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ORIGINAL ARTICLE

Predicting groundwater recharge potential zones using geospatial technique

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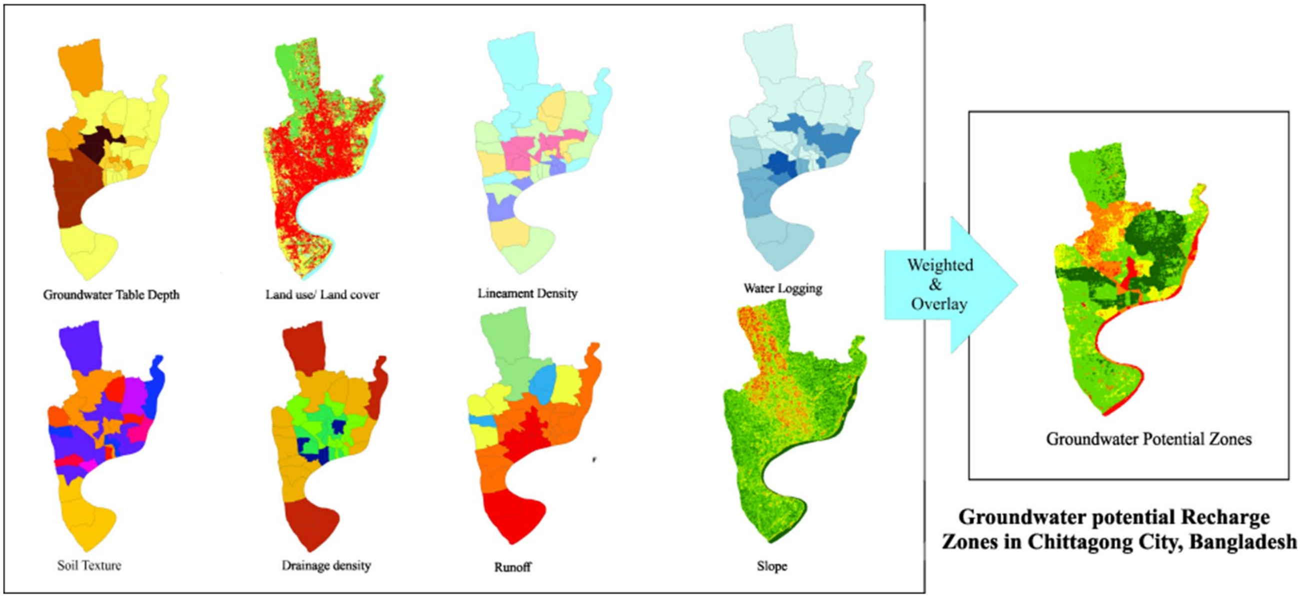
Abstract

Rapid urbanization increases impervious surfaces, thus interrupting natural groundwater recharge, and finally poses serious threat to the city water demands due to groundwater level depletion. In this context, artificial ground water recharge (GWR) using excess rainfall is getting interest among the urban areas. This study selected Chittagong, the second largest and commercial capital city of Bangladesh, is facing issues with groundwater level lowering. Potentialities of GWR were assessed using multi-criteria decision analysis (MCDA) in association with the geospatial techniques. After evaluating primary and secondary datasets, eight thematic layers, i.e., urban storm water logging depth, drainage density, slope, rainfall/runoff, soil texture, existing groundwater level, lineament and land use/land cover, were used to locate the potential areas for GWR. Using reclassification techniques, the thematic layers were individually classified into five categories and assigned a specific normalized weighted value using analytical hierarchy process (AHP) in ArcGIS environment. Then, weighted linear combination method was employed to predict the potential GWR areas. The whole study area was then divided into five categories, viz. low, medium, medium–high, high and very high potential zone. Analysis showed that 5.5% of the total area is highly potential for GWR. In this analysis, expertise knowledge and practical experiences were used to analyze the data and map preparation. Therefore, along with the high-resolution ground data, findings of this paper envisaged to provide useful information to the decision support system.

Graphic abstract



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Keywords Groundwater potential zone (GWPZ) · Groundwater recharge (GWR) · Remote sensing · GIS · Multi-criteria decision analysis (MCDA) · AHP

Background

Groundwater recharge is a part of the basic hydrological cycle, but increased impervious surface often fails to continue with stormwater penetration toward moisture content in aquifer. Thus, due to lower groundwater recharge urban areas are experiencing with groundwater depletion and water scarcity (Chatterjee 2002). Similar experiences are found in Sao Paul, Bengaluru, Beijing, Cairo, Jakarta, Sa'dah, Darab, Jahrom, Estahban, Moscow, Istanbul, Mexico city, London, Tokyo, Cape Town, Punjab, Haryana, Delhi, Rajasthan cities (Al-Sakkaf et al. 1999; Hojjati and Boustani 2010; Wester et al. 2011; Matthew et al. 2015; Shen et al. 2015). Thus, diminishing of the water level of in wells, streams and lakes with low water quality threatens the subsidence and expanding pumping cost (Sophocleous 2002; Wada et al. 2010). On the other hand, due to climate changes rapid urbanization poses 'urban storm waterlogging' around the world, for instance reported cities are from USA, Canada, Europe, Australia, Philippines, Sri Lanka, Japan, China, Nepal, Bangladesh and India (Li 2012; Zhang and Pan 2014; Han et al. 2006; Djordjević et al. 2011; Rahman et al. 2017). Recently, urban storm waterlogging becomes an unavoidable issue in Chittagong city during rainy season for the city dwellers like other parts of Bangladesh (Akter et al. 2017). To overcome water scarcity, natural or artificial groundwater recharge zones (GWRZs) could aid in proper advancement and implementation of water reserves (Rao 2006; Senanayake 2016). Moreover, the main advantages of the GWRZs include adequate utilization of available natural resources, increasing current supply acceptability, reducing contaminated loads of water body, reducing load of sewage network, avoiding soil erosion, reducing risk of flood and drought (Bouwer 2002; Samra et al. 2002; Mitchell et al. 2007; UNEP 2009; Bhattacharya 2010). Rain water harvesting (RWH) linked with the GWRZs could provide sustainable water resource management to improve the environmental condition and increase water management techniques and supply to overcome the issue of water scarcity (Singh et al. 2016). Thus, RWH would contribute on urban storm water logging with reduced runoff and, thus, can be great means to soil conservation.

