ASSESSMENT OF GROUNDWATER IN RAJSHAHI DISTRICT 2022.

Shaikh Shahrear*[1], Md. Al Amin[2], Md. Waliullah[3], Faria Hasan[4] and Md. Rashidul Hasan[5]

[1]*Student, Department Of Civil Engineering, Bangladesh Army University of Engineering & Technology, Natore-6431, Bangladesh, e-mail: shaikhshahrear1@gmail.com*
[2]*Student, Department Of Civil Engineering, Bangladesh Army University of Engineering & Technology, Natore-6431, Bangladesh, e-mail: mdalamin2308@gmail.com*
[3]*Student, Department Of Civil Engineering, Bangladesh Army University of Engineering & Technology, Natore-6431, Bangladesh, e-mail: mdwaliullah7272@gmail.com*
[4]*Lecturer, Department Of Civil Engineering, World University Of Bangladesh, Dhaka-1230, Bangladesh, e-mail: faria6000@gmail.com*
[5]*Professor, Department Of Civil Engineering, Prime University, Dhaka-1216, Bangladesh, e-mail: mrhasanraj@gmail.com*

***Corresponding Author**

ABSTRACT

The Barind region, also known as the rice bowl of Bangladesh, is facing a significant crisis due to the rapid depletion of its groundwater levels. This research examines the impact of excessive irrigation work on groundwater levels in Rajshahi district, specifically focusing on the adverse effects of Boro rice production in 2022. Secondary Data on primary crop patterns, monthly rainfall, static water levels, and bore logs were collected from every upazila in Rajshahi district in 2022. ArcGIS 10.8 was used to create maps for the study area, digital elevation, cropping patterns, groundwater levels, and groundwater level contours. The Digital Elevation Map shows Tanore Upazila and Godagari have the highest elevations (22.1mPWD to 62mPWD), Mohanpur, Bagmara, Durgapur, and Puthia Upazila have the lowest (-18mPWD to 16mPWD). The Cropping Pattern Map 2022 reveals (Boro-Fallow-T. Aman) as the most prevalent cropping pattern in the Rajshahi district, covering Godagari, Tanore, Mohanpur, and Paba upazila. In 2022, 68,600 hectares of land were utilized for Boro rice cultivation, yielding 28 and a half maunds per bigha using BRRI Dhan-92. In 2022, the Rajshahi district utilized an estimated 494710509m^3 (Cubic Meter) of irrigation water for Boro rice production. Godagari upazila is in its worst position in 2022 for Ground Water Level and Boro rice production. The depth to the phreatic surface reached 23m, with a total area of 16,560ha for Boro rice production and 23,690ha for T. Aman production. Durgapur upazila received the highest total rainfall of approximately 1852mm in 2022. In Charghat upazila 2022, the lowest rainfall recorded was approximately 365mm. Rajshahi City Corporation's population heavily relies on groundwater for household needs. Finally, according to Groundwater level and Boro rice production, Puthia upazila is in the best position. According to Bore Log lithology, a clayey formation dominates the area with a maximum thickness of 23.5 meters Based on the thickness of the clay layer, the order of the upazilas in Rajshahi district are: Godagari >Tanore >Mohanpur >Bagmara >RCC >Paba >Durgapur > Bagha >Charghat >Puthia. The thickness of composite sand ranges from 11.033 meters (on average) to 75 meters. Shallow aquifers are located between 12-60 meters(estimated) , containing fine and medium sand layers, while aquifers upper depth are mostly composed of fine sand. All the bills of the Barind region should be dug and water reservoirs should be created. So cultivation using surface water will reduce the pressure of underground water use. Besides, it has been asked to cultivate less irrigated crops instead of Boro. Not only this, more trees should be planted in the Barind area, then the annual rainfall will increase.

Keywords: *Groundwater, Barind Track, ArcGIS, Boro Rice, Bore Log data.*

1. INTRODUCTION

Since groundwater is often recognized as a significant supply of drinking water in low-income areas, it is essential to the fulfillment of the human right to water. (Carrard et al, 2019)

Agriculture in Bangladesh heavily relies on irrigation during the dry season which lasts for about 6 months as the rainfall is minimal. In most parts of Bangladesh, dry season irrigation is majorly dependent on ground water, and surface water sources require the use of high lift pumps. Additionally, all municipal water supplies in the country come from ground water. The increasing demand for food production has made ground water increasingly important, as floods usually damage a considerable amount of grain production every year. To tackle this issue, there are ongoing efforts to change the cropping pattern by extending the area under irrigation during the dry season, which in turn leads to an inexorable rise in the demand for ground water. The green revolution, which has made Bangladesh nearly self-sufficient in rice production since the mid-1980s, has been backed by ground water resources. (Ahmed, 1994).

The Barind region, which is known as the rice bowl of Bangladesh, is currently facing a major crisis as its groundwater levels are rapidly depleting. In this water-stressed area, irrigation tubewells have become a tool for influential individuals to exploit farmers with little political power.

The Barind Tract, also known as the Varendra Tract in English and Borendro Bhumi in Bengali is the largest physiographic unit of the Pleistocene era in the Bengal Basin. It spans across most of the Dinajpur, Rangpur, Pabna, Rajshahi, Bogra, and Joypurhat districts in the Rajshahi and Rangpur Divisions of Bangladesh, covering an area of about 10,000 square kilometers (3,900 sq mi) consisting mostly of old alluvium. The tract is divided into three units: the Recent Alluvial Fan, the Barind Pleistocene, and the Recent Floodplain, which are separated by long, narrow bands of recent alluvium. The eastern edge of the tract has a lower fault escarpment, and the fault troughs run the little Jamuna, Atrai, and Lower Punarbhaba rivers. The main area to the west is tilted up, while the area to the east is tilted downwards. The climate of the tract is different from that of much of India, with more extreme temperature variations ranging from 45 degrees Celsius down to five degrees Celsius. (Banglapedia, 2015)

The availability of irrigation in the Barind Tract has brought a revolution in its agriculture. However, the groundwater level all over the country is continuously falling due to excessive withdrawal, and this process is accelerating because of water withdrawal from major rivers by upstream countries. In the northwestern part of Bangladesh, the problem of groundwater depletion is severe, as this part is free from seasonal flooding. The only source of recharging the groundwater aquifer in this area is rainfall, but the amount of rainfall is also the lowest in the country. (Rahman & Mahbub, 2012)

