# A GIS Based Approach to Identify Potential Zones for Natural Groundwater Recharge in the Capital City of Bangladesh

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**Abstract—** Dhaka is one of the world's largest groundwater-dependent cities relies on groundwater from Plio-Pleistocene fluvio-deltaic sands of the Dupi Tila formation is facing severe declination of groundwater table in spite of receiving around 2000mm/year annual rainfall. Unplanned urban development due to rapid population growth has been the cause of encroachment on retention and natural drainage areas. This study attempts to identify the potential zones for natural groundwater recharge within the study area through GIS analysis. Satellite image analysis and GIS mapping reveal that about 27.81% of the city area allows natural recharge at present conditions (2018) which is much lower compared to the heavy abstractions for municipal and industrial supplies. Based on the topography, slope, soil, land use, drainage density and thickness of clay layer, potential zones for natural groundwater recharge have been identified. These remaining potential zones for natural groundwater recharge should be protected for the existence of the mega city.

**Index Terms—** Dupi Tila Formation, GIS, Potential Zones.

## 1 INTRODUCTION

The availability of groundwater is reducing gradually due to over exploitation (Morris BL et al (2003) and Hoque MA et al (2007)), and the lack of groundwater management (Khondaker AH (2006) and Kaliraj S (2014)). As groundwater is the largest available source of fresh water lying beneath the ground and constitutes an important source for various purposes like domestic needs, supply for industries and for agriculture etc. (Raviraj A (2017)), therefore it has now become crucial to target recharge zones for the protection of these zones in order to protect this vital resource for the future. Dhaka city, having a population of more than sixteen million, exclusively depends on groundwater as a source of quality drinking water (Rahman MM (2015)). But this megacity is facing severe groundwater depletion. Over exploitation due to high demands and lack of recharge due to shrinkage of waterbodies and open spaces are the main causes of this depletion. Rapid urbanization has been triggering this problem (Islam M (2018)). Demand is increasing day by day with the gradual reduction of natural recharge zones. An attempt has been made in this study to identify existing potential zones for natural groundwater recharge within Dhaka city corporation. Study findings will be helpful for the planners and decision makers for taking necessary steps to protect these potential zones of groundwater recharge as a safe guard for the Dhaka City Corporation.


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## 2. DETAILS OF THE STUDY AREA

Dhaka is not only capital and largest city of Bangladesh but also one of the most densely populated city in the world. It is

