Modeling groundwater potential zones of Puruliya district, West Bengal, India using remote sensing and GIS techniques

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1. Introduction

Water is an important part of our day-to-day life. Human civilization depends heavily upon the water. Although more than 70% of the earth’s surface is covered with water, we can only use merely 1% of the total water. Almost 97% of the total water is saline by nature and rest of the 3% remains as freshwater. Most of the freshwater is stored as ice in glaciers and polar ice sheets. Almost 30% of total freshwater is stored in aquifers as groundwater and less than 1% is available at lakes and rivers (Chow, Maidment, & Mays, 1988). There is a tremendous pressure on freshwater resources all over the world, especially in the developing countries. In India, demand for water is growing at an alarming rate (Black & Talbot, 2005; Holden, 2014). India is heavily dependent on groundwater for various purposes. Groundwater provides 80–90% of domestic water supply in rural areas. A total of 50% of urban and industrial demand is also dependent on groundwater. It also provides water for more than 50% of the irrigated area (Central Ground Water Board, 2014).

Groundwater is used heavily for various purposes as it can be accessed more cheaply and easily. Groundwater level is declining due to excessive groundwater extraction. The amount of groundwater is decreasing day by day. There will be a severe freshwater crisis within next 10–15 years in most of the countries (Barlow & Clarke, 2002). The exploitation of groundwater has taken place at a speed which does not allow the water table to recover its losses. Recharge process is inadequate in comparison of the rate of extraction. As a result of this, shallow aquifers are drying up and drought-like situation is happening over large parts of the country during pre-monsoon season.

Identification of groundwater potential zones is very important for the optimum utilization and conservation of this precious resource (Hutti & Nijagunappa, 2011). Test drilling and stratigraphy analysis are the conventional and reliable methods for determining the location of aquifers, but this method is very costly and time-consuming. Remote sensing and geographic information system (RS-GIS) technologies have emerged as an important tool for mapping the groundwater resources (Jha, Chowdhury, Chowdary, & Peiffer, 2007). Several factors such as geology, topography, climatic conditions, soil, land use land cover, etc. control the availability of groundwater in an area. Researchers have successfully used RS-GIS techniques to integrate these factors for modeling the groundwater potential zones in hard rocky terrain (Das, 2017; Fashae, Tijani, Talabi, & Adedeji, 2014; Ghosh, Bandyopadhyay, & Jana, 2016; Gupta & Srivastava, 2010; Hutti & Nijagunappa, 2011; Mukherjee, Singh, & Mukherjee, 2012).

ABSTRACT

Remote sensing and geographical information system (RS-GIS) have become a leading tool for modeling and mapping of groundwater resources. An attempt has been made to delineate the groundwater potential zones of Puruliya district using the integrated RS-GIS and AHP techniques. All the themes and their features have been assigned weights according to their relative importance and their normalized weights were calculated after the hierarchical ranking by pair-wise comparison matrix of analytical hierarchy process (AHP). Groundwater potential map has been prepared through weighted overlay model in GIS environment after integrating all the thematic layers. The entire district has been classified into three different groundwater potential zones—high, moderate, and low. Greater portion of the study area (60.92%) fall within the moderate potentiality zone, about 22.55% and 16.53% of the total area fall under the high and low potential zone, respectively. Potential zones have been validated with the groundwater yield data, 10 out of 14 validation points (71.43%), matches with the expected yield classes. It shows that the applied method produces significantly reliable results for the present study which can help the decision makers to formulate an effective plan for the study area.
Integrated RS-GIS technique has been applied successfully for demarcating groundwater prospect zones in different watersheds as well as in administrative units (Choudhari, Nigam, Singh, & Thakur, 2018; Chowdhury, Jha, Chowdary, & Mal, 2009; Deepa, Venkateswaran, Ayyandurai, Kannan, & Prabhu, 2016; Dey, 2014; Jaiswal, Mukherjee, Krishnamurthy, & Saxena, 2003; Jothibasu & Anbazhagan, 2017; Murugesan, Krishnaraj, Kannusamy, Selvaraj, & Subramanya, 2011; Nagarajan & Singh, 2009; Pothiraj & Rajagopalan, 2013; Prasad, Mondal, Banerjee, Nandakumar, & Singh, 2008; Sar, Khan, Chatterjee, &
Das, 2015). Analytic Hierarchy Process (AHP) of Multi-Criteria Decision Analysis (MCDA) has been successfully applied with RS-GIS technique to assess the groundwater potentiality in various regions (Jha, Chowdary, & Choudhury, 2010; Jhariya, Kumar, Gobinath, Diwan, & Kishore, 2016; Machiwal, Jha, & Mal, 2011; Machiwal, Rangi, & Sharma, 2015; Saha, 2017). RS-GIS and multi influencing factor (MIF) techniques were used for groundwater potential mapping in the rocky terrain of Theni district (Magesh, Chandrasekar, & Soundranayagam, 2012), semi-arid region of Hingoli district (Das, Gupta, & Ghosh, 2017). DRASTIC model was applied for groundwater vulnerability in Katri Watershed (Ghosh, Tiwari, & Das, 2015). RS-GIS technique is also used for mapping of artificial recharge zone in Indian Punjab region (Singh, Panda, Kumar, & Sharma, 2013).