The Barind Integrated Area Development Project was approved by the government in 1985 under the Bangladesh Agricultural Development Corporation. Despite using only 26% of the allocated funds, the project was declared complete in 1990. However, a review was conducted after completion, and to expedite further development in the Barind area, a separate authority was established on January 15th, 1992, named the Barind Multipurpose Development Authority (BMDA) under the Ministry of Agriculture. Since its inception, the authority has implemented 23 development projects.(Islam, 2012)

In the 1990s, the BMDA installed deep tube-wells, which allowed farmers to cultivate three crops a year and transformed the northwest into one of the country's major grain-producing regions. Recent estimates by the BMDA suggest that around 70% of the Barind region's annual groundwater extraction of 13,710 million cubic meters is done by unregulated private deep tubewells. To put this into perspective, this amount of water would fill up approximately 1.8 million ponds, each 2 meters deep and covering one bigha. (Dhaka Tribune, 2021)

The Rajshahi region is ideal for growing lentils, chickpeas, tomatoes, and potatoes. Major fruit crops in this area include mangoes, litchis, palmyra palms, and guavas. The cropping pattern in this region is not fixed and changes over time. The changes depend on various factors such as climate, soil type, rainfall, irrigation facilities, agricultural technology, marketing and transport facilities, and growth of agro-industries. (Rashid et al, 2017)
In recent times, many farmers have been converting their fields into mango orchards while still growing crops in the young orchards. In the Rajshahi region, like in other parts of the country, the major crop is monsoon T. Aman rice, which is the backbone of the rural economy. Starting from 1985, the Barind Multipurpose Development Authority (BMDA) has installed deep tube wells and brought 162,000 hectares of land under irrigation across the entire Barind of Bangladesh. To mitigate risks, farmers may consider adopting a diversified cropping pattern. (Mandal and Bezbaruah, 2013)

GIS or Geographical Information System is a widely used tool for surface hydrological modelling. Its capability to handle large spatial datasets over a large area allows it to model surface water at a regional scale. Additionally, GIS provides visual outputs, making the presentation of research findings clearer. However, in groundwater modelling, GIS has been limited to preparing model input parameters and presenting model outputs. This is because groundwater modelling requires complex 3D analysis. However, for screening groundwater status, a simpler model is sufficient. This study further explores the hydrological analysis tool of GIS for modelling groundwater. With the successful development of a simpler groundwater model, it can benefit people involved in planning, decision-making, and managing water resources, especially for an area that lacks groundwater information. (Jani, 2012)

A study that combines remote sensing (RS) and geographic information system (GIS) can reveal hydrogeological characteristics and provide useful information on groundwater recharge potentiality. The study examines surface features such as lineaments, drainage frequency and density, lithological character, land cover, and land use to estimate and assess the recharge potential. The drainage number (or frequency) has the strongest correlation with the recharge property (Shaban, 2003)

1.1 Objectives

- To understand Groundwater level variation in different upazilas of Rajshahi district.
- To identify impact of irrigation on groundwater depth in different upazilas of Rajshahi district.
- To know about the sub soil information and aquifer position in different upazilas of Rajshahi district.
- The future recommendation of crops production with Groundwater fluctuation and variation in rajshahi district.

2. METHODOLOGY

This research examines the impact of excessive irrigation work on groundwater levels in Rajshahi district, specifically focusing on the adverse effects of Boro rice production in 2022.

In 2022, a study was conducted on groundwater levels in Rajshahi district and Rajshahi City Corporation using secondary data. The collected quantitative data was statistically analysed using various tools such as charts, graphs, tables, and statistical programs.

We gathered data on the primary crop patterns, monthly rainfall, static water levels, and bore logs from every upazila in Rajshahi district 2022. The data was sourced from various government agencies in the district. Using this information, we created maps showcasing the condition and overall depth of groundwater in the different upazilas of Rajshahi district. We organized the data in Microsoft Excel and transferred it to the ArcGIS platform for upazila-wise water quality mapping. We utilized ArcGIS 10.8 to create maps for study area, cropping patterns, groundwater levels, and groundwater level contours. By analyzing the data, we created multiple graphs to understand the groundwater level and potential reasons for its depletion.

Additionally, we estimated the total amount of groundwater used for Boro rice production in 2022 and scrutinized the bore log data of Rajshahi district to gain insight into the subsoil conditions of the area.

2.1 STUDY AREA

The groundwater of every upazila in Rajshahi District 2022 has been examined by us. Rajshahi District is located in the Rajshahi Division and covers an area of 2425.37 square kilometers. It is situated between 24°07' and 24°43' north latitudes and 88°17' and 88°58' east longitudes. The district is bordered by Naogaon District to the north, the Indian state of West Bengal to the east, Kushtia District and the Ganges River to the south, and Nawabganj District to the west. The region is home to the Barind Tract, Diara, and Char lands. The district's main rivers are Padma, Mahananda, and Shiba, and notable water bodies include Paltola Beel in Godagari and Chalan Beel. Rajshahi district has nine upazilas: Godagari, Bagmara, Tanore, Mohanpur, Durgapur, Bagha, Paba, and Puthia. Rajshahi has a tropical wet and dry climate, with hot temperatures, significant humidity, and moderate rainfall. The hot season lasts from March to mid-July, with maximum temperatures between 32-36°C (90-97°F). January has minimum temperatures around 7-16°C (45-61°F). The monsoon months have the highest rainfall, with an annual rainfall of about 1,448mm in the district. (Banglapedia , 2023)

The lithostratigraphy of the region is composed of three geological units: the Barind clay residuum, which produced a top Pleistocene alluvium; the Holocene Ganges flood-plain alluvium; and the present alluvium, which is made up of active channel deposits of the Ganges and its distributaries. There are four different types of lithology found in the research region: marsh clay and peat, Barind clay residuum, alluvial sand, and alluvial silt. It also comprises the Ganges floodplain (8.5%), Tista floodplain (4.8%), and Barind land (78.4%). In the Barind Tract, Pleistocene Dupi Tila Sand serves as an aquifer. (HAQUE et al, 2010)

We obtained static water level data and bore-log data from each upazila's regional Barind Multipurpose Development Authority (BMDA) office. Additionally, we researched Rajshahi City Corporation and gathered the required information from Rajshahi WASA. Data on static water levels and bore logs were gathered from the wells shown on the map in Figure 1.

