Mapping and Analysis of Groundwater Table Fluctuations in Barind Area Using GIS Technology

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ABSTRACT

The study analyzed groundwater fluctuations potential in the Barind area of Naogaon district, North Bengal, Bangladesh, focusing on five Upazilas, Niamatpur, Badalgachi, Patnitala, Mohadevpur, and Manda. Utilizing GIS techniques and secondary data from the BMDA office, the study highlighted the critical need for sustainable water resource management due to significant groundwater depletion, especially from February to May, and recharge during August to October, the findings emphasize the insufficiency of groundwater in parts of the Barind region to meet current water demands, urging the adoption of balanced use of groundwater and surface water. Using data from the BMDA office and employing remote sensing and GIS techniques, the study maps groundwater depths from 2013 to 2022, revealing significant fluctuations with maximum depletion from February to May and elevated levels from August to October. Key findings include a 66.04 feet water table depth in Niamatpur in 2022 and 13.2 feet in Patnitala in 2021.

Keywords: Barind track, GIS, Groundwater table, Groundwater abstraction, Groundwater depletion.

INTRODUCTION

Approximately 71% of the Earth's surface is covered by water, with global water resources estimated at 1.36×10^8 million ha-m [1]. Despite this abundance, only 2.80% is available as fresh water, with 0.60% stored as groundwater. Bangladesh's intricate network of rivers and tributaries plays a pivotal role in its geography, agriculture, and economy. However, during the dry season, surface water becomes insufficient for irrigation, forcing reliance on groundwater from November to June. Agriculture, a vital sector, depends heavily on groundwater, with millions of tube wells supporting both agricultural and domestic needs. Bangladesh has one of the world's highest rates of groundwater extraction, highlighting its importance. In the last two decades, approximately 79.1% of agricultural lands, particularly those cultivating Boro rice, have been supplied with water from groundwater [2].

The study focuses on the Barind area of Naogaon district, where significant groundwater depletion occurs, particularly between February and May, with some recharge during August to October. Geographic Information System (GIS) techniques and data from the Barind Multipurpose Development Authority (BMDA) office reveal critical fluctuations. This depletion is exacerbated by unsustainable extraction practices, climate variability, and inadequate recharge, posing a threat to future food security and necessitating a holistic water management approach. Several factors influence groundwater geochemistry, including general geology, the degree of chemical weathering in different rock types, quality of recharge water, and interactions with other water sources [3-6].

Groundwater's dynamic nature depends on the balance between recharge and withdrawal. Over-exploitation disrupts this balance, leading to a continuous decline in the water table, which affects both surface and subsurface environments [7]. Effective water management in Bangladesh requires understanding the storage,

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discharge, and recharge patterns of underground reservoirs. While rainfall significantly impacts groundwater levels, natural discharge and pumping also play crucial roles. The Barind region, elevated and flood-free, relies solely on rainfall for groundwater recharge. Unfortunately, it experiences low rainfall and severe drought conditions. The area's thick, clayey surface hinders groundwater recharge, increasing surface runoff and exacerbating water depletion. Effective planning and sustainable practices are essential to manage groundwater resources, considering population growth and socioeconomic development. Overall, this study underscores the urgent need for sustainable groundwater management in the Barind area. By balancing the use of groundwater and surface water, and considering the impacts of climate and human activities on recharge and extraction, it aims to ensure a reliable water supply for agriculture and domestic use, securing food and water resources for future generations. The Millennium Development Goals (MDG) emphasize environmental sustainability, recognizing the increasing importance of groundwater due to rising demands for drinking and irrigation water. Urbanization has intensified the demand for groundwater resources, leading to deterioration in groundwater quality [8]. Several studies have been conducted in South Asia to assess groundwater prospects using thematic layers derived from satellite data and Survey of India top sheets, and integrating them in a GIS environment. Notable studies include those by [9-14].

