) for 5, 7 and 10 days and it turns into mild, occasional and occasional drought respectively in Rajshahi district. Starting from the chronic drought of all of these three periods the drought is being stable at specific stage (20th, 55th and 59th) for 5, 7 and 10 days and it turned into mild, occasional and occasional drought respectively in Rangpur district. In Dinajpur district, all of the three periods starting from chronic drought at it being stable at 37th, 46th and 56th stage and changed into mild, mild and occasional for the decade 1990 to 1999.

4.3 Drought Index for the decade 2000-2009

The drought index based on rainfall for the decade from 2000-2009 at 5 days, 7 days and 10 days are reported in Table 4 and Figure 4.

Table 4: Drought index for the decade 2000-2009

	5 days					
	Rajshahi		**Rangpur**		**Dinajpur**	
	First TPM	Higher TPM	First TPM	Higher TPM	First TPM	Higher TPM
DI	0.065	0.242	0.065	0.276	0.063	0.255
Comment	Chronic	Mild	Chronic	Mild	Chronic	Mild
	7 days					
DI	0.050	0.311	0.047	0.341	0.049	0.320
Comment	Chronic	Occasional	Chronic	Occasional	Chronic	Occasional
	10 days					
DI	0.036	0.382	0.036	0.405	0.039	0.394
Comment	Chronic	Occasional	Chronic	Occasioanl	Chronic	Occasional