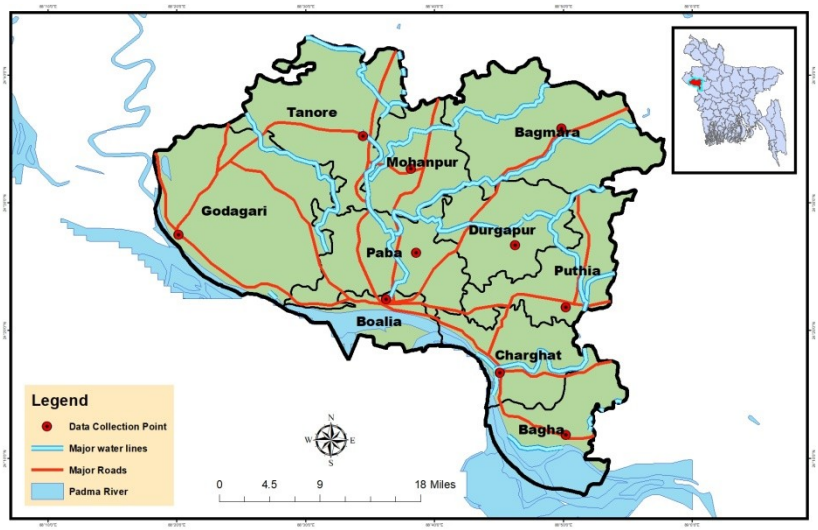


Fig 1: Study Area Map of Rajshahi District

2.1.1 Topography

A useful tool for determining the topographic features that contribute to landslide activity in a location is the digital elevation model (DEM). We utilized this digital elevation model to calculate the elevation in height. From the United States Geological Survey (USGS), we have extracted data. There are four classes from (-18 mPWD to 62 mPWD) in the elevation data layers. According to this model, we observed that, Tanore Upazila and Godagari have the highest elevations, ranging from 22.1 mPWD to 62 mPWD. Mohanpur, Bagmara,

Durgapur, and Puthia Upazila, on the other hand, have the lowest elevations, ranging from -18mPWD to 16mPWD . Finally, the modest elevations of Paba, Charghat, Boalia, and Bagha range from 16.1mPWD to 22 mPWD. Digital Elevation Model map in Fig 2

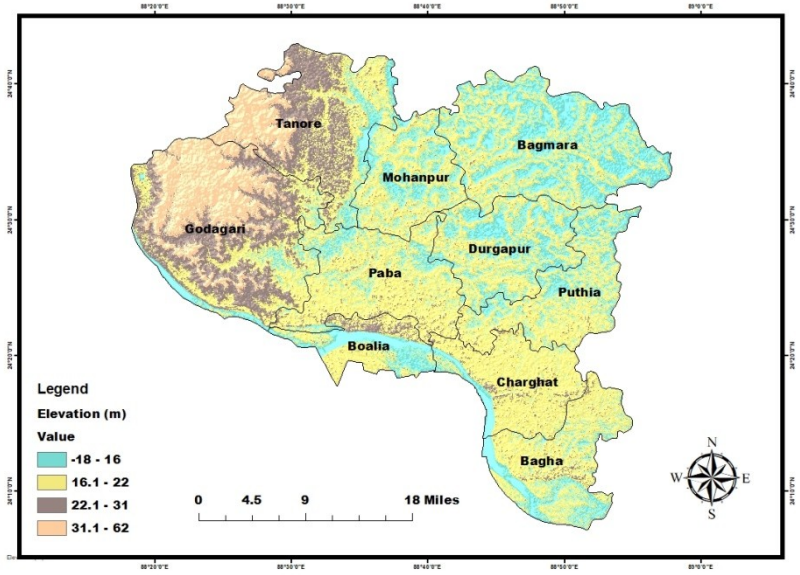


Fig 2: Digital Elevation Model Map of Rajshahi District

2.2 DATA COLLECTION

Secondary data was the main tools in this present study. In this research paper each and every data is Quantitative data. We've statistically analysed all the data through charts, tables and statistical program. For our research work we've collected Rainfall data, Bore Log data, Static water Level data, Major crops Pattern data for all the upazilas of Rajshahi district. We've also done detailed research work for our area of focus Puthia upazila. Each and every data collected from government organizations and related to hydrology and irrigation in the study area. Type of collected data and corresponding agency name are presented in Table 1.

Table 1: Secondary Data Type and Corresponding Source

Data Type	Government Organizations
Lithological Data	1. Barind Multipurpose Development Authority (BMDA), Rajshahi. 2. Department Of Public Health Engineering (DPHE), Rajshahi. 3. Water Supply and Sewerage Authority (WASA), Rajshahi.
Precipitation Data	1. Barind Multipurpose Development Authority (BMDA), Rajshahi.
Static Water Level Data	1. Barind Multipurpose Development Authority (BMDA),Rajshahi. 2. Water Supply and Sewerage Authority (WASA), Rajshahi.
Crop Database	1. Department Of Agricultural Extension (DAE), Rajshahi.

2.3 RESULTS AND DISCUSSION

2.3.1 Existing Land Use Pattern

In order to estimate the volume of water required for irrigation on the crops being cultivated in a specific area, the model takes into account factors such as vegetation and land usage. This study focuses on an agricultural region, where the primary crops requiring irrigation have been considered while simplifying the cropping types and patterns. The model relies on a crop database that contains information on each crop's leaf area index, root depth, and other characteristics. Based on the crop calendar for 2022, the primary crops in the

Rajshahi District are mustard, potatoes, Boro, and T. Aman. In this year, about 68,600 hectares of land were used to cultivate Boro rice, while a total of 80,832 hectares were utilized for T. Aman production. Mustard cultivation used around 42,550 hectares, and potatoes were planted on approximately 44,516 hectares of land. The Rajshahi district 2022 cropping pattern map is based on the largest quantity of irrigation water utilized, as seen in Fig (3). (Ahmed, The Hydrogeology of the Dupi Tila SAnds Aquifer of the Barind Track, NW Bangladesh, 1994)