METHODOLOGY AND ANALYSIS

Ground water fluctuation was analyzed in five selected Upazilas of Naogaon district. Selected locations were, Niamatpur, Badalgachi, Patnitala, Mohadevpur, and Manda. These locations are within Barind Tract of North Bengal. Study was based on secondary data collected from BMDA and questionary survey at study areas. Following mix approach of data collections were selected during this study-

1. Secondary Data: Information from governmental (BMDA) and non-governmental sources was used to contextualize and support the analysis

2. Surveys and Interviews: Local people provided qualitative data through surveys and interviews about their experiences and views.

Quantitative data were analyzed using statistical methods. Descriptive statistics analysis was used to identify significant fluctuations of groundwater level. Ten years data of five selected Upazilas were considered for this study. Data from multiple monitoring wells were used to map average groundwater depth contours from 2013 to 2022, evaluating groundwater movement trends in feet. ArcGIS 10.8 was employed for contouring and mapping. Qualitative data from interviews were analyzed thematically to identify key challenges of irrigation. Geographic Information System (GIS) technology has revolutionized the way spatial data is analyzed and utilized, becoming an essential tool in areas such as urban development, disaster response, and environmental conservation. We used GIS in our study to show groundwater level fluctuation with change of time for a certain period.

This study focuses on five selected upazilas within the Naogaon district encompassing 1,818.43 km². Niamatpur being the largest and Badalgachhi the smallest area among five selected locations. Major water body near the study area are Atrai River and Shib River. Study area is shown in figure 1.

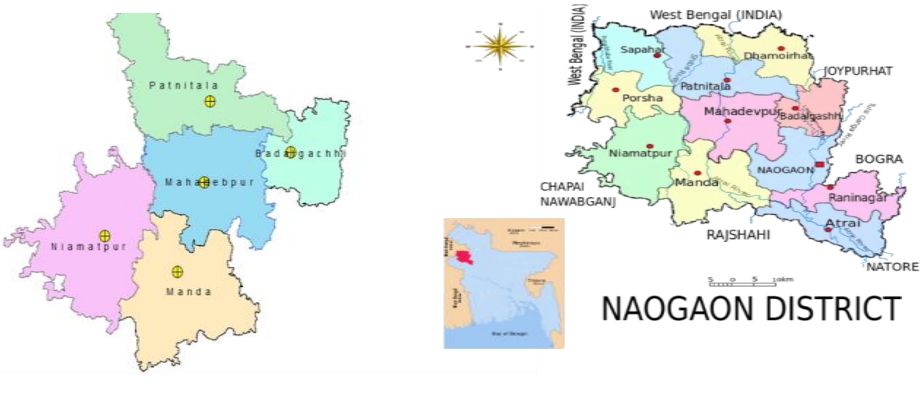

Figure 1: Study Area in the Naogaon District of Bangladesh

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RESULTS AND DISCUSSION

Considering groundwater depth, two contour maps was prepared. Analysis of groundwater depth in the study area reveals significant challenges, particularly in the high Barind Area where the groundwater level exceeded the practical suction limit for shallow tube wells or hand tube wells, set at 27 feet [15]. In contrast, the low Barind Area experiences groundwater depths within the acceptable suction limit. However, at specific locations such as Mohadevpur, Badalgachi, and Patnitala, the groundwater depth ranges between 30 to 50 feet, well beyond the suction capacity of traditional wells. Further groundwater development in these areas using shallow or hand tube wells would exacerbate the problem. All the shallow and hand tube wells will need the replacement by deep tube wells. GW level contour map based on GIS Mapping for the value of 2013 and 2022 are shown in figure 2 and 3.