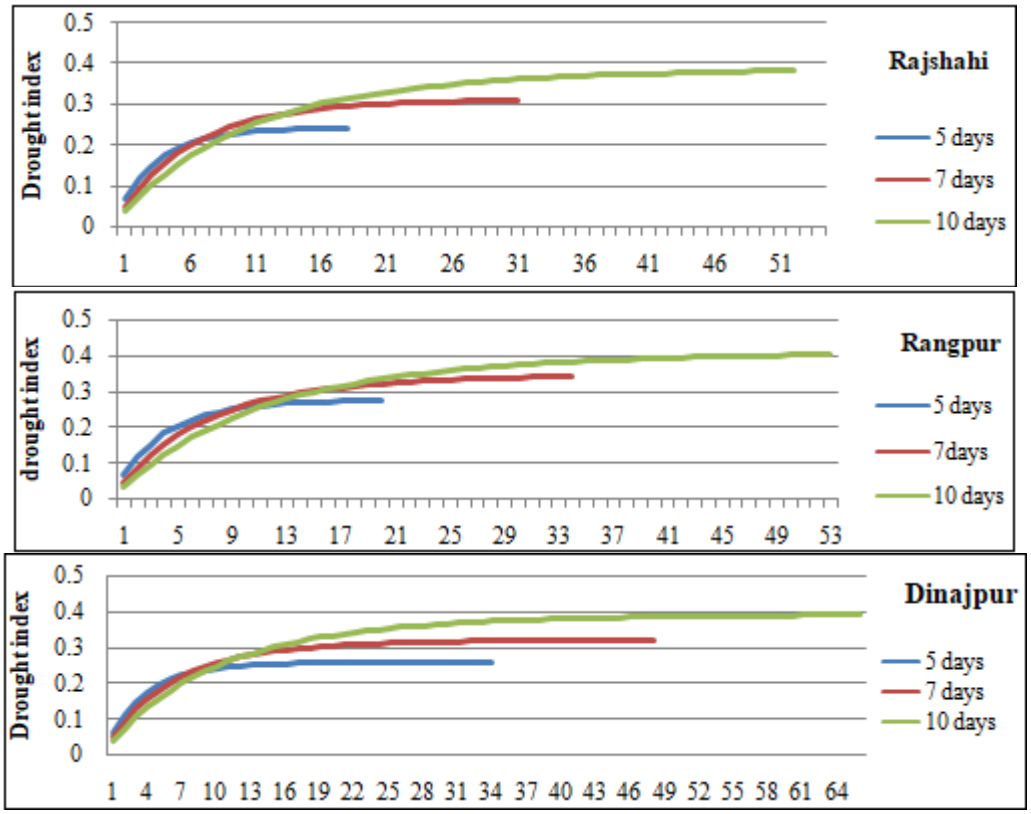

Figure 4: Drought index scenario for the time period 2000-2009

From Table 4 we observed that the chronic drought prone periods are found for each period at 1st TPM and at higher TPM the mild occasional and occasional respectively drought prone periods are found in Rajshahi district in the decade 2000-2009. The chronic drought prone periods are found for each period at 1st TPM and at higher TPM the mild and occasional drought prone periods are found in Rangpur district. In Dinajpur district, all of these three periods showed chronic drought at first TPM and it changed into mild, occasional and occasional drought respectively. Figure 4 indicated that for 5, 7 and 10 days drought are chronic in the starting stage for threshold value 3 mm and finally due to climate change it showed that the drought is being stable at specific stage (19th, 32th and 53th) for 5, 7 and 10 days and it turned into mild, occasional and occasional drought respectively in Rajshahi district. For Rangpur, this figure also showed that during the period 2000 to 2009 we see that for 5, 7 and 10 days drought are chronic in the starting stage for threshold value 3 mm and finally due to climate change it shows that the drought is being stable at specific stage (21th, 35th and 54th) for 5, 7 and 10 days and it turns into mild, occasional and occasional

drought. In Dinajpur district, all of the three periods starting from chronic drought at it being stable at 35th, 49th and 65th stage and changed into mild, mild and occasional for the decade 2000 to 2009.

4.4 Drought Index for the decade 2010-2015

The drought index based on rainfall for the decade from 2010-2015 at 5 days, 7 days and 10 days are reported in Table 5 and Figure 5.

Table 5: Drought index for the decade 2010-2015

	Rajshahi		Rangpur		Dinajpur	
	First TPM	Higher TPM	First TPM	Higher TPM	First TPM	Higher TPM
5 days						
DI	0.069	0.209	0.051	0.215	0.046	0.205
Comment	Chronic	Moderate	Chronic	Moderate	Chronic	Moderate
7 days						
DI	0.054	0.282	0.034	0.263	0.037	0.254
Comment	Chronic	Mild	Chronic	Mild	Chronic	Mild
10 days						
DI	0.040	0.369	0.027	0.318	0.030	0.313
Comment	Chronic	Occasional	Chronic	Occasional	Chronic	Occasional

