



# An approach to demarcate groundwater recharge potential zone using geospatial technology

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## Abstract

With the increasing demands for water due to growing population, urban expansion, agricultural development and groundwater resources are gaining much attention, particularly in Gopiballavpur block, Paschim Medinipur district (West Bengal, India). Present study used cohesive approach of remote sensing and geographic information system to deliver an appropriate platform for convergent study of multi-disciplinary data and decision building for artificial groundwater recharge. Thematic maps were generated from Landsat8-Operational land Imager (OLI) and Shuttle Radar Topographic Mission (SRTM), and aquifer parameter thematic layers were organized from conventional field data. The weighted linear combination method was used to determine the weights of various themes and their classes, namely 'very good', 'good', 'poor' and 'very poor' for identifying recharge potential zone. It has been concluded that 14.58% area has very good groundwater recharge potentiality of the study area. The area having 'good', 'moderate' and 'low' recharge potential is about 32.77%, 39.67% and 12.98%, respectively.

**Keywords** Groundwater recharge potential · Remote sensing and GIS · Weighted linear combination · Landsat data

## Introduction

Groundwater is the latest constituent of the hydrological cycle to comprehend the benefits or geospatial technology. Groundwater constitutes for 26% of universal renewable freshwater resources (Food and Agriculture Organization 2003), surface water sources from lakes and rivers comprises less than 0.3% (Senanayake et al. 2016). In India, groundwater is a vital source of water supply. Climate change likely to impact rainfall patterns leading to higher uncertainty and difficulties in management of water resources and recharge of aquifer. Hence, the groundwater withdrawal has become an essential part in numerous water management approaches, specifically for rural areas. In India, more than 90% of the rural and approximately 30% of the urban population reliant on groundwater resources for meeting their drinking and domestic requirements (Reddy et al. 1996).

Groundwater recharge is a type of controlled recharge where surface water is put on or in the ground for infiltration

and subsequent movement to the aquifer to augment the groundwater resources (Bhattacharya 2010). The groundwater recharge modelling has been made informal by the expansion of inverse modelling approaches (Sanford 2002). The water table depletes when pumping rates are higher than the rate of replenishment that causes a decrease in significant volume of groundwater reservoir (Wada et al. 2010). However, identifying the recharge potential sites is very difficult and depends on several factors containing rainfall, drainage, geology, slope, soil, geomorphology and so on (Senanayake et al. 2016). During rainy season, excessive amount of rain causes stored of surface water for long period of time, thereby influencing groundwater recharge (Senanayake et al. 2016). The existence of natural drainage system showed the high permeability and porosity of the landscape because of its association with surface runoff (Krishnamurthy et al. 2000).

To identify the groundwater recharge zone, several methods such as geological, hydro-geological geophysical and remote sensing techniques have been applied (Yeh et al. 2016). Several factors affect the occurrence and movement of groundwater in a region, including climate, topography, geological structure, depth of weathering, extent of fractures, primary and secondary porosity,

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slope, drainage patterns, landforms and land use/land cover characteristics (Yeh et al. 2016; Raviraj et al. 2017; Senthilkumar et al. 2019). Geospatial technologies have opened new vistas in groundwater studies due to their capability in evolving spatio-temporal data and efficiency in spatial data analysis and prediction (Bhunja et al. 2012; Hutti and Nijagunappa 2011). As remote sensors cannot detect groundwater directly, the presence of groundwater is inferred from different surface features derived from satellite imagery such as geology, landforms, soil, land use and surface water bodies, which acts as indicators of groundwater existence (Bhunja et al. 2012; Jha and Peiffer 2006). Most of the studies have been conducted and were based on knowledge-driven factors analysis, integrating different thematic layers with geospatial techniques (Yeh et al. 2009; Senanayake et al. 2016). Remotely sensed data, image processing operations and existing map and field data collection to be used in influencing factor demarcation in this study.

Due to irregularity of rainfall and physiographical characteristic, the dry zone periodically experiences drought conditions in Paschim Medinipur district (West Bengal, India) and causes the scarcity and inaccessibility to the surface water resources. The water resources in the Gopiballavpur block are mainly used for agriculture, irrigation, followed by domestic and industrial use. Despite the rich amount of surface water obtainable by the Subarnarekha river, the depth of water level during wet and dry seasons varies significantly. Till date, very few studies have aimed at quantifying the recharge contribution from different sources in dry and semi-arid areas. The present study demonstrates to identify and delineate groundwater recharge potential zones through integration of various thematic maps with remote sensing and GIS techniques.

## Study area

Gopiballavpur block is located at the bank of Subarnarekha river in Paschim Medinipur district (West Bengal, India), extended between  $22^{\circ}18'40.61''\text{N}$ – $22^{\circ}05'09.17''\text{N}$  and  $86^{\circ}43'06.04''\text{E}$ – $87^{\circ}03'40.75''\text{E}$  longitude (Fig. 1). It has an average elevation of 34 metres. As per 2011 census, Gopiballavpur block had a total population of 213,250, with a literacy ratio of 68%. The region characterized by Chorcita, Kuliana, Petbindhi soil is fertile, sandy and loamy in character, and in some parts of Tapsia and in Kharbandhi area soil is hard and not fertile. The people of this region are dependent on farming which depends on monsoon. People who reside by the river bank of the Subarnarekha and the rivulet Doulong have the alternative to harvest the advantage of multi-seasonal crops.