Delineation of groundwater potential zones through proper modeling approach is essential to handle the water scarcity problem of drought-prone region. Very few studies have been done over Puruliya district regarding the water issues. The objective of this study

Table 1. Detailed sources of database.

| Attribute          | Source                                                                 |
|--------------------|------------------------------------------------------------------------|
| Geology            | Geological Survey of India [Scale—1:250,000]                           |
| Lineaments         | Geological Survey of India [Scale—1:250,000]                           |
| Slope              | SRTM DEM, USGS                                                         |
| Rainfall           | Central Ground Water Board, Government of India [Scale—1:1,000,000]   |
| Soil               | National Bureau of Soil Survey & Land Use Planning (NBSS&LUP), Kolkata [Scale—1:1,000,000] |
| Land use land cover| LANDSAT 8, USGS [(Path/Row: 139/44, Acquired date: 2016–03-17, Scene center time: 04:36:59.8277429Z) and (Path/Row: 140/44, Acquired date: 2016–04-25, Scene center time: 04:42:52.2812010Z)] |
| Water table data   | Central Ground Water Board, Government of India                       |
| Yield of the bore wells | West Bengal Accelerated Development of Minor Irrigation Project, Government of West Bengal |

Figure 2. Flowchart of methodology.
is to identify the groundwater potential zones of Puruliya district of West Bengal through RS-GIS and AHP techniques.

2. Study area

Puruliya is the westernmost district of West Bengal. The study area is situated between 22°42’35” N—23°42’00” N and 85°49’25” E—86°54’37” E (Figure 1). It comprises 20 community development blocks (administrative units) with a total area of 6259 km² (Government of West Bengal, 1985). It is quite unique in physical setting. It is underlain by mainly metamorphic rocks. Influence of the Chhotanagpur plateau and Ranchi peneplains can be seen in the entire district. Porosity and permeability are very low in this hard rocky terrain. Impervious crystalline rocks are the main hindrance to the development of proper aquifer system. Groundwater occurs in shallow fractures and weathered mantles and remains in unconfined or semi-confined condition (Government of West Bengal, 1985; Roy, 2014). But it is also found in deep fractures (50–60 m below ground) of hard crystalline rocks. There is a certain limit of its availability due to the physical setting of the district. It is one of the backward districts of West Bengal in terms of economy and human development (Government of West Bengal, 1985). The district is suffering from acute water shortages for a long time and water scarcity is a major issue for the socio-economic development of Puruliya. Surface water bodies dries up every year during the summer season, people depend on groundwater for domestic, irrigation and other various purposes during this time, but excessive use of groundwater has worsened the situation. Therefore, proper evaluation, planning, and management of groundwater are essential for this region.

3. Materials and methods

Various types of data have been used for the present work. Detailed sources of the database are given in

Figure 3. Geology of Puruliya district.
Table 1. ArcGIS 10.1 and ERDAS IMAGINE 2014 software has been used for the representation of the data.

Integrated RS-GIS and AHP techniques have been used to delineate the groundwater potential zone. This method is very useful as it is less expensive and very much suitable for developing countries where adequate and good quality data are lacking for this type of evaluation. The thematic layers of geology, slope, lineament density, land use land cover, soil, rainfall and groundwater fluctuation has been used for the delineation of groundwater potential zones (Figure 2).