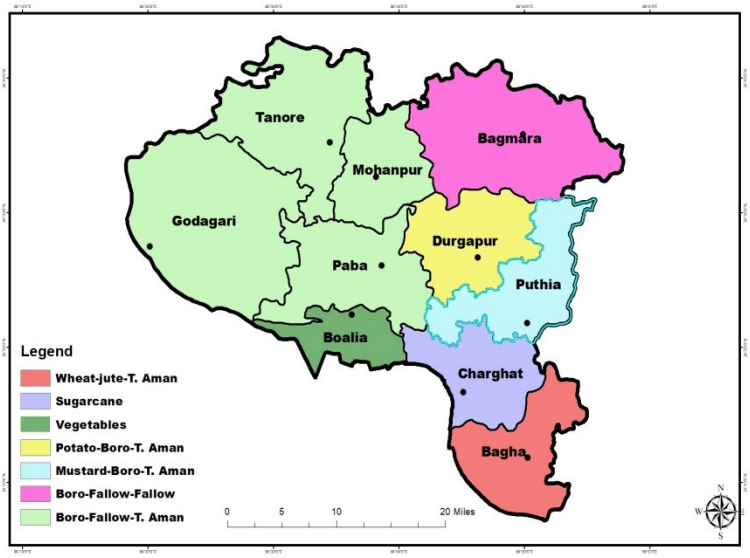
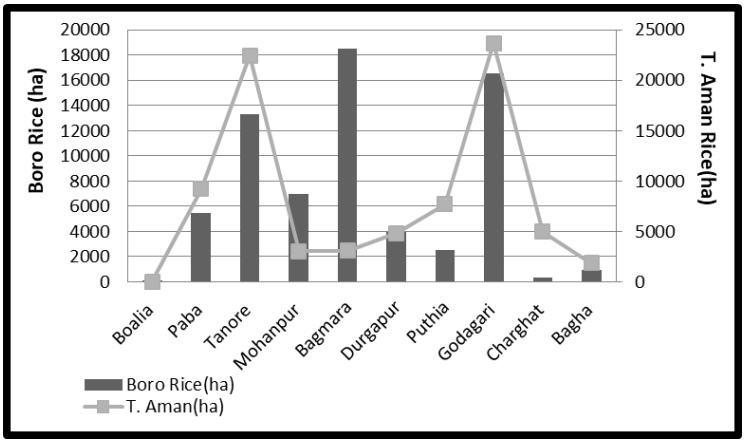


Fig 3: Cropping Pattern Map Of Rajshahi district 2022

However, to estimate the recharge of groundwater, we must select the crops that require the highest amount of groundwater for irrigation. Of these crops, Boro rice utilized the most groundwater for irrigation, followed by T. Aman, which used the second most groundwater. We have discovered that Bagmara Upazila has the most quantity of agricultural area utilized for the cultivation of Boro rice. Tanore upazila came in third, followed by Godagari upazila in second. Godagari Upazila ranked highest for T. Aman Production, followed by Tanore Upazila in second place and Paba Upazila in third. The lower amount of land used for Boro rice production in Puthia upazila and the moderate amount of land used for T. Aman production. Lands used for Boro Rice production and T. Aman production in Rajshahi district 2022 shown in graph (1)



Graph 1: Calibration of Boro rice production and T.Aman production in Rajshahi district 2022.

2.3.2 Spatial Distribution Map Of Depth to GW Table

Near certain pre-selected locations, hydrographs of simulated GW tables were obtained. These hydrographs reveal that the highest and minimum depths to the GW table occur near the end of April and October, respectively. The results above are further supported by hydrographs of the observed GW table. To observe the impact of pumping and determine if the GW table for 2022 regains its original positions, spatial distribution maps of maximum and lowest depth to GW tables were created for the Pre-Monsoon and Post-Monsoon periods (Figures 4 and 5). These maps were created based on these results. Figure 4 shows that the greatest depth to the phreatic surface (DTPS) in the Rajshahi district is still within the range of 7.33 m to 23.36 m. Figure 5 shows that in the Rajshahi area, the GW table stays within the range of 2.88 m to 22.93 m at peak time.

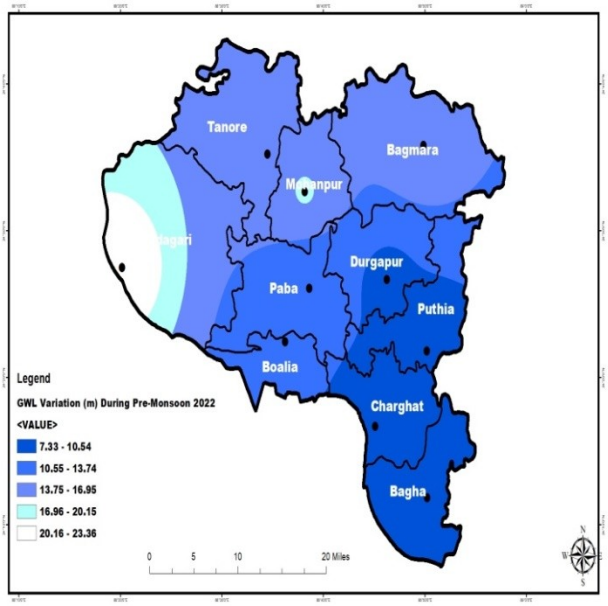


Fig 4: GWL Variation(m) map during Pre-Monsoon 2022

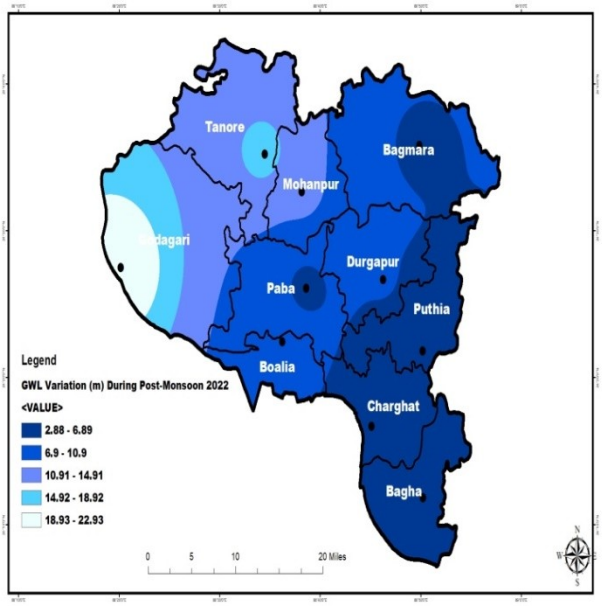
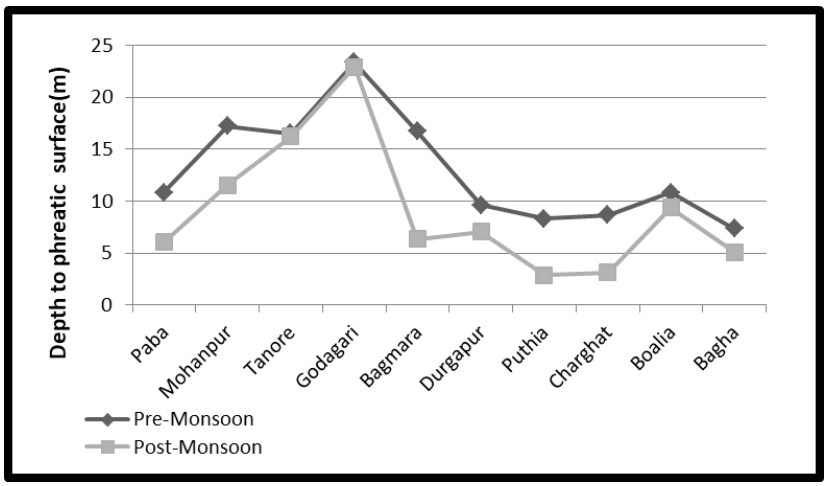