## Materials and methods

### Data collection and processing

Different types of datasets were used to identify the groundwater potential zone. The field sample of water depth in well at thirty location were collected during the pre-monsoon and post-monsoon season randomly. The geographic co-ordinate of each sample location was also recorded through Global Positioning System (GPS). Topographic map sheet at a scale of 1:50,000 was collected from the Survey of India (SOI) Kolkata (India). The administrative boundary layer was collected from the Land Revenue Department, Medinipur, West Bengal, India. The soil, lithology and geomorphology maps at scale of 1:50,000 were collected from the Irrigation Department, Medinipur, West Bengal (India). All the maps were registered in the World Geodetic System (WGS) 84 datum and Universal transverse Mercator (UTM) projection, zone N45 based on second order of polynomial function and nearest neighbour resampling method (Bhunja et al. 2012). The base map and administrative boundary layer were prepared from the registered administrative and SOI toposheet through heads up digitizing. The attribute layers of drainage, soil, geomorphology, lithology and well location in pre-monsoon and post-monsoon season were prepared in ArcGIS software v9.1. The local polynomial interpolation technique was used to measure the water level in pre-monsoon and post-monsoon season using spatial extension of geostatistical analysis of ArcGIS software v9.1.

### Satellite data analysis

Landsat 8 Operational Land Imager (OLI) sensor (Path/ Row: 139/44, Dated: 07/10/2017) with eleven spectral bands, and 30 m spatial resolution and Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) were used to extract the land use/land cover (LULC), vegetation characteristics, drainage characteristics and topographic characteristics. The satellite data were acquired from the USGS Earth Explorer Community (<http://earthexplorer.usgs.gov>). Using the layer stacking operation, false colour composite image of Landsat8 satellite data was prepared. The land use/land cover (LULC) map was prepared using the supervised classification technique through maximum likelihood algorithm in ERDAS Imagine (Leica Geosystems, 2008) software v 9.2 (Jensen, 2004). The lateritic land is dark bluish grey in the false colour composite. Open forest is identified by a dull red-greenish colour and dense forest are a bright red colour in the false colour composite, but the degraded forest showed

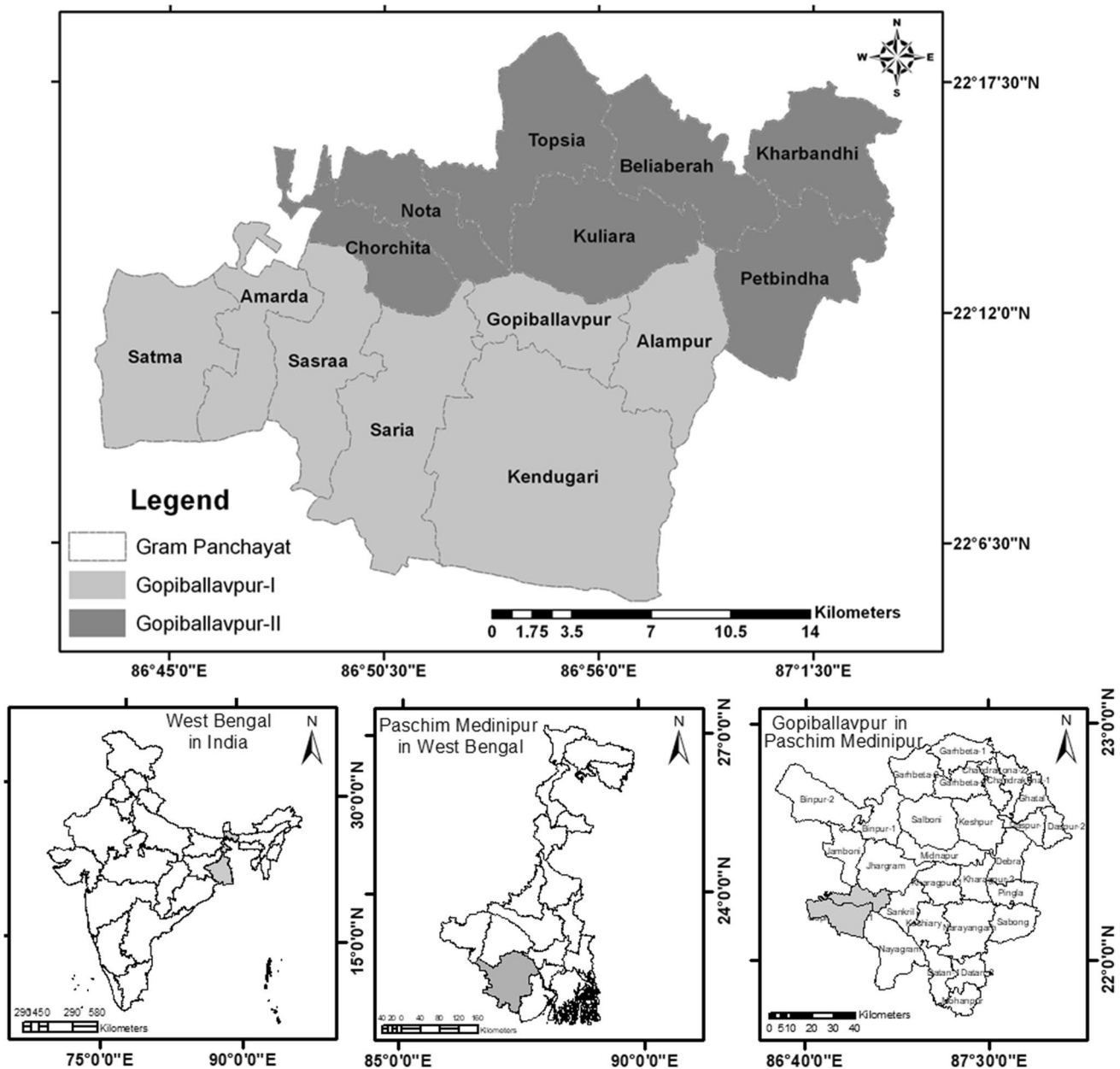
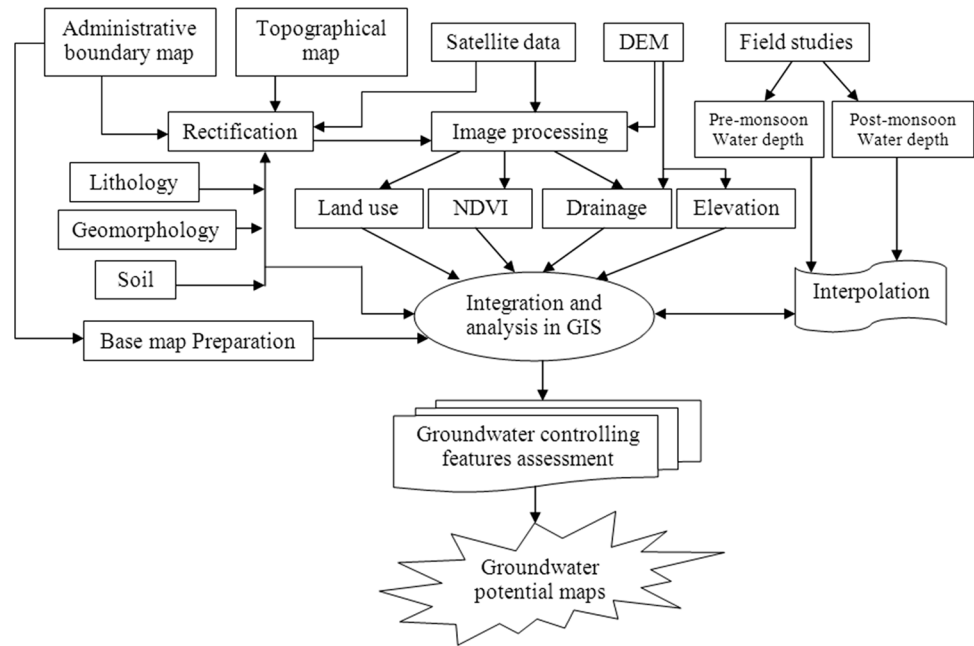