Analytical hierarchy process (AHP) is very useful for the multi-parametric evaluation (Saaty, 1980). It has been used to identify the themes with their rank and priority as it helps to arrange the criterions in hierarchical order through pair-wise comparison matrix. Consistency Index and Consistency Ratio have been calculated according to the procedure recommended by Saaty (1980). Decisions regarding the individual theme and class weight have been taken from their ranking through the AHP. AHP technique is the most widely used under multi-criteria decision analysis for natural resource management, site selection, suitability analysis, etc. (Malczewski, 2006; Malczewski & Rinner, 2015). Geologists and hydrologists have been consulted for the individual weights of the themes and their features for proper evaluation. The weights of the themes and their features were assigned on a scale of 1–9 based on their influences. All the themes and their classes with normalized weights were integrated into the weighted overlay model in ArcGIS software to demarcate the groundwater potential zones. Groundwater potential index has been calculated using the following equation (Malczewski, 1999; Rao & Briz-Kishore, 1991):

\[
GWPI = \left( \frac{GE_w \cdot GE_{wi}}{C_{GE_{wi}}} + \frac{SL_w \cdot SL_{wi}}{C_{SL_{wi}}} + \frac{LD_w \cdot LD_{wi}}{C_{LD_{wi}}} + \frac{LU_w \cdot LU_{wi}}{C_{LU_{wi}}} + \frac{ST_w \cdot ST_{wi}}{C_{ST_{wi}}} + \frac{RF_w \cdot RF_{wi}}{C_{RF_{wi}}} + \frac{GF_w \cdot GF_{wi}}{C_{GF_{wi}}} \right)
\]
where, GWPI refers to groundwater potential index, GE stands for geology, SL for slope, LD for lineament density, LU for land use land cover, ST for soil texture, RF for rainfall and GF for groundwater fluctuation, the subscripts w and wi refers to the normalized weight of a theme and normalized weight of individual features of a theme, respectively.

4. Results and discussion

4.1 Preparation of thematic layers

4.1.1. Geology
Geologically Puruliya district is a part of the peninsular shield, which was formed in the Archaean era (Government of West Bengal, 1985). Diverse groups of rocks from various geological ages including Chhotanagpur gneissic complex, meta-sedimentaries of Singhbhum group, intrusive Granites, volcanic rocks of Dalma group and sediments of Gondwana and Quaternary ages are found in the district (Geological Survey of India, 2001).

There are numerous rocks and minerals present in the district. Granite, gneiss, schist, phyllite, quartzite, sandstone, shale, mica, feldspar, china clay are abundant in nature (Geological Survey of India, 2001). The most common rocks are granites and granite gneisses. Intrusive granite is present in large extent throughout the northern and western part, it constitutes about 844.34 km$^2$ or 13.49% of the district. Granite gneiss is present throughout the whole district and it covers 4032.67 km$^2$ or 64.43% of total area. Phyllite and mica-schist are part of Singhbhum group, which is present in the southern part and in some patches over the western and northern part. It covers almost 950.12 km$^2$ or 15.18% of the district. Patches of Dalma lava is present in the form of metamorphosed volcanic rocks and it is scattered in the southern and eastern part. This constitutes about 4.81% or 301.06 km$^2$ of the total area. Sedimentary rocks of Gondwana age like sandstone is...
present in the north-eastern part in a small extent, it covers only 130.81 km$^2$ or 2.09% (Figure 3). Hard rocky terrain creates difficulties in the infiltration process, only the weathered and fractured areas form good potentiality zones for groundwater. Thin strip of alluvium deposits is seen along the stream courses, which could also be good potentiality zone.

4.1.2. Lineament density
Lineaments are linear and curvilinear structural features which play a major role in groundwater occurrences and movements (Prasad et al., 2008; Rao, 2006). In the hard rocky areas like Puruliya, occurrences of groundwater depend on secondary porosity and permeability (Acharya & Nag, 2013). Lineaments like joints and fractures help to infiltrate the surface run-off to subsurface. Lineaments are considered to be good potentials for groundwater.

Lineament density influences the development of groundwater. Lineaments have been collected from the geological map of Puruliya district and lineament density map has been prepared in the ArcGIS software. Lineament density is high (>0.3 km/km$^2$) in western and central parts whereas it is moderate (0.15–0.3 km/km$^2$) in some patches throughout the district. Lineament density is low (<0.15 km/km$^2$) in most of the areas (Figure 4).

