

# Modeling groundwater potential zones for sustainable water resource management in Khyrasol block, Birbhum district West Bengal India using remote sensing and GIS techniques

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## Abstract

Remote sensing and Geographical Information System (GIS) have played an important role in exploration and management of groundwater resources. In this study, we present modeling of groundwater potential zone in Khoyrasol block in Birbhum district, West Bengal by using remote sensing and GIS techniques. The objective of the study is to explore groundwater as well as surface water availability in different geomorphic units. Different thematic maps of geology, hydro-geomorphology, lineament, slope, land use/land cover (LULC), depth to water level and soil maps are prepared and groundwater potential zones are obtained by overlaying all thematic maps in terms of Weightage Index Overlay (WIO) method. All the thematic map classes have been assigned weightage according to their role in groundwater occurrence. Finally, groundwater potential zones are classified into four categories viz., excellent, good to medium, medium to poor and poor. The outcome of the present research work will help the local farmers, decision maker, researchers and planners for exploration, monitoring and management of groundwater resource for this study area.

Keywords: Remote sensing and Geographical Information System, hydro-geomorphology, Weightage Index Overlay, decision maker

## Introduction

Water either in the form of surface water or subsurface water is a precious resource gifted by nature. But this resource is not well distributed all over the earth. Most of the freshwater store is store as ice in glaciers and polar region. Only small portion of the fresh water is stored in aquifer which is mostly used for drinking as well as domestic, agricultural, industrial and different purposes. Groundwater comprises those parts of subsurface water which are confining in the pores within a geological stratum. These water bearing subsurface stratum acts as reservoirs for water. Presence of fractures, cracks, joints, cavities makes the rock porous through which rainwater can easily percolate through them and contribute to groundwater (Todd 1980). Ground water is an important source of freshwater resource which contribute more than 34% of the annual water supply (Magesh et al 2012). This water can be tapped by dug wells and boreholes to satisfy the ever increasing water demand. With the increase in the population demand for groundwater has been increased manifold and in recent time groundwater is being widely used in the irrigation, industrial uses and for various domestic purposes. However, availability of good quality and adequate quantity of ground water found to vary spatially and depends on several factors (Chowdhury et al. 2009). Simultaneously, the amounts of freshwater resources are shrinking day by day all over the world, especially in the developing countries due to unscientific use and improper management of water resource (Thapa et al. 2017). There is spatial variation in distribution of water resources due to several factors like the slope, presence of fractures, surface water bodies, canals, irrigated fields, depth of weathering etc. (Thapa et al. 2017; Ganapuram et al. 2017). Having appropriate knowledge about them may helpful for identification and zoning of potential groundwater zones which prove to be useful for proper utilization of groundwater resources and can be very helpful to overcome the problem of water scarcity. (Rao 2006). They are extremely necessary for the proper management of ground water resources. As indiscriminate exploitation of groundwater resource may lead to the depletion of groundwater level and consequent deterioration in groundwater quality. Which considered as a major global concern which needs to be properly addressed (Fashe et al. 2014).

Conventionally geological, hydro-geological, geophysical and photogeological techniques are commonly used to delineate groundwater potential zones (McNeill 1991; Meijerink 1996; Edet et al 1997; Sander et al. 1996; Srivastava and Bhattacharya 2006). These methods are quite laborious and time consuming. However, in the recent times, the process of delineation has become quite easy with the availability of satellite images and by the application of remote