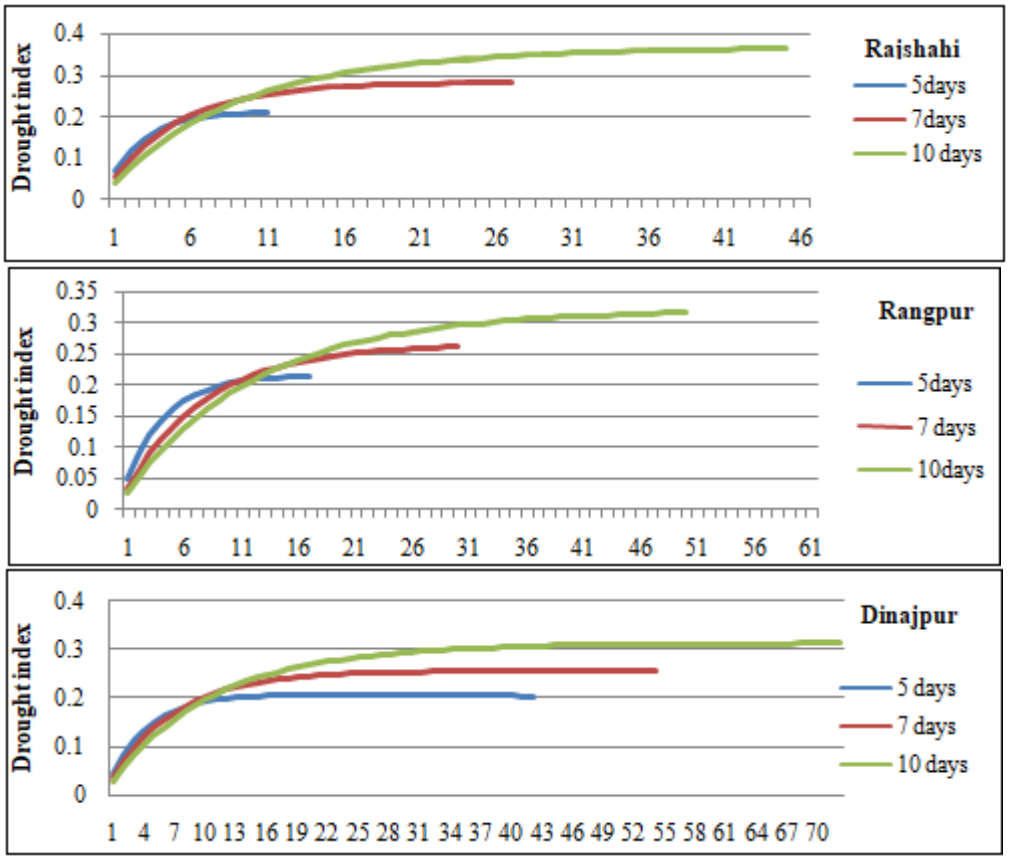

Figure 5: Drought index scenario for the time period 2010-2015

From Table 5, we observed that the chronic drought prone periods are found for each period at 1st TPM and at higher TPM the moderate, mild and occasional drought prone periods are found in Rajshahi district at decade 2010-2015. We also observed from this table that the chronic drought prone periods are found for each period at 1st TPM and at higher TPM the moderate, mild and occasional drought prone periods are found in Rangpur district. In Dinajpur district, the all of these three periods showed chronic drought at first TPM and it changed into moderate, mild and occasional. From Figure 5 during the period 2010 to 2015 we saw that for 5, 7 and 10 days drought are chronic in the starting stage for threshold value 3 mm and finally due to climate change it showed that the drought is being stable at specific stage (12th, 28th and 46th) for 5, 7 and 10 days and it turned into moderate, mild and occasional drought respectively in case of Rajshahi district. In Rangpur district, starting from the chronic drought for all of these three periods turned into moderate, mild and occasional and being stable at 18th, 31th and 51th stage. In Dinajpur district, all of the three periods starting from chronic drought at it being stable at 42th, 55th and 70th stage and changed into moderate, mild and occasional for the decade 2010 to 2015.

4.2 Overall Drought index during the time periods 1980-2015

The daily Rainfall for the decade from 1980-2015 for considering 5 days, 7 days and 10 days for these three districts are given in Table 6 and Figure 6.

Table 6: Drought index for the whole range data (1980-2015)

	Rajshahi		Rangpur		Dinajpur	
5 days						
	First TPM	Higher TPM	First TPM	Higher TPM	First TPM	Higher TPM
DI	0.056	0.270	0.060	0.267	0.072	0.272
Comment	Chronic	Mild	Chronic	Mild	Chronic	Mild
7 days						
DI	0.047	0.323	0.047	0.325	0.064	0.350
Comment	Chronic	Occasional	Chronic	Occasional	Chronic	Occasional
10 days						
DI	0.040	0.389	0.036	0.389	0.043	0.430
Comment	Chronic	Occasional	Chronic	Occasional	Chronic	Occasional