4.1.3. Slope
Slope is a major factor which controls the infiltration of surface water into the subsurface. Surface run-off is slow in gentle slope area which allows more time to percolate whereas high slope area allows less infiltration. The general elevation ranges between 150 and 300 m (Government of West Bengal, 1985), major part of the district is characterized by undulating topography. Some residual hills are scattered in different parts of the district.

Slope map has been prepared in the ArcGIS software using the SRTM DEM. The general slope of the district

![Figure 6. Rainfall map of Puruliya district.](image)
is from west to east. Ajodhya and Panchet are the two major hills, which are situated in the western and northern part, respectively. Slope ranges between 2° and 5° for a major part of the district (Figure 5). Steep slope is present in the hilly areas. Low slope is favorable for groundwater recharge whereas high slope of hilly areas is the main hindrance to groundwater recharge.

4.1.4 Rainfall

Dry tropical climate prevails in the district. Average annual rainfall for the district is around 1200–1400 mm (Government of West Bengal, 1985). A total of 80–85% of total rainfall happens during the July–September period, south-west monsoon is the main source of rainfall. Puruliya often suffers drought condition due to shortage of rainfall.

Rainfall map has been collected from the Central Ground Water Board. Southern part of the district receives maximum rainfall, whereas eastern and central part gets minimum rainfall (Figure 6). But this little variation in rainfall has no major influence on the occurrences and availability of groundwater, because most of the water goes away as surface run-off due to the hard rocky terrain.

4.1.5. Soil texture

Infiltration capacity heavily depends on the soil texture. Porosity and permeability are directly influenced by texture. Infiltration capacity of the fine-grained soil is low compared to coarse-grained soil because of porosity and permeability. Soil cover is very thin in this study area and it is composed of sandy and reddish materials which are derived from the weathering of granite and gneiss. Granitic and Lateritic—these are the two major types of soils which have been observed in the district. Soil is acidic in nature and the fertility is low (National Bureau of Soil Survey and Land Use Planning, 2010).

Various types of soil texture are present in the different parts of the district. Fine loamy soil covers 1852.04 km² or 29.59% of the district, gravelly loam—loam constitutes about 1759.4 km² or 28.11%. Fine soil covers almost 1343.81 km² (21.47%) whereas fine

![Soil Texture Map of Puruliya District](image)
loamy to coarse loamy covers about 779.25 km² (12.45%). Gravelly loamy and coarse loamy covers 498.21 km² (7.96%) and 26.29 km² (0.42%), respectively (Figure 7). Porosity and permeability are moderate to high in coarse loamy and gravelly loam soils, but it is much low in case of fine and fine loamy soils.

4.1.6. Land use land cover

Land use land cover is one of the main parameters which influence the occurrence and development of groundwater. Different types of land use act differently in the run-off and infiltration capacities. Forest area is generally favorable for groundwater recharge. Forest cover increases the infiltration rate, whereas fallow land and built-up area increase the run-off. Most of the rivers are non-perennial and flows only in monsoon season.

Land use land cover map has been prepared from a mosaicked Landsat OLI-TIRS imagery. Unsupervised image classification technique was applied to the bands 2, 3, 4, and 5 to obtain major LULC features. A total of 145 sample points were used to check the accuracy of the classification. The overall accuracy and kappa coefficient value of the classification are 96.67 and 95.87, respectively. Majority of land is under the forest cover, deciduous type of forest is present in the district. Agricultural activities depend on the monsoon rainfall, most of the land remains vacant during the non-monsoon season. Irregular and disperse type of rural settlements are found all over the district, but in some parts agglomerated urban settlements are also observed (Figure 8).

4.1.7. Groundwater fluctuation

Groundwater level of pre-monsoon and post-monsoon reflects the actual groundwater condition of the area. Groundwater level data of different observatory wells for the time period of 2012–2015 has been collected from the Central Ground Water Board (CGWB). Locations of groundwater observatory wells are given in Figure 1(c). The mean pre-monsoon groundwater level varies from 3 to 12 m below ground with a majority of the

Figure 8. Land use land cover of Puruliya district.
area having mean pre-monsoon groundwater depth of 5 to 8 m. On the other hand, mean post-monsoon groundwater level varies from 1 to 7 m.