Slope is the one of the most unavoidable part in both reducing urban storm water logging and increasing ground recharge. Drainage density map applied to determine the high permeable and porosity terrain due to identification of suitable recharge sites (Krishnamurthy et al. 2000; Kumar et al. 2007; Edet et al. 1998; Shaban et al. 2006). Geological discontinuities usually attributed to faults or fracture systems, and those channels groundwater mobilization and contributed toward storage. In this connection, lineament density limits high secondary porosity in a particular area; a buffer zone of 300 m around each lineament offers favorable groundwater recharge zones (Krishnamurthy et al. 2000). To identify best sites for recharge structures, soil properties and coefficient of permeability play vital roles. Permeability is influenced by the particle size distribution, structure of soil mass, shape of particles, void ratio, properties of water, degree of saturation, adsorbed water, impurities in water. Land use/land cover affects surface runoff, infiltration and, thus, on groundwater utilization. Usually, generation, movement and superiority of groundwater influence geological characteristics, structure and lithology. Thus, along with land use/land cover geomorphology also should be considered in groundwater recharging studies. Therefore, predicting the potential zones for artificial recharge includes many interdependent factors, i.e., rainfall, drainage density, lineament density, slope, soil permeability, land use/land cover, geology and geomorphology.

Geographic Information System (GIS) could be effective tools to evaluate the GWRZs and potential RWH sites for RWH structure based on modern science principle and techniques to provide sustainable water management and planning (Jha and Peiffer 2006; Jha et al. 2007; Mwenge-Kahinda et al. 2008; Jasrotia et al. 2009; Jha et al. 2010; Weerasinghe et al. 2011). Most of the relevant studies were based on integration of different parameters using remote sensing (RS) and GIS, viz. lineament density, drainage density, slope, soil permeability, land cover/land use, geology, geomorphology, water logging, ground water table depth, etc. (Sener et al. 2005; Shaban et al. 2006; Solomon and Quiel 2006; Tweed et al. 2007; Yeh et al. 2009; Riad et al. 2011; Krishnamurthy et al. 2000, Madan K. Jha et al. 2010). In order to deal with multi-factors given context, to identify RWH potential sites, recent studies preferred analytic hierarchy approach (AHP) by Saaty (1980) (Jha et al. 2010; Akter and Ahmed 2015; Hamilton 1994; Ghayoumian et al. 2007).

Due to increasing population and decreasing amount of barren land in order to cope with the water demand, implementations of GWRZs might minimize urban storm water loggings as well as water scarcity in Chittagong city. So far, very few studies working on RWH-based GWRZs in Bangladesh and most of the implementation fields are in Dhaka. This study aimed to identify the groundwater potential zone (GWPZ) in Chittagong city using AHP approach.

Overview of study area

This study focused on the Chittagong City Corporation area in Bangladesh of 160.99 sq. m (22° 13′–22° 27′ N and 91° 40′–91° 53′ E) covers total 41 wards (wards is the fourth level administrative division in Bangladesh) and residing about 2.5 million (Fig. 1). As per Bangladesh Meteorological Department (BMD), the annual rainfall volume is 3000 mm and 80% of these experienced during the monsoon (June–September). Compared to 1977, in 2013 urban/built-up area increases from 7.55 to 46.05%, while water bodies decrease from 2.64 to 3.88%. Similarly, land use changes also occurred in vegetation, barren lands as well as in forests. Eighty-eight hills exit within the study area of 18,304.11 acre; thus, about 20% area of Chittagong city having 8–16% slope exists in the middle and north of the study area (BBS 2012). According to the available records, most of the area comprise of clayey soil with a mixture of fine brown sand because of geological and geomorphological factors (BBS 2012). The soils are acidic and occasionally shallow over shale or sandstone bedrocks on the steepest high hills (BBS 2012). In the hard rock plate, lineaments ensure secondary porosity and permeability (Kumar et al.