Fig 5: GWL Variation(m)

2.3.3 map during Post-Monsoon 2022

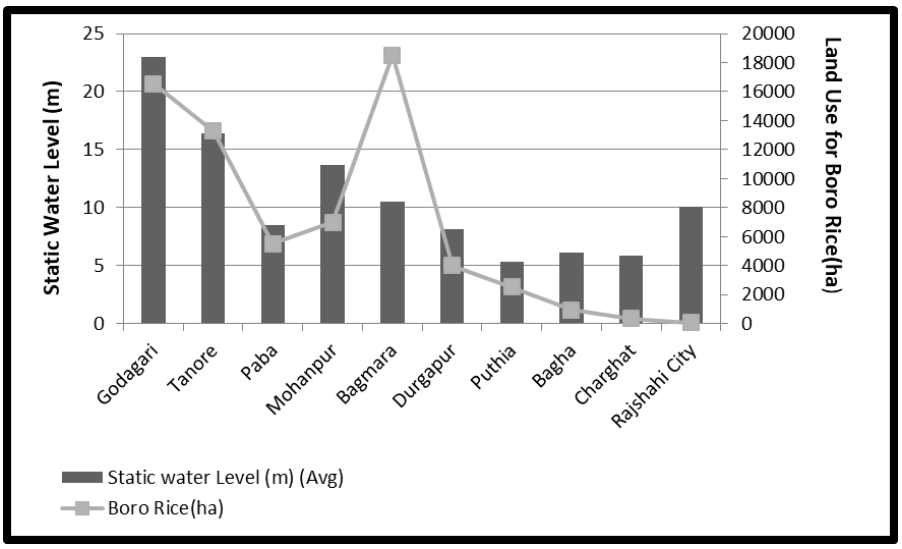
The greatest depth (in meters) to the phreatic surface was discovered in Godagari upazila Rajshahi in 2022, both before and after the monsoon. Similar outcomes were seen in the Rajshahi district's Tanore and Mohanpur upazilas. However, in 2022, Bagha, Charghat, and Puthia Upazila are in an excellent situation. In terms of greatest depth to the phreatic surface during Pre-Monsoon and Post-Monsoon 2022 in Rajshahi district, Paba, Durgapur, Bagmara upazila, and Rajshahi city corporation are in a middling position. Graph 2 displays the GWL fluctuation (m) in the Rajshahi district during the pre-and post-monsoon periods in 2022.



Graph 2: Calibration of GWL (m) during Pre-Monsoon & Post-Monsoon in Rajshahi district 2022.

2.3.4 Groundwater Level and Boro Rice Production

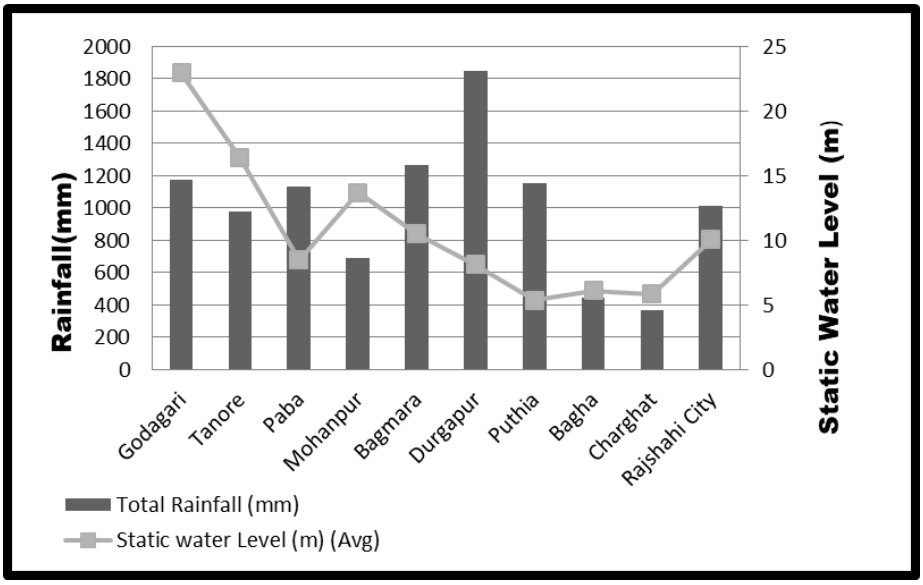
In Rajshahi, the groundwater table is dropping yearly. The average depth conditions of the wells across the nine upazilas and Rajshahi City corporation in Rajshahi District 2022 are shown in Graph 3. The relationship between the production of Boro and the state of the groundwater in 2022 is seen in Graph 3. The rate of groundwater depletion is accelerating because of the yearly rise in Boro production. According to Graph 3, Godagari Upazila 2022 has the largest land utilization for Boro rice cultivation and the highest depth to the phreatic table. In terms of producing more Boro rice and increasing the depth of the Phreatic Table, Tanore Upazila comes in second. Mohanpur Upazila stepped in third place based on this calibration. Based on the status of groundwater levels and the amount of land used by Boro, Bagha, Charghat and Puthia upazila are in quite excellent shape. However, the positions of Paba, Durgapur, and Rajshahi City Corporation are mediocre. Highest land use for Boro rice production found in the Bagmara upazila of 18510 ha.