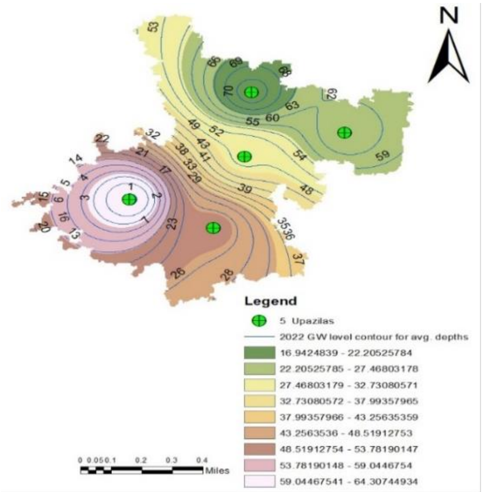

Fig 2: GW level contour map for 2013

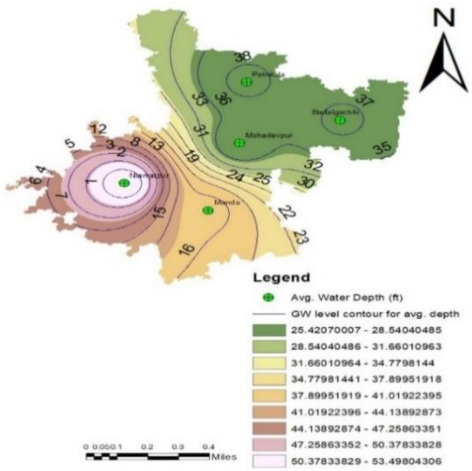

Fig 3: GW level contour map for 2022

Drastically change of ground water level in study area found from above contour maps. Depletion of groundwater level was significant from last ten years data analysis in Badalgachi, Niamatpur, and Manda area.

Based on the secondary data, collected from BMDA, figure 4 shows Maximum & Minimum depletion of GWL in five Upazilas of Naogoan district from 2013-2022. It meticulously depicts the maximum groundwater level depletion observed across the five Upazilas from 2013 to 2022, spotlighting Niamatpur's significant depletion at 66.41 ft in 2022 and Patnitala's comparatively lower depletion at 19.28 ft in the same year. Conversely, Figure 4 also provides an intricate portrayal of the minimum groundwater level depletion across the five Upazilas from 2012 to 2023. Here, Niamatpur once again emerges with the highest depletion at 61.2 ft below the surface in 2022, while Badalgachi records the lowest depletion at 12.2 ft in 2020, delineating the diverse groundwater dynamics prevalent across Naogoan district.

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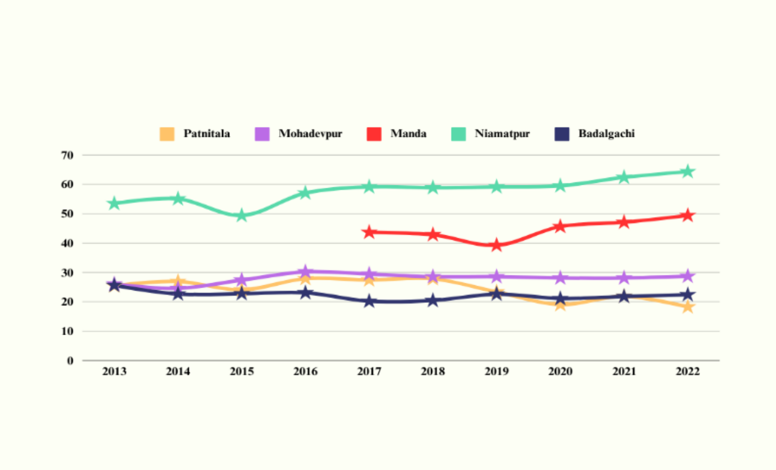

Fig. 4: Maximum & Minimum Depletion of GWL (2013-2022)

Figure 5 shows average maximum and minimum groundwater level declined in five Upazilas of Naogoan district through the years from 2013 to 2022. It was found from below figure 5 that, groundwater levels consistently declined across all Upazilas in the study region, with water levels decreasing by 0 to 2 feet per year. Badalgachi and Mohadevpur Upazilas experienced nearly identical rates of water level fluctuation. Patnitala Upazila saw a slight rise in water levels from 2013 to 2016, followed by a decline between 2016 and 2018, and then a significant increase by 2022, likely due to abundant rainfall. Notably, Niamatpur and Manda Upazilas faced a rapid and continuous decline in water levels, about 2 feet per year, raising serious concerns about the sustainability of groundwater management in the region.