Fig. 1 Location map of the Gopiballavpur block, Paschim Medinipur district, West Bengal (India)

light red colour in the image. Built-up area is identified by a blocky appearance, light bluish coloured in the FCC. Agricultural fallow appeared as dark bluish colour and the crop land appeared as dull red and pink colour. River and surface water bodies appeared as dark blue and black colour. A total of twelve LULC classes were identified. For each LULC class, five training sites were chosen to classify the satellite image. The normalized difference vegetation index (NDVI) was used to measure the vegetation characteristics using the near-infrared (band<sub>5</sub>) and red (band<sub>4</sub>) band from the Landsat 8 OLI sensor of the study areas (Tucker 1979). Slope map was prepared from SRTM

DEM using spatial analyst tool of the GIS software. The drainage network of the study area was delineated from topographical sheet and subsequently updated with the Landsat8 OLI data. Finally, the drainage density map was prepared using the spatial extension of Arc GIS software v 9.1. Groundwater level data of pre-monsoon and post-monsoon data have been acquired from the Central Government Groundwater Board (CGWB) booklet and finally groundwater depth was generated using Inverse Distance Weightage interpolation technique (Agarwal et al. 2013). The overall methodology of the study is represented in Fig. 2.

**Fig. 2** Flowchart showing data and methods employed in delineating groundwater recharge potential zone



### Integration of thematic layers

Groundwater recharge is an obligatory to enhance water resources and abate the diminution of groundwater level. Hereafter, recognizing appropriate groundwater reviving sites is a criterion in this endeavour. The thematic layers of lithology, soil, geomorphology, drainage and surface water-bodies, LULC, NDVI, elevation, pre-monsoon and post-monsoon water level were spatially systematized in the GIS platform with the same resolution and co-ordinate system. The testing of the spatial maps was completed in order to other database layers by the overlaying method and refined reciprocally as part of normalization of the database. The topological errors due to digitization and mis-mapping were aloof in this procedure.

### Identification of groundwater recharge potential zone

To delineate the groundwater potential zone, a weighted index overlay analysis technique is used to compute the index value. The weights of the different themes were assigned on a scale of 1–7 based on their influence on the groundwater development. Different features of each theme were assigned weights on a scale of 1–9 based on their influence on groundwater potential zones, derived through the World Health Organization (WHO) guidelines and the literature survey. Based on this scale, a qualitative evaluation of the different features of a given theme was performed with very, low, low, low to moderate, moderate, good and

very good. All thematic maps were integrated and classified based on the added weighted factors (capability to store and transmit water) to determine groundwater recharge potentiality using Eq. 1:

$$RP = f(\text{draingae density} * \text{lithology} * \text{geomorphology} * \text{soil} * \text{elevation} * \text{landuse} * \text{NDVI} * \text{pre-monsoon water level} * \text{post-monsoon water level}) \quad (1)$$

These scores were again rehabilitated to influence values through Bayesian statistics. These capability values ( $CV_i$ ) are then multiplied with the corresponding likelihood weight of each thematic map to attain at the ultimate weight map for groundwater potential zone (Eq. 2).

$$GWRP = \sum W_i * CV_i \quad (2)$$

where GWRP = groundwater recharge potential zone;  $W_i$  = map weight;  $CV_i$  = capability value.