Graph 3 : Calibration of Static Water Level(m) and land use for Boro rice (ha).

2.3.5 Total Annual Rainfall

For the year 2022, we have gathered monthly rainfall data for each upazila in the Rajshahi district. We have calculated the total yearly rainfall for each upazila in the Rajshahi district for the year 2022 by adding them up. In the Durgapur upazila of the Rajshahi district, the greatest recorded annual rainfall is around 1852 mm in 2022. Godagari Upazila came in third place with 1176 mm, followed by Bagmara Upazila in second place with around 1267.91 mm. Rainfall in the Rajshahi City Corporation for the year 2022 was 1016.4 mm. The Charghat upazila has the lowest yearly rainfall of around 365 mm. In Puthia Upazila, there was around 1154 mm of rainfall in 2022. Graph 3 displays the relationship between Rajshahi district 2022's average groundwater depth (m) and yearly total rainfall (mm).



Graph 4 : Calibration of Total Annual Rainfall and Static Water Level(m).

2.3.6 Bore Log Lithology

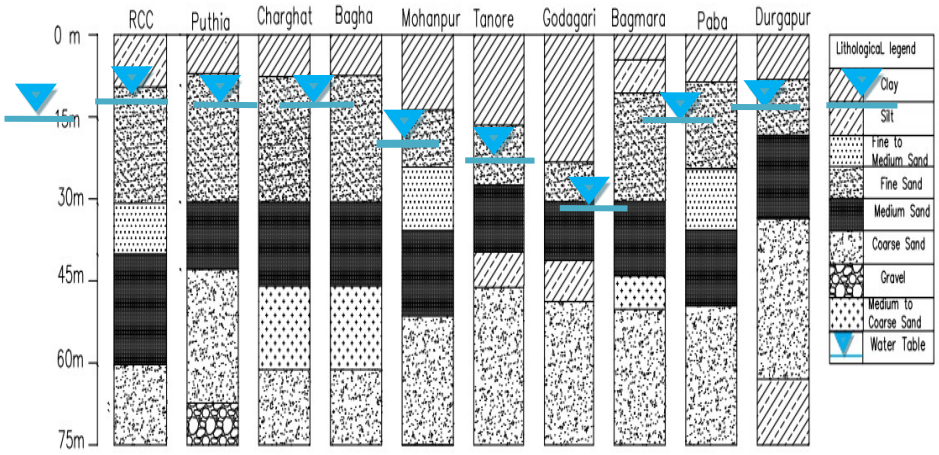


Fig 8: Bore Log data Calibration of Rajshahi district (Source : BMDA)

Bore log data has been collected from all the regional Barind Multipurpose Development Authority (BMDA) offices of the Rajshahi district as well as from the Rajshahi City Corporation by Rajshahi WASA. The study area's specified wells of BMDA were the source of the bore log data. Based on the calibration of the bore log data, it is evident that the topmost layer consists of a thick clay layer, followed by aquifer layers that are stacked alternately at varying depths and are separated from each other by clay layers. Subsurface lithology was observed in every Upazilas bore log data up to 75m depth. Godagari upazila has the highest thickness of the clay layer at 23m, followed by Tanore upazila with the second highest thickness of the clay layer at 16.37 m, and Mohanpur upazila with the clay layer of 13.7 m thickness. The average thickness of the clay layer in Rajshahi district is 11.033m.Fine sand was found in the range of 11.033m (average upper depth) to 28.11m (average lower depth) in the Rajshahi district with an average thickness of 16.01m. Medium sand and fine to medium sand layers can be found in the range of 28.11m (average upper depth) to 45.3m (average lower depth) in Rajshahi district, with an average thickness of 15.3 m. The average thickness of the coarse sand layer found is 25.5m

ANALYSIS AND DISCUSSION OF THE RESULTS

1) From The Digital Elevation Map in Fig 2 shows Tanore Upazila and Godagari have the highest elevations (22.1mPWD to 62mPWD), Mohanpur, Bagmara, Durgapur, and Puthia Upazila have the lowest (-18mPWD to 16mPWD), and Paba, Charghat, Boalia, and Bagha have the modest (16mPWD to 22mPWD).

2) It is concerning to note that in the Rajshahi district, the water table is decreasing every year, making it difficult to raise the groundwater level to its previous level. In 2022, Godagari Upazila recorded highest depth to phreatic surface of 23 meters, while Tanore Upazila recorded 16.38 meters, Mohanpur Upazila recorded 13.7 meters, Bagmara Upazila and Rajshahi City Corporation recorded 10.49 and 10.06 meters, Paba and Durgapur Upazila recorded 8.50 and 8.30 meters, Bagha Upazila recorded 6.11 meters, and Charghat and Puthia Upazila recorded 5.9 and 5.35 meters. Based on the depth to phreatic surface Godagari, Tanore and Mohanpur Upazila are in an alarming condition. Average depth to phreatic surface is 10.8 m in Rajshahi district 2022.

3) Based on the Ground Water Level Pre-Monsoon map shown in Figure 4, we have discovered that the depth to the phreatic surface varies between 7.33m and 23.36m before the monsoon. Puthia, Charghat, and Bagha upazilas have a depth ranging from 7.33m to 10.54m, while RCC, Paba, and Durgapur upazilas have a depth ranging from 10.54m to 13.75m. Tanore, Mohanpur, and Bagmara upazilas have a depth ranging from 13.75m to 16.95m. In Godagari upazila, the depth to the phreatic surface ranges from 16.96m to 23.36m.

4) Based on the Ground Water Level Post-Monsoon map shown in Figure 5, we have discovered that the depth to the phreatic surface varies from 2.88m to 22.93m. The districts of Puthia, Charghat, Bagha, and Bagmara have a depth to the phreatic surface ranging from 2.88m to 6.89m. RCC, Paba, and Durgapur districts have a depth ranging from 6.9m to 10.9m. On the other hand, Tanore and Mohanpur districts have a depth ranging from 14.92m to 18.92m. In Godagari upazila, the depth to the phreatic surface varies from 14.92m to 23.93m.

5) The Cropping Pattern Map 2022 reveals Boro-Fallow-T. Aman as the most prevalent cropping pattern in the Rajshahi district, covering Godagari, Tanore, Mohanpur, and Paba upazila.

