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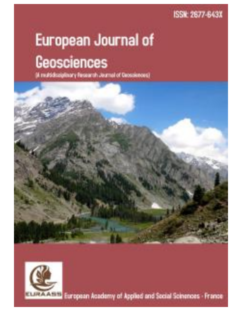

Research Article

Assessment of drought disaster risk in Boro rice cultivated areas of northwestern Bangladesh

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Abstract

Drought risk has become a major threat for sustaining food security in Bangladesh; the particularly northwestern region of Bangladesh. The objective of the study is to assess drought disaster risk on Boro paddy cultivated areas of northwestern Bangladesh using drought disaster risk index (DDRI) model. The sensitivity of Boro paddy to droughts during crop-growing seasons and irrigation recoverability were employed to reflect vulnerability condition. Moreover, the threshold level of the standardized precipitation evapotranspiration index (SPEI) was applied to evaluate the drought hazard on Boro paddy cultivated areas in the northwestern region of Bangladesh. The probability density function (PDF) was used to show the threshold level of drought hazard. The results show that drought hazard is comparatively severe in Ishardi area compared to other northwestern regions of Bangladesh. The drought disaster risk is higher in Ishardi and Rajshahi areas than Rangpur and Dinajpur areas. Although Ishardi area is more prone to high drought risk, at the same time, the recoverability rate is also quicker than any other areas. The relationship between Boro rice yield rates and drought disaster risk is insignificant. The average Boro yield rates during the period of 1976 to 2016 are 19% for Ishardi and Rajshahi areas, 20% for Rangpur and Dinajpur areas and 21% for Bogra respectively according to the total irrigation area. The outcomes of the study can aid to adopt drought condition under changing the climate and also provide guidance for future drought mitigation in the northwest region of Bangladesh.

Keywords: Drought risk, Sensitivity analysis, SPEI model, DDRI, Northwest Bangladesh.

1. Introduction

Drought is one of the most serious hazards in Bangladesh. It happens when evaporation and transpiration overcome the amount of precipitation for a specific period. Drought occurs on the earth to parch and a considerable hydrologic (water) imbalance resulting water shortages, leading to crop damage and scarcity in fodder for livestock. Droughts are common in the northwestern districts of Bangladesh (Islam et al., 2017). It can cause severe damage of agricultural production and livelihood. The effects of climate change on the agricultural sector are remarkable. Both positive and negative effects have occurred, but the negative effects are dominated in the agricultural sector of Bangladesh (Rosenzweig et al., 2014). Boro rice is the major dry season crop of Bangladesh, which requires irrigation from January to April. The annual average rainfall in North-West Bangladesh ranges from 1400 to 2000 mm, with 93% of rainfall occurring from May to October, and only about 6 percent rice season (Shahid, 2010). The North-west region, with its prolonged dry season was affected more severely than the rest of the country (Shahid, 2008). The economy of this area is mostly agriculture based, with 75% of the land under crop cultivation. About 31% of the land is used for single cropping, 56% For double cropping and 13% for triple cropping (Shahid and

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Hazarika, 2010). Boro rice is the main dry season crop in the study area, and is cultivated on more than 70% of the cultivable area from December to May. Wilhite (2000), studied that drought has priority to other natural disasters in the frequency of occurrence, duration and extent, loss of life, economic and social impacts and severe effects in the long run. Rice is the main staple food for the people of Bangladesh. Almost every year, the country experiences disasters of floods, and droughts, causing heavy loss of life and property and jeopardizing the development activities (Ali, 1996). High spatial and temporal climatic variability, extreme weather events, high population density, high incidence of poverty and social inequity, poor institutional capacity, inadequate financial resources, and poor infrastructure have made Bangladesh highly vulnerable to disaster (Ahmed, 2004). Northwestern regions of the country are suffering because of the extreme temperature problem (Islam et al., 2017). Northwestern area is the most drought-prone areas than the others (Shahid and Behrawan, 2008). Drought is one of the most common natural hazards in northwestern parts of Bangladesh. Every year Rangpur, Rajshahi, Dinajpur, Bogra, and Ishardi are facing drought hazards.