### Results and discussion

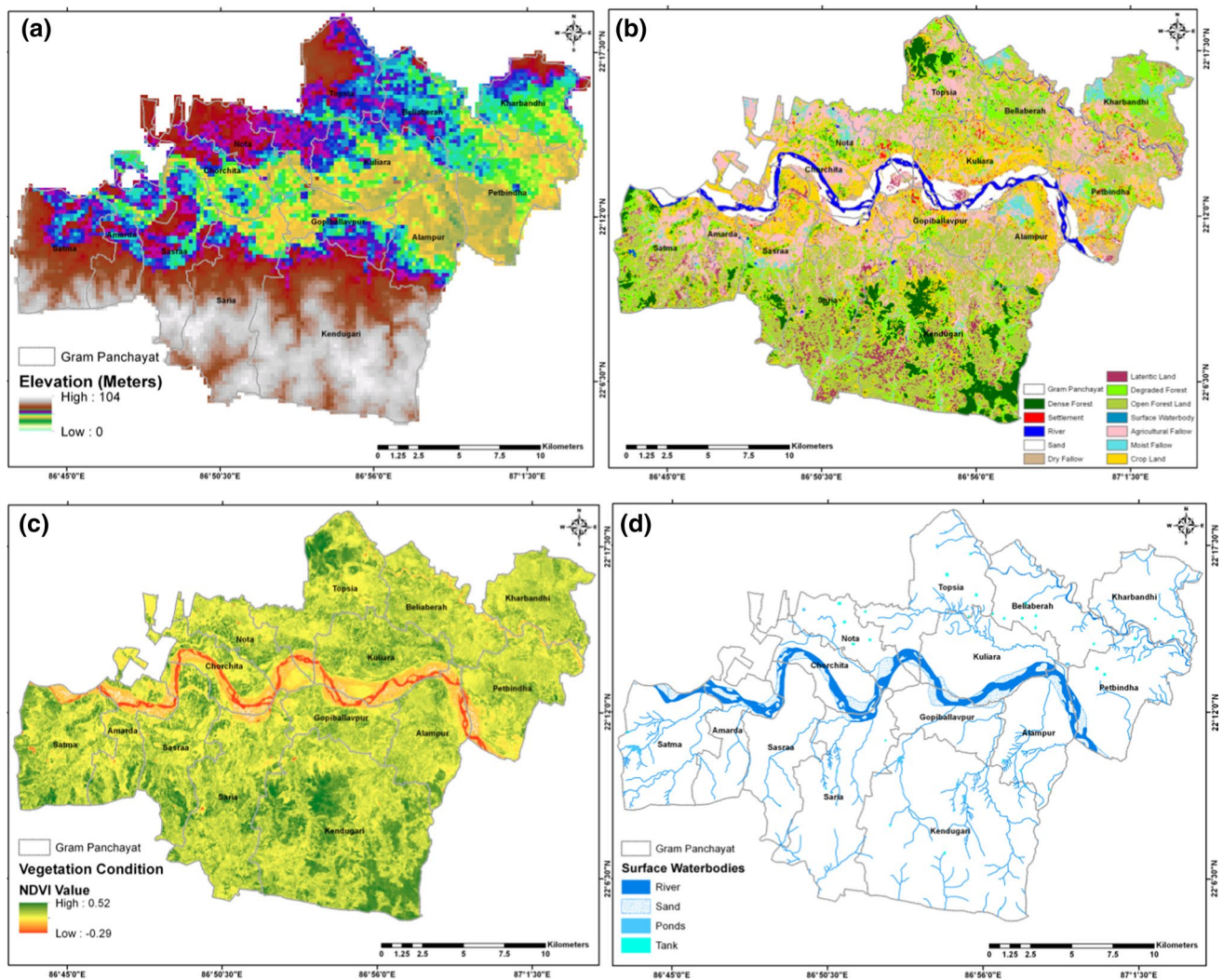
The recharge process is extremely complex, and the investigation on artificial recharge techniques is mostly site-specific and descriptive in nature. Estimation of groundwater recharge requires proper understanding of the recharge and discharge process and their interrelationship with geological, geomorphological soil, land use/land cover

and depth of water level. Assimilating influential factors using weighted overlay method on a GIS platform has been regularly employed in defining groundwater recharge potentiality by numerous scientists and scholars (Prasad et al. 2008; Nagarajan and Singh 2009; Yeh et al. 2014; Senanayake et al. 2016). Most of the studies have emphasized the ability of remote sensing and GIS techniques in groundwater studies as well as its cost and time effectiveness. The accuracy of the results depends on the assigned weight and thematic layers considered in the weighted overlay analysis (Bhunia et al. 2014). A discrepancy in weights specified for certain themes and sub-division based on varied attentions by researchers can be usually detected in various studies. Therefore, accessibility of thematic data, their accuracy level, local environments and considerations play a significant role in such groundwater management endeavours. In this study, GIS technique was

employed to delineate the groundwater recharge through knowledge-based factor analysis elevation, land use/land cover, vegetation vigour, density of surface waterbodies, lithology, geomorphology and soil.

### Elevation and groundwater potentiality

The altitude of any terrain plays a vivacious role in consenting the infiltration of water into the subsurface system (Patil and Mohite 2014). The SRTM DEM data are used to delineate the altitudinal distribution in the study area, characterized by undulating micro-relief along with some rolling plain in the southern part (Fig. 3a). The maximum elevation is recorded as 104 m in the study area, distributed in the southern part. The lower elevation is recorded in the central and eastern region. 29.76% of the study area was recorded as with an elevation of less than 50 m.



**Fig. 3** Remotely sensed environmental variables in relation to groundwater potentiality **a** elevation, **b** land use/land cover **c** vegetation characteristics **d** surface water bodies

The higher elevation indicates the greater slope due to relatively high runoff and less prospect of groundwater availability. The region having low elevation, the runoff will be slow due to almost flat terrain and will have more time for percolation of rainwater. Present result is also corroborated with the earlier study (Agarwal et al. 2013). The weightages were allocated to the respective elevation class based on the sub-class persuading the groundwater recharge, holding and its occurrence (Table 1).

### Land use/land cover and groundwater potentiality

The study area is divided into twelve LULC classes, namely dense forest, degraded forest, open forest land, river, sand, dry fallow, lateritic land, surface waterbody, agricultural fallow, crop land, moist fallow and settlement (Fig. 3b). Approximately 38% area is covered by the agricultural fallow and crop land (Table 2). The forest areas are distributed in the southern and some small part of northern and eastern region. The lateritic lands are distributed in the southern part of the block. The crop land is mainly found along the course of the Subarnarekha river. Dense forest areas are excellent sites for groundwater recharge potential, and hence given the highest rank. River and surface waterbodies are considered to have good recharge prospects, while urban area, lateritic upland have poor potentiality.

