Groundwater Table Variation in Rangunia Upazila Using GIS Application: A Case Study

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Abstract

Groundwater is a major source of freshwater that covers the direct supply of drinking water from the ground aquifer without any treatment. The over-extraction of groundwater not only causes high depletion of the water table in the ground but also has a significant impact on water quality due to saltwater intrusion. Nowadays, groundwater has become a major concern in big cities like Dhaka, Chattogram in Bangladesh, and people who are living in such areas are tremendously facing the freshwater crisis. This paper investigates the groundwater table variation of Rangunia Upazila in Chattogram city. The historical data of groundwater level of past ten years (2008-2017) in Rangunia Upazila have been analyzed by using ArcGIS 10.3 and Kriging Method. The result depicts some parts of the Rajanagar, Chondroghona, Islampur, Hosnabad, and Mariamnagar area have experienced a decline of groundwater table around 4.0 meters over the last ten years and the average rate of groundwater decline is around 0.4 meter per year. The depletion of water level in the aforementioned areas is due to the installation of new tube wells and over-pumping of groundwater. However, some regions such as Betagi and Podua have a small groundwater level variation because of stormwater infiltration, rainfalls during the wet season. The outcome of this study will be helpful in better planning and management of groundwater in Chattogram City in the future.

Keywords: *Groundwater; Water table; Aquifer; ArcGIS; Upazila.*

1. Introduction

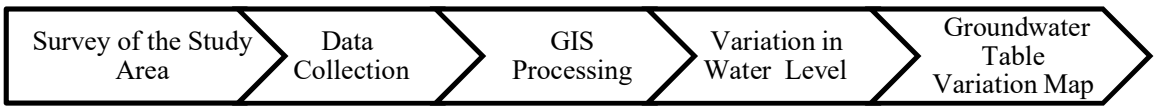
Groundwater (GW), water that occurs below the earth's surface, is an essential natural resource that plays a significant role in the supply of drinking water both in urban and rural regions. It also has a vital role in some aquatic and terrestrial ecosystems. The demand for groundwater usage is significantly increasing day by day because of its excellent quality, and low development cost (Todd and Mays, 2005). At present, the world's 34% of the annual water supply for industrial, agricultural purposes comes from groundwater (Magesh et al., 2012), which is an important source of freshwater, almost 95 percent on our planet (Sumiya

and Khatun, 2016). The vast expansion of agricultural land for food production of the increasing world's population is also noticeable (Siebert et al., 2015) during the last century. The over-extraction of water from the aquifer leads to a decline in the water level in the ground. The average aquifer level is experiencing a decline of over 45 meters in Texas, USA (Konikow, 2013). The water table in some parts of Pakistan, especially in the Potohar region was depleted by 115.82 meters in the last three decades due to large dependency on tube wells (Khattak, 2012). Bangladesh, a Southeast Asian country with around 180 million people, is an agricultural country whose 80-85% of people directly or indirectly involved in agriculture. About 75% of cultivated land is irrigated by groundwater and 25% is by surface water (Zahid and Ahmed, 2006). The use of groundwater for irrigation increases significant crop productivity in Bangladesh (Dey et al., 2013). Assessment of groundwater table is significant for sustainable groundwater management and planning. Some southeast and northern areas of Bangladesh were detected highest hazard-prone area for diverging GW using the Kriging Method (KM) (Zafor et al., 2017). Dhaka, the capital city of Bangladesh, is tremendously facing a freshwater crisis due to groundwater depletion in the last few decades, and 82% of water is supplied from groundwater (Islam and Islam, 2017). The maximum water level in some parts of Dhaka city especially Mirpur, Mohammadpur was decreased by almost 55 meters from 1980 to 2010 and the present declining rate is 2-3 meters each year (Islam and Islam, 2017). The amount of water lifted from the aquifer in Dhaka was 2231 MCM by 14 years from 1988 to 2002 (Hoque et al., 2007) and the water quality has become unsustainable in many regions in Bangladesh. More than 50 countries such as the Coastal Gulf of the USA, China, and Mexico have faced saltwater intrusion problems in groundwater aquifers (Bierkens and Wada, 2019).