Every year Bangladesh experiences a dry period for 7 months, from November to May, when rainfall is normally low. Since its independence in 1971, Bangladesh has suffered severe droughts in 1973, 1978, 1979, 1981, 1982, 1992, 1994, 1995, 2000 and 2006.The average annual rainfall in this northwestern region estimated 1,329 mm, whereas that in the northeastern part of the country is 4,338 mm (Shahid et al., 2005). Shahid et al., (2005) also highlighted that meteorological drought is a common phenomenon in this region, which is linked to rainfall pattern and related climatic conditions. In the severe drought years of 1978–1979, Brammer, (1987) estimated that drought caused not only the reduction of rice production by about 2 million tonnes but also directly affected about 42 percent of cultivated land and 44 per cent of the population. The drought of 1994–1995 led to a decrease in rice and wheat production of 3.5 × 106 tonnes (Rahman and Biswas, 1995). The 2006 data indicated that drought caused 25–30 per cent crop reduction in the northwestern part of Bangladesh (Rahman et al., 2008). Drought not only has caused loss of crop production but also has social and environmental impacts. Barlow et al. (2006) found that drought be the greatest natural hazard that negatively impacts on human livelihoods. According to the fourth assessment report of the Intergovernmental Panel on Climate Change, Bangladesh will experience severe floods and droughts in the coming decades due to the effect of climate change. According to the report of the National Drought Mitigation Center of the year 2006, Bangladesh has already shown an increased frequency of droughts in recent years. Additionally, agriculture, power generation, and industrial production depend upon precipitation (Devkota, 2006). Drought is closely related to food security, therefore, study on drought hazards and drought monitoring are essential for implementing mitigation to reduce drought impact in Bangladesh.

Drought risk was quantitatively estimated by simulated yield losses. It is regarded that the simulated yield losses are entirely caused by drought disaster (Sun et al., 2017). It describes the simulation process of the crop model integrated all the impact factors of drought intrinsically, and the ultimate yield losses completely come from water stresses. This is shown that the amount of rainfall in Liaoning is seriously low, which only 18% of the average annual value. Zhang et al. (2016) found the drought risk on corn cultivation area in China. She used two provinces of China where sensitivity of drought on corn were prevailing. She proved it by the DDRI formula with SPEI model. She shows the significant relationship between corn yield losses and drought disaster risk. According to Wang et al., (2015), Risk assessment of drought disaster is necessary for the sustained agriculture development under the background of global climate change, and, meanwhile, it is an urgent scientific issue needed to be solved in agricultural risk assessment discipline. He found that areas affected by drought disasters, areas with no harvest by drought disasters, areas planted, and yield per unit area data, agricultural drought disasters losses of the southern five provinces in China. Zhao et al., (2013) stated that severe drought in Yunnan province is mainly due to the much-less-than-normal precipitation and much-warmer-than-normal surface temperature. They focused on the future spatiotemporal heterogeneity of the temperature and precipitation, which has great impacts on the drug and identified the influencing factors of drought in Yunnan province were simulated with the Weather Research and Forecasting (WRF) model, and the risk of drought was spatially analyzed with the meteorological drought composite index. Indicate that the large-area forest plays a more important role in alleviating the risk of drought than other vegetation types do. Drought is a natural hazard with often significant societal, economic, and environmental Consequences. As of August 2012, drought has extended across more than two-thirds of the United States and has adversely affected agricultural producers and others (Folger et al., 2012). The SPEI is based on precipitation and temperature data, and it has the advantage of combining Multi-colour character with the capacity to include the effects of temperature variability in drought assessment (Sergio et al., 2009). It was reported by Ding et al., (2004) that although drought can occur in different seasons, rice farmers are heavily suffered from summer and autumn drought, which occurs during July and September. It is found that estimated rice yield loss due to drought is about 7 - 37% and it indicate the effect of drought at household level is widespread and may be substantial.

The threshold level of the Standardized Precipitation Evapotranspiration Index (SPEI) was employed to identify drought events and its probability distribution function (PDF) was applied to create the drought hazard index (Islam et al., 2017). They evaluate drought hazard at current and future climate change conditions in the Boro paddy cultivated areas of western Bangladesh using simulated climate data from the outputs of three global climate models (GCMs) based on the SRES A1B scenario for the period between 2041 and 2070. Drought is more complex, but least understood of all-natural hazards in Bangladesh. Long term instability of temperature and rainfall pattern leads to local and regional drought hazards which impact productive sector failure and worsen socioeconomic status (Rakib et al., 2015). Every year Bangladesh faces a different kind of natural disasters like flood, drought, cyclones, river bank erosions, earthquakes, etc. Drought is one which is the most frequently reoccurring events in Bangladesh. It is a slow onset hazard which evolves the characteristics of its own and its impacts on agriculture. The long periods of dryness and shortage of water supply provide a great impact on life and properties. Different mitigation and sustainability program are taken by the different country and organizations which can be effective for handling drought. The descriptive and inferential statistics indicated that there was a significant correlation between literacy and occupation type with social and agro-ecological impact of drought (Islam et al., 2014). In this paper, it is suggested that if awareness, build up and literacy level increase to reduce these adverse impacts of drought in the northern Bangladesh. Among the natural hazards, droughts possess certain unique features; in addition to delayed effects, droughts vary by multiple dynamic dimensions, including severity and duration, which in addition to causing a pervasive and subjective network of impacts makes them difficult to characterize (Zarger et al., 2014). Drought characterization is essential enabling both retrospective analyses (e.g., severity versus impact analysis) and prospective planning (e.g., risk assessment). These indices correspond to different types of drought, including meteorological, agricultural, and hydrological drought and their risk. Zarger et al., (2014) appeared different type of drought and its indices which reflect their effects on vegetation and life style. Using drought indices is a pragmatic way to assimilate large amounts of data into quantitative information that can be used in applications such as drought forecasting, declaring drought levels, and contingency planning impact assessment.

