Analysis of Drought and Ground Water Depletion of Naogaon District in Bangladesh

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***Abstract*-- Naogaon is the northwestern district of Bangladesh. It is a drought prone area in Bangladesh. Transplanted aman (T-aman) is mainly dependent on rainfall and boro rice is fully dependent groundwater irrigation. In early 1980s shallow tubewells were introduced to cultivate rabi crops using groundwater. The shallow tubewells is failed to withdrawal of groundwater. Deep tubewells were introduced in the early nineties to irrigate rabi crops and boro rice in dry season. Due to less rainfall the deep tubewells were used for irrigation of T-aman during monsson season in mid-nineties. It creates additional pressure on the groundwater. It is necessary to study on rainfall pattern, temperature variation and fluctuation of groundwater table which are directly related to the irrigation efficiency and crops yield. It is found from the present study that the variation of the minimum and maximum annual rainfall of the study area is from 500mm to 2100mm. The monthly rainfall is gradually decreasing in most of the upazilas of Naogaon district after 2000. The drought is occurred mainly due to several week gaps between two consecutive rainfalls or no rainfall in the late monsoon. It is observed from the present study that Porsha, Shapahar Patnitala and Atrai upazila are the more drought prone area in the Naogaon district. The annual maximum mean temperature is increasing trend. Average rate of depletion groundwater level of Naogaon district is one feet per year. The dug well and shallow tubewell is abandoned due to the depletion of groundwater table.**

***Index Term*— Temperature Variation, Rainfall, Drought, Groundwater Depletion**

I. INTRODUCTION

Naogaon district lies in a part of North West region of Bangladesh. The area is called Barind area. The practice of water resources use in this area is different from other regions of the country because of its geophysical location. The area has been experiencing drought for years as the major problem with less rainfall normally occurrence from May to November. According to Master Plan Organization MPO [1], water resources activities in the area are mainly dependent on groundwater resources. Based on Water Balance Model Study reports that available dry season water resources in the area is small and area is likely to be affected by extensive groundwater development. Irrigation coverage usig ground water has been rapidly increasing in Bangladesh every year as reported by Institute of Water modeling (IWM) [2]. Maximum depth to ground water table occurs at the end of April mainly due to irrigation abstraction and natural drainage in these area reported. Groundwater resources in some areas of medium to high Barind tract ares is inadequate to meet the drinking and irrigation water demand. The continuous lowering trend of the groundwater level indicates a non-sustainable situation with increasing draw down [3].

According to Space Research and Remote Sensing Organization (SPARRSO) reported that in the North-West part of the country, seasonal drought occurs almost on the regular basis. [4]. The National Water and Plan (NWP) [5] considered the occurrences of drought as a major water deficiency related issue in North-West region of Bangladesh (WARPO) [6]. In some it has been mentioned that the average occurrences of drought in Bangladesh is once in 2.5 years [7], [8]. Between 1960 and 1991, nineteen times droughts have occurred in Bangladesh [9]. Due to less rainfall than normal rainfall which is responsible for insufficient water resulting reduced groundwater recharge which affect the ecosystem maintenance and subsequent less amount of crop production and also affect household works. National Water Plan [5] describes that uneven and inadequate rainfall can greatly reduce crop production. Apart from loss to agriculture, a drought has significant effects on land degradation, livestock population, employment and health. Climate change issue also accelerate the adverse effect of drought in Bangladesh [10].

The average seasonal rainfall of about 1000 mm during the five monsoon months (June to October) in the north-west region of Bangladesh is the lowest relative to other part of Bangladesh and such rainfall is classified as low for a rain fed ecosystem [11]. This study was carried out to detect groundwater crisis in Naogaon district of Bangladesh and to identify the most drought prone area. Thus, the deep tube well

irrigation in Naogaon district faces problem during peak demand due to decline in groundwater table. Permanent decline of groundwater table due to over-abstraction of groundwater and less rainfall especially in some location of high and medium Barind area in Naogaon district may leads to decrease crop production and crisis of drinking water. The main objectives of the study are: (ii) to study on variation of temperature, (ii) to determine the variation of rainfall and meteorological drought,, (iii) to investigate fluctuating trend of the ground water level, and (iv) to assess the factors influencing the fluctuating trends of the groundwater table.

II. STUDY AREA

Naogaon district is located in between the northern latitudes $24^0 29'$ and $25^0 11'$ and the eastern longitude $88^0 18.8'$ and $89^0 18.7'$ is selected for the present study, since it is the drought prone area in the country. The district comprises of 11 Upazilas such as: Atrai, Badalgachi, Dhamoirhat, Manda, Mohadevpur, Naogaon sadar, Niamatpur, Patnitola, Porsha, Sapahar, Raninagor (Fig. 1).