LULC provides an important indicator of extent of groundwater requirement and utilization (Bhunia et al. 2014). The ranks of LULC categories were assigned in relation to high potentiality to water penetrability (Table 2). For instance, lateritic lands often provide a chance to water to handover through openings and linkages into deeper section, therefore frequently measured as improving parameter. Human habitation and construction hinder water infiltration through it and consequently avert water to spread groundwater reservoirs. Hence for vegetation cover, the greater the vegetation cover, the higher the evapotranspiration rate and this suggest less possibility for

**Table 2** Land use/land cover characteristics and their areal extent of Gopiballavpur block, Paschim Medinipur, West Bengal, India

Land use category	Area (in ha)	Percent	Groundwater recharge potentiality
Dense forest	2679.84	5.55	Very good
Settlement	636.93	1.32	Restricted
River	1139.85	2.36	Good
Sand	2188.54	4.53	Low
Dry fallow	1843.29	3.82	Low
Lateritic land	1820.61	3.77	Very low
Degraded forest	6054.12	12.54	Medium
Open forest land	11,720.51	24.27	Low to medium
Surface waterbody	16.2	0.03	Good
Agricultural fallow	10,098.44	20.91	Medium to low
Moist fallow	1464.82	3.03	Good
Crop land	8629.65	17.87	Medium

infiltration to the subsurface layers (Darwich et al. 2003). Taking into account the groundwater potentiality, mixed forest, river, surface waterbody, sand, crop land and moist land were given the maximum weightage, whereas open forest, lateritic land, dry fallow, agricultural fallow were given the lower weightage (Table 2).

### Vegetation vigour and groundwater potentiality

Vegetation condition derived through NDVI is subjugated as a secondary indicator of the accessibility of groundwater below the surface of the earth (Kondoh and Higuchi 2001). The intensity values of NDVI were categorized into seven classes through density slicing, namely luxurious vegetation, healthy vegetation, areas with moderate dense, stressed vegetation, areas with less vegetation, areas with very less vegetation and areas with no vegetation (Fig. 3c and Table 3). NDVI produced in the analysis was established to be interrelated well with water obtainability because of the good water content in the soil covers and weathered zones (Schoonover and Crim 2015). The higher NDVI values

**Table 1** Elevation characteristics and their areal extent of Gopiballavpur block, Paschim Medinipur, West Bengal, India

Elevation (m)	Area (in ha)	Percent	Groundwater recharge potentiality
<50	14,373.18	29.76	Good
51–60	8413.84	17.42	Low
61–70	6951.69	14.39	Low to medium
71–80	25.96	0.05	Medium to low
81–90	4169.70	8.63	Good
>90	3780.50	7.83	Very good

**Table 3** Vegetation characteristics and their areal extent of Gopiballavpur block, Paschim Medinipur, West Bengal, India

NDVI value	Area (in ha)	Percent	Groundwater recharge potentiality
<0.001	1367.84	2.83	Good
0.001–0.099	3553.49	7.36	Low
0.10–0.19	17,390.82	36.01	Low to medium
0.20–0.29	17,564.98	36.37	Medium to low
0.30–0.39	7090.42	14.68	Good
>0.40	1325.24	2.74	Very good

obscure accessibility of satisfactory shallow groundwater and surface to excite vegetation progression and to sustain local water needs (U.S. Geological Survey 2013).

### Density of surface water bodies and groundwater potentiality

The surface water bodies of the study area are portrayed in Fig. 3d. However, the surface waterbody density map was prepared using the spatial extension of Arc GIS software v 9.1. Thus, the study area is classified as moderate to fine drainage texture and low-to-moderate drainage density. Normally, poorer the drainage density indicated greater the groundwater recharge prospects and vice versa. It is found that the regions adjacent to the dry water courses have a high deliberation of luxurious and healthy vegetation as related to respite of the area (Agarwal et al. 2013). This is mainly because of enhanced groundwater resource and wetness replenishment from the alluvial deposits of the rivers.

### Lithology and groundwater potentiality

The study area was divided into five types of lithology, namely alluvium—sand/silt and clay alternating beds, alluvium—sand/silt dominant, conglomerate, laterite (ferricrete), river/surface waterbodies (Fig. 4e). The central and northern part is covered with alluvium—sand/silt and clay alternating beds whereas the southern part of the block is enclosed with laterite (ferricrete). The groundwater recharge potentiality of the areal extent of the lithological characteristics is represented in Table 4. Alluvium-sand/silt belt has better prospects because of the presence of pore spaces in sand and gravel beds, so it is given higher predilection in defining recharge potentiality.

### Geomorphology and groundwater potentiality

The geomorphological characteristic affects the hydrological behaviour of a basin into a considerable extent. Geomorphologically, the block is moderately flat and slightly rolling with insulated hillocks interfered by valley. Geomorphologically, the study area is classified into five zones, namely alluvial plain younger/lower, channel bar, deep alluvium, dissected upland, lateritic plain, valley fill—shallow and river/surface waterbodies (Fig. 4f). The low dissected structural hills show red reflectance in the FCC image. The alluvial plain is shown by a light blue tone and the river terrace are seen as a dark or light grey tone in the image. The highly dissected structural hills are observed as a light grey tone in the image, showing poor vegetation. The entire northern and central region is covered by deep alluvium, covered by 39.04% of the entire study area (Table 5). The deep alluvium plain illustrates red reflectance in the FCC image ensuing

from dense forest in which a succession of alluvial plains has united to produce deep alluvial plain. The alluvial plain younger/lower and channel bar were extended along the Subarnarekha river course. The southern part and some small pockets in north covered with lateritic plain and dissected upland. The details of geomorphological characteristics are represented in Table 5.