Murad and Islam, (2011) stated that timely information about the onset of drought, extent, intensity, duration and impacts can limit drought-related losses of life, human suffering and decrease damage to economy and environment. The risk is computed as the product of the hazard and vulnerability (Shahid and Behrawan, 2008). In this paper the risk of the drought is identified by the calculation of hazard and vulnerability. The condition of risk of an event can be identified through, the frequency and the vulnerability. Shahid and Behrawan, (2008) reported that droughts pose highest risk to the northern and northwestern districts of Bangladesh and found that the northern and northwestern part of Bangladesh has highest risk of drought. Bangladesh has experienced from nine historical droughts with high magnitude, which made a huge loss in our history. Based on above mentioned discussion, it is evident that few studies have been carried out on drought risk during Boro rice growing season in northwestern Bangladesh. Therefore, this research aims to assess the risk of drought disaster on Boro paddy cultivated areas in northwestern Bangladesh.

2. Materials and methods

2.1. Study area

Northwestern part is a drought prone area and most severe drought are occurred in history in this part of Bangladesh. Only five of the 16 administrative districts in North-west Bangladesh have a weather station. Five of these, namely Bogra, Rajshahi, Ishardi, Rangpur and Dinajpur were included in this study. Those areas are Rangpur (25044'N,89016'E), Rajshahi (24022'N,88042'E), Bogra (24051'N,89022'E), Ishardi (24009'N,89002'E) and Dinajpur (25039'N,88041'E) are northwestern part of the country. This part of the country belongs to the sub-humid agro-climatic class. Figure 1 shows the five study areas of northwestern Bangladesh. Ishardi and Rajshahi are the most vulnerable for drought hazard. Meteorological drought is a very common phenomenon during the dry months in this region (Shahid and Behrawan, 2008).

2.2 Data and its sources

Monthly precipitation and monthly temperature data of five meteorological station such as Bogra, Dinajpur, Ishardi, Rangpur and Rajshahi station used for SPEI calculation for find out the drought intensity and frequency of the northwestern Bangladesh. For drought intensity and frequency, data of SPEI are taken only January to Jun based on Boro growing season. Reanalysis data are used for this study and those data are collected from the Bangladesh Meteorological Department (BMD). All the temperature and rainfall data recorded from 1976 to 2016 were applied for the study. Most fluctuating temperature is found in Ishardi areas than the others. The average temperature of Ishardi increased 90C than the other area. The highest amount of rainfall occurred in the Bogra from 1976 to 2016 (Fig. 2), Rangpur and Dinajpur (Fig. 1) had received same amount of rainfall on that due time. The higher rate of precipitation in Bogra proved the well crop growing season of Boro rice. On the other hand, the lower amount of precipitation of the rest four areas referred the losses of yield rate of Boro rice. Therefore, this research uses the 1976-2016 period to study the drought disaster risk on Boro rice cultivation. The effective irrigation area accounting for the total cultivated area of each country was collected from 1976 to 2016. Rajshahi has the warmest temperatures than the other station of the northwestern part of Bangladesh. PDF of Rajshahi on April and May month, which is the most important for the crop-growing season of Boro rice (Fig. 2).

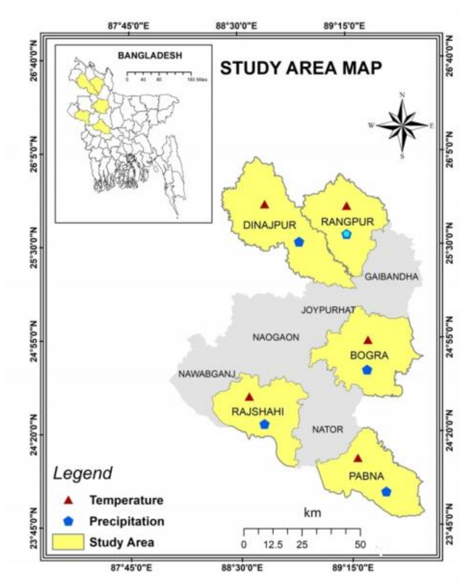

Figure 1: Location map showing the study area.

