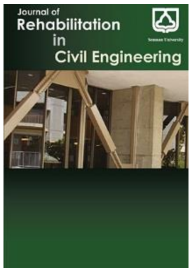
Journal of Rehabilitation in Civil Engineering 5-2 (2017) 82-100

Journal homepage: http://civiljournal.semnan.ac.ir/



Recent Trend Determination of Groundwater Level along with Inter-Reliant Hydrologic Components Applying the Mann-Kendall Test, Linear Regression and Geometrical Progression: A Case Study for Bogra District in Bangladesh

M. Abdullah[1, 2*]

1. Bangladesh University of Engineering and Technology, Dhaka, Bangladesh
2. Institute of Water Modelling, Dhaka, Bangladesh

Corresponding author: mabdullah03@gmail.com

ARTICLE INFO

Article history:
Received: 27 September 2014
Accepted: 09 July 2017

Keywords:
Groundwater,
Rainfall,
Irrigation,
Hydrologic Time Series,
Trend Analysis.

ABSTRACT

Groundwater, a special hydrological variable, and freshwater resource are completely inter-reliant with hydro-meteorological, topographic, land use and hydro-geological components of the hydrologic cycle. The trend of hydrologic components for future prediction is attempted to confer in this study applying the Man-Kendall test, linear regression, and geometric progression analysis on recorded data collected from recognizing the organization of Bangladesh. Bogra district is selected as the study area, which is characterized by fluctuating hydrological components over the years. Temporal distribution and the recent trend of dominating hydrologic variables are analyzed, and the spatial distribution map is presented to discuss localize disparity within the study area. Groundwater abstraction and corresponding recharge reliant with hydro-meteorology and hydro-geology simultaneously with land use pattern are attempted to comprehend in this research.

1. Introduction

Water is a renewable resource [1], and water availability is complicated by its uneven distribution over the localities. A combination of evaporation and precipitation replenish our freshwater supply continuously and quickly [2]. A part of freshwater resources, surface, and groundwater resources is projected to reduce as a result of climate change over 21st century in dry most tropical regions [3]. Groundwater is the largest source of usable, freshwater in the world [4]. Ground-water depletion, a term often defined as long-term water-level declines caused by sustained groundwater pumping, is a key issue associated with ground-water use [5].

DOI: 10.22075/jrce.2017.545.1082

In recent years, the decline of the groundwater table is a threat in the north-western region of Bangladesh as a result of over-abstraction of groundwater [6]. The groundwater level declined substantially during the last decade causing a threat to the sustainability of water use for irrigation in the region and impacting upon other sectors too [7]. In the north-western region of Bangladesh, groundwater declines 5-10m in the dry period [8]. In the greater Rajshahi area, extraction exceeds recharge, and groundwater table declined 3 meters between 2004 and 2010 [9]. Declination of water table effects on water quality; especially arsenic is a function of water depth [10].

In the north-west region of Bangladesh, tubewell intensity is augmented from 6.9 to 36 per square kilometer, deep tubewell& shallow tubewell reached about double and five times respectively; irrigated land increased 1.6 times from 1984-85 to 2010-2011 [8]. In consonance from the Bangladesh Bureau of Statistics, the population of Bangladesh increased from 28.93 million in 1901 to 149.77 million in 2011 [11]. More than 90% of the population relies on groundwater for its potable water supply. In rural areas, more than 97 percent of the rural population is using over 10 million hand tube wells to fulfill their drinking water demands. During 1980-1990, around 26% of the urban population and only 2% of the rural population had access to the piped water supply. At present, 75% of the urban population is served with piped water, and also 14% of the rural population benefits from piped water supply [12]. Piped households use on an average almost three times more water than that of un-piped households [13]. Under the circumstances, the current study has attempted to comprehend the trend and extent of groundwater table both at spatial and temporal scale through analyzing the status of expanding water demand. Particular attention has to be given to elucidate access and inequality in getting an adequate amount of groundwater in Bogra district. The objective of this study is to test the trend of hydrological components, necessary for groundwater development along with annual abstraction as a result of agricultural and domestic needs.

The purpose of the trend testing is the determination of whether the probability distribution from which they arise has changed over time and is like to describe the amount or rate of modification, in terms of changes in some central value of distribution such as mean or [14]. Applying linear regression analysis, it is common practice to examine the significance trend assume recorded data have a normal distribution with the mean value that possibly varies with time [15]. Non-parametric Mann-Kendall test is widely applied for the trend analysis in climatologic [16] and hydrologic time-series data [17], which makes no assumption about the distribution of the data [15].

2. Materials and Methods

The study area is Bogra district consisting of 12 upazilas is presented in Fig. 1. The study area is bounded on the north by Gaibandha and Joypurhatzila, on the east by Jamalpur and Sirajganjzila, on the south by Sirajganj and NatoreZila, and on the West by Naogaon and Joypurhatzila. It lies between $24^0 32'$ and $25^0 07'$ north latitudes and between $88^0 58'$ and $88^0 95'$ east longitudes. Confirming to Bangladesh Bureau of Statistics (2011), the total area of the study area is 2898.68 sq km.

2.1 Data Collection, Analysis, and Processing

In consonance to the model requirements, a significant data has been accumulated from Institute of Water Modelling (IWM), Bangladesh Bureau of Statistics (BBS), Bangladesh Agricultural Development Corporation (BADC) and Bangladesh University of Engineering and Technology (BUET).

2.1.1. Climate, Topography and Drainage System of the Study Area

According to the Bangladesh Bureau of Statistics (BBS, 2011), Rainfall of the study area in 2011 is 1721mm, monthly average maximum and minimum temperature is 33.8^0C in October 2011 and 10.1^0C in January 2011. The monthly average relative humidity is about 85% in August 2011 (maximum) and 66% in March 2011 (minimum).The topography of the study area varies from 10.34 mPWD in Dhunat to 23.57 mPWD in Shibganjupazila. Topographical condition represented by the Digital Elevation Model (DEM) is illustrated in Fig. 2.The study area is drained mainly by Jamuna, Karatoya, Nagar, Bangali, and Ichamati Rivers is depicted in Fig. 3. The study area appears to be well-drained because of these rivers, which crosses the study area. However, there are some low lying areas and small beels in the study area. These low-lying areas and beels get dried up during the dry season.

2.1.2. Hydro-Meteorological Data of the Study Area

Precipitation, evapotranspiration, river water are the main hydro-meteorological components affecting the groundwater level of Bogra district.

Precipitation

There are eight BWDB rainfall stations (Table 1) that have an influence on the study area is presented in Fig.4. Data is assembled on a daily basis for 1985 to 2011. Station wise rainfall data for recent years has portrayed in Fig.5. The mean rainfall in the study area has come out around 1775mm during the period 1985 – 2011. Missing data are filled up by taking the average of the data of stations surrounding the station in question. It is presumed that the normal rainfalls of surrounding stations are within 10 to 12% of that concerned station [4]. Quality checking of rainfall data consists of the visual inspection of plots, preparation of double mass curves, estimation of yearly mean values, and comparison of monthly values. An example plot of a double mass curve is given in Fig.6.

Evapotranspiration

BWDB maintains only one evaporation station in the study area presented in Fig.4 and Table 2. From this base data, evapotranspiration has been calculated by IWM [18]. It has been observed that there is a relatively little variation of evapotranspiration between the study area and outside the study area. It is due to the fact that important parameters such as temperature and sunshine hours are largely similar across the area. From 1985 to 2011 data, annual evaporation value in the study area is around 1462mm (about 4 mm/day).

River Water Level

The river water level data of the Jamuna River and other major rivers in the study area were acquired from hydrology circle from BWDB stations. The water level is recorded five times daily at these locations. These water level data were assembled and processed for the period of 2005to 2012 as daily data. Collected data was checked by plotting hydrograph. In the dry period, other river passes through the Bogra district is almost dried up. therefore, only Jamuna River water level data is applied for trend analysis.