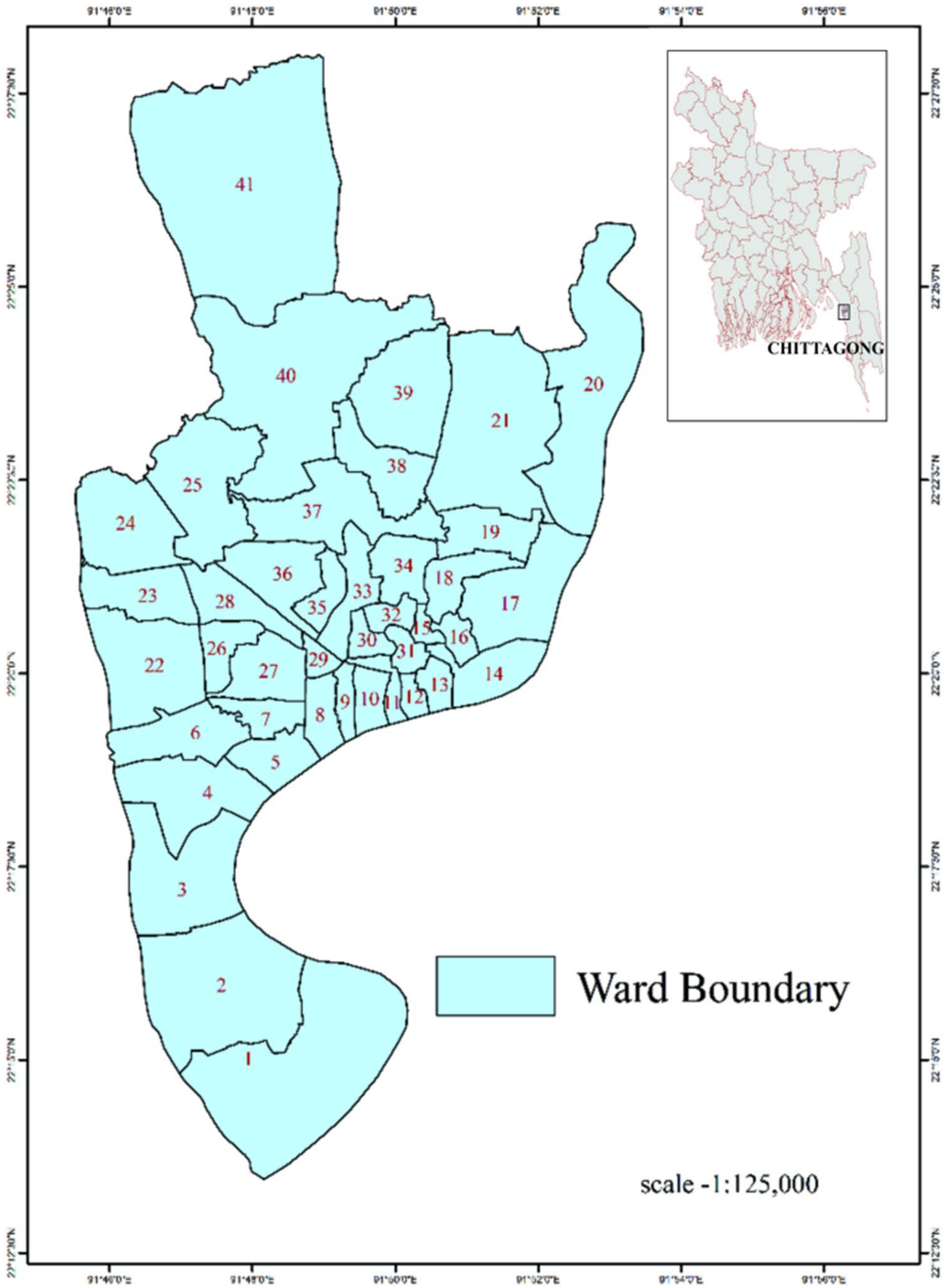

Fig. 1 Location map of study area

2007; Selvam et al. 2015a, b). The groundwater depletion rate was recorded 0.122–7.922 m/year in the studied wells in this city. During monsoon, the Chittagong city dwellers suffer urban storm water logging on an average 13 times per year in the affected areas and in the extreme cases the sufferings extend up to 48 h and cause a massive stagnant water about 0.3–1.27 m (Akter et al. 2017). A case study showed that rooftop RWH potentialities to minimize stagnant runoff up to 26% and the harvested water supply can be done annually up to 20 L/person/day (Akter and Ahmed 2015). This study envisaged that the RWH-based GWRZs could play a vital role in supplementing water supply and reducing water logging problem through maintaining groundwater table in Chittagong city.

Theory and approach

Multiple-criteria decision analysis (MCDA) is the most applicable approach to solve problems that are characterized as a choice among alternatives. AHP-based MCDA described by Saaty (1980) was applied in this study, and the detailed approach is presented in Fig. 2. Based on the primary and secondary data assessments, weights were assigned for the relevant criteria as well as for their associated features on a scale of 1–9 suggested by Saaty (1980), i.e., 1—equal, 2—weak, 3—moderate, 4—moderate plus, 5—strong, 6—strong plus, 7—very strong, 8—super strong, 9—extreme. Thus, assigned weights and pair-wise comparison matrices of the assigned weights in the AHP following Saaty (1980) predicts the GWRZs. Then, these assigned weights were normalized by the eigenvector technique followed by a consistency test using the consistency ratio as:

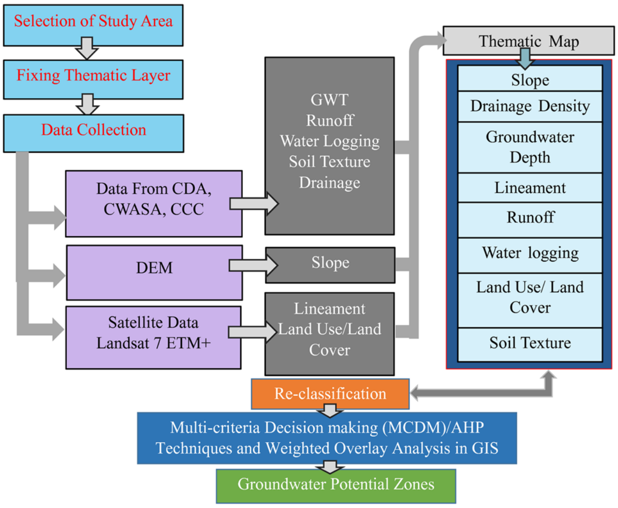

Fig. 2 Methodology flow chart for potential groundwater recharge zone

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \tag{1}$$

where λ = average value of consistency vector and n = number of factors.