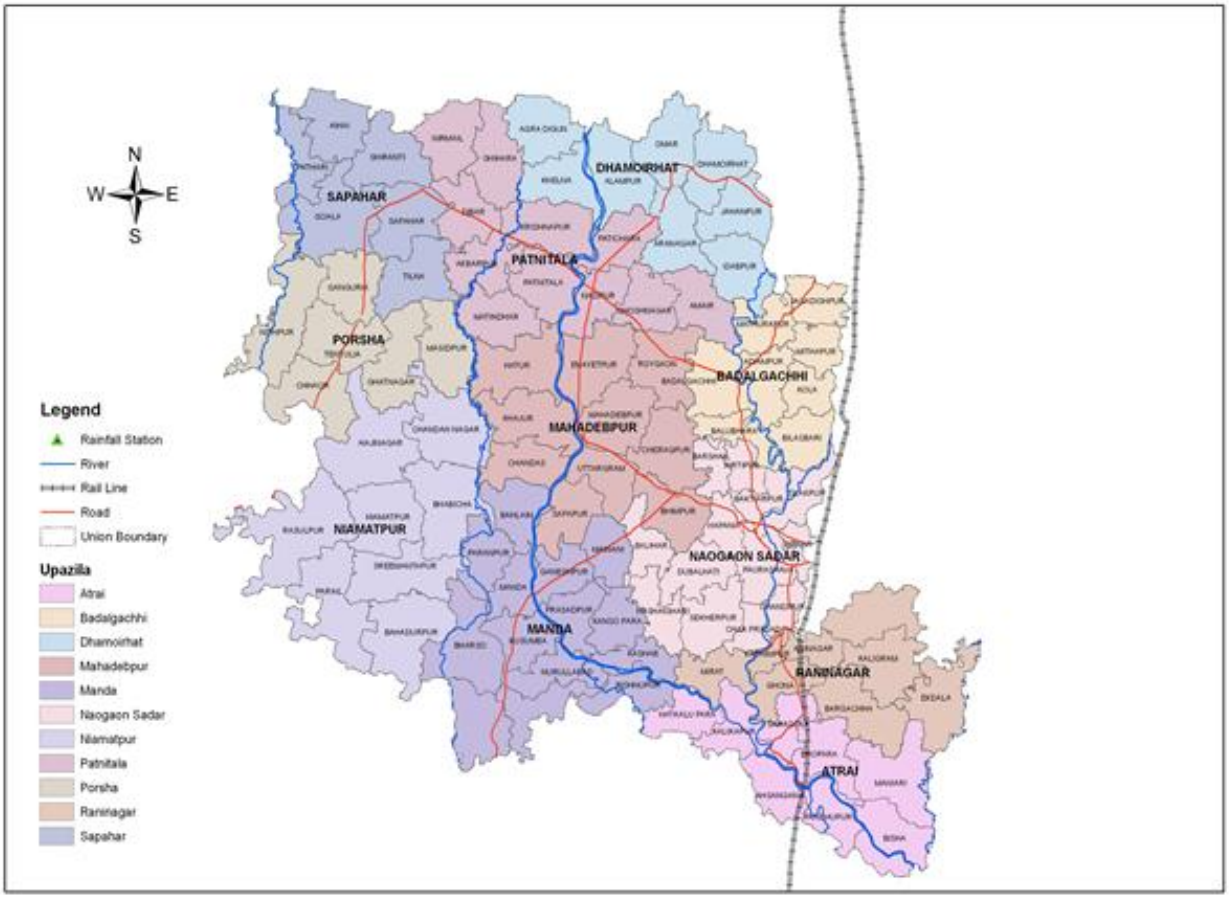


Fig. 1. Map of the study area

III. METHODOLOGY

A. *Data Collection*

For the present study different data have been collected from different organizations of Bangladesh.

Hydro-Meteorological Data

Twenty years meteorological data (from 1990 to 2011) pertaining to monthly rainfall was collected from Bangladesh Water Development Board (BWDB). Daily rainfall data was obtained from 8 rainfall stations of Naogaon district. Those rainfall data was used to derive Standardized Precipitation Index (SPI). The location of BWDB rainfall station is shown in Fig. 2. Forty years daily maximum and minimum temperature data (from 1972 to 2012) was collected from Bangladesh Meteorological Department (BMD).

Groundwater Level Data

Seventeen years (from January 1995 to May 2012) groundwater level data of groundwater monitoring well of 10 upazilas under Barind Tract in Naogaon district has been collected from Barind Multipurpose Development Authority (BMDA).

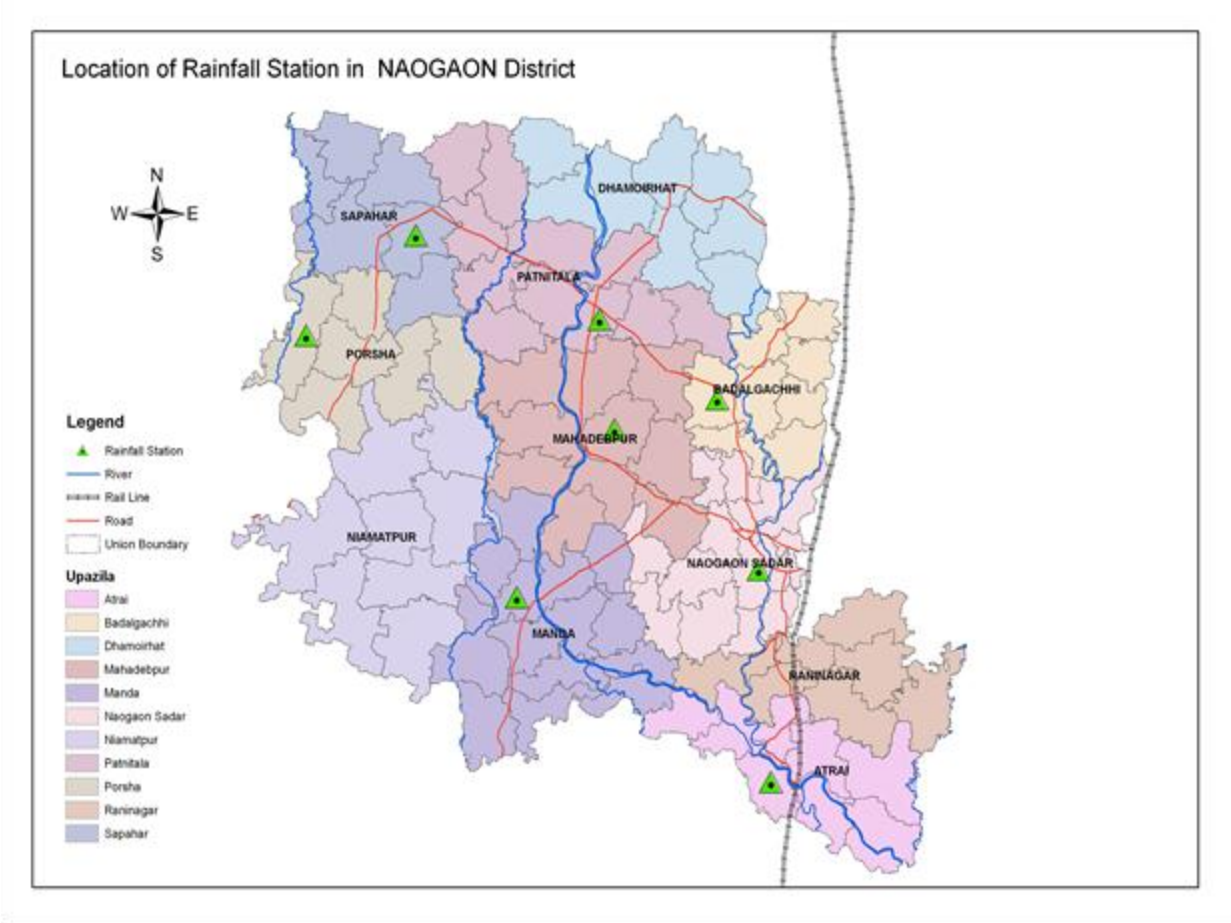


Fig. 2. Location of rainfall stations of BWDB in Naogaon district

B. Data Analysis

The raw data collected from the different organizations has been processed and analysed.

Variation Temperature and Rainfall Data

The variations of temperature, rainfall and groundwater level data were graphically represented in the present study.

Drought Analysis

Wilhite has defined "Drought as an environmental phenomenon is an integral part of climatic variability. Drought is an natural hazard that results from a deficiency of precipitation from expected or'normal' such that when it is extended over a season or longer period of time, the amount of precipitation is insufficient to meet the demands of human activities and the environment" [12]. Wilhite classified, drought is in four major categories as: meteorological drought, hydrological drought, agricultural drought and socie-economic drought. In the present study the meteorological drought was determined. Meteorological drought simply implies rainfall deficiency where the precipitation is reduced by more than 25% from normal in any given area. Different methods could be uded to determine the meteorological drought indices. In this study Standardized Precipitation Index (SPI) was used. SPI is usually used to quantify precipitation deficit at different time scales. 1-month SPI reflects short-term conditions and its application can be closely related to soil moisture; the 3-month SPI provides a seasonal estimation of precipitation; 6- and 9-month SPI indicates medium term trends in precipitation patterns. In the present study only one month SPI value was determined for 8 rainfall stations using monthly rainfall data for the period of 1990 to 2011. The rainfall data was used for crop growing season (i.e. July to November).

