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Determination of Groundwater Recharge Variation in Sylhet Sadar Upazila Using Water Table Fluctuation Method

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Abstract

This study efforts to determine the variation of groundwater recharge and recharge rate with rainfall in Sylhet Sadar Upazila by water table fluctuation method. Rainfall and groundwater level data of the period 1990-2014 were collected and analyzed. The annual recharge varied from 56.35 mm to 225.19 mm with average of 110.31 mm. The annual groundwater recharge rate for the study period varied from only 1.68% to 5.13% with an average of 2.89% due to lower specific yield. In case of seasonal recharge, it is observed that the recharge was almost twice in monsoon (average 66.64 mm) than the pre-monsoon (average 31.69 mm). In contrast, the recharge rate in comparison with rainfall during the study period showed a higher recharge percentage in pre-monsoon (average 3.20%) than that of the monsoon (average 2.45%). This indicates that there are other factors that influence reasonably on groundwater recharge apart from rainfall.

Keywords: Groundwater recharge; Recharge rate; Sylhet Sadar; Water table fluctuation; Specific yield

1. Introduction

Water is important for any lifecycle progression and there is no substitute for it. Water is additionally used for domestic consumption, agriculture and trade [1]. Groundwater means the water that is found underneath the soil surface. It starts with precipitation that percolates into the soil. The quantity of water that percolates into the soil varies greatly from one place to another because of various soil surface [2]. Groundwater is the world's most significant freshwater resource. It is an important and suitable drinking water resource both in village and city areas. Among all water sources of Bangladesh, groundwater is a major one used for both drinking and irrigation purposes. It is also the main source of water in the study area [3]. Though the groundwater lies underneath the soil surface, it is a very significant portion of the hydrologic cycle. It is one of the largest freshwater resource within the hydrologic cycle, which contains more freshwater than surface water sources like as lakes and streams contain. It is found that about 83,40,000 cubic kilometers of water is existing below the earth's surface. It is the main resource of freshwater in the city areas of Bangladesh [4]. Groundwater has traditionally been chosen more than surface water due to its reliability in droughts/floods and for lower pollution. The requirement of little or even without any treatment for consumption of groundwater makes it a popular and reliable source of water [5]. The abstraction of groundwater is increasing dramatically because the rapidly increase of world's population. Groundwater extraction is the primary reason for lowering the groundwater table in many areas [6]. The geologic formation which can store, transmit and yield a significant amount of groundwater is called an aquifer. Two properties of an aquifer material that are related to its storage function are its porosity and specific yield. Porosity is defined as the measure of volume of void in its total volume. Specific yield is the amount of water that can be extracted from storage by gravity (or even by pumping) per unit area of an aquifer under the unit drop of the groundwater level. Groundwater recharge indicates the part of the total rainfall that falls into a catchment area, which ultimately reaches in the aquifer [7,8]. The climate change and human disruption like as disproportionate extraction or withdrawal of groundwater is strongly influenced on groundwater recharge [2]. The research conducted in India and Bangladesh found that 0.1-0.5 m/yr declination of groundwater level which indicates reduction of aquifer storage due to excessive and unjustifiable groundwater extraction mainly for agriculture, industrial and domestic purposes [9]. Accurate determination of recharge rate is important for proper water management, groundwater conservation and modeling [10]. A mass of techniques has been used to estimate groundwater recharge. There are four most significant methods or techniques are generally used for groundwater recharge estimation: Physical methods (the water-balance, water table fluctuation) Chemical Tracer techniques, Lysimeter and Numerical Simulation Methods [11]. Groundwater level based techniques are commonly used methods for assessing recharge. The accessibility of groundwater

level data and flexibility of recharge rate estimation from time-based or spatial fluctuations of groundwater level makes this method a widespread application [12]. This study emphasizes the need to estimate groundwater recharge on the basis of groundwater level data. This method is called the Water Table Fluctuation (WTF) method, which is considered as commonly used method for estimating recharge. Because of its accurateness, simplicity to use and low cost, makes this method as one of the most promising and attractive [13,14].

1.1. Objectives

This study is conducted to fulfill the following specific objectives:

i. To investigate the effects of rainfall on groundwater recharge in the selected locations and

ii. To estimate the amount of annual and seasonal groundwater recharge in the study area.