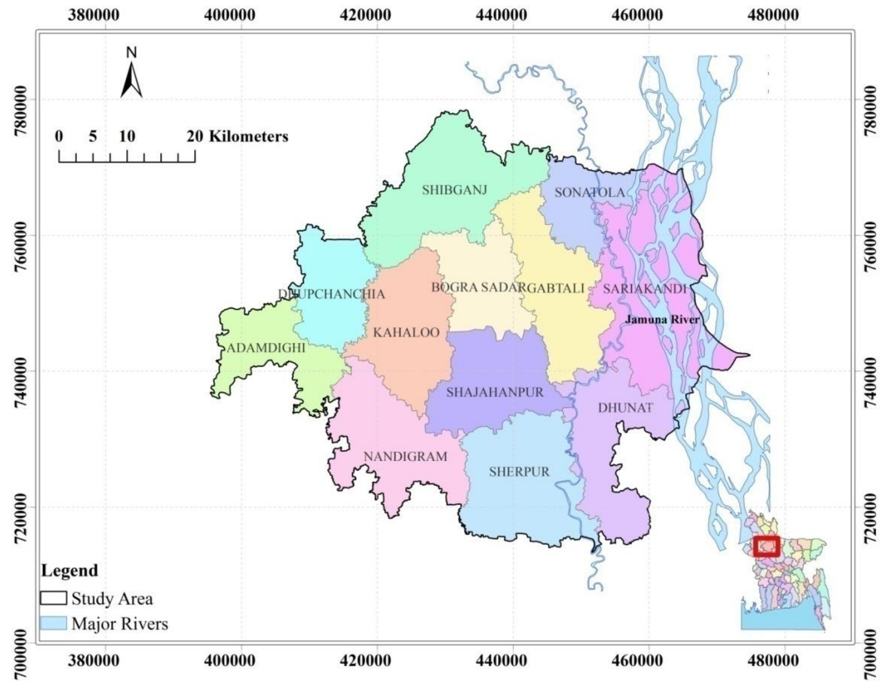


Fig.1. Study Area.

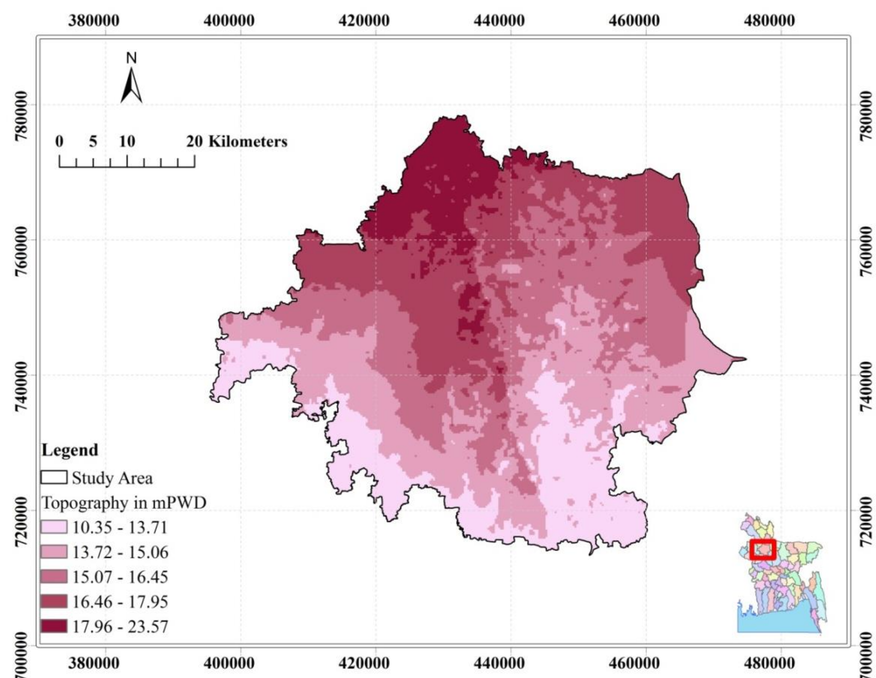


Fig. 2. Topography of the study area from the Digital Elevation Model (Data Source: IWM).

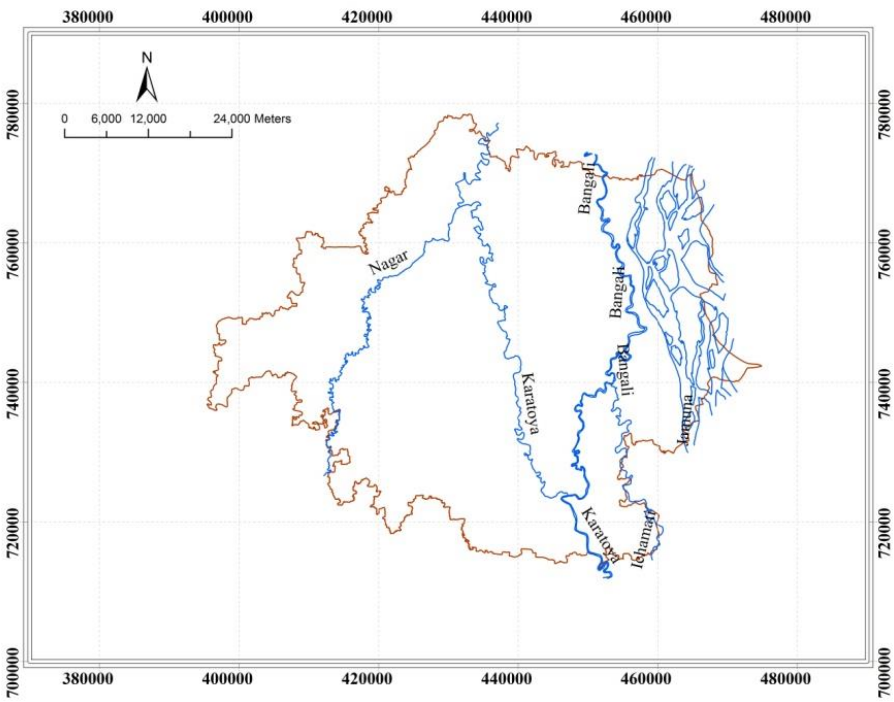


Fig. 3. Major Rivers in the study area (Data Source: IWM)

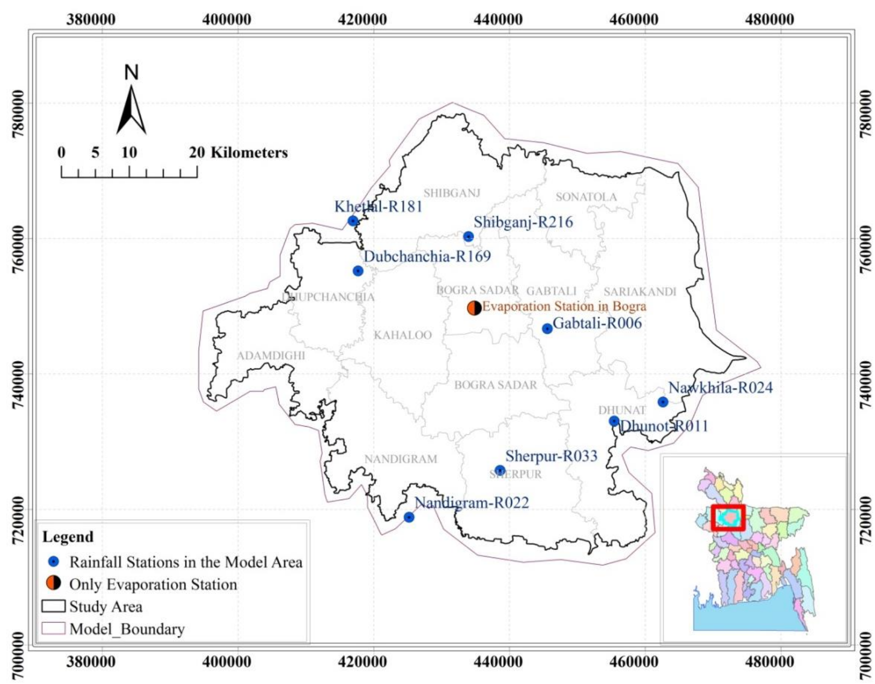


Fig. 4. Rainfall and Evaporation Stations under BWDB in the Study area.