Standardized Precipitation Index (SPI) is calculated based on Gamma Distribution:

$$SPI = \frac{(X_i - X_m)}{\sigma} \quad (1)$$

Where Xi is monthly rainfall recorded of the station; X_m is rainfall mean; and σ is the standard deviation.

McKee et al. [13] designed SPI for 3, 6, 12, 24, and 48-month time scales and classified the drought for several

purposes. The positive values of SPI indicate the rainfall is greater than median rainfall and negative values indicate the rainfall is less than median rainfall. To monitor the dry condition the drought part of the SPI ranges are divided into near normal conditions (0.99 < SPI <-0.99), moderately dry (-1.0 < SPI < -1.49), severely dry (-1.5 < SPI <-1.99) and extremely dry (SPI < -2.0). A drought event starts when SPI value reaches -1.0 and ends when SPI becomes positive again. It present study after determining the SPI values ArcGIS has been used to represent the drought severity through GIS mapping.

IV. RESULT AND DISCUSSION

A. *Analysis of Temperature*

Forty years rainfall data was analyzed in this study. The annual maximum mean temperature varies from 29.5 ^{0}C to 32.5 ^{0}C in Naogaon District from 1972 to 2011 (Fig. 3). The highest annual maximum mean temperature 32.5 ^{0}C occurred in 2010. The lowest annual maximum mean temperature 29.5 ^{0}C occurred in 1977. It is also observed from Fig .3 that the frequency of maximum mean temperature is increasing from year 2004 to 2010. Overall the maximum mean temperature from 1972 to 2010 is increasing trend.