Consistency ratio (CR) is a measure of consistency of pair-wise comparison matrix

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{2}$$

where RI is the ratio index which depends on 'n' values (Table 1).

If the CR becomes greater than 10%, then revision is required for the subjective judgment (Saaty 1980, 2004; Dalalah et al. 2010; Agarwal et al. 2013; Kumar et al. 2014).

To obtain GWRZs using the AHP, this study comprises of eight thematic maps. Development of these maps involved RS image processing, existing maps digitization and field data for extraction of relevant information (Fig. 2). Shuttle Radar Topographic Mission (SRTM) Landsat 7 ETM + of USGS provided 30 m DEM to evaluate lineaments; then to calculate lineament density ENVI Classic, Geomatica and ArcGIS10.1 software was used.

Preparation for thematic maps

The relationships among the factors, i.e., lineament, slope, groundwater depth, rainfall/runoff, urban storm water logging, land use/land cover, soil texture and drainage density, were weighted according to their response for groundwater existence. High to low weight showed larger to smaller impact on groundwater potentialities, respectively. Combination of these factors with their relevant weights was computed through weighted overlay analysis in the GIS environment to predict GWRZs. Surface runoff and infiltration rate greatly depend on slope or gradient, i.e., higher slope would generate a higher runoff and lower recharge. Slopes ranged from 1 to 37%, as per IMSD guidelines (NRSA 1995) categorized into five classes, i.e., 0–1.0% (nearly level), 1.01–4.00% (very gently sloping), 4.01–8.00% (gently sloping), 8.01–16.00% (steep), and > 16% (moderately steep) (Fig. 3a). Slope class with higher value was assigned lower

Table 1 Saaty's ratio index for different values of n

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.89	1.12	1.24	1.32	1.41	1.45	1.49

rank to secure runoff for possible groundwater recharge following Jhariya et al. (2016). Denser drainage network usually contributes less recharge rate; required drainage dataset was acquired from topographic maps, field records and satellite images. Then, the drainage densities were calculated per grid square following Murthy (2000):

$$\text{Drainage density} = \frac{\text{LWS}}{\text{AWS}} \tag{3}$$

where LWS = total stream length in the watershed and AWS = watershed area.

Thus, the obtained drainage density ranging from 0 to 51.5 km/km^2, reclassified into five categories, i.e., drainage density of (i) very low: < 2.00 km/km^2, (ii) low 2.01–10.00 km/km^2, (iii) moderate 10.01–20.00 km/km^2, (iv) high 20.01–30.00 km/km^2 and (v) very high 30.01–51.5 km/km^2 (Fig. 3b). Low drainage densities indicated high permeable surface stream frequency of the area compared to the high drainage density, i.e., impermeable ground surface/rock formation. With respect to the groundwater occurrences, the higher drainage density is related to less infiltration of water to the ground and produce higher runoff.

The ground water table was collected from Chittagong Water Supply and Sewerage Authority (CWASA), the static water level was obtained by subtracting the elevation of water depth of different tube well in 2016, and the groundwater depth map was prepared. Then, the obtained depth of water level ranged between 18.28 and 134.11 m and the study area has been categorized into five classes, i.e., 18.28–28.34 m as very shallow groundwater table, 28.35–45.23 m as shallow groundwater table, 45.24–64.00 m as moderate groundwater table, 64.01–99.09 m as deep groundwater table and > 99.10 m as very deep groundwater table (Fig. 3c). Wells with deeper water levels during dry season indicated at considerable water extraction, in this study this location identified as a favorable site for recharge. Thus, high score value was given for deeper water level following Duraiswami et al. (2009). Lower groundwater table was observed in the Ward #3, #4, #5, #6, #7, #8, # 22, #26, #27, #28, #29, #35, #36, #37 with a depth range of 134.11–99.07 m, and moderate groundwater table depth range of 64.02–99.06 m was recorded in the Ward #16, #23, #24, #25, #32 and #41 (Fig. 3c). Lineament-length density was obtained by the total length of all recorded lineaments per area under this study following Greenbaum (1985).

$$\text{Lineament density} = \sum_{n=1}^{i} L_i / A\left(\mathrm{m}^{-1}\right) \tag{4}$$

where $\sum_{n=1}^{i} L_i$ is the total length of lineaments (L) and A is the unit area (L^2).

Lineaments were extracted and then getting lineament density map by ArcGIS 10.1. Groundwater potential is high near lineament intersection zones. The lineament density in the study area is categorized into five classes, i.e., < 0.430 km\km^2 as very low density, 0.431–0.844 km\km^2 as low density, 0.845–1.30 km\km^2 as moderate density, 1.31–1.90 km\km^2 as high density and > 1.91 km\km^2 as very high density (Fig. 3).