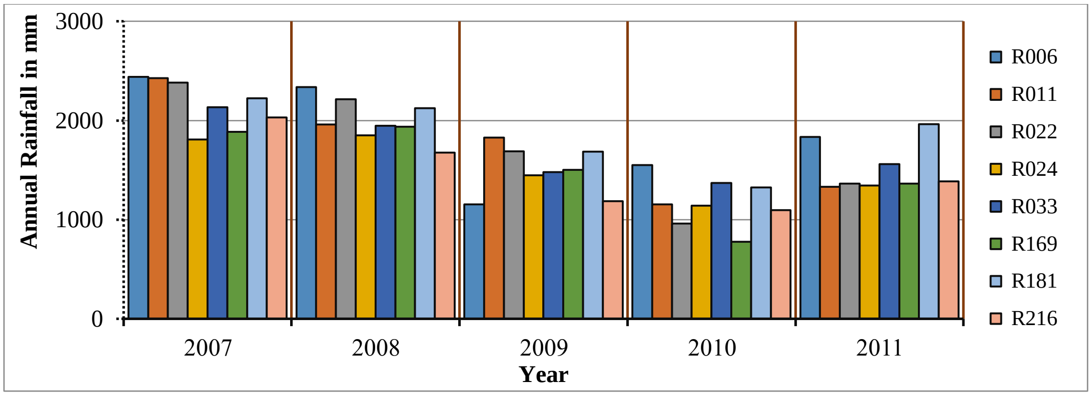


Fig. 5. Annual Rainfall of eight stations in Study Area for the year 2007 – 2011.

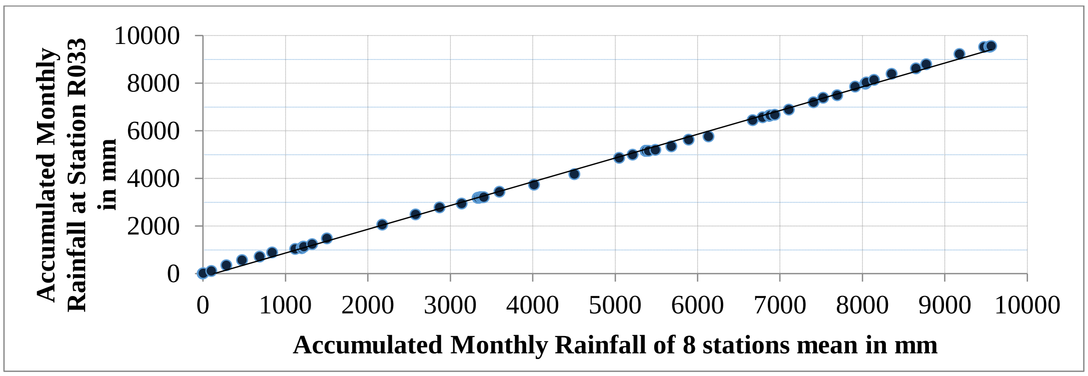


Fig. 6. Double Mass Curve for the hydrologic year 2006 to 2011 under Rainfall Station, R033 in Sherpurupazila (Data Source: IWM).

Table. 1. BWDB rainfall stations influenced the study area.

SL No.	Station ID	Station Name	Data Availability
1	R006	Gabtali	1985 - 2011
2	R011	Dhunat	1985 - 2011
3	R022	Nandigram	1985 - 2011
4	R024	Nawkhila	1985 - 2011
5	R033	Sherpur	1985 - 2011
6	R169	Dubchanchia	1985 - 2011
7	R181	Khetlal	1985 - 2011
8	R216	Shibganj	1985 - 2011

Table 2. Evaporation Station under BWDB in Bogra District.

Sl. No.	Station ID	Station Name	Data Availability
1	CL6	Bogra	1985 - 2011

2.1.3. Hydro-Geological Data of the Study Area

Groundwater wells at/around the study area and abstraction data due to irrigation & domestic water requirement are discussed in this article.

Groundwater Level

There are 21 groundwater observation wells under BWDB is selected in/around the study area presented in Fig.7.Among them, 6 observation wells are on the study area boundary, and other 15 observation wells are inside the study area. The frequency of measurement in the observation wells is generally once in a week. The measured groundwater levels are expressed in terms of national datum, mPWD. Data has been checked by visual inspection of those time series plots of groundwater levels, and missing data is filled up by interpolation of nearby stations. However, topology, groundwater level fluctuation, and rainfall pattern of those nearby stations are contemplated while filling the missing data.

Abstraction Due to Classified Land Use Pattern

In the study area, main crops area rice-paddy, jute, wheat, potato and variety of vegetables and they grow in the rain fed and irrigated condition. The following major cropping patterns prevail within the study area based on survey data conducted by IWM [18]. Boro, Wheat, potato, and winter vegetables are the main Rabi (December to May) crops, while Kharif-I (May to August) crops are Aus& Jute and Kharif-II (August to December) grow HYV Aman, Local variety Aman and rainy season vegetables. Sugarcane grows on a very small scale. Drought and inadequate irrigation facilities are the major limitations to intensive land use and optimum crop production. In the Dry season (Rabi), the major contribution of land occupies boro rice is about 53.2% of the total study area and about 70% of crop area within Bogra district. Occupied areas, specially boro, and nonboro area are depicted in Table 3 and Fig. 8. Confirming to the demand pattern, land use is categorized into seven (7) individual patterns is presented in Fig. 9 and Table 4.

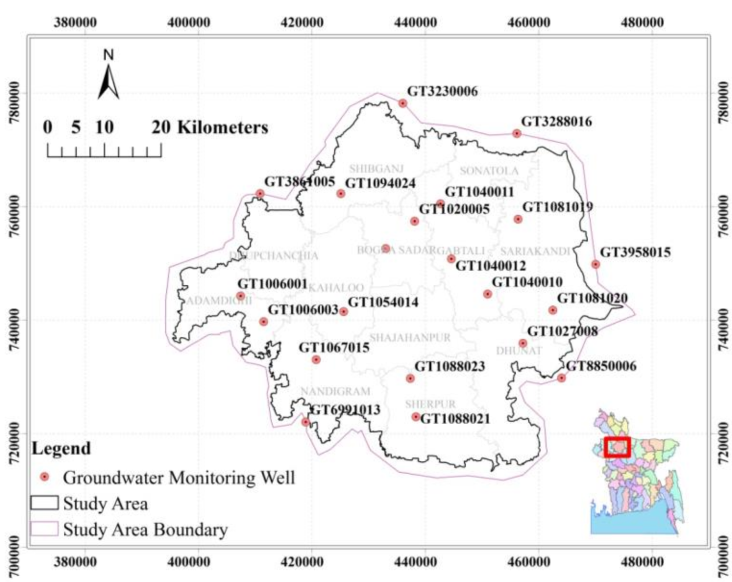


Fig. 7. Groundwater observation wells under BWDB within the study boundary.

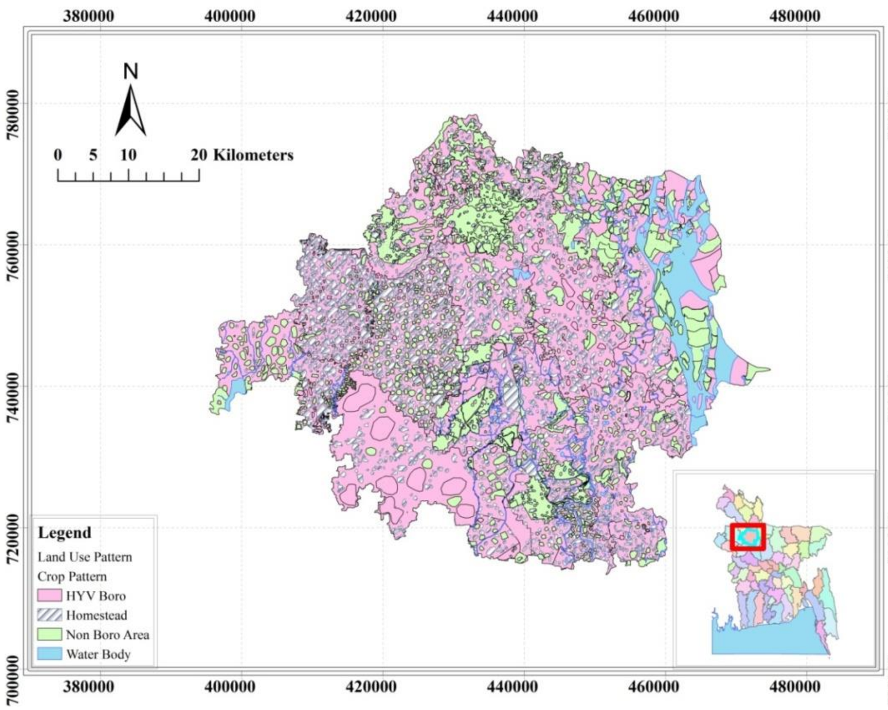


Fig. 8. Land Use Pattern according to Boro Crop throughout the study area.