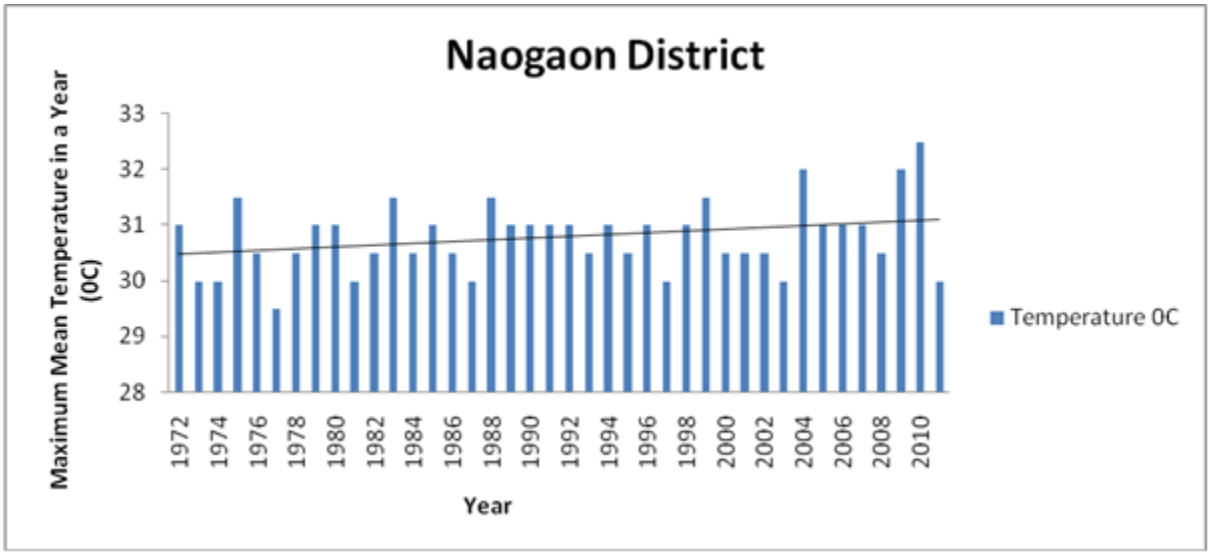


Fig. 3. Variation of annual mean temperature (1972-2011) in Naogaon district

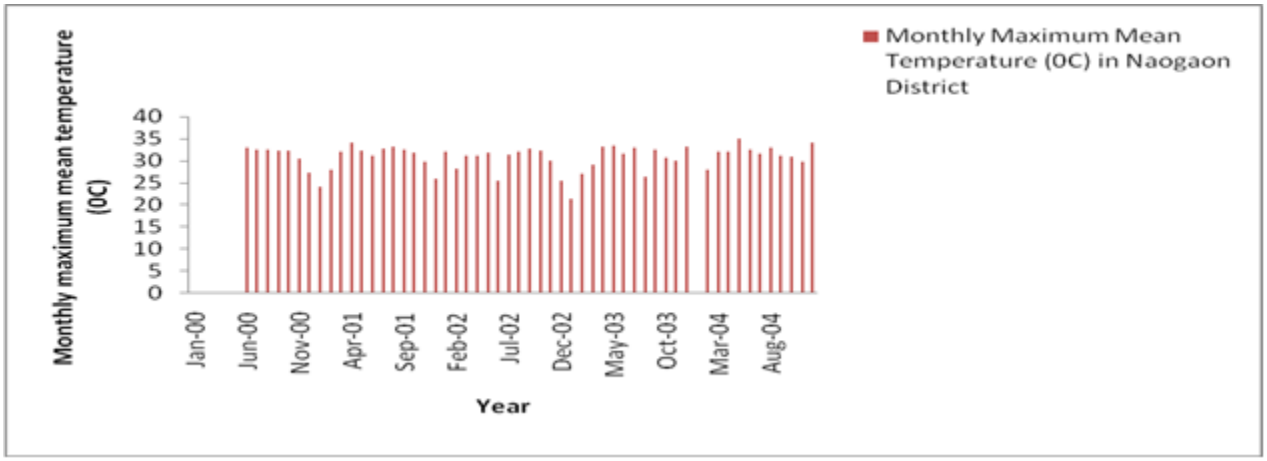


Fig. 4 (a). Variation of monthly maximum temperature from 2000 to 2004

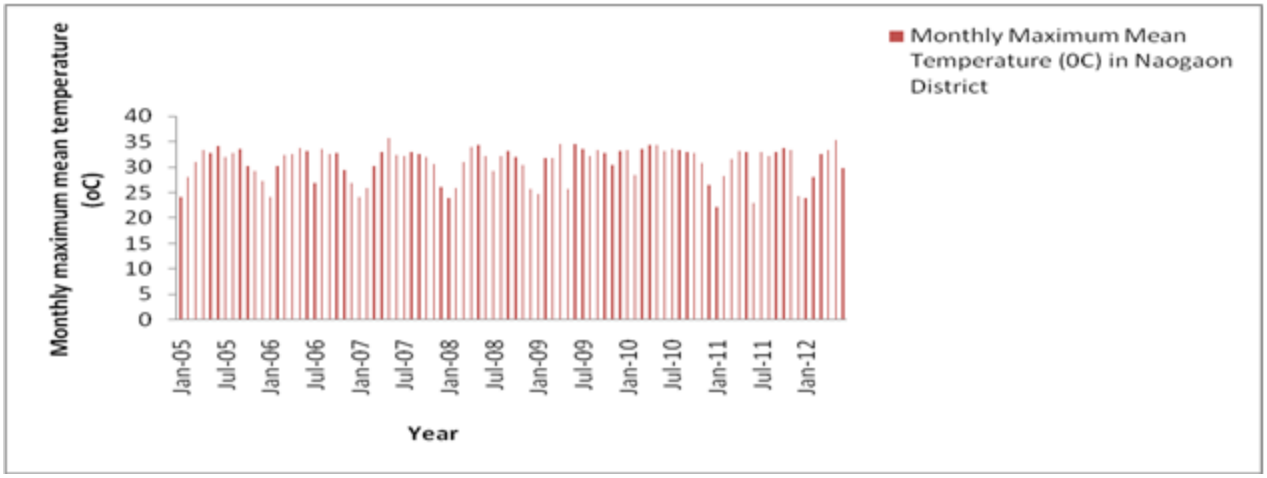


Fig. 4 (b). Variation of monthly maximum temperature from 2005 to 2012

The variation of monthly maximum temperature from 2000 to 2004 is shown in Fig. 4(a). The variation of monthly maximum temperature from 2005 to 2012 is shown in Fig. 4(b). It found that the highest monthly maximum temperature was in the month of March to June (highest in the month of April). Monthly maximum mean temperature was low in the month of November to February (lowest in the month of December).

B. Analysis of Rainfall Data

Five rainfall stations have been selection for analyzing the variation of rainfall. The five selected stations area Porsha, Shapahar, Mohadebpur, Atrai and Naogaon. The variation of minimum and maximum annual rainfall was from 500 mm to 2100 mm. Sometimes the monthly maximum rainfall was up to 850 mm.

Porsha Upazila- It is observed from Fig. 5 (a-b) that the maximum amount of monthly rainfall was occurred in May to September. The minimum amount of monthly rainfall occurred in January to April. The variation of average rainfall was from 200 to 1100 mm in the months of May to September from 1990 to 2010. The variation of maximum rainfall was 200 mm to 300 mm in the months of May to September in 1994, 1999, 2000, 2008, and 2009. But the variation of rainfall in the months of May to September from 750mm to 1100 mm in 1995, 1996 , 2007 and 2010 maximum rainfall.

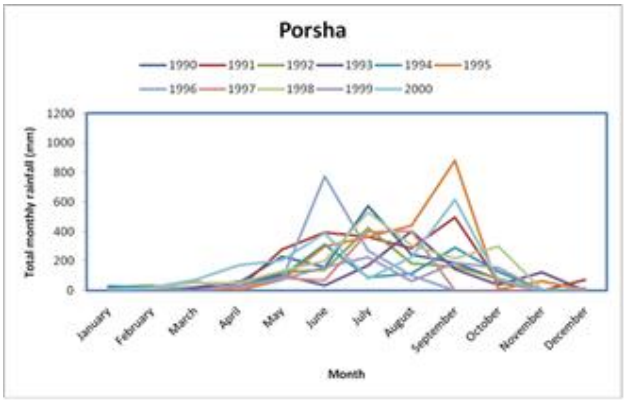
Sapahar Upazila- It is observed from Fig 5 (c-d) that the maximum amount of monthly rainfall was occurred in the months of May to September. The minimum amount of monthly rainfall was occurred in the months January to April. The variation of average rainfall was from 100 mm to 800 mm in this upazila in the month of September from 1990 to 2009. The variation of rainfall in May to September was 100mm to 450mm from 1990 to 2010 except in 1995. The rainfall pattern was exceptional in in the month of September in 1995. The total amount of rainfall was 750mm which was recorded maximum rainfall.

Mohadevpur Upazila- It is observed from Fig 5 (e-f) that the monthly maximum rainfall occurred in May to September and minimum rainfall occurred January to April. The variation of average rainfall was 200 mm to 800 mm in the month of September from 1990 to 2009. It is also found that in the years of 1990 to 2010 maximum rainfall occurred in the months of May to September 200 to 450mm accept 1995. The maximum amount of rainfall occurred in September, 1995. The total amount of rainfall was 800mm.

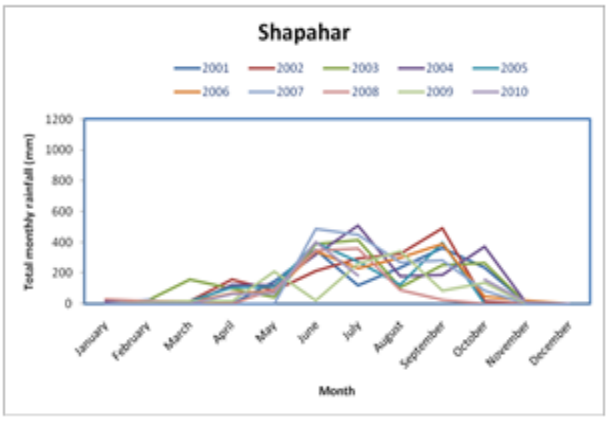
Atrai Upazila- It is observed from Fig 5 (g-h) that the maximum monthly rainfall usually occurred in May to September months and minimum rainfall usually occurred January to April months. The variation of average rainfall was from 200 mm to 850 mm in the month of September from 1990 to 2009. The maximum amount of rainfall occurred in the month of September in 1998. The total amount of rainfall was 850mm.

Naogaon Upazila- It is observed from Fig 5 (i to j) that the total amount of monthly maximum rainfall was occurred in the months of May to September and minimum rainfall is occurred January to April. The variation of average rainfall was from 100mm to 750 mm in the month of September from 1990 to 2009. The maximum amount of rainfall occurred in the month of August in 1998. The total amount of rainfall was 750mm.

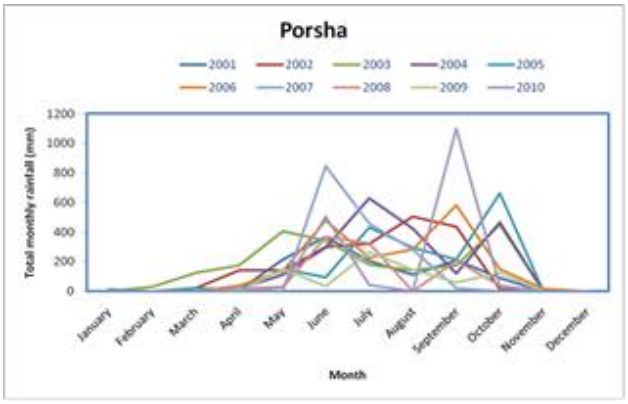
From the above analysis is found that the intensive rainfall was occurred within short duration in month of September in Mohadevpur and Shapahar upazila. As a consequence of heavy rainfall flood was occurred in Naoagaon district in 1995. T-amam rice faces drought due to less rainfall in October and November. The supplementary irrigation is necessary for the T-aman rice to cover the shortfall of rainfall. It creates additional pressure on groundwater resource.