### Soil and groundwater recharge potentiality

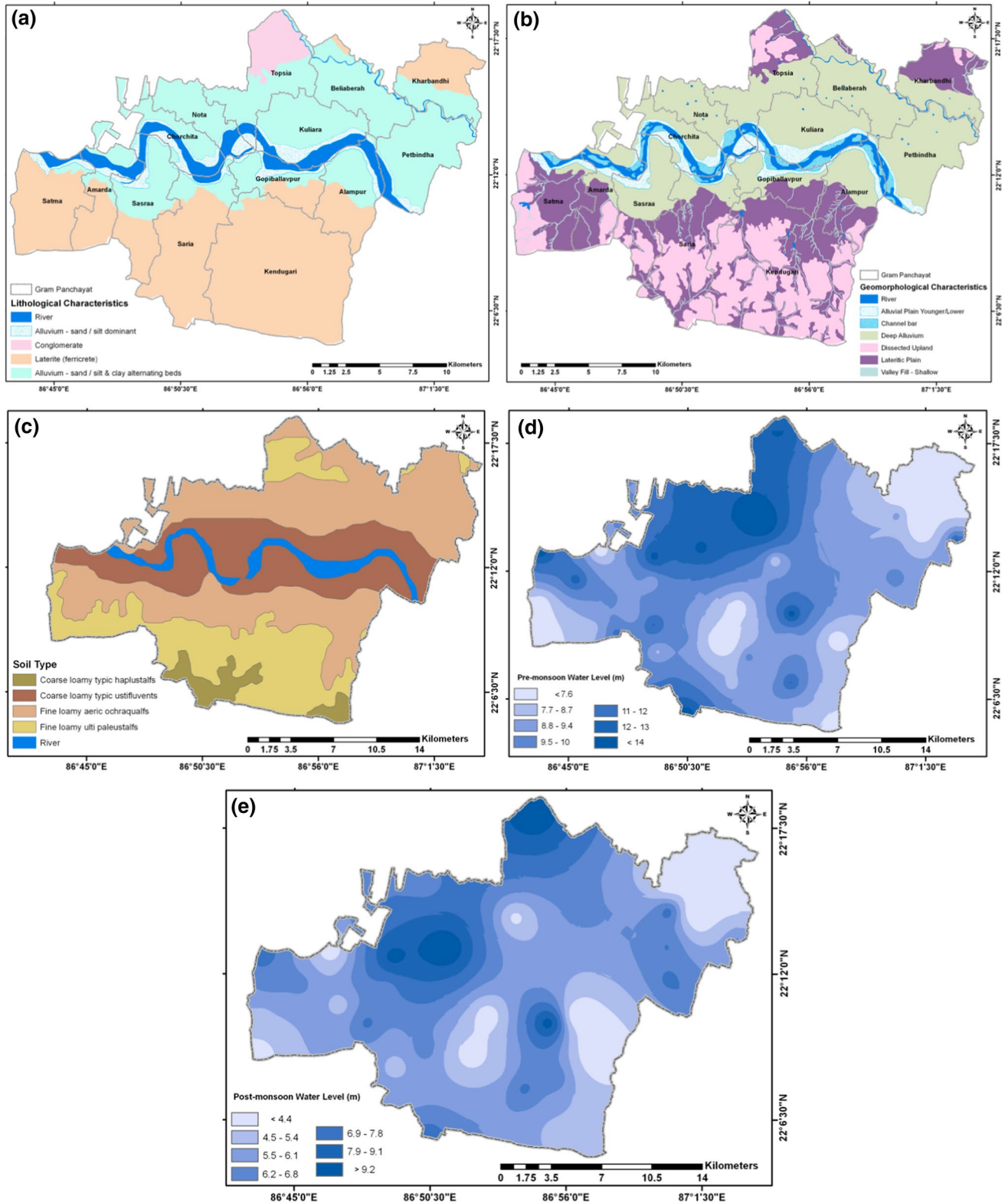
The soil map (Fig. 4g) of the study area reveals four major categories of soil: fine loamy ulti paleustalfs, coarse loamy typic haplustalfs, fine loamy aerich ochraqualfs, and coarse loamy typic ustifluvents. It is apparent from Fig. 4g most of the block is covered by fine loamy aerich ochraqualfs (44.05%) which is good for groundwater potential, mainly found in the valley fill areas. Another major soil type is coarse loamy typic ustifluvents, which is found along the Subarnarekha river course, provide good to moderately suitable for groundwater recharge. A very small portion of south and south-east of the study area is under coarse loamy typic haplustalfs which is very deep, but poorly drained. The soil classes are categorized into very low, low, medium and good according to their influence on infiltration capability (Table 6). The result of this study is also corroborated with the earlier study (Pani et al. 2016; Bhunia et al. 2012).

### Depth of water level and groundwater potentiality

Appropriately and decorously observation wells to measure the periodical variations in groundwater level are the most beneficial to plan groundwater development programmes indicators (Bhunja et al. 2012). Pre- and post-monsoon depth of water table data was gained from the dug wells around the Gopiballavpur block offers groundwater recharging environments. In the present study, the water-level depth during pre-monsoon and post-monsoon were collected. During the pre-monsoon, the water level depth is ranged from 5.1 to 15.8 m, with an average depth of  $9.31 \text{ m} \pm 2.45$ . The interpolated value of pre-monsoon water level is divided into seven categories (Fig. 4h). During post-monsoon, the minimum water level was recorded as 2.1 m and maximum 11.2 m with a mean value of  $5.90 \pm 1.85$ . The interpolated map of post-monsoon season is illustrated in Fig. 4i. However, the higher well yields designate comparatively better groundwater accessibility than areas with small well yields.