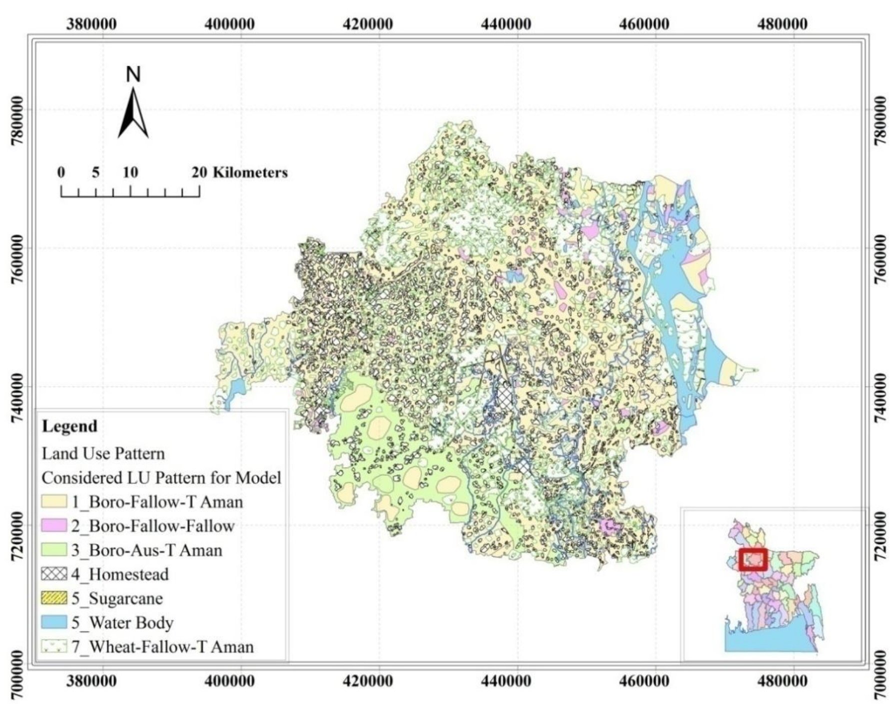


Fig. 9. Adopted land use pattern for the MIKE SHE model (Data Source: IWM).

Table 3. Occupied area in Rabi (Dry) season for boro and non boro crops.

Sl. No.	Area Type	Area in sq.km	% of Crop Area
1	Boro Area	1,570.10	69.63
2	Non-Boro Area	684.12	30.37

Table 4. Crop Calendar for the study area (Data Source: IWM).

Month	Land I.D.			
	1	2	3	7
July	Fallow	Fallow	Aus	Fallow
August	Fallow	Fallow	Aus	Fallow
	T-Aman	Fallow	T-Aman	T-Aman
September	T-Aman	Fallow	T-Aman	T-Aman
October	T-Aman	Fallow	T-Aman	T-Aman
November	T-Aman	Fallow	T-Aman	T-Aman
December	T-Aman	Fallow	T-Aman	T-Aman
	T-Aman	Fallow	T-Aman	T-Aman
January	T-Aman	Fallow	T-Aman	T-Aman
	HYV-Boro	HYV-Boro	HYV-Boro	Wheat
February	HYV-Boro	HYV-Boro	HYV-Boro	Wheat
March	HYV-Boro	HYV-Boro	HYV-Boro	Wheat
April	HYV-Boro	HYV-Boro	HYV-Boro	Wheat
May	HYV-Boro	HYV-Boro	HYV-Boro	Wheat
	Fallow	Fallow	Aus	Fallow
June	Fallow	Fallow	Aus	Fallow

2.2 Methods for Trend Analysis

For statistical analysis of the trend of hydrological data, Mann-Kendall test, Sen's slope, and Linear Regression is applied . For irrigation and domestic demand is calculated by using the geometrical progression method.

Mann-Kendall Trend test

The Mann-Kendall test [19] statistic is calculated as,

$$S = \sum_{i=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn}(x_j - x_k) \qquad (1)$$

Where

$$\text{sgn}(x_j - x_k) = \begin{cases} 1 & if \quad x_j - x_k > 0 \\ 0 & if \quad x_j - x_k = 0 \\ -1 & if \quad x_j - x_k < 0 \end{cases}$$

;j>k and n is the number of data, S is asymptotically normally distributed; which is the number of positive differences minus the number of negative differences. If S is a positive number, observations obtained later in time tend to be larger than observations made earlier. If S is a negative number, then observations made later in time tend to be smaller than observations made earlier.

Kendall's tau is defined as

$$tau = \frac{S}{D} \qquad (2)$$

Where

$$D = \begin{cases} \sqrt{\left\{\frac{n(n-1)}{2} - \sum_{j=1}^{p} t_j(t_j-1)\right\}}\sqrt{\frac{n(n-1)}{2}} & if \quad ties \\ \frac{n(n-1)}{2} & no \quad ties \end{cases}$$

The distribution of Kendall's tau can be easily obtained from the distribution of S.A positive value of tau indicates that there is an upward (increasing) trend (e.g., observations increase with time). A negative value of tau means that there is a downward (decreasing) trend.

Sen's Slope method

Sen's method [21] for the estimation of slope (Q) requires a time series of equally spaced data.

$$Q = \frac{x_{i'} - x_i}{i' - i} \quad (3)$$

where: Q = slope between data points $x_{i'}$ and x_i , $x_{i'}$ = data measurement at a time i' , x_i = data measurement at a time i , i' = time after time i .

Linear Regression

A linear regression line has an equation of the form Y = a + bX, where X is the explanatory variable, and Y is the dependent variable [22].

Geometrical Progression Method

This method should be applied carefully as there is the risk of erroneously high results when applied to young and rapidly advancing cities having the expansion of short duration only [20].

Future data, $P_f = P_p(1+r)^n$

Where, P_p = Present data, r = probably rate of yearly, n = number of years to be considered.

3. Results and Discussions

Trend analysis of hydrological components, their spatial distribution throughout the study area, and probable reasons for that are described in this article. The data that are used to detect hydrologic trend is presented in Table 5.

3.1 Trend Analysis of Recent Groundwater Level

According to selected 21 groundwater monitoring wells information (Fig. 7), trend applying Mann-Kendall test, Sen's slope method and linear regression has been analyzed and presented in Table 6.

Above trend analysis concludes a definite depletion of groundwater level over the recent years. But dissimilar depletion rate is distributed spatially throughout the Bogra district is depicted in Fig. 10. The western portion of the study area indicates that higher groundwater depletion than the eastern portion. Soil profile (Fig. 11), hydraulic conductivity (Fig. 12), groundwater recharge from River Jamuna (Fig. 1), etc. can be the probable reason for this distribution pattern associated for groundwater depletion.

3.2 Trend Analysis of other Hydrological Components

Rainfall, evapotranspiration, river water are the dominating hydrological factors that can affect the groundwater level in the study area. Rainfall data trend is displayed in Table7 and evapotranspiration and the river water level is given in Table 8.

Rainfall distribution is found higher in the northern portion than the southern portion from 27 years (1985 to 2011) station wise recorded data (Fig. 13 and Table 9). From 1985 to the present year, the rainfall falling rate is decreasing over the years at a non-uniform rate throughout the study area (Fig. 14).