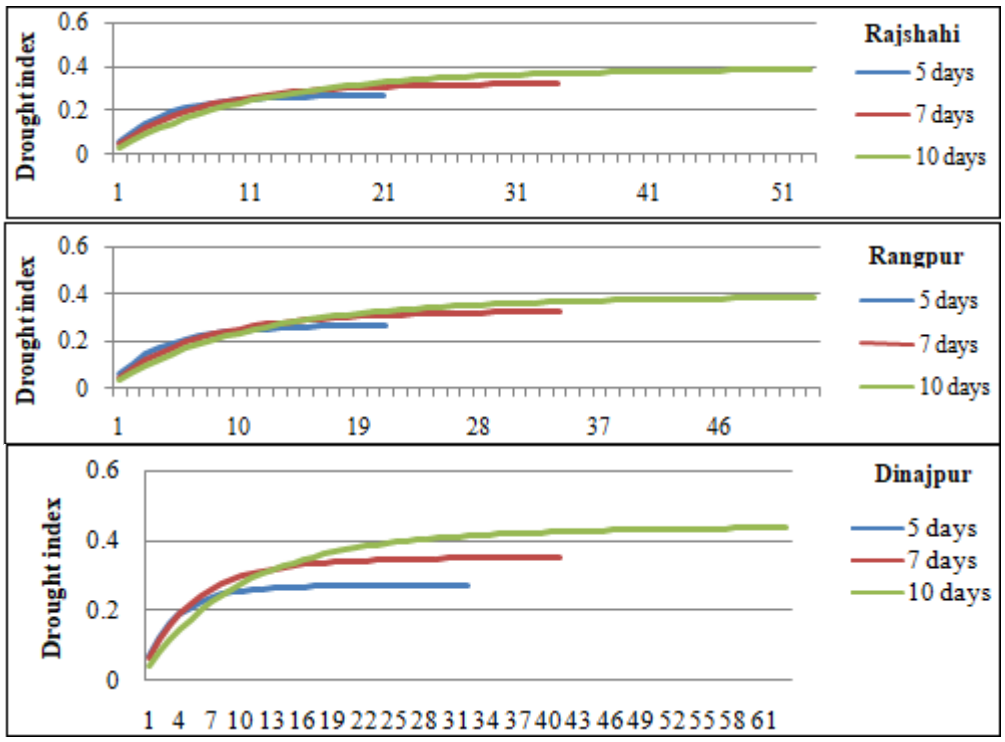

Figure 6: Drought index scenario for the time period 1980-2015

We observed from the Table 6, in Rajshahi district the first TPM for 5 days, 7 days and 10 days are chronic. But at higher TPM the drought are mild and occasional for the whole period 1980 to 2015. This table also showed that all of these three data showed chronic drought at first TPM and it changed into mild, occasional and occasional respectively in case of Rangpur district. In Dinajpur district, all of these three periods showed chronic drought at first TPM and it converted into mild, occasional and occasional respectively for the time period 1980-2015. Figure 6 indicated that during the period 1980 to 2015 we saw that for 5, 7 and 10 days drought are chronic in the starting stage for threshold value 3 mm and finally due to climate change it showed that the drought is being stable at specific stage (25th, 35th and 51th) for 5, 7 and 10 days and converted into mild, occasional and occasional respectively in Rajshahi district. In Rangpur district, starting from the chronic drought for all of these three periods turned into mild, occasional and occasional and being stable at 22th, 35th and 54th stage. In Dinajpur district, all of the three periods starting from chronic drought at it being stable at 32th, 42th and 62th stage and changed into mild, occasional and occasional respectively for these three periods all over the data range i.e. 1980 to 2015.

5. Conclusion

Drought is a slow onset natural disaster which creates a threat to social and agro-ecological balance in any country. The failure of rain and the occurrence of drought during any particular growing season may lead to severe food shortage. Irrigation plan will not be implemented properly due to lack of water. The whole agro-economic system of a country is hampered due to this natural disaster. Markov chain model have been used to estimate probabilities of getting a sequence of dry-wet period for Rajshahi, Rangpur and Dinajpur district of Bangladesh. At first, we find out the Drought Index from the very first transition probability matrix. Then we estimate the higher transition probability matrix. When the higher transition probability matrix is became stable, then we estimate the Drought index of that stable transition probability matrix. After all this we can make a comparison between this Drought Index. The sensivity of crop damage without rain depends on soil

moisture holding capacity as well as duration of drought proneness particularly tolerance levels are 5 days, 7 days and 10 days. The empirical study showed that for five days in Rajshahi and Rangpur station Drought index followed chronic to mild for the decade 1980-1989, 1990-1999, 2000-2009 and for the whole range data 1980-2015. The decade 2010-2015 showed that the chronic to moderate drought in case of Rajshahi and Rangpur district. In Dinajpur district for 5 days the drought are found as chronic to moderate, chronic to mild, chronic to mild, chronic to mild, chronic to moderate for the decade 1980-1989, 1990-1999, 2000-2009, 2010-2015 respectively and for all over the data range the drought index are found and chronic to mild in case of Dinajpur district.

For 7 and 10 days data, the drought index showed chronic to occasional for all of the decade except the decade 2010-2015 in case of Rajshahi and Rangpur district. The decade 2010-1015 showed the drought chronic to mild in case of both two district. The overall drought index is also present chronic to occasional drought index of these two Rajshahi and Rangpur district. The eratic behavior of rainfall pattern indicate drought proneness scenario fluctuate year to year, seasons to seasons, region to region. For 7 days the Dinajpur district showed the drought index as chronic to mild, chronic to mild, chronic to occasional, chronic to mild for all of these decades. The overall drought for the data 1980-2015 showed chronic to occasional. For 10 days data all of these decade showed the drought chronic to occasional for all these four decades and whole data range in case of Dinajpur district.

From the above findings we observed that the decades of different time scale in Rajshahi, Rangpur and Dinajpur are stable in different stages. Different decades of Rajshahi and Rangpur districts are similar due to the similar climatic change. Based on the stage of TPM we conclude that Rajshahi and Rangpur districts are more drought prone than Dinajpur district. Among these three districts Rajshahi is the highest drought prone area and Dinajpur is the lowest drought prone area during the study period 1980 to 2015. This study will contribute to policy formulation and strategic planning in the areas such as, agricultural practices and crop diversification, investments in irrigation development works and allocation of water to different uses.

6. Acknowledgement

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7. Conflicts of Interest

The authors declare no conflict of interest.

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