Porsha
1990 1991 1992 1993 1994 1995
1996 1997 1998 1999 2000
Total monthly rainfall (mm)
1200
1000
800
600
400
200
0
January February March April May June July August September October November December
Month

(a)


Shapahar
2001 2002 2003 2004 2005
2006 2007 2008 2009 2010
Total monthly rainfall (mm)
1200
1000
800
600
400
200
0
January February March April May June July August September October November December
Month

(c)


Porsha
2001 2002 2003 2004 2005
2006 2007 2008 2009 2010
Total monthly rainfall (mm)
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Month

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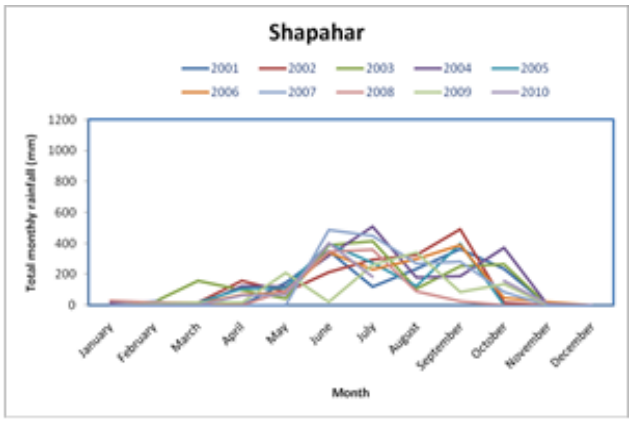
Shapahar
2001 2002 2003 2004 2005
2006 2007 2008 2009 2010
Total monthly rainfall (mm)
1200
1000
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600
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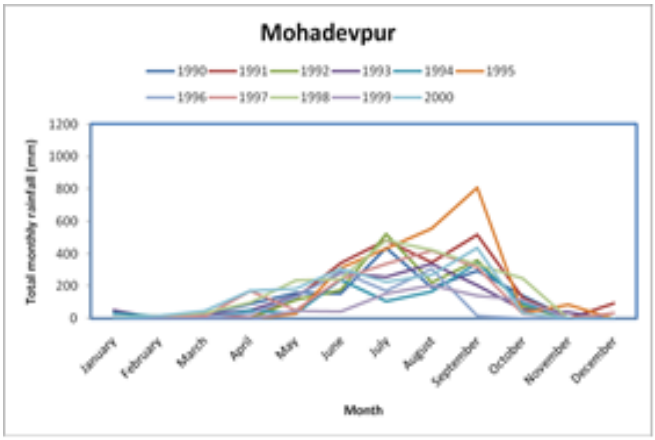
200
0
January February March April May June July August September October November December
Month

(d)


Mohadevpur
1990 1991 1992 1993 1994 1995
1996 1997 1998 1999 2000
Total monthly rainfall (mm)
1200
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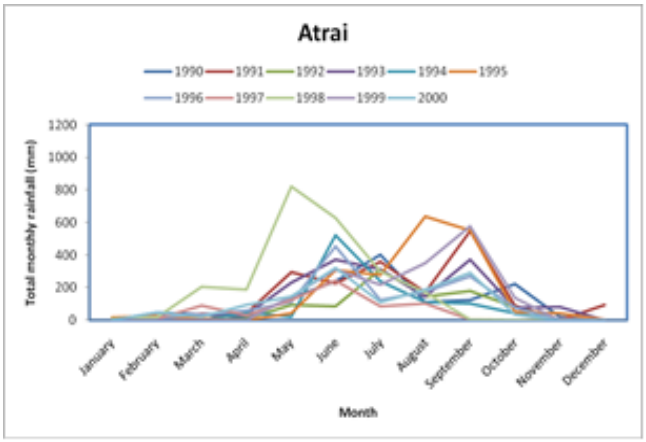
200
0
January February March April May June July August September October November December
Month

(e)


Atrai
1990 1991 1992 1993 1994 1995
1996 1997 1998 1999 2000
Total monthly rainfall (mm)
1200
1000
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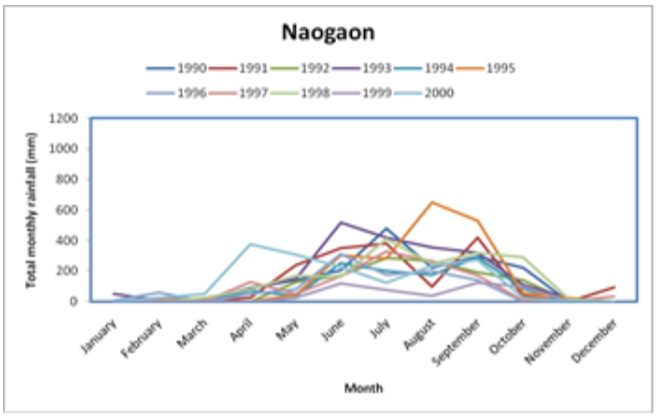
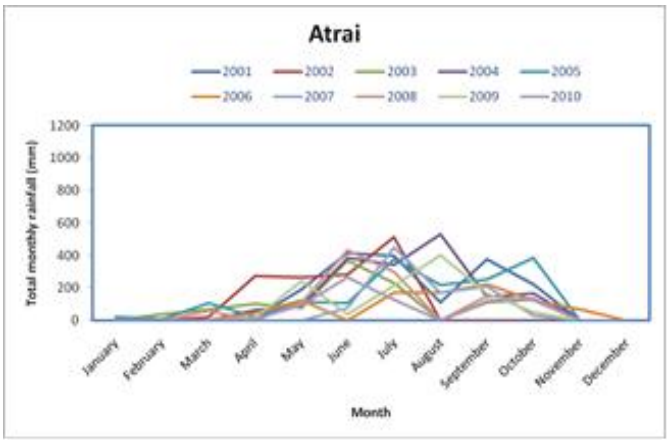
600
400
200
0
January February March April May June July August September October November December
Month

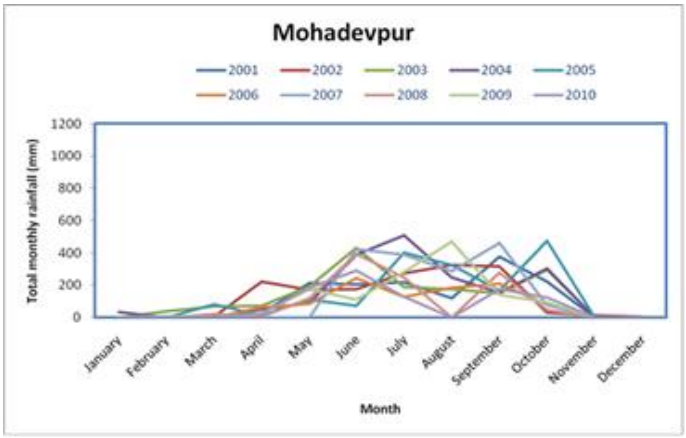
(g)



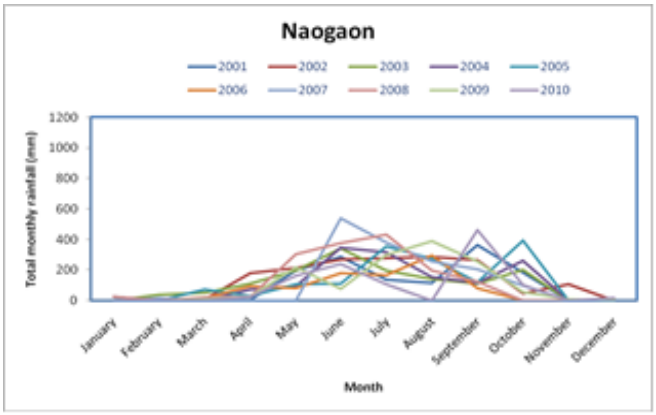
(i)