Remote sensing and GIS application are useful tools for delineating potential groundwater in recent years as GIS not only provides large-scale groundwater observations but also saves huge time and money (Magesh et al., 2012). Groundwater table (GWT) is significantly influenced by some factors such as topography, precipitation, evaporation, river stage, seawater intrusion, seasonal variation, etc. (Yan et al., 2015). The derived results from GIS are found to be satisfactory based on field data, although geological conditions are varied from region to region (Lee et al., 2012). There have been many studies done by the early researchers on groundwater table variation in Dhaka city and recommended many sustainable approaches for groundwater table management recharged by rainwater harvesting, vegetative treatment, etc. However, very few studies have been conducted for groundwater table mapping and management in Chattogram City. Therefore, the purpose of this study is to analyze the groundwater table variation of Rangunia Upazila from historical data using Kriging Interpolation (KI) under a GIS environment. In addition, the study would also help to understand the hydrological cycle of this region, and getting a clear idea of the groundwater level which is inevitable for the future sustainable development of GW.

2. Methodologies

The whole methodology of the study can be divided into several steps which can be summarized as cited in the following flow chart:



2.1 Study Area

The study area is located in between 22°18′ and 22°37′ north latitudes and in between 91°58′ and 92°08′ east longitudes which is Rangunia Upazila, Chattogram, Bangladesh. The geological location of the study area has been presented in Figure 1. The population of the area is almost 340,000 within its total area of 347.72 square kilometers (Bangladesh Census, 2011). The availability of groundwater in this area is decreasing in recent days because of large groundwater extraction for irrigation and drinking purposes, which lower the water table. The methodology applied to accomplish the objective mentioned above is as follows.

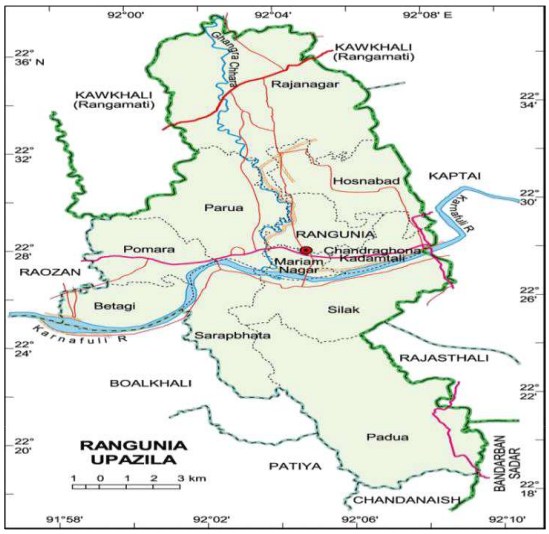


Figure 1 Map of Rangunia Upazila (www.wikipedia.com)

2.2 Data Collection and Preparation

The Department of Public Health Engineering (DPHE) has a list of tube wells and time-series depth records union-wise. Continuous datasets are in general needed for getting the actual water level scenario in any region. It is very important to get a clear idea about the current position of groundwater level from shallow and depth tube wells in Rangunia Upazila so that it will ensure the future sustainable use of water for daily purposes. The data was collected from DPHE to measure the groundwater level and the declination rate. The water depth of 57 monitoring wells in different unions of Rangunia Upazila has been observed. The historical data of the last ten years (2008-2017) have been analyzed in this study to get the current position of the water level. The observation well data have been processed with Microsoft Excel spreadsheets, and ArcGIS 10.3 software has been used for mapping the groundwater location. There are different GIS interpolation techniques available such as Inverse Distance Weighted (IDW), Thin-Plate Splines (TPS), and Kriging Method (KM). The sum of the least-squares method under the time-series regression analysis was used to compute the groundwater level trend. The Kriging Method and IDW are applied for interpolation, and then errors are calculated with the standard value.

3. Results and Discussion

57 groundwater tube wells data from different regions of Rangunia Upazila such as Rajanagar, Parua, 9 No Shilok, Podua, Kodala, Islampur, South Rajanagar, Lalanagar,

Pourosova, Hosnabad, Sonirvor Rangunia, Mariamnagar, Chondraghona, Pomra, Betagi, and Sorofvata have been selected for this study. Shallow tube wells and deep tube wells are being used for domestic and agricultural purposes. Water from Hand tube wells is being used for only drinking and cooking. 57 tube wells data have been presented and observed for groundwater table variation, it is found that some areas are experiencing high depletion of water than the remaining areas.