Inverse distance weighted technique is applied in the GIS environment for the interpolation of the groundwater level data. Groundwater level for the pre-

Table 2. Pair-wise comparison matrix for AHP.

| Theme          | Geology | Slope | LULC | Soil texture | Rainfall | Lineament density | GW fluctuation |
|---------------|---------|-------|------|--------------|----------|------------------|---------------|
| Geology       | 1       | 2     | 2    | 2            | 3        | 3                | 4             |
| Slope         | 0.50    | 1     | 2    | 3            | 3        | 3                | 4             |
| LULC          | 0.50    | 0.50  | 1    | 2            | 3        | 3                | 4             |
| Soil texture  | 0.50    | 0.33  | 0.50 | 1            | 3        | 3                | 4             |
| Rainfall      | 0.33    | 0.33  | 0.33 | 0.33         | 1        | 2                | 2             |
| Lineament density | 0.33 | 0.33  | 0.33 | 0.33         | 0.50     | 1                | 3             |
| GW fluctuation| 0.25    | 0.25  | 0.25 | 0.25         | 0.50     | 0.33             | 1             |

Table 3. Priority and rank of themes.

| Theme          | Priority | Rank |
|---------------|----------|------|
| Geology       | 26.5%    | 1    |
| Slope         | 23.4%    | 2    |
| LULC          | 17.6%    | 3    |
| Soil texture  | 14.0%    | 4    |
| Rainfall      | 7.6%     | 5    |
| Lineament density | 6.8% | 6    |
| GW fluctuation| 4.1%     | 7    |

Table 4. Assigned weights of the themes.

| Theme                        | Weight |
|------------------------------|--------|
| Geology                      | 8      |
| Slope                        | 7      |
| Land use land cover          | 6      |
| Soil texture                 | 5      |
| Rainfall                     | 3      |
| Lineament density            | 2      |
| Groundwater fluctuation      | 1      |
monsoon is very low in parts of Manbazar-I, Manbazar-II, Bandowan, Jhalda-I, Jhalda-II, Hura, and Balarampur blocks. It increases in the post-monsoon season and reaches close to the surface in Puruliya-I, Puruliya-II, Neturia, Santuri, Raghunathpur-I, Raghunathpur-II, and Puncha blocks.

Higher groundwater fluctuation indicates excellent recharge capacity and in turn, it reflects the good potentiality zones of groundwater. Fluctuation rate is high in parts of Manbazar-I, Manbazar-II, Bandowan, and Balarampur blocks whereas the rate is low in parts of Puruliya-II, Baghmundi, Jhalda-I, and Para blocks (Figure 9).

4.2 Groundwater potential zoning

Pair-wise comparison matrix (Table 2) has been done according to the AHP technique to identify the priority and rank of the themes (Table 3). Preferences are given in 1–9 scale to each pair of criteria. The pair-wise comparisons are arranged into a matrix: \( C = [C_{kp}]_{n \times n} \), where \( C_{kp} \) is the priority of the pair-wise comparison for the \( k \)th and \( p \)th criteria. It is a reciprocal matrix. Ultimately a vector of criterion weights, \( w = [w_1, w_2, \ldots, w_n] \) are obtained from the pair-wise comparison matrix. The weights are attained from the equation, \( C_w = \lambda_{\text{max}} w \) where \( \lambda_{\text{max}} \) is the largest eigen value of \( C \) (Malczewski & Rinner, 2015; Saaty, 1980). Consistency ratio of the pair-wise comparison matrix is 5.1%, which is below the 10% limit suggested by Saaty (1980).

Individual weights are assigned to the themes according to the hierarchical ranking from AHP analysis. The weights assigned to different themes are presented in Table 4 and the process of obtaining the normalized weight is presented in Table 5.

Priority, rank, and consistency ratio has been calculated for different classes of each theme in the same way as presented in Tables 2 and 3. Consistency ratio for features of geology, slope, LULC, soil texture, rainfall, lineament density, and groundwater fluctuation are 5.2%, 3.4%, 5.4%, 6.6%, 1.9%, 1.9%, and 5.6% respectively. So, consistency ratio for the features of all themes remains under the stipulated 10% limit. The normalized weights of different classes of the themes have