Excess rainfall or runoff of the study area was estimated from precipitation records for the Patenga station using Hydrologic Engineering Center–Hydrologic Modeling System (HEC–HMS) v4.0 model, and the relevant input data for all 41 wards were processed using Geospatial Hydrologic Modeling Extension (HEC-GeoHMS) v 5.0. The details on the model setup can be found in Akter and Ahmed (2015). After validation, the model estimated spatial distribution of annual runoff ranging from 3.34 to 3.58 m in the study area. Then, this depth is categorized into five classes, i.e., 3.34–3.38 m, 3.381–3.43 m, 3.431–3.51 m, 3.511–3.55 m and 3.56–3.58 m (Fig. 3e). During the wet period, this city experiences urban storm water logging as well as some parts usually inundated due to tidal effect. The details on urban storm water logged locations and the amounts were obtained from Akter et al. (2017) along with the primary data. For weighted average, a minimum value (0.01 m) was used for less vulnerable areas. The urban storm water logging depth varies between 0.01 and 1.828 m, and the study area is categorized into five classes, i.e., > 0.01 m, 0.011–0.3088 m, 0.3089–0.6096 m, 0.6097–1.2192 m and 1.2193–1.828 m (Fig. 3f). Land use/land cover maps were prepared from RS data using supervised classification under ERDAS IMAGINE software with field verification. The whole area was characterized into barren land, buildup area, vegetation and water body (Fig. 3g). Water bodies are continuous and excellent source of groundwater recharge. Therefore, water bodies were assigned highest weight for groundwater potential. The agricultural fields with sufficient vegetation cover promote the infiltration rate and prevent excess runoff and, therefore, are assigned high rank for groundwater prospecting. The infiltration rate is proportional to the direct vegetation density, i.e., with dense forest, the penetration will be even greater and the flow will be less. Therefore, barren lands and built-up areas were assigned with medium weightage and very low weightage, respectively. An average value of 5-m-depth soil texture was taken from the numerous boreholes of the specific ward as well as was collected from BBS (2012). The soil texture of study area reveals ten soil texture categories (Fig. 3h); soil ranking was done based on their infiltration rate, i.e., sandy soil with high infiltration rate assigned higher priority compared to less priority for the clayey. The main purpose of artificial recharge is to harvest maximum quantity of water according to the availability. The maximum water availability for recharge is expected as

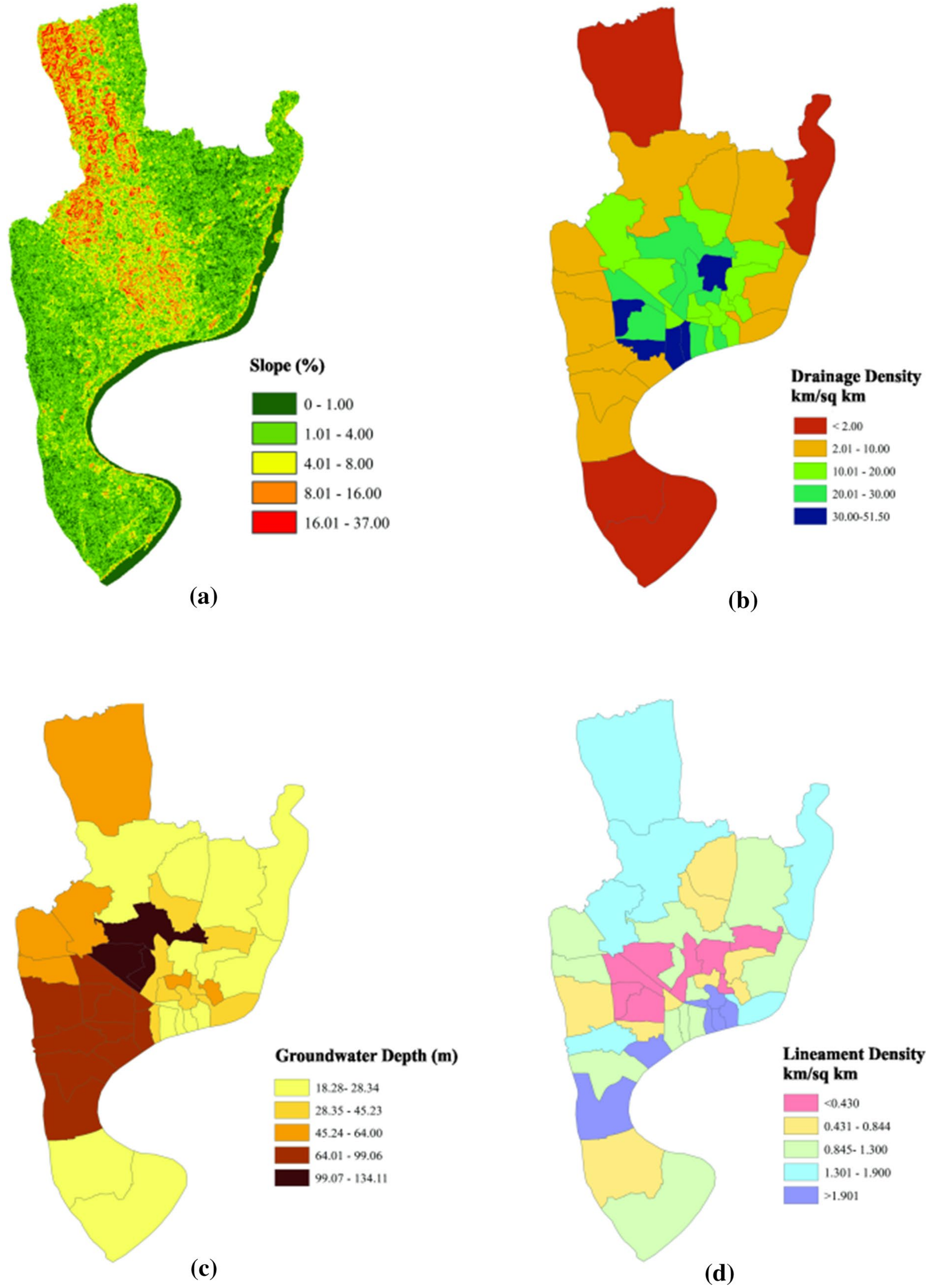

Fig. 3 **a** Slope, **b** drainage density, **c** groundwater table depth, **d** lineament density maps of Chittagong city. **e** Runoff, **f** water logging, **g** LULC, **h** soil texture maps of Chittagong city