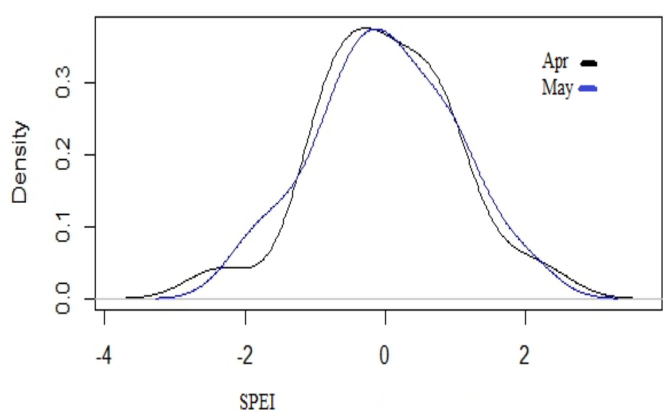

Figure 2: Location map of the study area.

2.3 The Standardized Precipitation Evapotranspiration Index (SPEI)

SPEI is used to identify drought for risk assessment in the study. The method of computing the SPEI may be found extensively described in Vicente-Serrano et al., (2010). To get the value of SPEI of drought and drought sensitivity, the SPEI model is applied by using R software. SPEI is an extension of the standardized precipitation index (SPI), which make up the criticism of the SPI is that its calculation is based only precipitation data. It is readily comparable in time, space and widely used than the SPI. Here SPEI used for calculation of drought frequency by the PET tho_ value and after getting the value from SPEI those values were used for identifying the drought sensitivity. The Standardized Precipitation Evapotranspiration Index (SPEI) is an extension of the widely used Standardized Precipitation Index (SPI). The SPEI is designed to take into account both precipitation and potential evapotranspiration (PET) in determining drought. Drought is a major cause of agricultural, economic and environmental damage. Drought effects are apparent after a long period with a shortage of precipitation, making it very difficult to determine their onset, extent and end. The SPEI allows comparison of drought severity through time and space since it can be calculated over a wide range of climates, as can the SPI. Moreover, Keyantash and Dracup, (2002) indicated that drought indices must be statistically robust and easily calculated, and have a clear and comprehensible calculation procedure.

2.4 Drought Disaster Risk Index (DDRI) Model

Based on the theory of disaster risk information, risk can be represented as hazard and vulnerability (IPCC, 2007). High frequency and intensity of drought bear the risk of drought. Crop sensitivity to drought (DS) and regional recoverability (IRR) are used to reflect drought vulnerability. High sensitivity refers crop is prone to drought. Therefore, following Eq. 1 are used to assess the drought disaster risk index (DDRI)

$$DDRI = \sum_{I=1}^{I=6} (\mathrm{DH} \times \mathrm{DS}) \times (1 - \mathrm{IRR}) \quad (1)$$

where i is the month

DH=Drought hazard

DS=Drought sensitivity

IRR=Regional recoverability

In previous studies, the frequency of historical drought events was used as the factor of drought hazard (Hu et al., 2014; Zhang, 2004). In this study, we use the value of SPEI to identify drought intensities during 1976-2016. Probability density functions of SPEI are used for each station. To assess the risk through calculation, there are three parts of calculation is required. Those are Drought Hazard (DH), Drought Sensitivity (DS) and IRR. All of these three parts need different methods for getting accurate results.

2.4.1 Drought Hazard (DH)

For assessing Drought hazard, it is required SPEI data for calculating droughts intensity and frequency. Here Drought Hazard (DH) is calculated by the following Eq. (2)

$$\mathrm{DH} = \int_{-1}^{-4} \mathrm{SPEI} \times \mathrm{f(SPEI)} \quad (2)$$

where the value of SPEI reflects the intensity of drought and, f(SPEI) is the frequency of SPEI.

Figure 2 displays PDFs of Apr and May in Rajshahi. It shows the drought frequencies (SPEI<-1) of those months are almost same. Major Boro crop production rate is mostly depending on these two months. Here SPEI limit is -1 to -4, which is collected from the SPEI table for effective calculation. Major drought intensity in May is distributed from -.5 to -.3.5, and Apr is from -.5 to -.3. Intensity is higher in May than April.