### Groundwater recharge potential map

The recharge potential areas are evaluated by integration of all the thematic layers, the groundwater recharge prospective map is illustrated in Fig. 5. Table 7 represents the weight of each thematic classes and their corresponding classes using



**Fig. 4** Thematic layers of environmental variables in relation to groundwater potentiality **a** lithology, **b** geomorphology **c** soil **d** pre-monsoon water level **e** post-monsoon water level



**Table 4** Lithological characteristics and their areal extent of Gopiballavpur block, Paschim Medinipur, West Bengal, India

Lithology type	Area (in ha)	Percent	Groundwater potentiality
Alluvium—sand/silt and clay alternating beds	18,940.26	39.22	Medium
Alluvium—sand/silt dominant	2657.31	5.50	Very good
Conglomerate	1457.18	3.02	Low
Laterite (ferricrete)	22,183.21	45.93	Very low
River/surface waterbodies	3054.84	6.33	Good

**Table 5** Geomorphological characteristics and their areal extent of Gopiballavpur block, Paschim Medinipur, West Bengal, India

Geomorphology type	Area (in ha)	Percent	Groundwater recharge potentiality
Alluvial plain younger/lower	2617.75	5.42	Very good
Channel bar	1233.96	2.56	Good
Deep alluvium	18,853.76	39.04	Good to medium
Dissected upland	10,392.35	21.52	Very low
Lateritic plain	12,144.06	25.15	Low
Valley fill—shallow	1124.46	2.33	Medium
River/surface waterbodies	1926.42	3.99	Good

weighted linear combination method. The highest value for groundwater potential zone of the study area is calculated as 54.3 which are delimited in the northern part. The central and eastern part of the block demarcated as moderate-to-high potential. The entire southern part and small pockets of north-east corner showed very less potentiality. However, the Chorchita and Kuliara gram Panchayat showed the maximum potentiality of groundwater recharge. Consequently, the Kendugari, Satma and Saria Gram Panchayat showed the very less potentiality of groundwater recharge. This provides a realistic groundwater recharge potential map of the Gopiballavpur block which is used for sustainable development

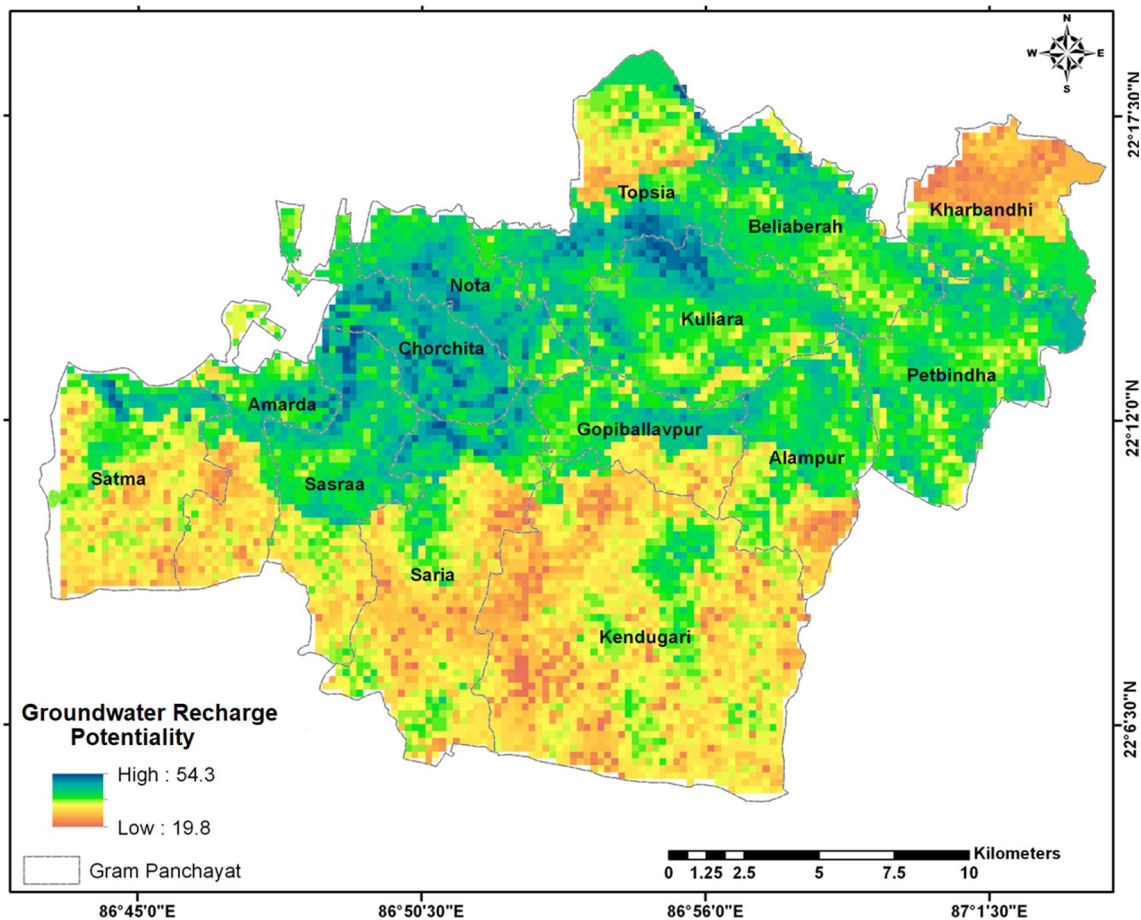
of groundwater resource management. Based on the results of the study, concerned decision architects can articulate an effective groundwater consumption plan for the study area.

Geographically, the very high potential area is disseminated along poor drainage density, lesser elevation, older alluvium region, and the flood plain deposits regions are influenced by the ancillary edifice and having interrelated by pore spaces (Table 7). Regions with moderate groundwater prospects are ascribed to contributions from the amalgamations of dense forest, moist fallow, crop land, higher NDVI, valley fill deposits, fluvio-deltic sediments superimposed by moderate well yields are existent. The low to poor types of groundwater probable areas are spatially disseminated mostly along the ridges, complex lithology, low to very low well yields and farthest distance from drainage over the entire study area. The resultant map has been classified into four classes (very high, high, moderate and low) based on the integrated values, indicating the suitable area for recharge site (Table 8). The very high groundwater recharge potentiality is covered by 14.58% of the study area. 32.77% of the study area falls under high recharge potentiality and 39.67% falls under moderate recharge potentiality. The artificial recharging construction can be executed in Gopiballavpur area so as to recover the renewal of the groundwater resources.