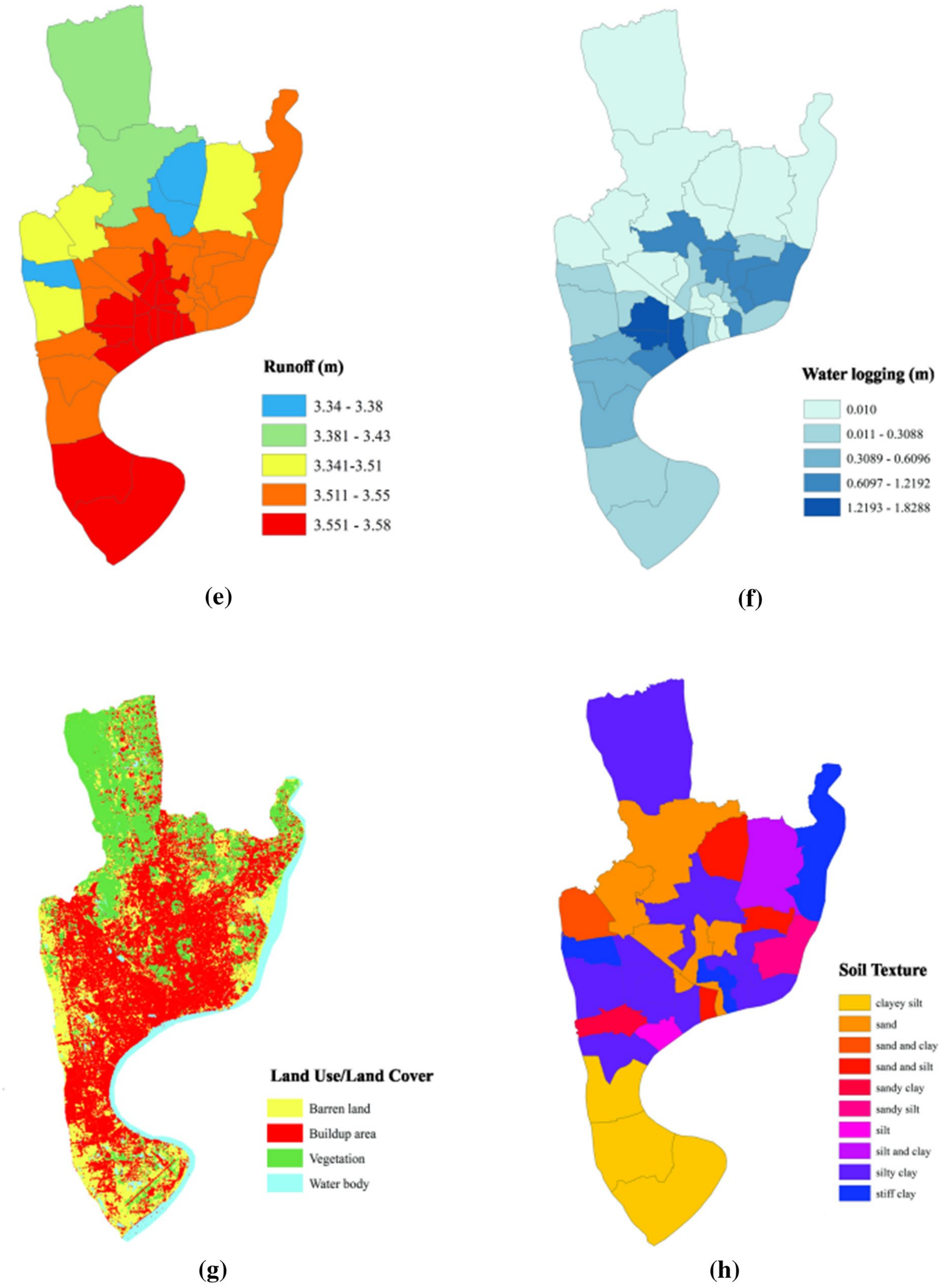

Fig. 3 (continued)

overflown areas; thus, higher surface overflow was assigned higher scores.

Reclassification

In connection to the thematic map preparation, in the former stage various criteria were set to analysis, i.e., runoff/rainfall, drainage density, slope, groundwater table depth, lineament,

Table 2 Relative weight of various thematic layers and their corresponding classes

Influencing factor	Category	Potentiality for GWR	Rating	Normalized weight
Slope (%)	0–1	Very high	5	0.043
	1.01–4	High	4	
	4.01–8	Moderate	3	
	8.01–16	Low	2	
	16.01–37	Very low	1	
Drainage density (km/km^2)	< 2	Very high	5	0.054
	2.01–10	High	4	
	9.99–20	Moderate	3	
	19.99–30	Low	2	
	30.1–51.5	Very low	1	
Groundwater depth (m)	134.1–99.07	Very deep	5	0.062
	99.06–64.01	Deep	4	
	64–5.24	Intermediate	3	
	45.23-28.35	Shallow	2	
Lineament density (km/km^2)	1.9 <	Very high	5	0.07
	1.9–1.31	High	4	
	1.3–0.845	Moderate	3	
	0.844–0.43	Poor	2	
	< 0.43	Very poor	1	
Runoff depth (m)	3.55–3.51	Very very high	5	0.097
	3.51–3.43	Very high	5	
	3.43–3.38	High	4	
	3.38–3.34	Moderate very high	3	
Water logging (m)	1.83–1.22	Very high	5	0.115
	1.219–0.06097	High	4	
	0.6096–0.3089	Moderate	3	
	0.308–0.11	Low	2	
	0.10–0.01	Very low	1	
Land use and land cover	Water body	Very high	5	0.196
	Vegetation	High	4	
	Barren land	Moderate	3	
	Buildup area	Very low	1	
Soil texture	Sand	Very high	5	0.363
	Sand and clay	Very high	5	
	Silt	High	4	
	Sand and silt	High	4	
	sandy silt	Moderate	3	
	Clayey silt	Moderate	3	
	Sandy clay	Low	2	
	Silt and clay	Low	2	
	Silty clay	Very low	1	
	Stiff clay	Very low	1	