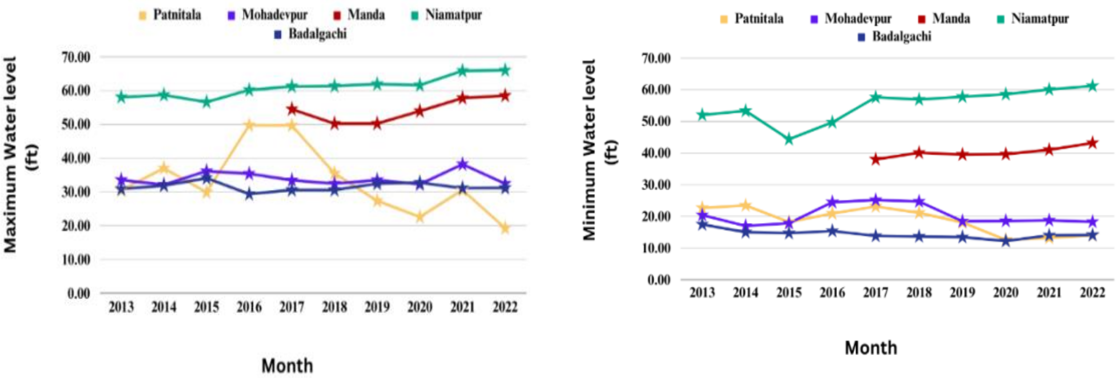

Fig 5: Average groundwater level declined from 2013 to 2022.

Key findings include a 66.04 feet water table depth in Niamatpur in 2022 and 13.2 feet in Patnitala in 2021. From a questionary survey at study area, water scarcity for irrigation was found, especially in dry season. Also, local people informed Arsenic of ground water of study area. Higher temperatures in lower ground levels facilitate in dissolving elements including arsenic, fluoride and heavy metal ions that are more prevalent at deeper levels. The consumption of such contaminated water leads to the well-known "Arsenicosis" disease and the disease has been reported in Southern parts of India and Bangladesh [16, 17]. Another major concern of local people was drought in Barind area. Same issue also came out from study considering depletion of ground water level. Hydrological drought is characterized by shortages in both surface and subsurface water supplies, leading to insufficient water availability to meet normal and specific demands [18]. A specific form of hydrological drought is groundwater drought, which occurs when groundwater recharge, levels, or discharge diverge from typical conditions [19]. Groundwater recharge is influenced by both climate variability and human activities, including unsustainable extraction and groundwater abstraction. In South Asia, groundwater-fed irrigation is essential for growing high-yield rice during the dry season, with India and Bangladesh being leading rice producers [20]. The process of groundwater recharge, where water infiltrates the ground to replenish aquifers, plays a vital role in ensuring sustainable water resources, particularly in the face of increasing water scarcity. This process occurs through pathways like direct percolation and indirect recharge, with its efficiency shaped by variables such as land use, climatic conditions, and geological characteristics. Modern tools like GIS and remote sensing have significantly improved the ability to analyze and map recharge potential by capturing critical surface and subsurface features. Accurately estimating recharge rates is essential for addressing aquifer depletion and urban water needs, requiring an integrated approach that combines hydrogeological, meteorological, and spatial data—especially in regions grappling with rapid urban expansion and climate change effects.

CONCLUSION

This research examines rainfall and groundwater fluctuations across five Upazilas in the Barind area of Naogaon district to ensure sustainable irrigation and understand groundwater impacts on water resources. Using data from the BMDA office and employing remote sensing and GIS techniques, the study maps groundwater depths from 2013 to 2022, revealing significant fluctuations with maximum depletion from February to May and elevated levels from August to October. Key findings include a 66.04 feet water table depth in Niamatpur in 2022 and 13.2 feet in Patnitala in 2021. Recommendations for sustainable groundwater management include enhancing rainwater harvesting, using surface water for irrigation, preventing aquifer overexploitation, storing monsoon water, promoting cooperative water management, engaging communities, providing planners with comprehensive data, and implementing mitigation measures. These steps aim to ensure sustainable food production and secure water supply.

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