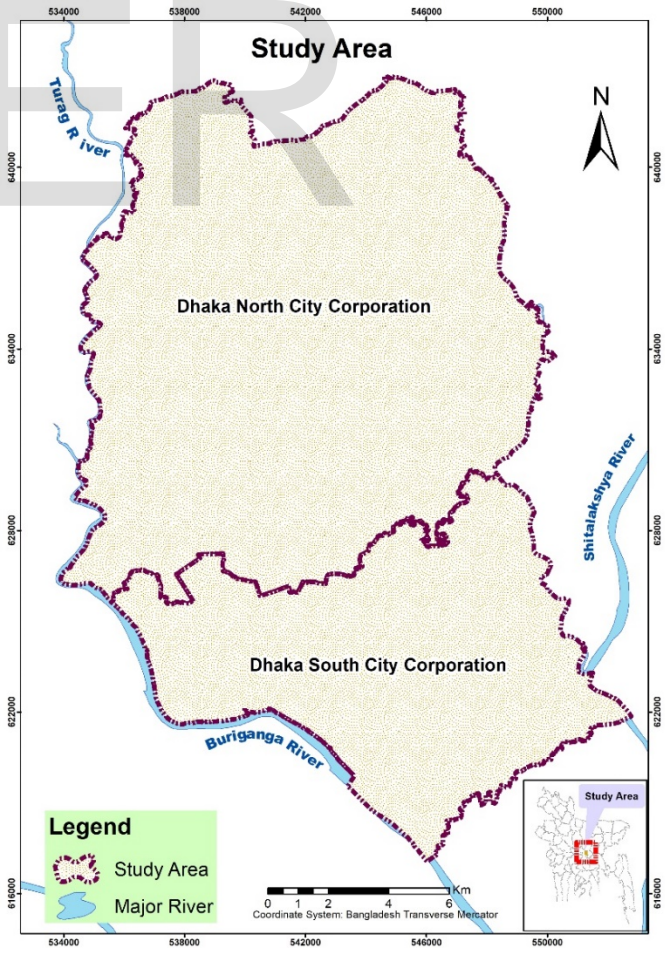


Fig. 1. Study area

situated between latitudes 23°42' and 23°54'N and longitudes 90°20' and 90°28'E which is an economic, political and cultural center of Bangladesh. The area of the study is 306.4 square km. The city is bounded by the rivers Buriganga to the south, Turag to the west, Balu to the east and Tongi Khal to the north. Dhaka experiences about 2,000 mm rain annually, of which about 80% falls during the monsoon. Since the dwellers of this city is greatly dependent on groundwater resources, therefore, identification of potential recharge zones is necessary to improve the groundwater condition of the study area. The location map of the study area is shown in Figure 1.

## 3 METHODOLOGY

The tasks can basically be divided in to the following categories:

- Collection and processing of data of the study area
- Thematic layer preparation
- Assigning weightage
- Identification of potential recharge zones using weighted overlay technique in ArcGIS

### 3.1 Data Collection and Processing

This study involves mapping of different features that influence groundwater recharge in different degrees. Hence the required data to produce thematic maps of Topography, Slope, Soil, Land use, Thickness of Clay Layer and Drainage Density of the study area were obtained from various sources for analyzing and integrating to get the final result.

Soil Map was collected from SRDI, Lithological data were collected from DWASA, Land use Map was collected from RAJUK, Drainage network was collected from IWM, Topography data was collected from USGS Earth Explorer and Slope was generated from topographic data.

These data were used to produce thematic map of the study area using Arc GIS 10.4.

### 3.2 Thematic Layer Preparation

#### Topography

Dhaka city falls in a flat terrain, where elevation of land surface varies from 0.8 to 14.1 m PWD. High elevated area is not suitable for groundwater recharge but depressed area is good for groundwater recharge. Northeast and Southeast parts are more suitable for groundwater recharge in Dhaka city based on topography. Based on topography, the study area was divided in five categories is shown in figure 2 (A).

#### Slope

The slope of an area is an important parameter which determines the groundwater recharge capability. The slope of Dhaka city ranges from 0 to 2.19 (degree). The majority of the study area is under low degree of slope, this plain to gentle slope area characterized by very good category for groundwater recharge due to nearly flat terrain, and slow surface runoff allowing more time for rain water to percolate. The area with a steep slope is considered as poor groundwater recharge areas due to higher slope, higher runoff, and low infiltration. Based on slope, the study area was divided in five categories is shown in figure 2 (B).

#### Thickness of Clay Layer

Thickness of clay layer plays an important role in groundwater recharging. Less thickness of clay layer is suitable for groundwater recharge because it allows water to percolate and boost underneath aquifer. High thickness of clay layer acts as aquitard which impedes groundwater recharge. The value of clay thickness ranges from 3.05 to 41.14 m within this study area. Most of the study area has less thickness of clay layer ranges from 3.05 to 7.08 m which is good for groundwater recharge. Based on clay thickness, the study area was divided in five categories is shown in figure 2 (C).

#### Land use

The study area mostly consists of built-up area, mixed area, water bodies, agricultural land and open spaces. In this study there are some areas where combination of different land use types exists in a small area, they were categorized as mixed area in this study. From the land use point of view, agricultural lands are an excellent site for groundwater potential. Meanwhile built up land is given a low score due to the affected recharge of the groundwater regime by inhibiting precipitation through the aquifers. Because of being the most densely populated city in the world, most of the city falls under built-up area and there are very few open spaces left at present. Based on land use, the study area was divided in five categories is shown in figure 2 (D).