6) Boro rice is known to require the highest amount of irrigation water among crops in the Rajshahi district. In 2022, around 68,600 hectares of land in the region were used for Boro rice cultivation, which yielded 28 and a half maunds per bigha using BRRI Dhan-92 (Source: Bangladesh Rice Research Institute, Rajshahi). According to the Bangladesh Rice Research Institute, it takes approximately 1,600 liters of water to produce one kilogram of Boro rice in the country's north-western region. Based on this information, an estimated minimum of 494710509m^3 (Cubic Meter) of irrigation water was used for Boro rice production in the Rajshahi district in 2022. This indicates that Boro rice requires the maximum amount of irrigation water in the region. However, other crops such as T. Aman, Potato, Mustard, Onion, and Jute also rely on groundwater for irrigation in the study area.

7) Based on the data from Graph 3, it is evident that the Godagari upazila is in its worst position ever in 2022 when it comes to Ground Water Level and Boro rice production. The depth to the phreatic surface has reached 23m in Godagari upazila, and the total area used for Boro rice production is 16,560ha in 2022, while the area used for T. Aman production is 23,690ha. Similarly, in Tanore upazila, the depth to the phreatic surface has reached 16.38m in 2022, and the area used for Boro rice production is 13280ha, while the area used for T. Aman production is 22439ha. In contrast, in Bagmara upazila, the Groundwater level is moderate, and the highest area used for Boro rice production in 2022 is about 18510ha. Finally, according to Groundwater level and Boro rice production, Puthia upazila is in the best position.

8) A clayey formation dominates the area with a maximum thickness of 23.5 meters. Figure 8 illustrates the variation of clay thickness in the study area. Based on the thickness of the clay layer, the order of the upazilas in Rajshahi district are: Godagari >Tanore >Mohanpur >Bagmara >RCC >Paba >Durgapur >Bagha >Charghat >Puthia. This layer blankets the only sandy formation identified in the region . The composite sandy layer is the only usable source of groundwater in the studied region. The thickness of the composite sandy layer was estimated using lithological data and depicted in Figure 8. The figure provides a clear understanding of the presence of water-saturated formations in various regions of the area. The thickness of composite sand ranges from 11.033 meters (on average) to 75 meters. In Figure 8, it is evident that the water table starts from the Fine sand layer. Shallow aquifers exist between the fine and medium sand layers from 12 to 60 meters (estimated) and while aquifers upper depth contained mostly fine sand. Therefore, it can be concluded that the area with a thick bed of composite sand is more conducive to groundwater exploration.

9) Based on Graph 4, Durgapur upazila received the highest total rainfall of approximately 1852mm in 2022. Bagmara Upazila took the second spot with around 1267.91 mm of rainfall, while Godagari Upazila followed with 1176 mm, and Puthia upazila received a good amount of rainfall of about 1154 mm in 2022. In Charghat upazila 2022, the lowest rainfall recorded was approximately 365mm.The average rainfall recorded in Rajshahi district in the year 2022 was 1008.025 mm.

10) As of 2022, the phreatic surface depth in Rajshahi City Corporation has reached 10.065 m. Only a small portion of land, measuring 38 ha, is used for Boro rice production within the city. Rajshahi City Corporation received a rainfall of 1016.4mm in the same year. In Rajshahi city corporation, most people rely on groundwater for their household needs. The amount of groundwater used for crop irrigation is significantly lower in Rajshahi City Corporation. The Rajshahi Water Supply and Sewerage Authority (RWASA) has been the main water supplier for the city corporation since 2010.Currently, the water demand of 1,13,290 m3/day is met by 106 deep tube wells that produce 95,000 m3 of water per day. The water is supplied through a pipeline network of 712.5 km for 12 hours a day, meeting about 84% of the total demand.

4. CONCLUSIONS AND RECOMMENDATIONS

From our study we've found that Godagari, Tanore and Mohanpur upazila has the highest depth to phreatic surface in 2022, As well as the highest rate of Boro Rice production. In Bagmara upazila the depth to phreatic surface is quite good but the Boro rice production rate is highest in 2022. If it continues like this , same kind of result will found in Bagmara upazila after few years. The highest thickness of clay layer found in Godagari upazila, second highest thickness found in Tanore upazila and Mohanpur upazila comes third. As a result the groundwater recharge rate is also very low in these upazilas. The average rainfall is also very low in Rajshahi district. If this situation does not change, desertification will start in Rajshahi district very soon

Satellite imagery and historical records show that major rivers in the area have migrated from the Barind tract over the past few hundred years, causing significant changes in hydrodynamics. As a result, groundwater irrigation has increased, leading to farmers withdrawing excess water, causing the water table to decline. The Farakka barrage also contributes to this decline. The aquifer system is confined and inhomogeneous, with no vertical recharge through clay beds. Recharge occurs through sandy strata in river beds, which flood during the Monsoon season. Annual rainfall is decreasing and overall temperature is increasing, leading to a water scarcity zone. The environment has changed significantly due to population growth, landform modification, cropping patterns, and deforestation. These observations could be considered for better urbanization, land use, groundwater use, and policy, law, and governance. Boro rice is the most inefficient crop, consuming a large amount of water and causing overexploitation. (Rashid et al, 2013)

It is concerning to note that in the Rajshahi district, the water table is decreasing every year, making it impossible to raise the groundwater level to its previous level. A recent study conducted by the Institute of Water Modelling (IWM) on behalf of the Water Resource Planning Organization (WARPO) found that the

situation is getting worse due to climate change and the scope of water crisis areas is expanding. Godagari and Tanore upazila have identified as very high water crisis areas in Rajshahi district.

We've some recommendations :

1) **Use of surface water to reduce pressure on groundwater for irrigation purposes:**
   Compared to other regions of the nation, the Barind area receives substantially less rainfall. Its volume has significantly decreased in the last several years. Rainfall is not occurring as frequently as it used to. Due to a lack of comprehensive changes, rivers and streams have lost their ability to store water, making agriculture increasingly dependent on groundwater. Consequently, the groundwater table is gradually decreasing. To address this issue, BMDA has recently made significant strides in surface water irrigation.

2) **Installation of rubber dams in rivers:**
   An efficient way to adapt to climate change is to build rubber dams on small rivers to store groundwater and utilize it for irrigation and other non-agricultural uses. Rubber dam construction has already begun on the Barnai River in Puthia Upazila; the dams are scheduled to be put into service by June of the 2016 fiscal year, according to the BMDA. With this method, 8000 hectares of land may be permanently irrigated by putting 200 irrigation units along a 30-kilometer stretch and 20 canals next to the river.