2.4.2 Drought Sensitivity (DS)

Sensitivity of drought reflects the drought risk and vulnerable condition of Boro crops. The crops are mostly affected by the drought hazard. But the meteorological drought may not bring severe damage or loss to crops if soil water storage capacity is better. Sensitivity of drought is measured by the high amount of intensity level of drought from SPEI value. The minimum level of sensitivity was assigned -1.

2.4.3 Drought Recoverability (IRR)

Irrigation is the most effective measure for easing drought. For this, the rate of effective irrigation area accounting for the total cultivated area is used as the factor of drought recoverability (IRR) in this study by the following Eq. (3)

$$\mathrm{IRR} = \frac{\mathrm{EIA}}{\mathrm{CA}} \quad (3)$$

Before DH, DS, and IRR were used in the study, they needed to be made dimensionless with the following Eq. (4)

$$\mathrm{X} = \frac{\mathrm{x - x(minimium)}}{\mathrm{x(max) - x(min)}} \quad (4)$$

where x' is the dimensionless value of x, and x_{min} and x_{max} are the maximum and minimum value of the indicator.

3. Results

3.1 Drought Hazard Assessment

Figure 3 shows the spatial distribution of DH. In Ishardi, drought hazard is more severe and this indicates that this region is easily affected by the drought in the Boro rice growing season. In northern part, particularly Rangpur and Dinajpur, it is clearly shown that those are less affected by drought hazard. In Western part, Bogra is lower affected by drought hazard. Intensities of drought and its frequency have mostly increased in northwestern part of Bangladesh. The Ishardi and Rajshahi areas are the more affected region than other areas according to drought hazard distribution map. Drought is becoming more serious in the northwestern part of Bangladesh. It can be said that crop production in Ishardi is faced with severe threat of drought. It is observed that the dryness level is getting higher in recent years and it is the symbol of drought hazard to become drought disaster.

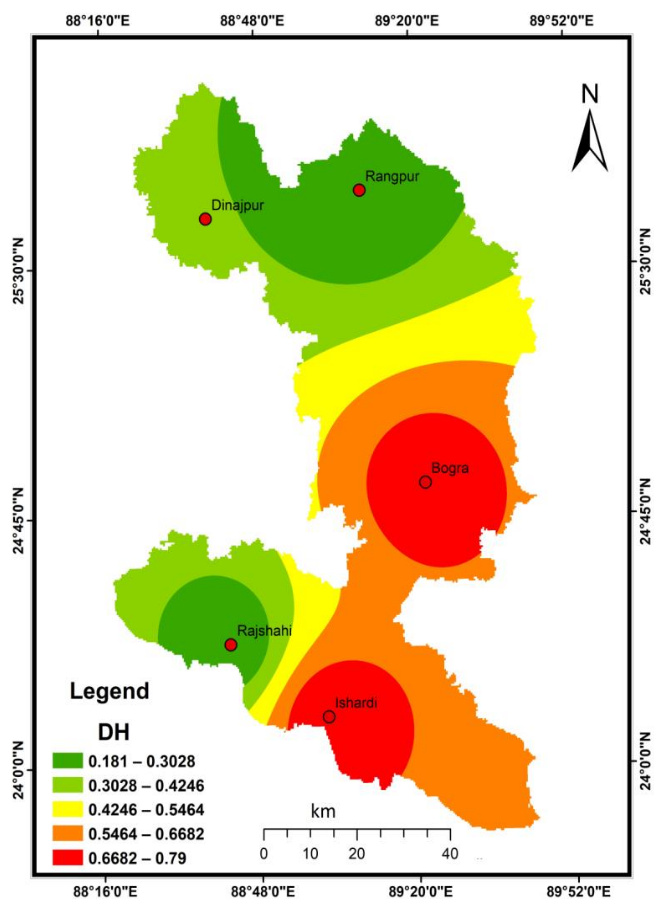

Figure 3: Spatial distribution of Drought Hazard (DH).

3.2 Assessment of Boro Crop Sensitivity of Drought

The spatial distribution of drought sensible on Boro paddy is shown in Figure 4. Values of drought sensitivity express that the Ishardi is the most drought-prone areas which is very vulnerable for Boro rice cultivation. As every month is having the possibilities of strong drought conditions and then Rajshahi is the 2nd vulnerable for drought risk and for agriculture. The Rangpur and Dinajpur of northern most part is in 3rd and 4th vulnerable position respectfully, according to the results. Comparing with others, Bogra is very low vulnerable for drought risk.