(h)



(f)



(j)

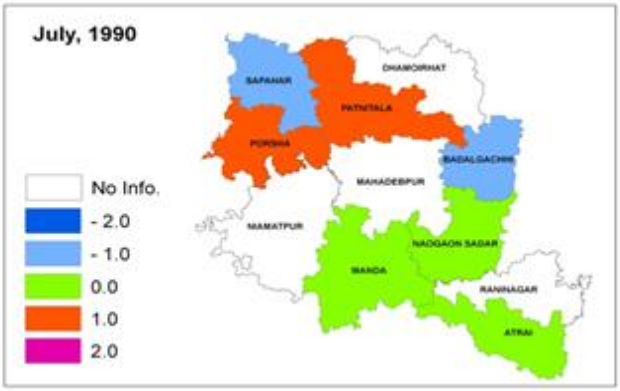
Fig. 5. Variation of rainfall from 1990 to 2010 of different rainfall stations

C. Drought Analysis

From analysing the twenty years rainfall data one-month SPI value has been determined for the study area. Drought risk has been identified using SPI value of in Naogaon district. Depending on the SPI analysis different year was selected either drought prone or normal. The year 2000, 2004, 2008 and 2010 were selected as drought prone years and 1990 was selected as normal year. The one-month SPI values of April, July and September have been presented in Fig. 6. (a to e). It is evident that the one-month SPI values varies from -0.95 to 2.1 and the rainfall probability varies from 0.154 to 0.98 in the Naogaon district during the year 1990, which states that this year was wet years. In year 2000 the SPI value varies from -1.14 to 1.83 and the rainfall probability varies from 0.13 to 0.95 and it was a drought year (Fig. 6.b). In this year moderate and normal drought is found in Shapahar and Porsha upazila, respectively. In 2004 the SPI value varies from -1.71 to 2.18 and the rainfall probability varies from 0.02 to 0.99 and this year was drought year (Fig. 6.c). In this year severe and moderate droughts were occurred in Porsha and Patnitala upazila, respectively. In 2008 the SPI value varies from -1.58 to 1.44 and the rainfall probability varies from 0.03 to 0.94 (Fig. 6.d). In this year severe and moderate droughts were occurred in Shapahar and Patnitala, respectively. In 2010 the SPI value varies -1.4 to 2 and the rainfall probability varies from 0.1 to 0.99 (Fig. 6.e). Moderate drought was occurred in Porsha upazila. The low rainfall data was recorded at 8 rainfall station in Naogaon district. It was found that from analysis that the SPI value was less than -1.5 in 2004. So it could be stated that that 2004 year was the extreme drought year in Naogaon district. This result has been confirmed from the focus group discussion (FGD) method during the present study.

The SPI is a good and cost-effective method to detect meteorological drought and its magnitude. The real time assessment can plays a significant role to mitigating the adverse impacts drought.

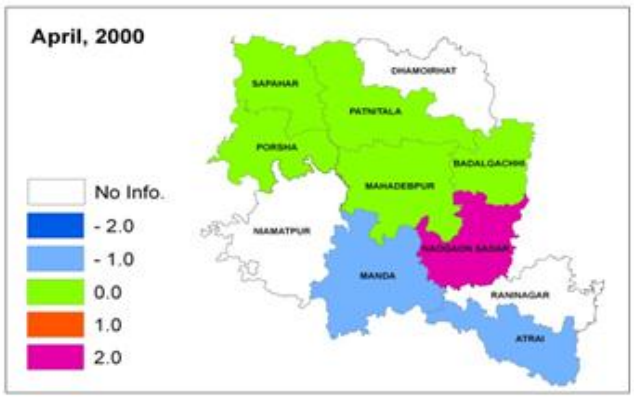
(i)



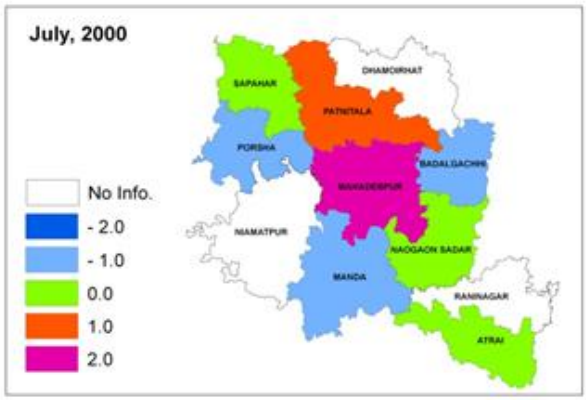
(ii)

(iii)

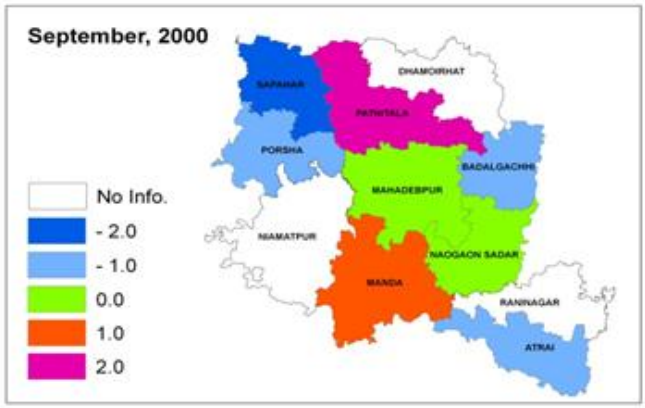
a) One-month interpolated SPI values for 1990



(i)

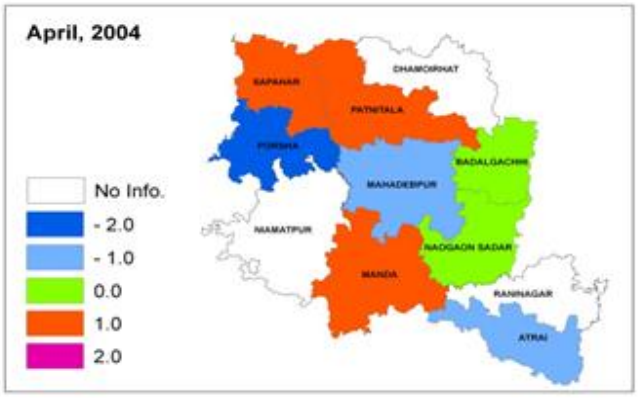


(ii)



(iii)

b) One-month interpolated values SPI for 2000



(i)

(i)

(ii)

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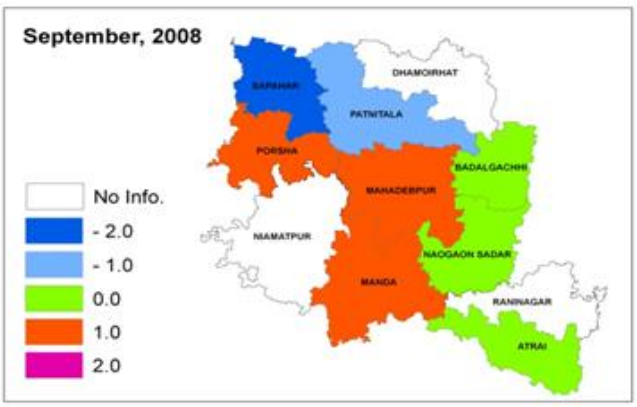
c) One-month interpolated SPI values for 2004