Several artificial recharging process, like percolation pits, recharge wells, ridges and furrows, check dams, gully control and land flooding can be considered in such endeavour (Central Groundwater Board 2007). Presently, ponds have mislaid their stowage capacity and dilapidated condition in some parts of the study area; so, the natural groundwater infiltration from these water bodies has become very negligible. Desilting coupled with provision of proper waste weirs will convert the village ponds into recharge structure. The ditches and recharge ponds which collects rainwater and stores it for future use. The regions with irregular topography, closely spaced ditches and furrows provide maximum water content area for recharge water from source stream. The ditches/furrows depth may be considered according to

**Table 6** Soil characteristics and their areal extent of Gopiballavpur block, Paschim Medinipur, West Bengal, India

Soil Type	Area (in Ha)	Percent	Groundwater recharge potentiality
Fine loamy ultil paleustalfs (FLUP)	11,390.51	23.59	Very low
Coarse loamy typic haplustalfs (CLTH)	1949.39	4.04	Low
Fine loamy aeric ochraqualfs (FLAO)	21,274.78	44.05	Medium
Coarse loamy typic ustifluvents (CLTU)	11,416.27	23.64	Good
River	2263.53	4.69	Good



**Fig. 5** Groundwater potential map Gopiballavpur block, Paschim Medinipur, West Bengal, India

the topography and also with the aim that maximum wetted surface is available and uniform velocity can be maintained.

## Conclusion

Groundwater delineation is one of the main sources of ecosystem variation and has been particularly significant in the past five decades. It is ascertained that the fortification of environments that are maintained by groundwater is domineering assumed the rising risk of diminution of groundwater properties in most parts of the biosphere. The artificial recharge process provides little insight into the possible accomplishment of executing this technology in others areas. The benefits of remote sensing and GIS for groundwater planning and mapping comprise the prospect of assembling data for enormous and inaccessible areas in addition to consistent progressive coverage. For the identification of groundwater recharge potentiality, nine thematic layers (lithology, geomorphology, drainage density, soil, land use/land cover, NDVI, elevation, pre-monsoon water level, post-monsoon water level) were integrated. Resultant

maps show recharge potential zone, portraying in the central and north-west of the study site. About 32.77% of the study area fall under the high groundwater recharge potentiality. Based on the recharge potentiality suitable artificial structure has also been proposed. These structures at various locations shall rejuvenate the aquifer system of Gopiballavpur block and increase the sustainability of groundwater abstraction structures.

The results of the present study can be enhanced by increasing the spatial resolution and accuracy of the aspects. The methodology used to delineate the groundwater recharge potentiality can be generalized for the entire Paschim Medinipur district (West Bengal), seeing suitable parameters weights and ranks. Further, it can be protracted into other dry zone of the country to delineate recharge potentiality with appropriate amendments. The field confirmations are beneficial in recognizing the most suitable artificial recharge zone to refill groundwater in the study area based on the predominant terrain circumstances, LULC and drainage characteristics. Hence, it will offer a clear guideline to the planners and decision builders in executing suitable groundwater management endeavours. This alarming condition offers for

**Table 7** The classification of influencing factors on groundwater potentiality

Groundwater recharge potentiality									
Low							High		
Class (factors/weight)	I	II	III	IV	V	VI	VII	Multiplier	
Drainage density (sq. km)	> 4.21	3.60–4.20	2.70–3.59	2.11–2.69	1.41–2.10	0.72–1.40	< 0.71	1.6	
$CV_i$	0.02	0.04	0.08	0.13	0.19	0.24	0.28		
Geomorphology	DU	LP	DA	R	CB	VF	APY	1.5	
$CV_i$	0.00	0.02	0.06	0.11	0.19	0.25	0.27		
Lithology		L	C	R	ASSD	ASSC		1.0	
$CV_i$		0.03	0.06	0.10	0.16	0.25			
Soil		FLUP	CLTH	FLAO	CLTO	R		0.8	
$CV_i$		0.06	0.13	0.14	0.20	0.33			
Elevation (m)	> 90	81–90	71–80	61–70	51–60	41–50	< 40	1.2	
$CV_i$	0.03	0.04	0.07	0.10	0.15	0.24	0.31		
Land use/land cover	L	D/AF	CL	OF/MF	DEF	DF/MF	R	1.5	
$CV_i$	0.03	0.04	0.07	0.10	0.15	0.24	0.31		
NDVI	< 0.001	0.001–0.099	0.10–0.19	0.20–0.29	0.30–0.39	> 0.40		0.9	
$CV_i$	0.13	0.04	0.06	0.10	0.15	0.24			
Pre-monsoon water level (m)	< 7.6	7.7–8.7	8.8–9.4	9.5–10.0	10.1–11.0	11.1–12.0	> 12.1	0.7	
$CV_i$	0.03	0.04	0.06	0.10	0.16	0.24	0.37		
Post-monsoon water level (m)	< 4.40	4.5–5.5	5.5–6.2	6.3–6.8	6.9–7.8	7.9–9.1	> 9.2	0.8	
$CV_i$	0.01	0.02	0.03	0.06	0.18	0.27	0.34		

APY alluvial plain younger/lower, CB channel bar, DA deep alluvium, DU dissected upland, LP lateritic plain, VF valley fill—shallow, R river/ surface waterbodies, ASSC alluvium—sand/silt and clay alternating beds, ASSD alluvium—sand/silt dominant, C conglomerate, L laterite (ferricrete), D/AF dry fallow and agricultural fallow, CL crop land, OF/MF open forest/moist fallow, DEF degraded forest, DF/MF dense and mixed forest

**Table 8** Resultant output showing percentage of zone wise area of coverage

Zone	% of area coverage	Suitable structures
Very high	14.58	Suitable for all recharge structures like percolation pond and check dam etc.
High	32.77	Suitable for recharge structure like spreading stream water through a network of ditches and furrows, nala bunds
Moderate	39.67	Suitable for recharge structure like earthen check dam, boulder check dam, gully plugging etc.
Low	12.98	Less suitable

a cost and time-effective practice for suitable appraisal of groundwater resources and management planning.

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**Compliance with ethical standards**

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