3.3 Recoverability

Irrigation recoverability (IRR) is use for indicating drought recoverability. Effective irrigation is one of the solutions to ease the drought. As given from figure 5, the value of IRR shows the irrigation conditions of each area. Figure 5 clearly shows that the drought recoverability condition is good in Ishardi, Dinajpur and Bogra but Rangpur and Rajshahi indicate worse condition.

3.4 Spatial Distribution of Drought Disaster Risk in Northwestern Bangladesh

Figure 6 shows the spatial distribution of DDRI, it is clearly shown that Ishardi is ranked first where drought risk is highly recognized, Rajshahi in second position after the Ishardi according to the calculation of DDRI results. It indicates that Bogra is less risk of drought hazard and is also less affected by drought than the others. Figure 6 show that drought hazard is serious in Ishardi and low drought recoverability. Ishardi faces much more serious drought condition than other areas.

3.5 Validation of Drought Disaster Risk Model

The lowest rate in yield of Boro crop is the main finding of drought risk. The greater the risk of drought increases the lower rate of yield. Here, this study provides a linear regression model between yield rate and drought disaster risk. Figure 7 shows that there is an insignificant relationship between Boro rice yield rate and DDRI (R^2=0.011). In addition, the root mean square error (RMSE) is 1.433, indicating the validation of DDRI model. It demonstrates that yield rate is lower, where drought risk is high. The Figure 7 shows that Ishardi has much yield losses than other stations.

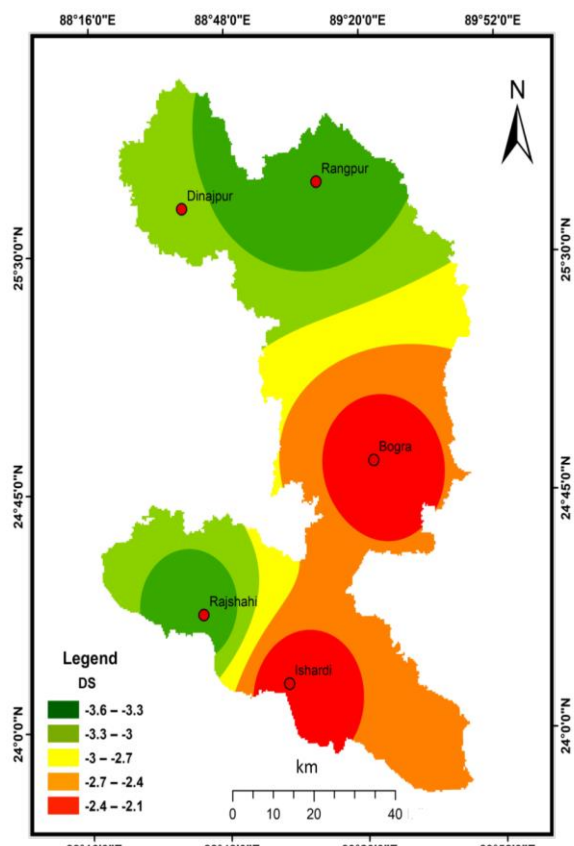

Figure 4: Spatial distribution of drought sensitivity in northwestern Bangladesh.

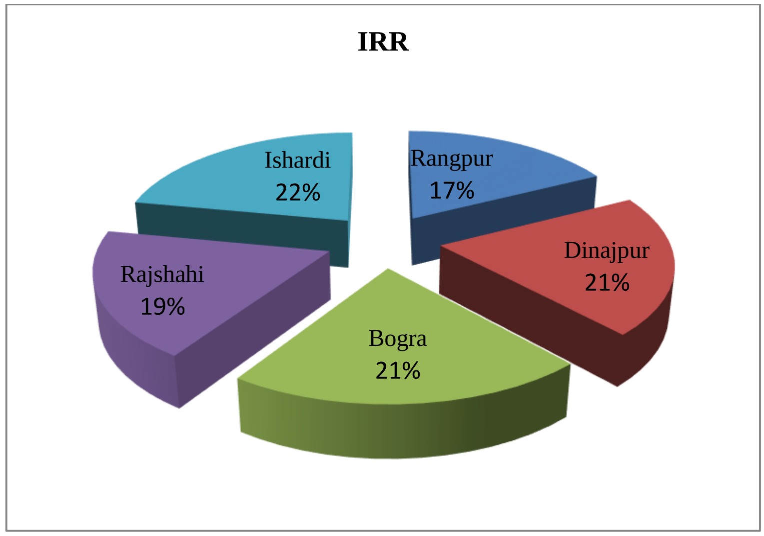

Figure 5: Irrigation recoverability (IRR) values in the study sites.