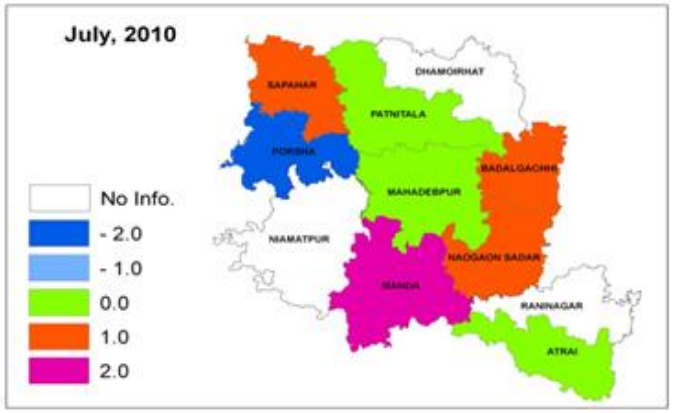
(iii)

d) One-month interpolated SPI values for 2008

(i)

(iii)

e) one-month interpolated SPI values for 2010



(ii)

Fig. 6. One-month interpolated SPI values for selected drought

D. Analysis of Groundwater Level

It is earlier stated that the groundwater irrigation was started in Naogaon district in 1980s and spread after the initiating of Barind Integrated Area Development Project (BIADP) in 1985. Under the BIADP project only shallow tubewel were used for irrigation. During initiating the groundwater irrigation in Naogaon district the eastern part and western part was excluded due to groundwater available in deep aquifer. Later the the groundwater irrigation spread different upazilas in Naoganon district with the formation of Barind Multipurpose Development Authority (BMDA) in 1992. After formation of BMDA deep tubewells were used to abstracted groundwater from deep aquifer.

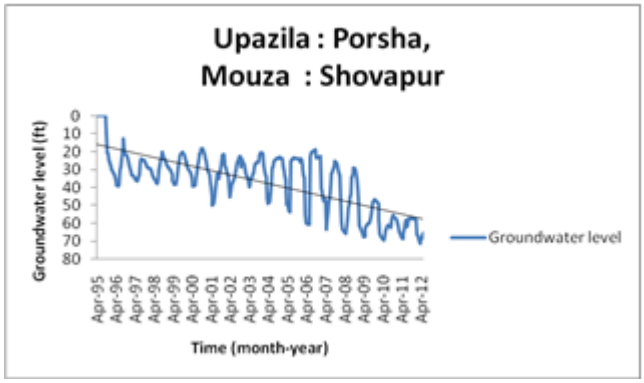
The groundwater level data of 10 upazilas out of 11 upazilas were used in this study. The data was available from January 1995 to May 2012. The groundwater level fluctuations and average depletion trends of different upazilas are shown in Fig. 7 (a to j). The groundwater level usually rises in Bangladesh in wet season due to monsoon rain and flooding in the river. The water level rises to maximum level in August to September. The water level starts to fall and reach to minimum level in the pre-monsoon months of April to May. The maximum declination of groundwater level of Shovapur mouza under Porsha upazila is shown in Fig 7(a). The total declination of groundwater table is about 48 ft that was occurred from 1995 to 2012. The declination rate is 2.8ft/yr (Table I). The declination of groundwater level of Rasulpur mouza under Shapahar upazila is shown in Fig 7(b). The depletion rate of the Shapahar upazila is 1.6 ft/yr (Table I). The depletion rate of the Mohadevpur and Atrai are 0.2 ft ft/yr and 0.3 ft/yr, respectively that is relatively low compare to the other upazila of Naogaon ndistrict. The groundwater level is abruptly going down from 2008 to 2012. The average depletion rate of groundwater levels overall the Naogaon district is about 1 ft annually. Every year the rate of depletion of groundwater level is accelerating in dry season due to sinking of new deep tube well and gradually decreasing total annual rainfall. The high rate of decreasing of groundwater level of Porsha and Shapahar is due to mainly two reasons. First reason is rapidly increasing deep tubewell and second reason is steep land slope. Due to steep slope the runoff volume quickly reaches to the Punarbhaba river. So the runoff volume gets less time for groundwater recharge. The low rate of decreasing of groundwater level of Mohadevpur and Atrai upazilas is due to low lying area. Actually most of the area of the Mohadevpur upazila is under the Barind Tract. But the observation well is situated in low lying area. So the rate of

depletion of ground water level is relatively low among all other the observation wells.

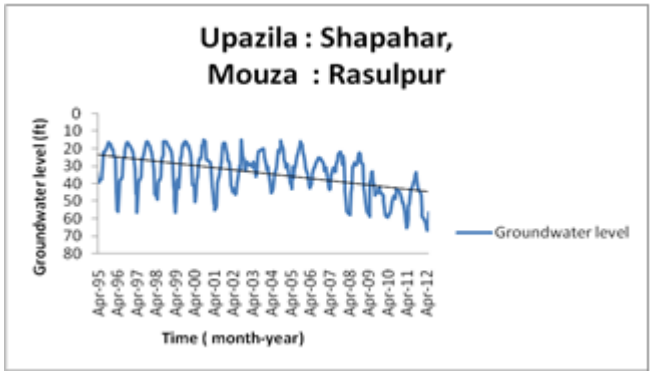
The depth of groundwater level below surface in Porsha upazila was 38 in 2000 but it was 72 ft in 2012. The depth of groundwater level below surface in Shapahar upazila was 50 in 2000 but it was 69 ft in 2012.

Major food production in Naogaon district is mainly dependent on rain-fed agriculture especially T-aman rice Boro rice production which is fully dependent of ground water irrigation in dry season. Inadequate pre-monsoon showers, a delay in the onset of rainy season or/and early departure of the monsoon usually create drought conditions. Permanent decline of groundwater table is due to over-abstraction of groundwater and less rainfall especially in Porsha ana Shapahar upazila of high and medium Barind area in Naogaon district. Recurrent drought events cause serious economic, social and environmental problem and are devastating particularly the agriculture economy. The situation is alarming for some specific areas like Porsha and Shapahar upazila in Naogaon district. These two upazilas severely suffer from drought resulting less amount of rice production. Continuous depletion of ground water level many hand tube wells suffer layer failure problems which causes crisis of drinking water during dry season. Not only the hand tube wells but also the deep tube wells failed due to lowering of water table. Many deep wells are needed to re-sink into the deep aquifer.

It was earlier stated that the groundwater is mainly used for irrigation of boro crop. But due to shortfall or uneven rainfall during monsoon supplementary irrigation also need for T-aman crop. Instead of boro crop which is usually needed need huge amount of water for its production. It is essential diversified crop should be introduce to use the less amount of wate for better management of groundwater. The alternative source should be identified for irrigation. A large number of ponds are available in the Barid Tract. The water from ponds should be used for irrigation for those crop which needs less amount of water. Different artificial ground water recharge method should be adopted for the development of groundwater resource.