land use/land cover, soil texture and water logging (stagnant water). The runoff coefficients were acquired from the ratio of HEC-HMS simulated annual runoff and the annual rainfall. Slope calculation was discussed in the previous subsection. Then, the drainage density and lineament density were taken as the total length of the drains and the lineament, respectively, at each basin divided by the respective basin area, i.e., using Eqs. 2 and 3. Groundwater table depth was obtained from the secondary source as described earlier. Soil texture of the study area was collected from both secondary and primary sources. Land use/land cover map was prepared from RS data (satellite images) using supervised classification in ERDAS IMAGINE software with field verification. For each criteria, ratings of 1–5 were adopted where rates 1, 2, 3, 4 and 5 represent very low, low, medium, high and very high groundwater storage potential, respectively (Table 2).

Application of AHP

To determine the relative criteria weight, class-wise weight of each thematic layer was assigned using AHP (Table 3). The determined weights were 0.196, 0.054, 0.043, 0.097, 0.363, 0.062, 0.115 and 0.07, respectively, for land use/land cover, drainage density, slope, runoff, soil texture, groundwater depth, water logging and lineament (Table 3). The groundwater potential was evaluated by the weighted linear combination (WLC) of these weights.

On the basis of weighting of the different thematic layers and theirs individual features, a potential groundwater zone map was produced (Fig. 4). The potential groundwater zone of the study area revealed five distinct zones, i.e., very high, high, medium–high, medium and low zones. The distribution and extents of different potential groundwater zones are found as 9.44 km^2 (5.5%), 27.43 km^2 (15.98%), 18.01 km^2 (10.5%), 81.9 km^2 (47.7%), and 34.9 km^2 (20.32%) for very high, high, moderate, low and very low zone, respectively (Table 4).

Predicted groundwater potential zones

In this study area, prediction showed that Bagmoniram (Ward #15), Pahartali (Ward #13), North Pahartali (Ward #09), Jalalabad (Ward #02), South Potenga (Ward #40), North Patenga (Ward #41), North Pathantooly (Ward #23), and Gosail Danga (Ward #36) are higher potentials for GWR and South-Middle Halishahar (Ward #38), North-Middle Halishahar (Ward #37), South Halishahar (Ward #39), Alkaran (Ward #31), North-Agrabad (Ward #24), Mohra (Ward #05), Lalkhan Bazaar (Ward #14), Patharghata (Ward #34), North-Agrabad (Ward #24), East Sholashahar (Ward #06), Jamal Khan (Ward #21), Rampur (Ward #25), North Halishahar (Ward #26), Anderkilla (Ward #32), Boxirhat (Ward #35) showed moderate potential for GWR. GWRZs were prepared by the influence factors based on RS, GIS, geospatial techniques and MCDA that increase the recharge potentiality.

In order to locate the preferable location for RWH structure in the GWPZs (Fig. 4) analysis was required. The main purpose of RWH structure helps to identify the recharge process for low moderate zones, and this zone would be preferable for recharge structure as this zone fails to recharge naturally (Fig. 4). According to Fig. 4, Ward #7, #8, #10, #15, #16, #18, #19, #21, #23, #26, #28, #30, #31, #32, #38, and #39 are very low potential recharge zones and highly suitable for recharge structure like rooftop RWH and GWR. Then, Ward #1, #2, #3, #4, #6, #9, #13, #17, #20, #22, #27, #35, #37, and #41 are low potential recharge zones and suitable for recharge structure. Also, Ward #5, #14, #24, #34, #40 are moderate potential recharge zone and fairly suitable for recharge structure. The proposed structures are recharge pit, recharge trench, recharge well and rooftop RWH. For Chittagong city, recharge trench with baffle wall or road side RWH system might be a great choice for the service providers. However, proper implementation could minimize water logging problem and ensure safe road from inundation. This is assumed that the future sewer system of the Chittagong

Table 3 Determining the relative criterion weights

Thematic layers	T1	T2	T3	T4	T5	T6	T7	T8	Weight	Consistency ratio
T1	1	2	3	4	5	6	7	8	0.048	1%
T2	0.5	1	1.5	2	2.5	3	3.5	4	0.054	1%
T3	0.33	0.67	1	1.33	1.67	2	2.33	2.67	0.062	1%
T4	0.25	0.5	0.75	1	1.25	1.5	1.75	2	0.07	1%
T5	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	0.097	1%
T6	0.17	0.33	0.5	0.67	0.83	1	1.17	1.33	0.115	1%
T7	0.14	0.29	0.43	0.57	0.71	0.86	1	1.14	0.196	1%
T8	0.13	0.25	0.38	0.5	0.63	0.75	0.88	1	0.363	1%

Here, T1 = slope, T2 = drainage density, T3 = groundwater table depth, T4 = lineament, T5 = runoff, T6 = water logging, T7 = land use land cover, T8 = soil texture