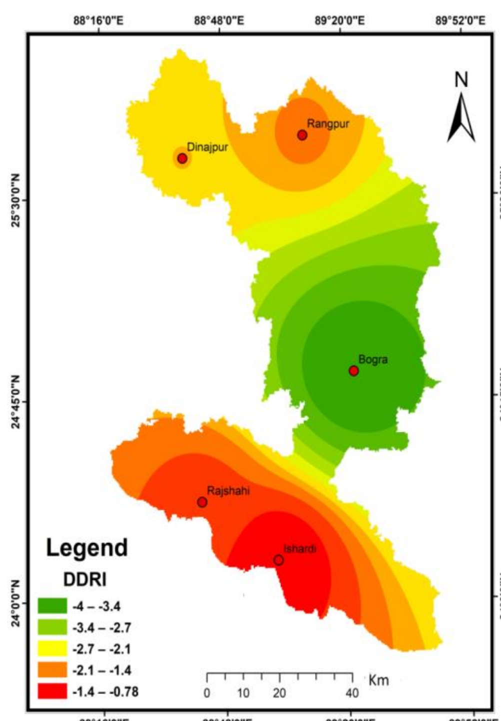

Figure 6: Spatial distribution of drought disaster risk in the northwestern Bangladesh.

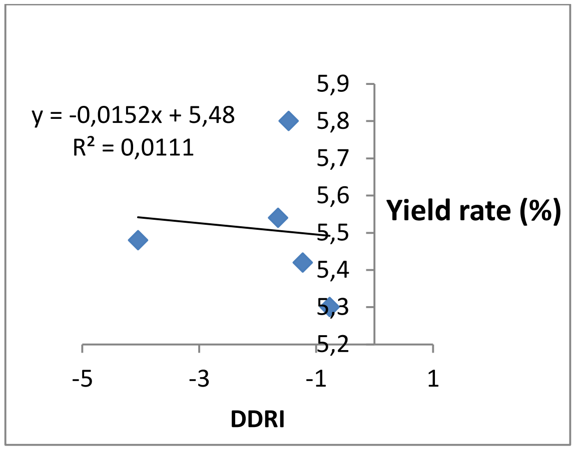

Figure 7: Linear regression between DDRI value and yield rate of Boro rice crop.