(a)



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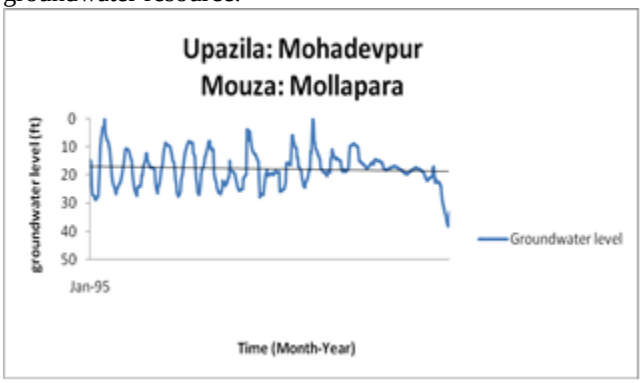

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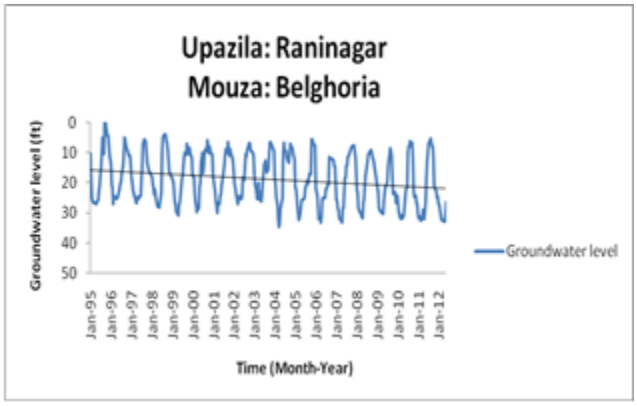

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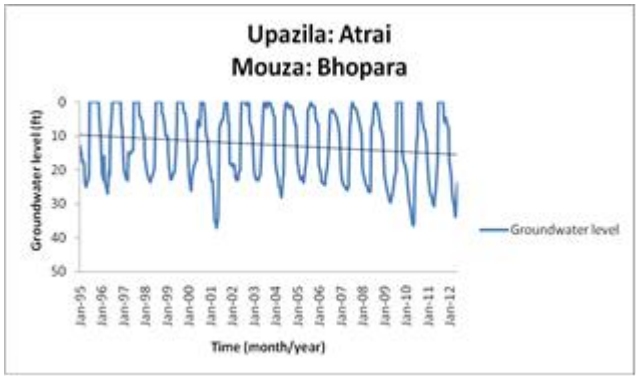

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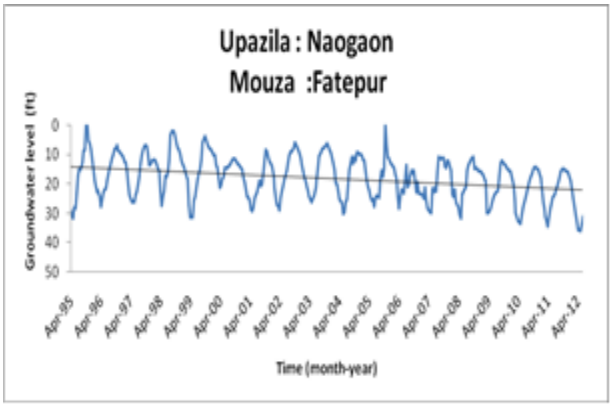

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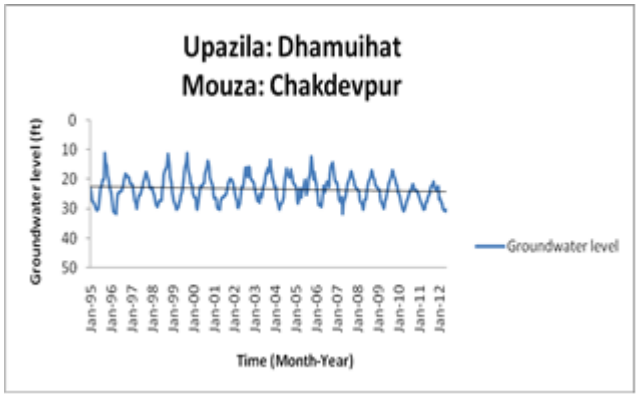
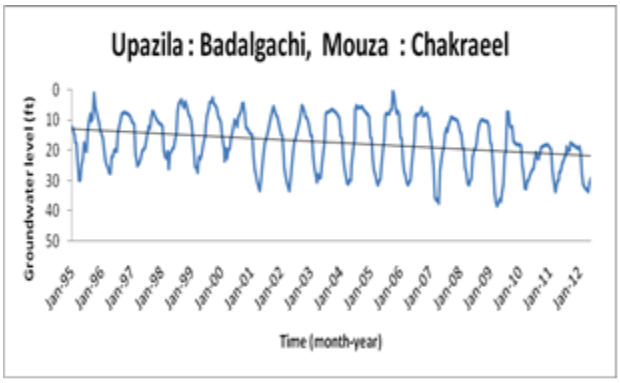


(i)



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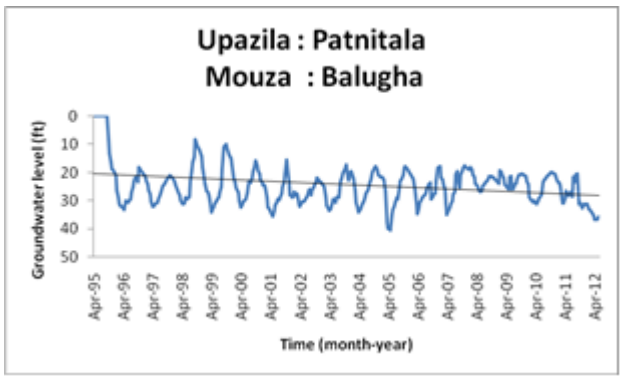

(d)

Fig. 7. Fluctuation Groundwater table and trends line of different upazilas in Naogaon district

TABLE I
DEPLATION OF GROUNDWATER TABLE FROM 1995 TO 2012

Upazila	Total depletion last 17 years (ft)	Rate of depletion ft/year
Porsha	48	2.8
Shapahar	26	1.6
Raninagar	11	0.6
Mohadevpur	3	0.2
Atrai	5	0.3
Dhamorhat	7	0.4
Patnitola	15	0.9
Naogaon Sadar	8	0.5
Manda	21	1.3
Badalgachi	8	0.5

V. CONCLUSION

The following conclusions are drawn from the present study. The variation of the minimum and maximum annual rainfall of the study area is from 500mm to 2100mm. The monthly rainfall varies from 100mm to 800mm. The monthly rainfall is decreased in most of the upazilas of Naogaon district after 2000. Porsha, Shapahar Patnitala and Atrai are the more drought prone area in Naogaon district. The SPI value varies from -1.71 to 2.18. The annual maximum mean temperature is increasing trend. The groundwater level is decreasing trend all over the Naogaon district. The alternative source should be used for irrigation purpose. Crop diversification is necessary for using less amount of water for irrigation.

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