3.1 Variation of Groundwater Table Depth

In 2008, the average depth of the water table is around 3 meters shown in Figure 2, while some areas of the study region such as 9 No Shilok-3,4; Kodala-3,4; Islampur-3,4; Mariamnagar-1,2; Chondraghnona-1,2 have no water depletion at all. However, the depth of groundwater level is decreasing day by day due to the usage of large amounts of water extracted from the ground during the dry season. Afterward, it is shown in Figure 3 that the average depth of groundwater was more than 3.30 meters in 2013. Besides, the number of tube wells used for lifting water was also increased in 2013.

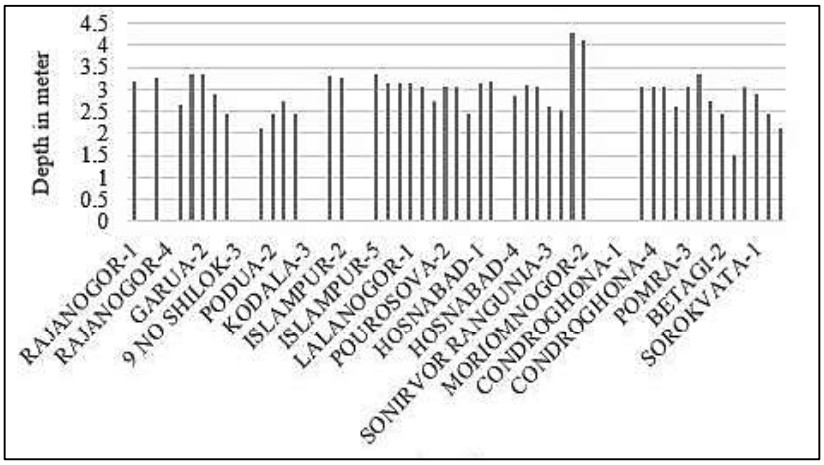


Figure 2 Groundwater table depths in 2008

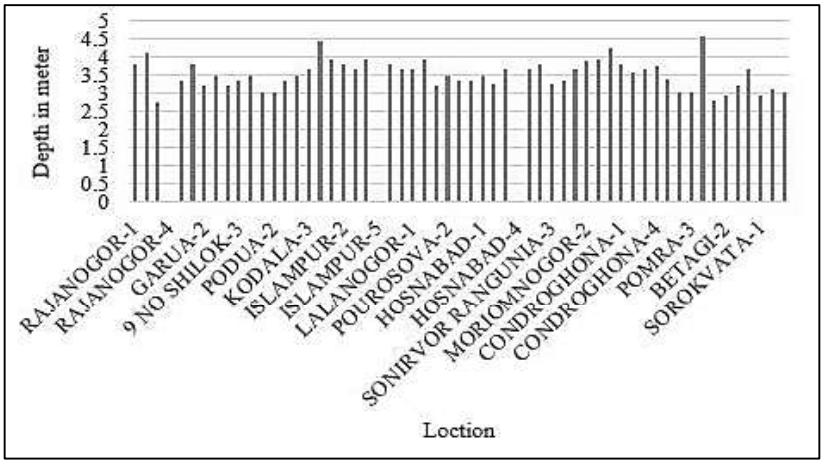


Figure 3 Groundwater table depths in 2013

The depth of groundwater level is around 4 meters shown in Figure 4 and all selected tube wells were used for groundwater extraction in 2017. The highest amount of water was a decline in Chondraghona, Islampur, Pomra, and Mariamnagar. A small water table variation

in observed in Betagi and Rajanagar. These three figures uphold the sharp decrease of groundwater table in the most of areas of Rangunia Upazila.