#### Soils

The predominant soil types found in this study area are Urban land, Calcareous dark grey and calcareous brown floodplain soil (grey clay), Grey floodplain soil (Silt, Loam, clay) and Non-calcareous dark grey floodplain soil (dark grey and brown soils). These types of soils are not good for groundwater recharge, because of dominating urban land and floodplain clay. Based of soil type, the study area was divided in four categories is shown in figure 2 (E).

#### Drainage density

Drainage density is an expression of the closeness of spacing channels, thus providing a quantitative measure of length of stream with a square grid of the area in terms of km/km2. Drainage density has less influence in Dhaka city because of thick clay layer beneath the land surface which impedes groundwater recharge. The value of drainage density ranges from 0 to 11.22 km/km2. Based of drainage density, the study area was divided in five categories is shown in figure 2 (F).

### 3.3 Assigning Weightage

Each of the thematic maps has been reclassified and assigned suitable weightage according to multi influencing factor. Groundwater potential recharge zones were identified by overlaying all the thematic maps in terms of weighted overlay methods using the spatial analysis tool in ArcGIS 10.4.

The multiple parameter analysis for delineating groundwater recharge sites in the study area has been done by

Multiple Influencing Factor (MIF) technique. In this study, six spatial parameters such as slope, land use, soil, drainage density, topography and thickness of clay layer are analyzed by MIF approach.

Weight of each factor has been assigned based on their influence in groundwater recharge in the study area. Class which is most suitable for groundwater recharge has been given maximum rank and class which is not suitable for groundwater recharge has been given minimum rank.

Classes of each influencing factors were then assigned ranks with respect to its groundwater recharge potential as shown in Table 1.

Table 1: Weighted factors influencing the recharge zones

| SL. No. | Factors | Classes | Ranking (In no.) | Weightage (%) |
|---|---|---|---|---|
| 1 | Land use classes | Built-up Area | 1 | 25 |
| | | Mixed Area | 2 | |
| | | Open Space | 3 | |
| | | Agricultural Land | 4 | |
| | | Waterbody | 5 | |
| 2 | Topography | 0.80-3.04 | 5 | 15 |
| | | 3.04-4.60 | 4 | |
| | | 4.60-6.36 | 3 | |
| | | 6.36-9.07 | 2 | |
| | | 9.07-14.06 | 1 | |
| 3 | Thickness of Clay Layer | 3.0-5.30 | 5 | 15 |
| | | 5.30-7.10 | 4 | |
| | | 7.10-11.56 | 3 | |
| | | 11.56-21.0 | 2 | |
| | | 21.0-41.1 | 1 | |
| 4 | Slope classes (Degree) | 0-0.10 | 5 | 15 |
| | | 0.10-0.23 | 4 | |
| | | 0.23-0.42 | 3 | |
| | | 0.42-0.74 | 2 | |
| | | 0.74-2.19 | 1 | |
| 5 | Drainage density Classes (km/km2) | 0-0.75 | 1 | 15 |
| | | 0.75-2.03 | 2 | |
| | | 2.03-3.39 | 3 | |
| | | 3.39-5.06 | 4 | |
| | | 5.06-11.23 | 5 | |
| 6 | Soil classes | Urban land | 1 | 15 |
| | | Grey floodplain soil (Silt, Loam, clay) | 2 | |
| | | Calcareous dark grey and calcareous brown floodplain soil (grey clay) | 3 | |
| | | Non-calcareous dark grey floodplain soil (dark grey and brown soils). | 4 | |