### Table 5. Calculation of normalized theme weight.

| Theme               | Geology | Slope | LULC | Soil texture | Rainfall | Lineament density | GW fluctuation | Geometric mean | Normalized weight |
|---------------------|---------|-------|------|--------------|----------|-------------------|----------------|-----------------|-------------------|
| Geology             | 8/8     | 8/7   | 8/6  | 8/5          | 8/3      | 8/2               | 8/1            | 2.14            | 0.25              |
| Slope               | 7/8     | 7/7   | 7/6  | 7/5          | 7/3      | 7/2               | 7/1            | 1.88            | 0.22              |
| LULC                | 6/8     | 6/7   | 6/6  | 6/5          | 6/3      | 6/2               | 6/1            | 1.61            | 0.19              |
| Soil texture        | 5/8     | 5/7   | 5/6  | 5/5          | 5/3      | 5/2               | 5/1            | 1.34            | 0.16              |
| Rainfall            | 3/8     | 3/7   | 3/6  | 3/5          | 3/3      | 3/2               | 3/1            | 0.81            | 0.09              |
| Lineament density   | 2/8     | 2/7   | 2/6  | 2/5          | 2/3      | 2/2               | 2/1            | 0.54            | 0.06              |
| GW fluctuation      | 1/8     | 1/7   | 1/6  | 1/5          | 1/3      | 1/2               | 1/1            | 0.27            | 0.03              |

### Table 6. Assigned and normalized weight of the different classes of each theme.

| Theme               | Class                        | Assigned weight | Normalized weight |
|---------------------|------------------------------|-----------------|-------------------|
| Geology             | Sandstone                    | 7               | 0.37              |
|                     | Granite gneiss               | 5               | 0.26              |
|                     | Phyllite and mica schist     | 4               | 0.21              |
|                     | Intrusive granite            | 2               | 0.11              |
|                     | Metamorphosed volcanic rocks | 1               | 0.05              |
| Slope               | Low                          | 9               | 0.60              |
|                     | Moderate                     | 5               | 0.33              |
|                     | High                         | 1               | 0.07              |
| LULC                | River and waterbody          | 9               | 0.35              |
|                     | Forest                       | 8               | 0.31              |
|                     | Cultivated land              | 5               | 0.19              |
|                     | Fallow land                  | 3               | 0.11              |
|                     | Built-up area                | 1               | 0.04              |
| Soil Texture        | Gravelly loam                | 9               | 0.31              |
|                     | Gravelly loam—Loam           | 7               | 0.24              |
|                     | Coarse loamy                 | 5               | 0.17              |
|                     | Fine loamy—Coarse loamy      | 4               | 0.14              |
|                     | Fine loamy                   | 3               | 0.10              |
|                     | Fine                         | 1               | 0.04              |
| Rainfall            | High                         | 7               | 0.47              |
|                     | Moderate                     | 5               | 0.33              |
|                     | Low                          | 3               | 0.20              |
| Lineament Density   | High                         | 9               | 0.56              |
|                     | Moderate                     | 5               | 0.31              |
|                     | Low                          | 2               | 0.13              |
| Groundwater Fluctuation | High                      | 8               | 0.53              |
|                     | Moderate                     | 5               | 0.33              |
|                     | Low                          | 2               | 0.14              |
been calculated in a similar manner and it is presented in Table 6.

Normalized class weights are applied to reclassify the classes of each theme and the reclassified thematic layers have been integrated into the GIS environment. Finally, overlay analysis has been done with the normalized theme weights to demarcate the groundwater potential zones in the study area. The final integrated layer has been derived by summing up the weights of polygons from individual layers. Groundwater potential map has been classified into three classes, i.e., "high," "moderate," and "low."

The groundwater potential map of the Puruliya district (Figure 10) reveals that the percentage of moderate potentiality zone is high, which covers almost 3812.98 km² (60.92%) of the district. High potentiality zone is scattered mainly in the northern and eastern part covering 1411.41 km² (22.55%). Low potential zone spreads over the western and southern part, it covers 1034.61 km² (16.53%) of the district. Favorable geological conditions, low slope, forest cover, coarse-grained soil, and presence of lineaments helps in the development of high potentiality zone whereas hindrances of these factors play major role behind low potentiality zone.