The river water level of Jamunaat Mathurpara station is also depleting over the years from 1985 to 2012 is illustrated in Fig. 15 and Table 8. Evapotranspiration rate is considered as constant from input data [18].

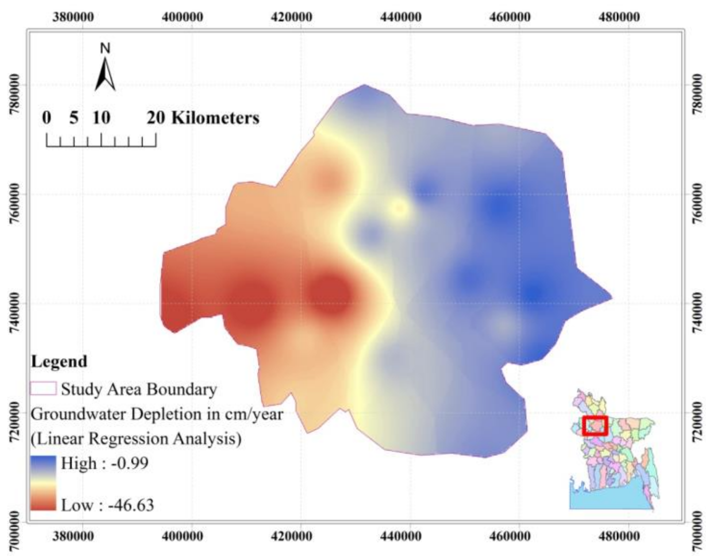


Fig. 10. Spatial Distribution of groundwater level depletion rate throughout the study area using linear regression.

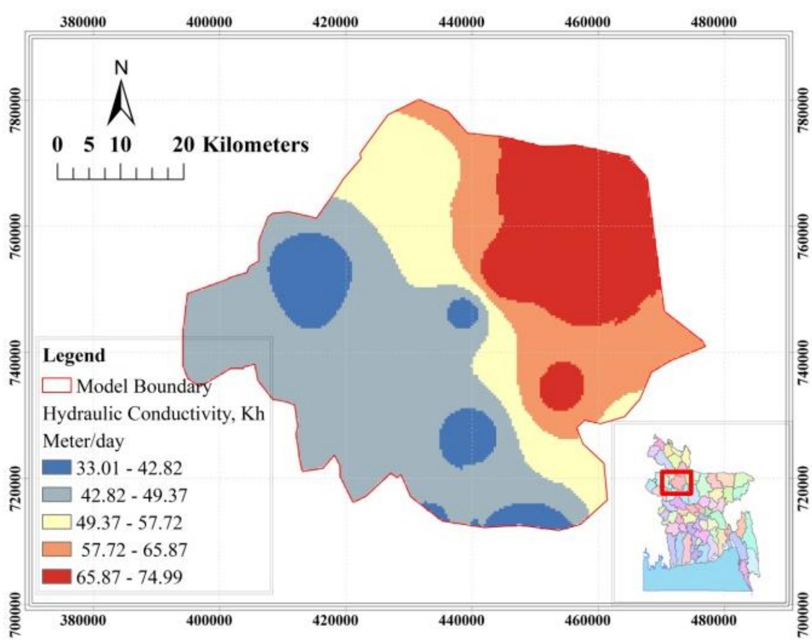


Fig. 11. Distribution of Aquifer Hydraulic conductivity in the study area.

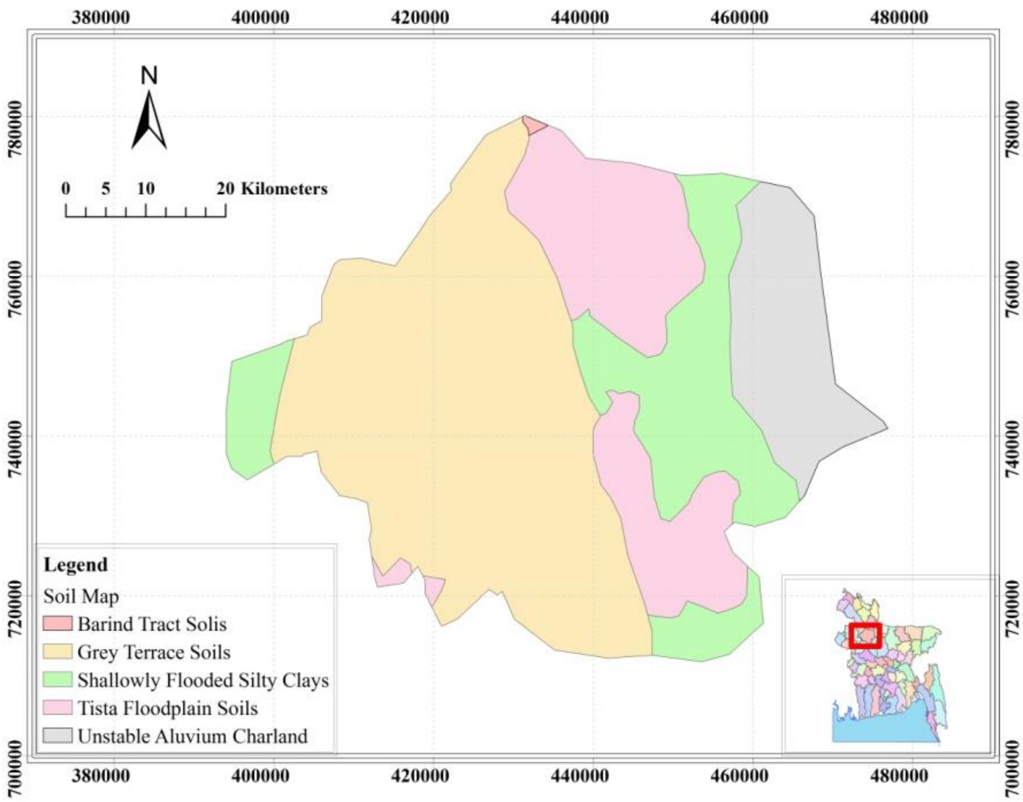


Fig. 12. Topsoil condition of the study area.

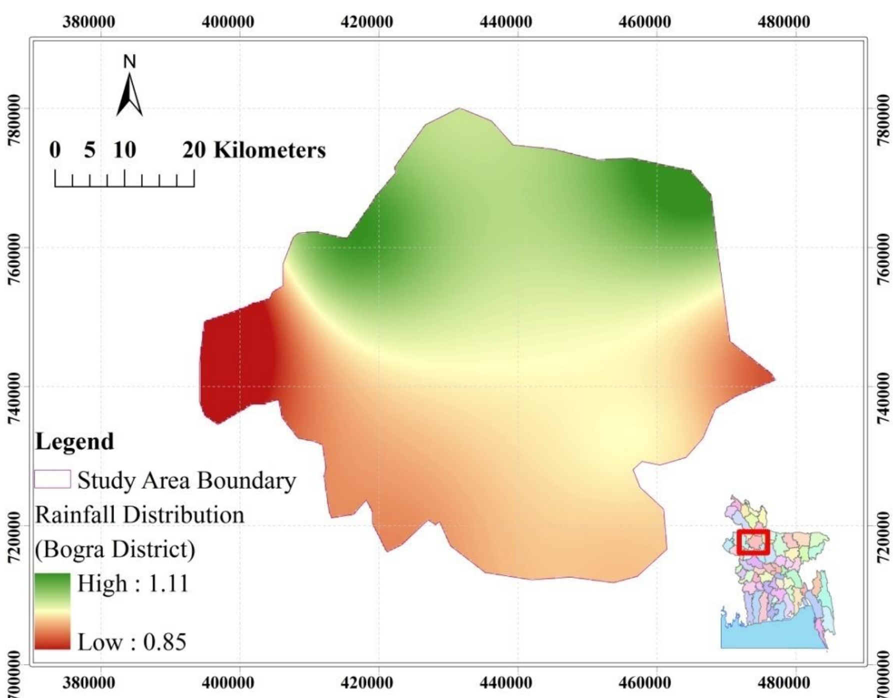


Fig. 13. Rainfall distribution throughout the study area from 27 years of rainfall data (Source: IWM).