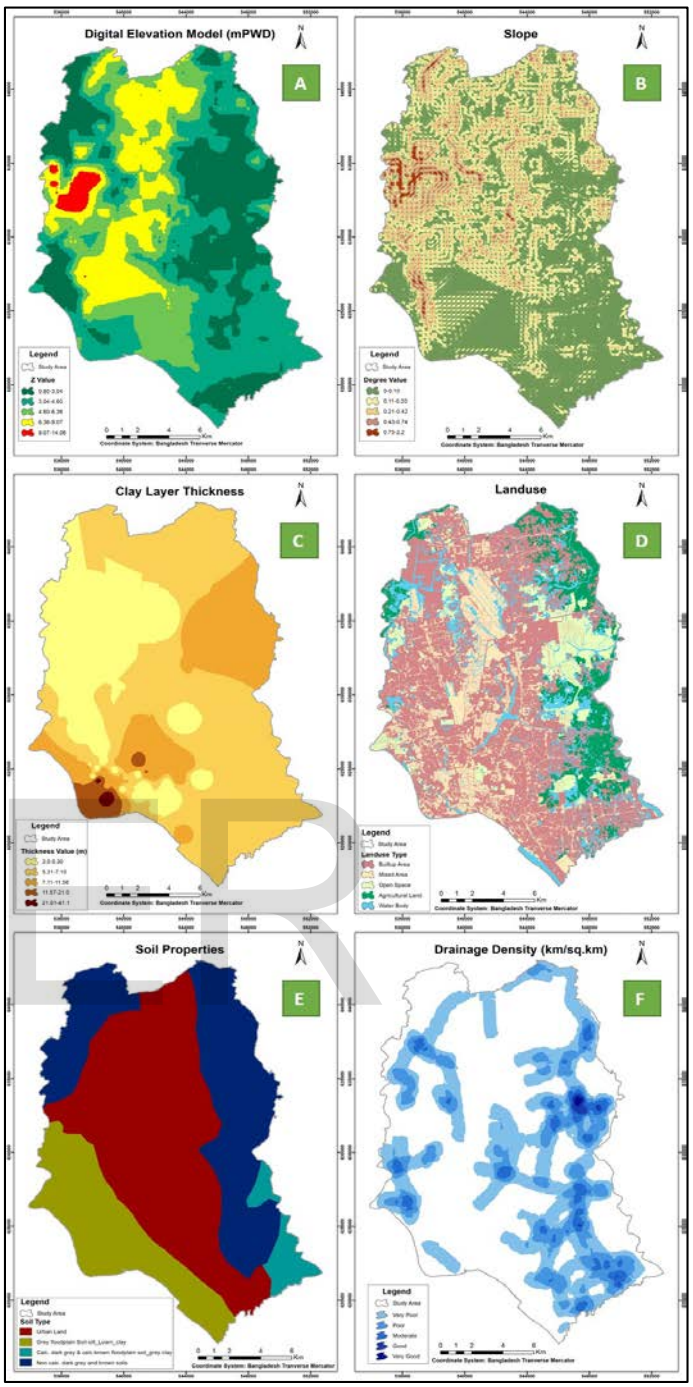


Fig. 2. Thematic Layers

### 3.4 Identification of Potential Recharge Zones

Finally, after successful integration of all the thematic maps, an output raster map was obtained which indicates the potential groundwater recharge zones (Figure.3). Earlier, ranks from 1 to 5 were assigned for individual classes of topography, slope, land use, drainage density and ranks from 1 to 4 were assigned for individual classes of soil type. Based on the influence on water recharge hence the final output raster was generated with 4 classes. Value 1 indicates 'POOR' recharge, 2 indicates 'MODERATE' recharge, 3 indicates 'GOOD' recharge and 4 indicates 'VERY GOOD' recharge areas.