4.3 Validation with bore well yield data
Validation is one of the most important criteria in scientific research. Groundwater yield data of 14 bore wells have been collected to validate the groundwater potential zone because rest of the bore wells has no such available records in regard to this. Locations of these bore wells are shown in the groundwater potential map (Figure 10) and the details are given in Table 7. The actual yields are classified into three categories as low (<2 l/second),

Figure 10. Groundwater potential zones.
moderate (2–4 l/second), and high (>4 l/second). This classification is done after the discussion with local hydrogeologists and field knowledge. Accuracy of the groundwater potential zone has been estimated through the similarity analysis (Table 7) and the correlation value (Figure 11). Result of the similarity analysis shows that 10 out of the 14 validation points (71.43%) matches with the expected yield classes and the correlation analysis also confirm this as the $r^2$ value is 0.439.

5. Conclusion

The present study attempts to identify the groundwater potential zones in one of the water-stressed districts of West Bengal. Delineation has been done through weighted overlay model by integrating RS-GIS and AHP techniques. This integrated technique helps to reveal the potentiality of phreatic aquifers through the overlay analysis of various influencing factors. The study reveals that 16.53% of the total area is under the low potential zone, it is mainly due to impervious geological setting and high slope. Major portion of the study area (60.92%) falls under moderate groundwater potentiality zones and rest of the area (22.55%) is under the high potential zone. It is clear that porous geological setting, low slope, permeable soil texture coupled with higher lineament density and vegetative cover helps in the development of the high potential zone. Similarity analysis and $r^2$ value show that the applied method produces significantly reliable results for the present study. The applied approach has merits and can be used elsewhere effectively with suitable modifications. This study can help the concerned decision makers to formulate an effective plan for the study area.

Table 7. Detail account of the validation points.

| Sl. no. | Bore well no. | Latitude | Longitude | Total depth (m) | Static water level (m) | Draw down (m) | Actual yield (liters/second) | Actual yield class | Expected yield class | Similarity between actual and expected class |
|---------|---------------|----------|-----------|----------------|------------------------|--------------|-----------------------------|--------------------|----------------------|--------------------------------------------|
| 1       | 1             | 23°40’55" | 86°49’05" | 31.91          | 5.75                   | 15           | 5.54                        | High               | High                 | Yes                                        |
| 2       | 2             | 23°38’44" | 86°47’04" | 36.44          | 14.32                  | 20           | 3.32                        | High               | High                 | Yes                                        |
| 3       | 3             | 23°30’19" | 86°43’22" | 34.41          | 3.93                   | 18           | 0.33                        | Low                | Low                  | Yes                                        |
| 4       | 4             | 23°33’26" | 86°40’52" | 37             | 5.84                   | 18           | 0.49                        | Low                | Moderate             | No                                         |
| 5       | 5             | 23°34’59" | 86°43’15" | 37.45          | 4.43                   | 24           | 2.77                        | Moderate           | Moderate             | Yes                                        |
| 6       | 6             | 23°33’30" | 86°39’42" | 31             | 6.29                   | 9.1          | 2.77                        | Moderate           | Low                  | No                                         |
| 7       | 7             | 23°36’28" | 86°33’07" | 17.1           | 3.78                   | 13           | 2.21                        | Moderate           | Moderate             | Yes                                        |
| 8       | 8             | 23°35’27" | 86°35’04" | 18             | 4.97                   | 10.1         | 0.97                        | Low                | Moderate             | No                                         |
| 9       | 9             | 23°32’55" | 86°51’11" | 12.87          | 2.79                   | 6            | 0.97                        | Low                | Low                  | Yes                                        |
| 10      | 10            | 23°25’48" | 86°40’10" | 24.61          | 5.65                   | 21           | 0.05                        | Low                | Low                  | Yes                                        |
| 11      | 11            | 23°23’44" | 86°47’54" | 19             | 4.73                   | 10           | 0.33                        | Low                | Low                  | Yes                                        |
| 12      | 12            | 23°04’40" | 86°40’55" | 19.2           | 5.58                   | 8.7          | 6.64                        | High               | High                 | Yes                                        |
| 13      | 13            | 23°05’02" | 86°16’09" | 23             | 3.7                    | 19.1         | 3.21                        | Moderate           | Moderate             | Yes                                        |
| 14      | 14            | 23°29’28" | 86°33’43" | 28             | 4.7                    | 15           | 1.11                        | Low                | Moderate             | No                                         |

Figure 11. Relation between groundwater potential index and actual yield of aquifers.
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Compliance with ethical standards
On behalf of all authors, the corresponding author states that there is no conflict of interest.

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