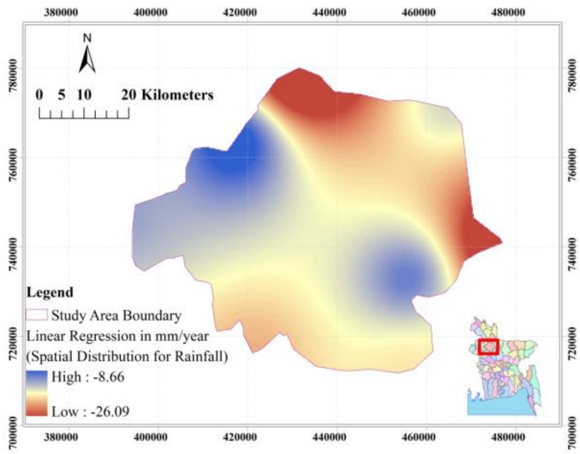


Fig. 14. Rainfall depletion rate throughout the study area from 27 years of rainfall data using linear regression (Source: IWM).

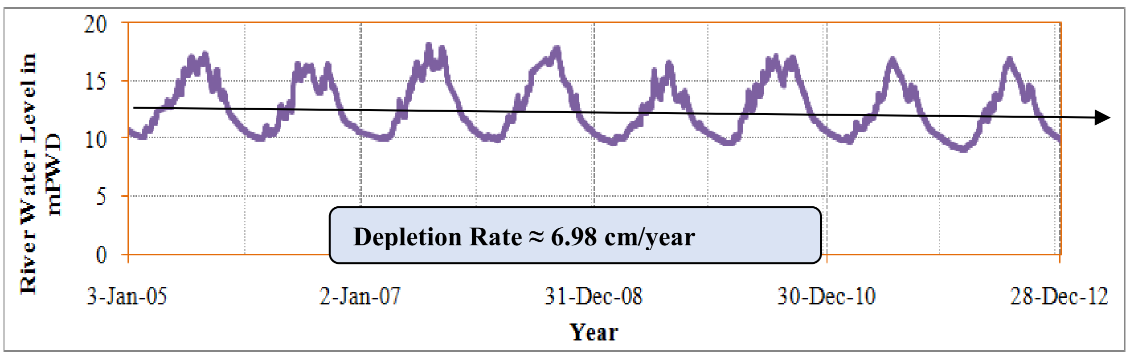


Fig. 15. River Water Level Hydrograph from the year 2005 to 2012 for River Jamuna at Mathurpara Station (Data Source: IWM).

Table 5. Hydrologic data list in details used for trend analysis.

Data Type	Main Source	Collected from	Data Range	Details	Representation
Data Collection and Projection					
Rainfall	BWDB	IWM	1985 to 2011	Rainfall stations: CL006, CL011, CL022, CL024, CL033, CL169, CL181, and CL216.	**Table 2**
	BBS	BUET	1985 to 2011	Declared rainfall for Bogra district.	
Evapo-transpiration	BWDB	IWM	1985 to 2012	Evaporation station: CL6.	**Table 3**
Surface water level	BWDB	IWM	2005 to 2012	River Jamuna at Mathurpara Station.	
Groundwater level	BWDB	IWM	2005 to 2012	Study area boundary wells: GT323006, GT328806, GT3958015, GT8850006, GT6991013, and GT3861005. Study area inside wells: calibrated wells.	**Table 4**
DTW and STW	BADC	IWM	2004-05 to 2010-11	Recorded DTW and STW numbers according to the minor irrigation survey report.	**Table 5**
Population	BBS	BBS	1991 to 2011	Population Census data published in 1991, 2001 and 2011 respectively.	**Table 6**

Table 6. Trend of groundwater level using Mann-Kendall trend test, Sen's slope method, and linear regression analysis.

Station ID/ Area	Data Type	Data Range	Mann-Kendall trend test		Sen's slope (cm/year)	The trend from linear regression (cm/year)
			Statistics, S	Kendall's tau		
GT3230006	Weekly groundwater level at study area boundary	2005 to 2012	-10,971	-0.126	-6.94	-7.41
GT3288016			-9,441	-0.108	-13.70	-11.61
GT3958015			-4,587	-0.053	-5.05	-5.48
GT8850006			-153	-0.002	0	-2.01
GT6991013			-23,938	-0.275	-27.10	-24.35
GT3861005			-29,083	-0.334	-24.51	-27.67
GT1006001	Weekly groundwater level inside the study area	2005 to 2012	-55397	-0.640	-36.82	-43.29
GT1006003			-60565	-0.700	-39.66	-42.85
GT1020004			-2298	-0.027	-2.71	-10.55
GT1020005			-21838	-0.252	-16.73	-21.21
GT1027008			-7843	-0.091	-6.38	-11.46
GT1040010			400	0.005	0.33	-3.39
GT1040011			-1555	-0.018	-1.44	-4.78
GT1040012			-8235	-0.095	-7.55	-10.69
GT1054014			-41755	-0.482	-32.69	-46.65
GT1067015			-45745	-0.528	-23.58	-25.81
GT1081019			2661	0.031	2.19	-1.64
GT1081020			5156	0.060	6.23	-0.99
GT1088021			-4209	-0.049	-4.21	-7.67
GT1088023			-3907	-0.045	-6.87	-12.56
GT1094024			-28856	-0.333	-24.56	-29.6

Table 7. Trend of rainfall data using the Mann-Kendall trend test, Sen's slope method, and linear regression analysis

Station ID/ Area	Data Type	Data Range	Mann-Kendall trend test		Sen's slope (mm/year)	The trend from linear regression (mm/year)
			Statistics, S	Kendall's tau		
R006	Annual rainfall data	1985 to 2011	-47	-0.13	-10.90	-13.93
R011			-37	-0.11	-6.60	-11.04
R022			-79	-0.23	-18.93	-17.03
R024			-115	-0.33	-23.69	-24.38
R033			-67	-0.19	-15.21	-15.58
R169			-71	-0.20	-14.10	-12.23
R181			-41	-0.12	-7.19	-8.66
R216			-121	-0.35	-27.21	-26.14
Bogra district	Annual Rainfall	1985 to 2011	-79	-0.23	-16.09	-15.62
	Nov. to Apr.		-23	-0.07	-1.16	-0.80
	May to Oct.		-67	-0.21	-15.89	-14.02

Table 8. Trend of evapotranspiration and surface water level data using Mann-Kendall trend test, Sen's slope method, and linear regression analysis

Station ID/ Area	Data Type	Data Range	Mann-Kendall trend test		Sen's slope (cm/year)	The trend from linear regression (cm/year)
			Statistics, S	Kendall's tau		
CL06	Daily or monthly evapo-transpiration	1985 to 2012	-	-	0	0
Mathurpara	Daily water level of river Jamuna	2005 to 2012	-3,04,781	-0.073	-9.12	-6.98

Table 9. Rainfall distribution into 8 rainfall stations in/around the Bogra district

SL No.	Station ID (BWDB)	Sum of total Rainfall in mm from the year 1985 to 2011 (Data Source: IWM)	% of Total Rainfall	Multiplying Factor	Remarks
1	R006	53,456	13.84	1.11	Average of 8 rainfall stations is 12.5%
2	R011	48,812	12.64	1.01	
3	R022	46,986	12.16	0.97	
4	R024	45,820	11.86	0.95	
5	R033	47,988	12.42	0.99	
6	R169	40,682	10.53	0.84	
7	R181	52,733	13.65	1.09	
8	R216	49,769	12.89	1.03	

3.3. Trend Analysis of Abstraction Data

The abstraction of groundwater mainly depends on irrigation and domestic water requirement round the year. Irrigation water is the dominating percentage compared with domestic needs. The trend of irrigation equipment as per minor irrigation report is presented in Table 10.The average capacity of DTW and STW under Bogra district is considered as 56 l/s and 14 l/s respectively [18]. According to this data, irrigation abstraction has increased by 1.13% in the last 6 years, from 2004-05 to 2010-11 [23,24,25]Last 3 years this rate was higher than previous, is about 1.47%.