3) **Removal of waterlogging:**
   Large reservoirs that once held a lot of water have lost that capacity in various parts of the Barind region owing to a lengthy period of neglect. 3000 hectares of land that were prone to flooding during the rainy season have been freed from it under this approach, and by irrigating the land throughout the Rabi season, agricultural productivity has increased. Large reservoirs in the Barind area that originally stored large amounts of water have lost capacity as a result of long-term neglect. With this strategy, 3000 hectares of land that were vulnerable to floods during the rainy season have been liberated from it, and agricultural output has grown as a result of the land being irrigated throughout the Rabi season.
4) **Crop diversification:**
   The cultivation of Boro rice uses a lot of water. To alleviate the strain on groundwater for irrigation, measures have been implemented to educate and inspire farmers to grow more lucrative crops (such as wheat, potatoes, mustard, and pulses) while utilizing less irrigation water by diversifying their crop portfolio and avoiding Boro rice. The growing acceptance of this training and reward scheme among farmers has led to a steady increase in the production of other crops as well as Boro rice. Alternate wetness and drying (AWD) irrigation techniques are being taught to farmers in the regions where Boro rice is grown. 20% less water is used with this method. Because Boro rice agriculture is declining, efforts have been made to supply and train better types of rice seeds, BRRI-Paddy-48 and BRRI-Paddy-55, to enhance the production of Aush rice. Currently, 3.50 tons of traditional Aush paddy seeds are produced per hectare, whereas 5 tons of BRRI-Rice-48 and BRRI-Paddy-55 rice are produced per hectare.
5) **Production and supply of high quality seeds:**
   The Barind authority not only provides irrigation but also produces and sells to farmers a fair variety of high-quality, high-yielding agricultural seeds, including rice, wheat, gram, maskalai, mustard, and others. The farmers have a great demand for Barind's seeds because of their excellent quality. Consequently, not a single seed generated by the Barind authority is unsold.

ACKNOWLEDGEMENTS

First of all, we would like to thank Allah that he let us finish our work. I would like to thank my honourable supervisor Md. Rashidul Hasan Sir (Professor, USET). I would also like to thank Md. Torikul Islam sir (Executive Engineer, BMDA, Rajshahi), Md. Hanif Shikdar sir (Assistant Engineer, BMDA, Puthia), Md. Iqbal Hossen sir (Executive Engineer, WASA Zone-2, Rajshahi), Md. Azad Ali (SAAO, DAE, Rajshahi) for providing the necessary data. Especially I would like to thank my father Md. Shawkat

Ali (SAAO, DAE, Pabna Sadar) for helping me in my research work. I'm grateful to my university Bangladesh Army University Of Engineering and Technology (BAUET), Barind Multipurpose Development Authority (BMDA), Water Supply and Sewerage Authority, (WASA).

REFERENCES

Ahmed, K. M. (1994). *The hyydrology of the Dupi Tila Sands Aquifer of the Barind Track, NW Bangladesh.* London: ProQuest LLC (2016).

Aziz, M. A., Majumder, M. A., Kabir, M. S., Hossain, M. I., Rahman, N. M., Rahman, F., & Hosen, S. (2015). Groundwater Depletion with Expansion of Irrigation in Barind Tract: A Case Study of Rajshahi District of Bangladesh. *International Journal of Geology, Agriculture and Environmental Sciences*, 1-35.

Bari, Q. S., & Bari, Q. H. (2023). Water supply history of Rajshahi city. *American Institute Of Physics*, 1.

BMDA. (2019, February 24). *Activities Of BMDA.* Retrieved from Barind Multipurpose Development Authority.: https://bmda.gov.bd/site/page/db57511d-2cd1-4ce3-8678-a7d83423b991/-

Carrard, N., Foster, T., & Willetts, J. (2019). Groundwater as a Source of Drinking Water inSoutheast Asia and the Pacific: A Multi-CountryReview of Current Reliance and Resource Concerns. *MDPI*, 1.

Hossain, A. B., Chowdhury, R. M., & Afifah, F. (2016). Groundwater Resource Assessment: in the Context of Bhawaniganj Pourashava. *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, 1-72.

Hossain, M. I., Bari, M. N., Miah, S. U., Kafy, A. -A., & Nasher, N. R. (2021). Application of modified managed aquifer recharge model for groundwatermanagement in drought-prone water-stressed Barind Tract, Bangladesh. *ELSEVIER*, 3-7.

Jani, j. (2012). GIS as a tool for modelling groundwater flow. *Business, Engineering and Industrial Applications (ISBEIA), 2012 IEEE Symposium on* (p. 1). Shah Alam: ResearchGate.

M. Al Mamunul Haque, C. S. (2012). Hydrogeological Condition and Assessment of Groundwater Resource Using Visual Modflow Modeling, Rajshahi City Aquifer, Bangladesh. *Journal of the Geological Society of India*, 79.

Md Ibrahim Adham, C. S. (2010). Study on Groundwater Recharge Potentiality of Barind Tract,Rajshahi District, Bangladesh Using GIS andRemote Sensing Techniqu. *Journal of the Geological Society of India*, 1,2.

Md, M. R., & Mahbub, A. (2012). Groundwater Depletion with Expansion of Irrigation in Barind Tract: A Case Study of Tanore Upazila. *Journal of Water Resource and Protection*, 1.

Mojid, M. A., Mainuddin, M., Parvez, M. F., & Hodgson, G. (2019). Water Table Trend—A Sustainability Status of. *MDPI*, 10,11,12.

Rashid, M. B., Islam, M. B., & Sultan-Ul-Islam, M. (2013). Causes of Acute Water Scarcity in the Barind Tract, Bangladesh. *International Journal of Economic and Environmental Geology*, 10.

Rashid, M. H., Islam2, A. B., Shirazy, B. J., & Shahidullah, S. M. (2017). Cropping Systems and Land Use Pattern in Rajshahi Region. *Bangladesh Rice Journal*, 237-238.

Shamsuzzoha, M., Parvez, A., & A.F.M.K.Chowdhury. (2014). Analysis of Variability in Rainfall Patterns in Greater Rajshahi Division using GIS. *Journal of Environmental Science and Natural Resources* , 148-149.