2. Materials and Methods

2.1. Study Area

The study area lies in the northeastern portion of Bangladesh. Sylhet Sadar is an Upazila of Sylhet district, Bangladesh. It is situated at 24.8917°N latitude and at 91.8833°E longitude. It has a total area of 323.17 km² [15]. It is surrounded by Companiganj, Gowainghat and Jaintiapur Upazilas on the north, South Surma Upazila on the south, Jaintiapur and Golapganj Upazilas on the east, Chhatak and Bishwanath Upazilas on the west [16]. The climate of Sylhet Sadar is hot monsoon with mostly warm and humid summer while the winter is relatively cold [6]. The usual temperature of the Sylhet Sadar varies from 7.2?C to 20.6°C in winter and 23.9°C to 31.1°C in summer [17]. It is noted that the average annual precipitation in Sylhet Sadar is about 4195.9 mm and the major portion of this rainfall (66.40 %) is occured during the monsoon and the pre-monsoon period (26.23 %) [18].

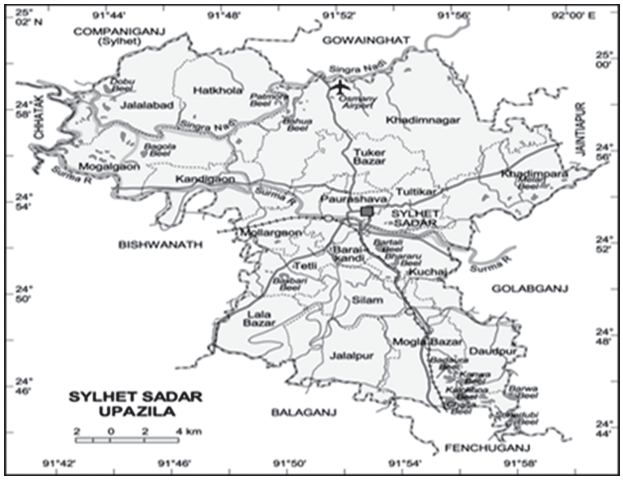

Figure 1: Geographical map of the study area (Sylhet Sadar Upazila).

2.2. Data collection and analysis

The weekly groundwater level data of Sylhet station were collected from the Bangladesh Water Development Board (BWDB) for the period of 1990-2014. The daily rainfall data of the study area as required for this research, were collected from the local station of BMD (Bangladesh Meteorological Department) between the period of 1990 to 2014. The weekly water level data were converted to the monthly and yearly maximum and minimum water level data to determine water level fluctuation. The daily rainfall data were converted to total monthly and yearly rainfall data. After that, for the estimation of seasonal difference of groundwater recharge in Sylhet Sadar Upazila, the data were categorized into three paticular seasons namely:

i. Dry Season (November- February)

ii. Pre-Monsoon Season (March-May) and

iii. Monsoon Season (June-October)

Since there is a very little amount of rainfall received in the dry season so the recharge amount from rainfall in this season was not analyzed. The processed data were analyzed using MS Excel programme and presented graphically. This groundwater level and rainfall data were analyzed to evaluate the variation with time and to see the pattern of recharge fluctuation.

2.3. Water Table Fluctuation (WTF) Method

The water level fluctuation method is a very common method for estimating recharge. Healy and Cook [19] provided a comprhensive formula for calculating groundwater recharge using changes in groundwater levels. This method consider the response of groundwater level fluctuation and specific yield, which is more scientific, realistic and is directly measurable, unlike other approaches where assumptions are to be made for most of the components. The recharge amount is given by:

$$R = Sy \times \triangle H \quad \text{..... (1)}$$

Where,

R = Recharge amount during the study period (mm)

Sy = Specific yield of the recharge area

$\triangle H$ = Peak water level fluctuation during recharge period (mm)

The Specific yield is a property of an aquifer which depends on soil characteristics. The basic information of Specific yield of different Upazilas of Sylhet district is presented in Table 1.

Table 1: Specific yields of different Upazilas of Sylhet [20]

Name of Upazila	Specific Yield (S_y)
Beanibazar	4.0×10^{-2}
Fenchuganj	0.1
Golapgonj	5.1×10^{-2}
Gowainghat	3.3×10^{-2}
Jaintiapur	0.16
Sylhet Sadar	4.9×10^{-2}
Zakigonj	5.3×10^{-2}

3. Results and Discussion

3.1. Variation of Annual Rainfall

Figure 2 shows the variation of total rainfall in every year during the period of 1990 to 2014. The total annual rainfall varied from 2762 mm to 4939 mm per year with an average of 3849 mm through the study period. The maximum and the minimum rainfall received in the year 2010 and 2011, respectively. It is also observed that the variation of rainfall from 1990 to 2007 was not very different in each year. From 2008 to 2014, it was observed that the rainfall difference in each year was more than the rest of the study period. In 2008 and 2009, the rainfall decreased gradually but after that, the highest rainfall occurred in 2010. During the last two years, a decreasing trend was observed.