Similarly, from 1991 to 2011, the population growth rate of urban and rural area in Bogra district is 4.68% and 0.7% respectively [26,27,11]. Urban population is becoming high compared with the rural population (Table 11). The urban population uses more water (about 120 l/c/d for zila town and 100 l/c/d for Upazila town) compared with the rural population (about 50 l/c/d) [28]. Moreover, piped water supply increasing especially in the urban area including with rural areas, which will require on an average almost three times more water than that of un-piped households [13]. Domestic water demand in Bogra district has enhanced from about 151.53 MLD in 1991 to 210.57 MLD in 2011, and last 20 years domestic demand has increased about 59 MLD. Last decade pursuant to Census [11], this rate was higher, about 1.91% from 174.31 MLD in 2001 to 210.57 MLD in 2011 compare with last 20 years rate is about 1.66%.

Table 10. Trend of DTW and STW in Bogra district as per minor irrigation survey report

Upazila	Numbers of DTW			Numbers of STW			DTW Nos. Increasing Rate in %			STW Nos. Increasing Rate in %		
	2004-05	2007-08	2010-11	2004-05	2007-08	2010-11	2004-05 to 2007-08	2007-08 to 2010-11	2004-05 to 2010-11	2004-05 to 2007-08	2007-08 to 2010-11	2004-05 to 2010-11
Adamdighi	212	217	216	1,384	1,240	1,429	0.78	-0.15	0.31	-3.60	4.84	0.53
Dhubchancia	231	235	281	1,064	1,076	1,083	0.57	6.14	3.32	0.37	0.22	0.30
Dhunat	1	2	9	10,028	10,101	14,092	25.99	65.10	44.22	0.24	11.74	5.83
Gabtali	16	22	22	8,082	8,472	10,370	11.20	0.00	5.45	1.58	6.97	4.24
Kahaloo	533	596	563	684	615	735	3.79	-1.88	0.92	-3.48	6.12	1.21
BograSadar	122	150	140	2,740	2,599	3,222	7.13	-2.27	2.32	-1.75	7.43	2.74
Nandigram	236	326	330	4,774	4,102	4,659	11.37	0.41	5.75	-4.93	4.34	-0.41
Sariakandi	3	5	6	5,077	6,152	8,085	18.56	6.27	12.25	6.61	9.54	8.06
Sherpur	44	93	146	8,526	9,070	9,414	28.33	16.22	22.13	2.08	1.25	1.67
Shibganj	236	259	285	7,177	8,515	9,606	3.15	3.24	3.19	5.86	4.10	4.98
Sonatola	6	3	105	5,546	4,335	7,541	-20.63	227.11	61.13	-7.88	20.27	5.25
Shajahanpur	67	92	17	4,637	3,853	4,600	11.15	-43.04	-20.43	-5.99	6.08	-0.13
Total	**1,707**	**2,000**	**2,120**	**59,719**	**64,022**	**74,836**	**5.42**	**1.96**	**3.68**	**2.35**	**5.34**	**3.83**

Table 11. Trend of Population and House connection in Bogra district as per Census data [26,27,11]

Upazila Name	Population			Population Growth Rate			Household			Population Growth Rate		
	2011	2001	1991	1991-2011	2001-2011	1991-2001	2011	2001	1991	1991-2011	2001-2011	1991-2001
Adamdanga	**195,186**	**187,012**	**170,326**	**0.68**	**0.43**	**0.94**	**49,600**	**41,495**	**31,785**	**2.25**	**1.80**	**2.70**
Total Urban	39,946	38,390	31,968	1.12	0.40	1.85	10,118	8,518	5,973	2.67	1.74	3.61
Rural	155,240	148,622	138,358	0.58	0.44	0.72	39,482	32,977	25,812	2.15	1.82	2.48
BograSadar	**555,014**	**694,077**	**588,783**	**-0.29**	**-2.21**	**1.66**	**131,862**	**150,300**	**107,224**	**1.04**	**-1.30**	**3.43**
Total Urban	350,397	210,038	164,114	3.87	5.25	2.50	81,251	40,205	28,803	5.32	7.29	3.39
Rural	204,617	484,039	424,669	-3.59	-8.25	1.32	50,611	110,095	78,421	-2.17	-7.48	3.45
Dhunat	**292,404**	**270,810**	**246,984**	**0.85**	**0.77**	**0.93**	**74,897**	**63,557**	**48,901**	**2.15**	**1.66**	**2.66**
Total Urban	22,673	18,058	16,653	1.55	2.30	0.81	5,606	4,042	3,331	2.64	3.33	1.95
Rural	269,731	252,752	230,331	0.79	0.65	0.93	69,291	59,515	45,570	2.12	1.53	2.71
Dhupchanchia	**176,678**	**160,894**	**149,112**	**0.85**	**0.94**	**0.76**	**45,390**	**37,436**	**29,153**	**2.24**	**1.95**	**2.53**
Total Urban	22,406	21,761	14,037	2.37	0.29	4.48	5,401	4,795	2,696	3.54	1.20	5.93
Rural	154,272	139,133	135,075	0.67	1.04	0.30	39,989	32,641	26,457	2.09	2.05	2.12
Gabtali	**319,588**	**290,190**	**265,926**	**0.92**	**0.97**	**0.88**	**83,411**	**67,685**	**52,782**	**2.31**	**2.11**	**2.52**
Total Urban	21,455	3,143	2,789	10.74	21.18	1.20	5,493	703	535	12.35	22.82	2.77
Rural	298,133	287,047	263,137	0.63	0.38	0.87	77,918	66,982	52,247	2.02	1.52	2.52
Kahaloo	**222,376**	**195,565**	**183,230**	**0.97**	**1.29**	**0.65**	**58,261**	**45,303**	**36,537**	**2.36**	**2.55**	**2.17**
Total Urban	13,887	9,477	8,104	2.73	3.89	1.58	3,636	2,147	1,550	4.36	5.41	3.31
Rural	208,489	186,088	175,126	0.88	1.14	0.61	54,625	43,156	34,987	2.25	2.38	2.12
Nandigram	**180,802**	**168,155**	**147,557**	**1.02**	**0.73**	**1.32**	**45,853**	**37,042**	**27,470**	**2.59**	**2.16**	**3.03**
Total Urban	18,496	5,423	4,014	7.94	13.05	3.05	4,528	1,146	731	9.55	14.73	4.60
Rural	162,306	162,732	143,543	0.62	-0.03	1.26	41,325	35,896	26,739	2.20	1.42	2.99
Sariakandi	**270,719**	**240,083**	**229,563**	**0.83**	**1.21**	**0.45**	**75,614**	**55,719**	**46,406**	**2.47**	**3.10**	**1.85**
Total Urban	18,543	17,320	6,640	5.27	0.68	10.06	5,069	4,049	1,392	6.68	2.27	11.27
Rural	252,176	222,763	222,923	0.62	1.25	-0.01	70,545	51,670	45,014	2.27	3.16	1.39

Upazila Name	Population			Population Growth Rate			Household			Population Growth Rate		
	2011	2001	1991	1991-2011	2001-2011	1991-2001	2011	2001	1991	1991-2011	2001-2011	1991-2001
Sherpur	**332,825**	**286,308**	**229,005**	**1.89**	**1.52**	**2.26**	**81,753**	**68,346**	**45,258**	**3.00**	**1.81**	**4.21**
Total Urban	54,082	45,445	29,195	3.13	1.76	4.52	12,473	10,431	5,680	4.01	1.80	6.27
Rural	278,743	240,863	199,810	1.68	1.47	1.89	69,280	57,915	39,578	2.84	1.81	3.88
Shibganj	**378,700**	**352,415**	**312,773**	**0.96**	**0.72**	**1.20**	**99,242**	**83,120**	**63,721**	**2.24**	**1.79**	**2.69**
Total Urban	21,643	8,609	8,111	5.03	9.66	0.60	5,576	1,978	1,456	6.94	10.92	3.11
Rural	357,057	343,806	304,662	0.80	0.38	1.22	93,666	81,142	62,265	2.06	1.45	2.68
Sonatola	**186,778**	**167,547**	**146,028**	**1.24**	**1.09**	**1.38**	**48,569**	**38,364**	**27,170**	**2.95**	**2.39**	**3.51**
Total Urban	24,720	11,405	9,982	4.64	8.04	1.34	6,514	2,450	0	N/A	10.27	N/A
Rural	162,058	156,142	136,046	0.88	0.37	1.39	42,055	35,914	0	N/A	1.59	N/A
Shajahanpur	**289,804**	N/A			N/A			**72,685**	N/A		N/A		
Total Urban	62,140							13,454					
Rural	227,664							59,231					
Bogra District	**3,400,874**	**3,013,056**	**2,669,287**	**1.22**	**1.22**	**1.22**	**867,137**	**688,367**	**489,237**	**2.90**	**2.34**	**3.47**
Total Urban	**670,388**	**389,069**	**295,607**	**4.18**	**5.59**	**2.79**	**159,119**	**80,464**	**52,147**	**5.74**	**7.06**	**4.43**
Rural	**2,730,486**	**2,623,987**	**2,373,680**	**0.70**	**0.40**	**1.01**	**708,018**	**607,903**	**437,090**	**2.44**	**1.54**	**3.35**