4. Discussions

Drought hazard in the northwestern part of Bangladesh has been investigated based on the frequency of the events for each area by SPEI. The spatial distribution of droughts (Fig. 3) indicates that it tends to occur more frequently in Ishardi of western area. The northwestern parts experience drought with high and low frequencies. Distribution of drought (Fig. 3) shows that the high frequency of drought is prevailing in Ishardi and Bogra and medium frequencies of drought are found in Rajshahi, Dinajpur and Rangpur. The analysis of drought occurrences of different categories indicates northwestern parts of the country are most prone to severe and very severe droughts. The northern region generally receives more than average rainfall, but the area is highly prone to drought. It is noted that Barind Tract, a largest Pleistocene photographic unit of the Bengal basin that covers most parts of the northern and northwestern Bangladesh, which is prone to drought. The drought hazard map obtained in the present study validates this concept. The higher occurrence of droughts in the northwestern part of the country is due to the high annual variability of rainfall in the region. For instance, the rainfall recorded in the northwestern part of the area in 1981 was about 1,738 mm, but in 1992 it was about 798 mm. Despite technological advances such as improved crop varieties and irrigation systems, weather and climate are still key factors in agricultural productivity. Variations in rainfall pattern over the growing period have been found to affect rice yield and water requirement. Water is needed for Boro paddy rice during its growing seasons. Bangladesh needs to increase the rice yield in order to meet the growing demand for food emanating from population growth. Irrigated rice or Boro rice is a potential area for increasing rice yield, which currently accounts for about 50% of total rice production in the country (BRRI, 2006). Devastating and regular droughts caused by a lack or a late/early arrival of rainfall happen very often in many parts of Bangladesh, badly affecting agriculture. More recently the droughts of 1994-95 in the northwestern districts of Bangladesh led to a 3.5 million tonne shortfall of rice and wheat production while the 1997 drought caused at around 1 million tonnes of food grain, of which about 0.6 million tonnes was transplanted aman rice valued at around US$500 million to be lost (Selvaraju et al., 2006). Boro is cultivated in high amount when the others because before our climate was so suitable for Boro crops grown. The result of DS show that Ishardi is the most sensitive place for living due to drought, others area is also sensible for living conditions but they are little better than Ishardi area (Fig. 4). The finding of this research is echoed with the Zhang et al., (2016) results. Selvaraju et al., (2006) found that during Rabi droughts in winter months affect Boro rice, wheat and other crops grown in the dry season, most severely in the Barind Tract and west of Khulna division, severely in areas of the Chittagong Hill Tracts, and other parts of Rajshahi Division and slightly in remaining areas of western, northern and central Bangladesh. Drought recoverability is the process of easing drought by the effective irrigation area and cultivated area. The increasing rate of irrigation and yield rate of crops is aid to reduce the drought impacts and its sensitivity on the economy. The mean value of irrigated area and cultivated area of Rangpur, Rajshahi, Bogra, Ishardi and Dinajpur showed that the value of IRR is 0.63, 0.67, 0.76, 0.79 and 0.74 respectively (Fig. 5). The effect of drought can be reduced from the effective irrigation system. The IRR value indicates the 22% recoverability rate for Ishardi, 21% for Bogra and Dinajpur, 19% for Rajshahi and 17% for Rangpur respectively. Drought hazard and drought vulnerability maps are integrated using GIS to produce the drought risk map in the northwest Bangladesh (Fig. 6). Figure 6 shows that droughts pose the highest risk to northwestern districts of Bangladesh. Few districts in the central part of the study area are exposed to moderate risk. Shahid, (2008) found in his study that the western and northern parts experience moderate drought with lower frequencies. This study is consistent with the result of Shahid and Behrawan (2008), distribution of severe droughts shows a complete different pattern from moderate drought. Figure 6 presents the risk of drought hazard on Boro yield rate. The yield rate of Boro paddy is affected by the drought hazard. The highest risk of drought on Boro crops is in the Ishardi areas because of the high intensity of drought hazard. It is obvious that the PDFs of monthly total SPEI values below -1 in the Boro paddy cultivated area will change drastically in the near future (Islam et al., 2017). According to Islam et al. (2017), Dinajpur subregion shows a severe increased drought event in terms of intensity and frequency and Rajsahhi and Bogra subregion exhibits more drought intensity in potential future climate change compared to the current period under AIB scenario using future model, but this results of this study are in disagreement with the outcomes of Islam et al. (2017), where Ishardi appeared as a high risk zone and Bogra is a lower risk zone for Boro crops. Drought vulnerability reveals the quality of risk level in the study area. Drought risk increases the level of drought and its adverse effects on life and on the environment. The decrease level of yield rate to the increasing level of drought, increase the vulnerable condition of drought. The concepts and definitions of vulnerability have been studied by many authors (Kates, 1985; Blaikie et al., 1994; Downing and Baker, 2000). Shahid, (2008) predicted the pattern of vulnerability to drought in the western part of Bangladesh; the study area can be separated into three vulnerable zones: low vulnerability in the southern parts, moderate vulnerability in the central parts and high to very high vulnerability in the northern parts. The highest vulnerabilities are concentrated in the northern and northwestern part of the country where poverty rate is comparatively high, more than 70% of the people depend only on agriculture and a high percentage of land is under irrigation.

5. Conclusion

This study aims to evaluate the risk of drought disaster on Boro rice cultivated areas in the northwestern Bangladesh. The areas of highest hazard correspond very well, in general, with the areas that usually thought as drought prone and have records of high levels of agricultural damage due to droughts. The study provides a comprehensive idea about the frequency and intensity of drought events during the Boro rice growing season. In this study, the SPEI is used to measure the frequency and intensity of drought hazard in northwestern regions. A major outcome of the study is the production of a drought risk map of the northwestern part of Bangladesh. DDRI equation is employed under SPEI model and PDF for illustrate a risk map of northwestern Bangladesh. The sensitivity of Boro crops to drought that happened in different crop growing season and irrigation ability are used to reflect vulnerability. In this research, the higher risk of drought disaster in Ishardi and Rajshahi, the western part of Bangladesh. Interestingly, it is found that the drought recoverability rate is very quicker in Ishardi than other areas. Rangpur and Dinajpur are also having the risk of drought disaster but less than Ishardi and Rajshahi. Bogra has little risk of drought event. It can be said that priority should be given in the northwestern region compared for making future drought management strategies in agriculture of Bangladesh. This research is done over drought disaster risk on Boro paddy areas in northwestern of Bangladesh. It evaluates the risk of drought disaster on Boro rice which plays an important role in climate change perspective. It can be helpful for climate researcher and policy makers to implement some drought adaptation measures. It is hoped that the study will be beneficial to a number of stakeholders in the country, particularly disaster management, but also the agricultural organizations for achieve better improvement in future.

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