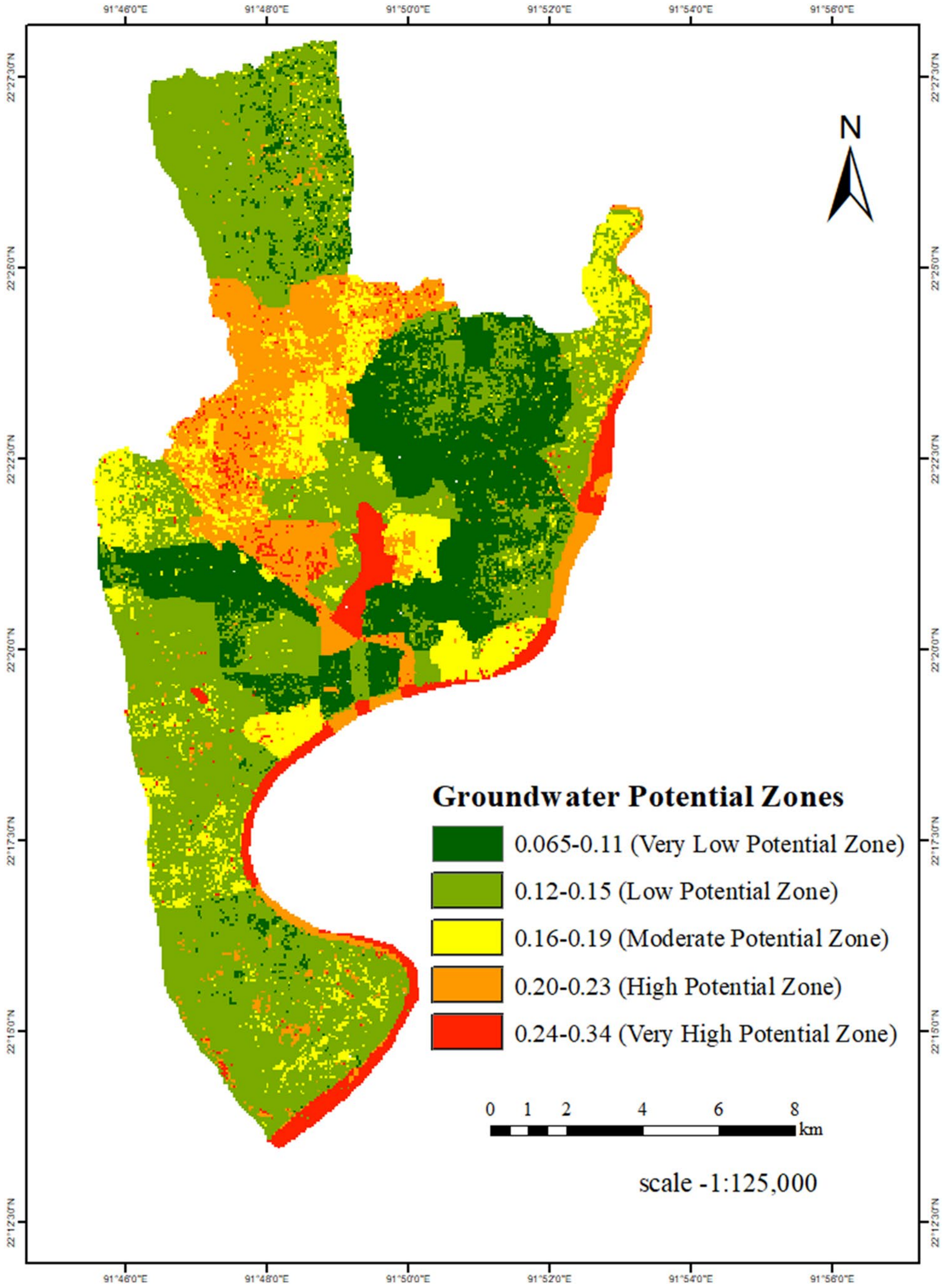

Fig. 4 Groundwater potential zones in Chittagong city

city will be separated in order to implement the road side GWR system. On the other hand, rooftop RWH can conserve rainwater for either potable use or for recharge of groundwater. This approach requires connecting the outlet pipe from a guttered rooftop to divert rainwater to either existing wells or other recharge structures or to storage tanks. To avoid polluting the rainwater, drainpipes, roof surfaces, and storage tanks should be made of chemically inactive materials such as plastic, aluminum, galvanized iron, or fiber glass. Where the water is used for direct consumption, the initial water from a rainstorm is often flushed out in order to get rid of the accumulated dirt from the collection area and gutters. Advantages of collecting and storing rainwater in urban areas include an increase in water supply as well as a decrease in the amount of urban runoff and consequent flooding, drainage congestion, or water logging.

Conclusions

To predict GWPZs in Chittagong city an AHP-based MCDM using RS and GIS was intensively applied. A pragmatic technique was utilized that combines progress of thematic layers, deriving the weights utilizing AHP and

Table 4 Groundwater potential zone

Groundwater Potential Zone Class	Area (km^2)	Area in percent
Low	34.89	20.32
Medium	81.90	47.7
Medium–high	18.01	10.49
High	27.43	15.98
Very high	9.44	5.5

overlay examination to discover groundwater potential zone. Remotely perceived satellite picture evidence and digitization of existing maps operating GIS were applied for the development these thematic layers. Rapid urbanization in the Chittagong city threatened to the groundwater storage and at the same time sufferings due to urban storm water logging. By applying multi-criteria choice strategy, in this study an intensive groundwater reestablish zones were identified and possibilities to recharge stagnant water or abundance extent of flow. In this study, application of RS and GIS could reasonably offer the GWPZs for recharging. Thus, this is envisaged with high-resolution ground data which could enrich this model setup for providing detailed information to the decision support system.

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