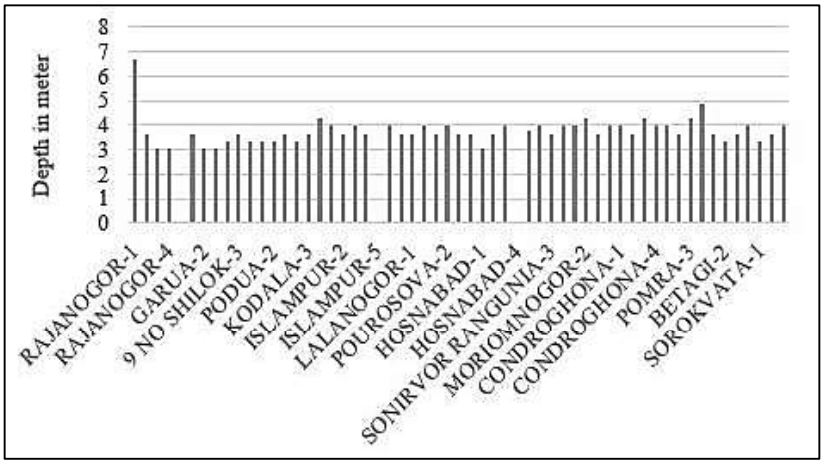


Figure 4 Groundwater table depths in 2017

The average depth of groundwater level in 2008 from selected tube wells is shown in Figure 5 by using GIS analysis. It is observed that most of the areas such as Rajanagar, Islampur, Hosnabad, Chondraghona had a groundwater table of around 2 meters, whereas Kodala and Podua experienced a water depth below 1.5 meters.

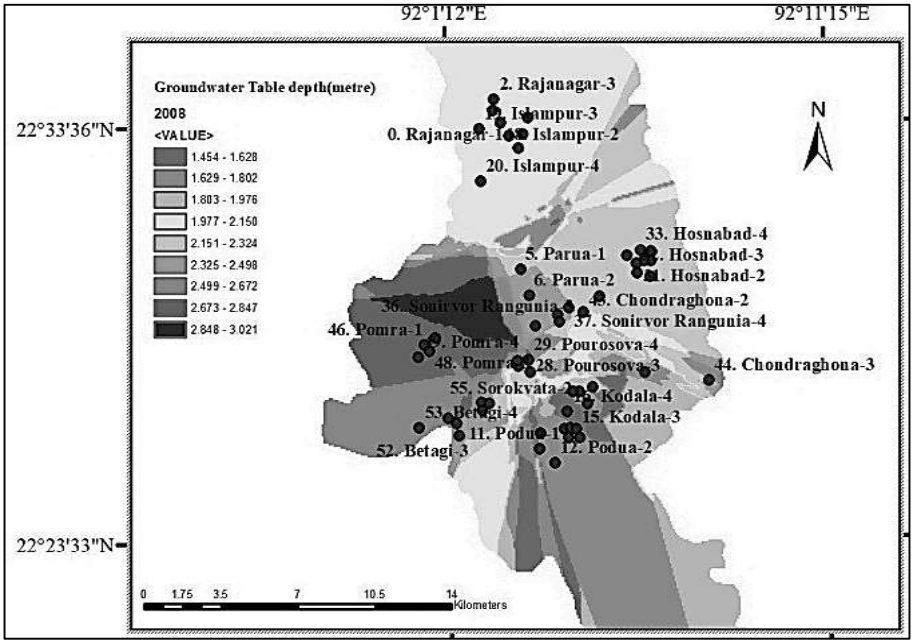


Figure 5 Variation in the water table in selected tube wells in 2008

The groundwater extraction from the confined aquifer was significantly increased shown in Figure 6. In 2013, the depth of water level in Chondraghona was 3.85 meters which was almost doubled that the water level in the year 2008. No area has a water level of fewer than 2.5 meters in 2013. Figure 7 represents the water level variation in Rangunia Upazila in 2017. The water table ranges from 1.75 to 4.3 meters. Compared to other areas of Rangunia Upazila, Chondraghona, Mariamnagar, and Pomra are still experienced the highest water

table decline over the last 10 years and the present annual declining rate is 0.4 meters. Rajanagar, Islampur, and Betagi have experienced little changes in water level in the entire observation period and the depth of groundwater is shallow there. Some parts of Rangunia Upazila such as Rajanagar and Betagi are being recharged by stormwater infiltration, precipitation, geological factors, etc. Overall, the historical data and the GIS application have found similar results on groundwater table variation in the selected areas.