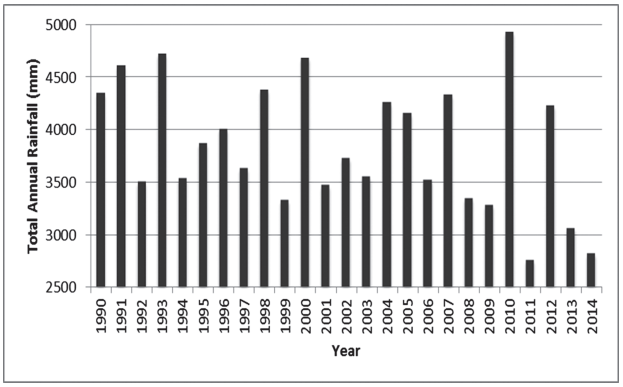

Figure 2: Variation of total annual rainfall in the study area (Sylhet Sadar Upazila).

3.2. Variation of Annual Recharge

Figure 3 represents the fluctuation pattern of annual recharge during the period of 1990 to 2014. The annual recharge in the study area varied from 56.35 mm to 225.19 mm with the average annual recharge of 110.31 mm. The maximum recharge occurred in 1998 and the minimum in 2014. It should be noted that, from 1990 to 2009 the recharge variation of recharge was almost similar. However, from 2010 to 2014 the variation increased every year. During the last three years, the study showed that the groundwater recharge continuously decreased in every year.

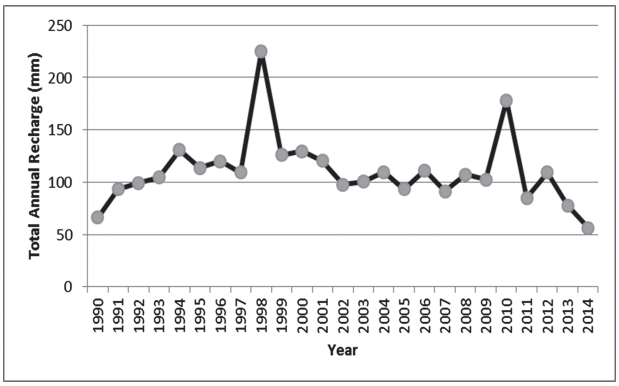

Figure 3: Fluctuation pattern of annual recharge in the study area.

3.3. Variation of Annual Recharge Rate with Rainfall

The relationship between rainfall and groundwater recharge rate is shown in Figure 4. The recharge percentage during 1990 to 2014 varied from 1.68% to 5.13% with an average of 2.89% in Sylhet Sadar. The increasing trend of groundwater recharge is observed before 2000. After that, from 2001 to 2014, a decreasing trend was found in many years. Though the rainfall and the recharge rate in some of the years from 2001 to 2014 had a higher value but the recharge rate in most of the year of the study period showed a little amount (Figure 4).

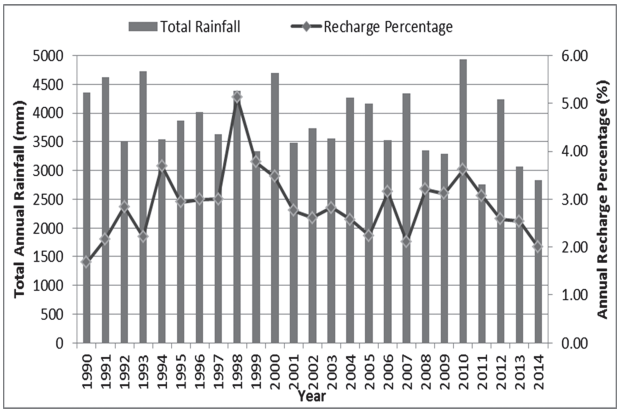

Figure 4: Annual rainfall and recharge rate in the study area.

3.4. Pre-monsoon Rainfall and Recharge Rate

In Figure 5, the pre-monsoon rainfall and the recharge rate of this season for each year are presented. It is observed that the recharge rate varied from 0.95% in 2007 to 9.80% in 1998 with an average of 3.20%. The recharge rate showed almost an increasing trend from 1990 to 1998. After that, the recharge variation in pre-monsoon season is different in each year. From 2000 to 2010, it was found that the recharge rate was almost 2% only. Although in 2011 the recharge rate was increased but from 2012 to 2014 the decreasing trend of recharge was observed.