4. Conclusion

The groundwater level in Bogra district and surrounding areas are depleting over the recent years. The western part of the study area has a higher depletion rate (about 43 cm/year), whether comparative less depletion rate has found in the eastern area is almost zero. Irrigation equipment is increasing at a huge rate, in consequence, requires huge water to meet extending irrigation demand, especially due to boro crop in the dry period. Growth of the domestic demand and pipe water supply inclusion will be added some extra water that will make stress on the main aquifer of the study area. The river water level is also depleting, and some rivers have no sufficient amount of water in the dry. Precipitation indicates fluctuation nature over the year, but the trend is downward as well. It can be concluded that all freshwater resources related to hydrology are depleting with the increasing trend of water use, especially for irrigation and domestic purpose. Now, today is the time to take long run step considering future scenarios under the hydrological limit of the study area.

Acknowledgment

The author acknowledged to Institute of Water Modelling and their experts for supporting data base.

REFERENCES

[1] Food and Agriculture Organization [FAO] (2012).Coping with water scarcity.An action framework for agriculture and food security. Retrieved from http://www.fao.org/docrep/016/i3015e/i3015e.pdf

[2] Altaner S. (2012). Physical Resources: Water, Pollution, and Minerals – Chapter Introduction. Connexions module: m41523. Revision 3.

[3] Inter governmental Panel on Climate Change [IPCC] (2014). Climate Change 2014, Impacts, Adaptation and Vulnerability. Summary for Policy makers, Working group II Contribution to the fifth assessment report of the inter-governmental panel on climate change.WMO, UNEP (Changing

precipitation is affecting water resources & quality).

[4] Subramanya, K. (1994). Engineering Hydrology.Second Edition. Tata McGraw Hill Publishing Company Limited. ISBN 0-07-462449-8.

[5] United States Geological Survey [USGS] (2004). Ground-Water Depletion Across the Nation. USGS- science for a challenging world.http://water.usgs.gov/ogw.

[6] National Water Management Plan [NWMP] (2001). Main Report, Volume 2, Ministry of Water Resources. Government of Bangladesh.

[7] Jahan, C.S., Mazumder, Q.H., Islam, A.T.M.M. and Adham, M.I. (2010).Impact of irrigation in barind area, NW Bangladesh-an evaluation based on the meteorological parameters and fluctuation trend in groundwater table.Journal Geological Society of India.

[8] Dey, N.C., Bala, S.K., Islam, A.K.M.S. Rashid, M.A. and Hossain M. (2013).Sustainability of Groundwater Use for Irrigation in Northwest Bangladesh, brac, Bangladesh.Retrived from http://182.160.112.236/agridrupal/sites/default/files/Sustainability%20of%20Groundwater%20Use%20for%20Irrigation%20in%20Northwest%20Bangladesh.pdf.

[9] Luby, S. (2013). Water management for a healthy Bangladesh: The need for multi-sector collaboration. Paper presented at National Public Health Conference, Dhaka, Bangladesh. 15 January. [22] Spence, R. (2007). Saving lives in earthquakes: successes and failures in seismic protection since 1960, Bulletin of Earthquake Engineering, 5(2):139–251.

[10] Harvey, C.F., Ashfaque, K.N., Yu, W., Badruzzaman, A.B.M., Ali, M.A., Oates, P.M., Michael, H.A., Neumann, R.B., Beckie, R., Islam, S. and Ahmed, M.F. (2006). Groundwater Dynamics and Arsenic Contamination in Bangladesh, Chemical Geology, 228, 112-136.

[11] Bangladesh Bureau of Statistics [BBS] (2011).Bangladesh Population & Housing Census.Retrieved from http://www.bbs.gov.bd/.

12] Amin, M.N. (2009). Ground Water Utilization for Agricultural Development: Some Policy Suggestions. Thoughts on Economics, Vol. 19, No. 01. ISSN: 02568586.

[13] Thompson, J., Porras, I.T., Tumwine, J.K., Mujwahuzi, M.R., Katui-Katua, M., Johnstone, N. & Wood, L. (2001). 30 years of Change in Domestic Water Use & Environmental Health in East Africa. International Institute for Environment and Development. Russell Press, Nottingham.

[14] Helsel, D.R. and Hirsch, R.M. (2002).Statistical Methods in Water Resources.Techniques of Water Resources Investigations of the United States Geological Survey Book, Hydrologic Analysis and Interpretation.Chapter 12.USGS.http://water.usgs.gov/pubs/twri/twri4a3/.

[15] Clarke, R.T. (2002). Fitting and testing the significance of linear trends in Gumbel-distribution data. Hydrology and Earth System Sciences, 6(1), 17-24 (2002) @EGS.

[16] Mavromatis T. and Stathis D. (2011).Response of the Water Balance in Greece to Temperature and Precipitation Trends. Theoretical and Applied Climatology 104:13-24, DOI 10.1007/s00704-010-0320-9. [24] Yang, Y., Zhan, F. B., Li, L. (2011). E stimating seismic losses of schools using SELENA: The case of Wenchuan earthquake. In Geoinformatics, 2011 19th International Conference on IEEE, 1-6.

[17] Yue S. and Wang, C., (2004). The Mann-Kendall Test Modified by Effective Sample Size to Detect Trend in Serially Correlated Hydrological Series. Water Resources Management 18, 201–218.

[18] BMDA-IWM (2013).Groundwater Resources Study and IIS Development of Pabna, Sirajgonj, Bogra, Gaibandha, Rangpur, Kurigram, Nilphamari and Lalmonirhat Districts through Mathematical Model Study.Interim Report.

[19] Gilbert, R.O. (1987). Statistical Methods for Environmental Pollution Monitoring. Van NostrandRienhold Company, Inc., New York.

[20] Aziz, M.A. (1984). A Text book of Water Supply Engineering.Hafiz Book Centre, 167, Govt. New Market, Dhaka.

[21] Sen, P.K. (1968). Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association. 63:1379-1389

[22] Wikipedia (2014).Retrieved from: http://en.wikipedia.org/wiki/Simple_linear_regression.The Free Encyclopedia.

[23] Bangladesh Agricultural Development Corporation (2005). Minor Irrigation Report 2004-05. Government of the People's Republic of Bangladesh Ministry of Agriculture.

[24] Bangladesh Agricultural Development Corporation (2008). Minor Irrigation Report 2007-08. Government of the People's Republic of Bangladesh Ministry of Agriculture.

[25] Bangladesh Agricultural Development Corporation (2011). Minor Irrigation Report 2010-11. Government of the People's Republic of Bangladesh Ministry of Agriculture.

[26] Bangladesh Bureau of Statistics (1991).Bangladesh Population & Housing Census.

[27] Bangladesh Bureau of Statistics (2001).Bangladesh Population & Housing Census.

[28] Ahmed, M.F. &Rahman, M.M. (Eds.) (2003). Water Supply & Sanitation: Rural and Low Income Urban Communities. ITN-Bangladesh, BUET, Dhaka.ISBN 984-31-0936-8.