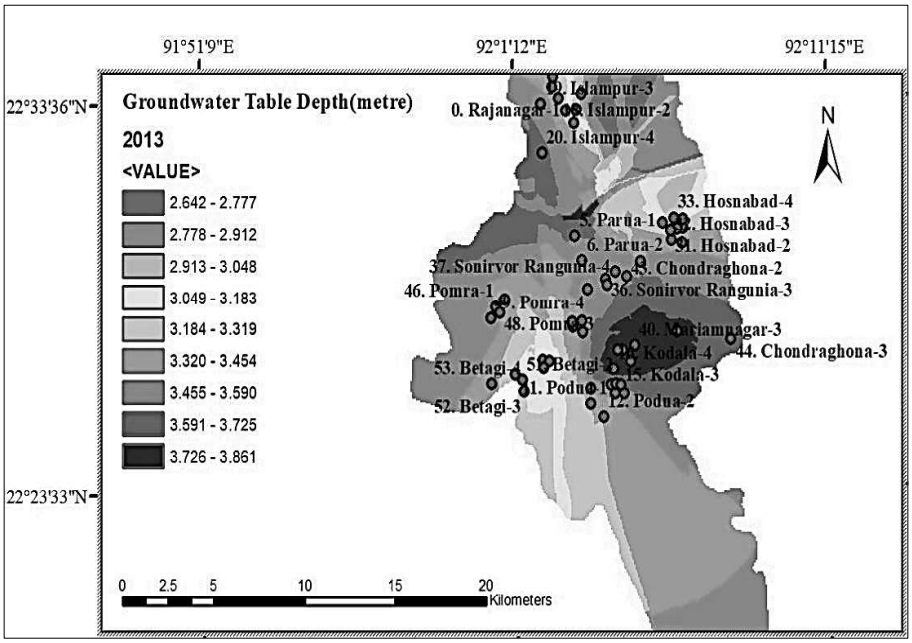


Figure 6 Variation in the water table in selected tube wells in 2013

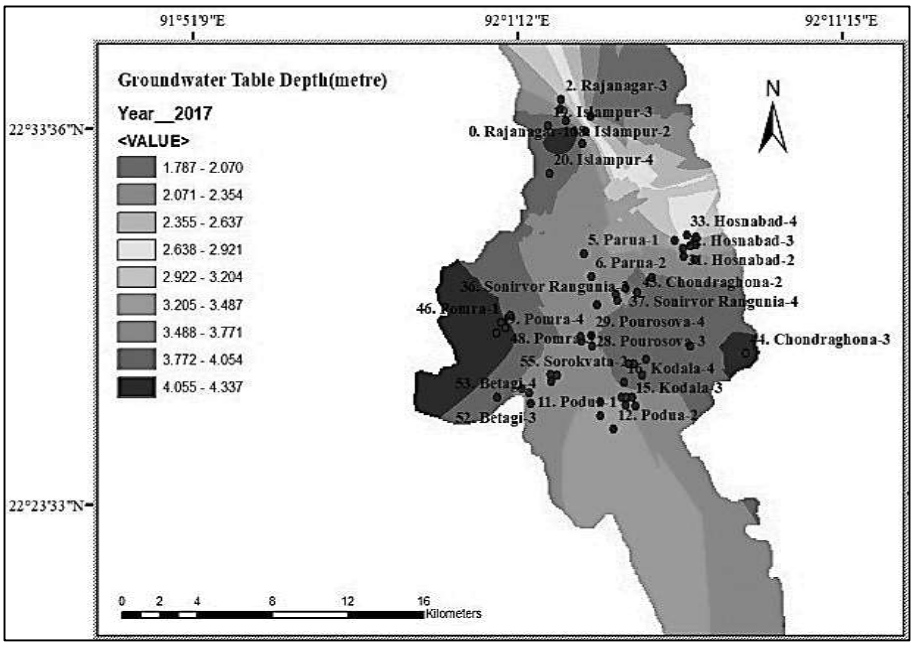


Figure 7 Variation in the water table in selected tube wells in 2017

4. Conclusions and Recommendation

From the data analysis and data visualization of groundwater depth records, the study shows that the depth of groundwater table is decreasing day by day in Rangunia Upazila which might cause various difficulties in their daily functions. First of all, the lack of groundwater would require them to pump water into the Earth deeper, which ultimately might be more depletion of groundwater in the future in that area. Secondly, large water bodies would turn shallower in that region, and contamination of saltwater might happen abruptly in the upcoming days. At last, food supply and people's life would be hurt when major aquifers in this Upazila are exhausted. Ultimately, these adverse impacts might be a great concerned for those people who are involved in fisheries, agriculture, and health sectors. In this case, the findings of this study may help planners, policymakers, and researchers to know the existing water level in this region and to take necessary actions for ensuring the proper use of groundwater and keeping the optimum level of the groundwater table. For upgrading this research work, there is much scope to work such as capturing the adverse impacts of decrement of groundwater table in this area, the extension of the study area to make in comparison with other regions, future prediction of groundwater level with measurable climate data, etc. Those areas must be emphasized for conducting future research more accurately and scientifically to precipitate more water in-ground for reclamation of groundwater levels.

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