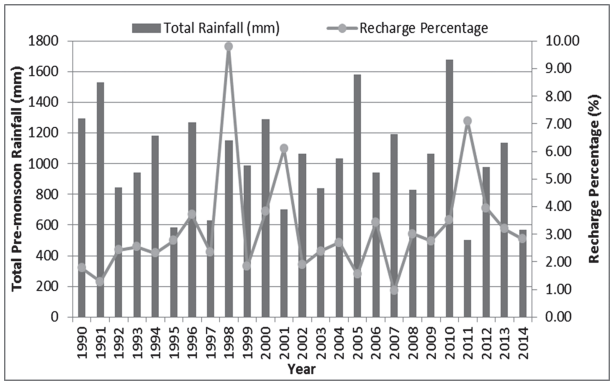

Figure 5: Pre-monsoon rainfall and recharge rate in the study area.

3.5. Relationship of Monsoon Rainfall with Recharge Rate

Figure 6 showed the relationship between monsoon rainfall and the recharge rate during the study period of 1990 to 2014. It is observed that the recharge rate of monsoon season varied from 1.27% in 2012 to 4.98% in 1998 with an average of 2.45%. The recharge rate showed higher variation one year after another. From 1990 to 1992, an increasing trend is observed then in 1993 the recharge rate is decreased. From 1998 to 2011, the recharge variation in the monsoon season was greater than 2% whereas from 2012 to 2014, the recharge rate was found below 2% with a decreasing trend.

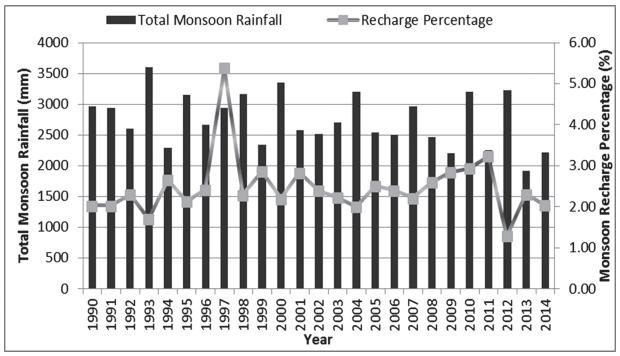

Figure 6: Monsoon rainfall and recharge rate in the study area.

3.6. Comparison of Seasonal Recharge Amount

Figure 7 described the variation of groundwater recharge in different seasons over the study period. From the graph, it is observed that the maximum recharge occurred in the monsoon period among the seasons. Between dry and pre-monsoon season, the recharge did not vary reasonably. Sometimes, the recharge amount is higher in the dry season (may be for artificial recharge by irrigation during Boro season) while during the other years the recharge amount was higher in pre-monsoon season. However, the maximum recharge occurred in 1998 amounting to about 295 mm. The dry season recharge amount varied from 6.86 mm to 58.80 mm with average of 30.27 mm. The pre-monsoon recharge varied from 11.27 mm to 112.98 mm with 31.69 mm average. The monsoon season recharge varied from 41.16 mm to 158.06 mm with the average of 66.64 mm.

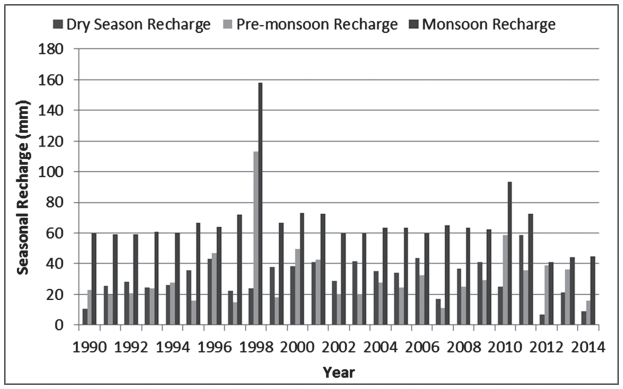

Figure 7: Variation of seasonal recharge in the study area.

4. Conclusion

The results obtained from the study showed the annual and seasonal recharge fluctuation pattern in the Sylhet Sadar area. The results illustrated that, the higher rainfall caused higher recharge. The study also revealed that, although higher rainfall caused a higher amount of recharge but the rate of annual recharge was not as much higher as rainfall. The results showed that higher recharge observed before the year 2000. From 2001, the recharge rate was lower although, during that time, a significant amount of rainfall occurred. From 2012 to 2014, a decreasing trend of recharge amount was found. From the amount of seasonal recharge, it was found that the maximum amount of recharge occurred in monsoon season with an average of 66.64 mm and the minimum amount of recharge occurred in the dry season with an average of only 30.27 mm. Although the recharge contribution of the monsoon season was higher than the pre-monsoon season, the recharge rate against the rainfall amount in some years of pre-monsoon season contained higher value than that of monsoon season. So, from the study it may be concluded that, there are also some additional factors except rainfall which might regulate the groundwater recharge pattern in this area. These factors help to fulfill the excess part of the recharge rate variability.

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