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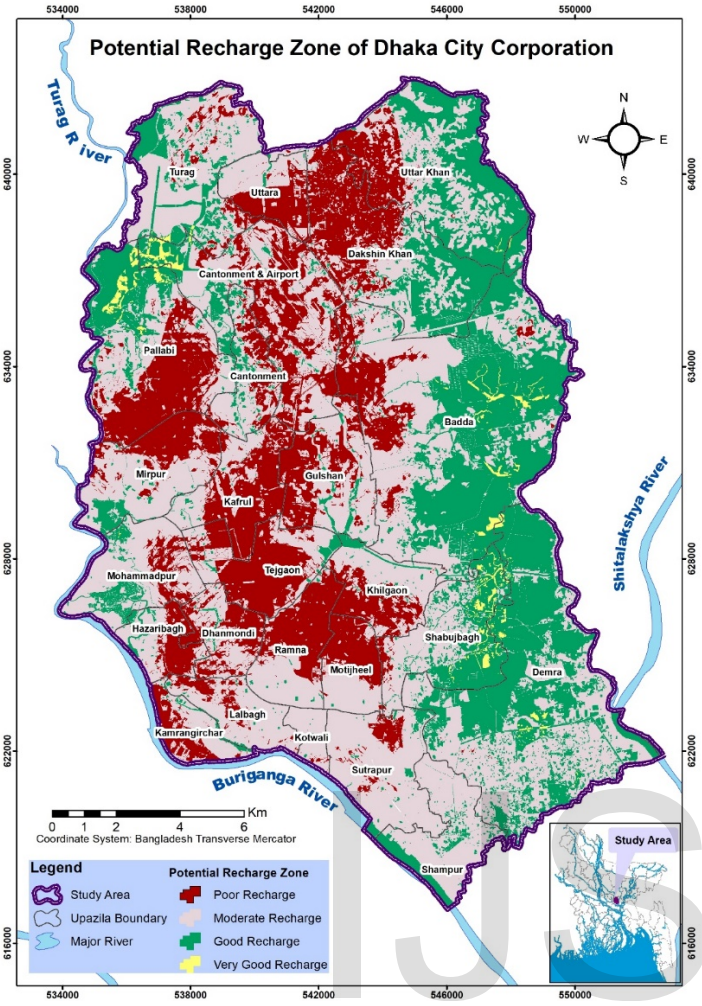


Fig. 3. Potential Zones for Natural Groundwater Recharge

## 4 CONCLUSION

From our study, GOOD (26.87%) and VERY GOOD (0.94%) classes were considered potential zones for natural groundwater recharge in Dhaka city of Bangladesh. Around 27.81% area within the study area is suitable for natural groundwater recharge among which Badda (27.90%), Uttar Khan (23.94%), Pallabi (7.17%), Dakshin Khan (6.35%), Turag (4.20%), Cantonment and Airport (3.28%), Mohammadpur (1.96%), Mirpur (1.21%) Upazilas of Dhaka North City Corporation and Demra (23.94%) and Sobujbagh (6.98%) Upazilas of Dhaka South City Corporation are the major contributing areas. This percentage is very small and alarming too. Potential zones for natural groundwater recharge have been declining day by day. Since this city is greatly dependent on its groundwater resources, therefore protection of these potential zones should be ensured for the protection of the future of this mega city.

## REFERENCES

[1]. Morris BL, Seddique AA, Ahmed KM (2003). Response of the Dupi Tila aquifer to intensive pumping in Dhaka, Bangladesh, Hydrogeology Journal. Vol-11. 496-503 pp.

[2]. Hoque MA, Hoque MM, Ahmed KM (2007). Declining groundwater level and aquifer dewatering in Dhaka metropolitan area, Bangladesh: Causes and quantification, Hydrogeology Journal. Vol-15. 1523-1534 pp.

[3]. Khondaker AH (2006). Water Management in Dhaka, International Journal of Water Resources Development. Vol-22. 291-311 pp.

[4]. Kaliraj S, Chandrasekar N, Magesh NS (2014). Identification of potential groundwater recharge zones in Vaigaiupper basin, Tamil Nadu, using GIS-based analytical hierarchical process (AHP) technique, Arabian Journal of Geosciences. Vol 7. 1385–1401 pp.

[5]. Raviraj A, Kuruppath N, Kannan B (2017). Identification of Potential Groundwater Recharge Zones Using Remote Sensing and Geographical Information System in Amaravathy Basin, Journal of Remote Sensing & GIS 6: 213.

[6]. Rahman MM, Jerin T (2015). Groundwater Depletion in Dhaka City: A Spatio-temporal Analysis, Oriental Geographer, vol. 56, no. 1 & 2, 57-81 pp.

[7]. Islam M (2018). Spatial Disparity of Groundwater Depletion in Dhaka City, 15th International Conference on Environmental Science and Technology Rhodes, Greece.

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