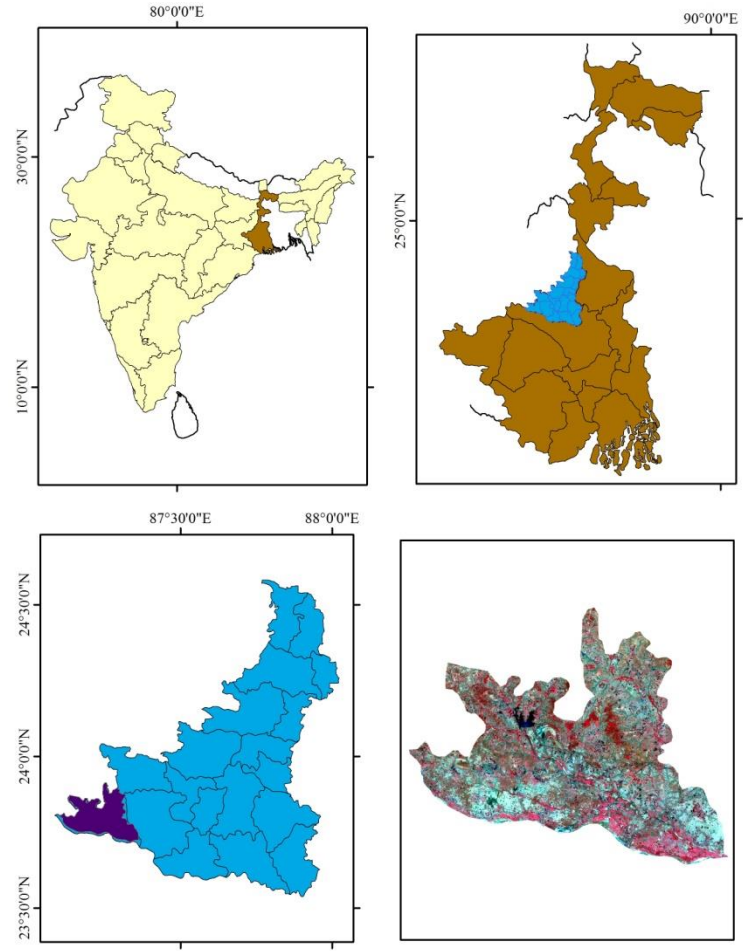
sensing (RS) and geographical information systems (GIS) technology (Chenini et al. 2010; Machiwal et al. 2011). In fact, GIS techniques have been widely employed for handling spatial data to manage the natural resources on local and global scale. Hence the integration of these modern techniques with the conventional methods may help to delineate the groundwater potential zone quite efficiently in the one hand and also helps to overcome the shortcomings of various traditional models of delineation of groundwater potential zone on the other. (Rao and Jugran 2003). Besides that, one can integrate various spatial data of large areal extent on geology, geomorphology, lineaments slope etc for systematic exploration of groundwater potential zone (Prasad et al. 2008) and this process is fast, efficient and also cost effective (Singh et al. 2013). Briefly employment of such process can enhance our understanding on the assessment of groundwater potential zone and also necessary for their proper evaluation, exploitation and management. Consequently a number of studies have been carried out by several scholars. Using the GIS environment some (Nag 2005; Singh et al. 2014; Taheri et al. 2015) emphasize on the physical parameters like lineament, presence of faults, geological set up. Others (Magesh et al. 2012) emphasize on the climatic and edaphic factors and highlighted the role of rainfall, soil, lithology and soil texture. The role of physiographic factors like slope, elevation has been focused by various scholars (Magesh et al. 2011; Thomas et al. 2012). Finally the role of drainage systems has also been assessed by the Rassam et al. 2008 for the delineation of groundwater potential zone.

The present study has been carried out in the Khoyrasol block of Birbhum district. It experiences tropical monsoonal climate with alternating dry and wet seasons. Majority of the rainfall received during the late summer and rest of the month remains without rainfall. Hence the region experiences high fluctuations of groundwater table. So, shortage in the water has been in agriculture (Nag and Ray 2015) with increasing events of crop failure and also for domestic uses. The situation compelled the people to rely heavily on the exploitation of groundwater. But several reports (Mondal et al. 2014; Thapa et al. 2016) indicate the incident of fluoride contamination in groundwater in some parts of the district as a consequence of over-exploitation of groundwater. It is a matter of serious concern that needs to be properly addressed. The present study aims to delineate the potential groundwater zone within Khoyrasol block with the help of remote sensing, and GIS techniques to ensure sustainable utilization of groundwater resources. This methodology can be successfully applied in any area with similar climatic and hydro-

geologic unit, where acute shortage of water for agricultural and domestic purposes. The results of the present study can get very useful information to policy makers, farmers, researchers, and local administrations for future planning of this area.

### **Study area**

The Khoyrasol block is the located southwestern part of the Birbhum district and which is situated between  $23^{\circ} 43' N$  to  $23^{\circ} 55' N$  and  $87^{\circ} 6' E$  to  $87^{\circ} 22' E$  (Fig. 1). The total geographical area of the block is  $275 \text{ km}^2$ . This block is quite unique in physical setting which is characterized by dissected pedimental landforms with alluvial plain land. The area has a monsoonal climate, characterized by rainfall during June to August and pleasant winter from December till February. The important drainage of the block is Hinglan R, Bakreswar nadi, Mayurakshi Bakeswar main canal (Fig. 2). The elevation range of the study area is 153 m to 59 m above mean sea level (Fig. 3). The agricultural practice of this region is predominately single cropped mainly Aman rice and agricultural productivity is also low as compared to other region of West Bengal. Central Ground Water Board (CGWB) availability data support that exploitation of groundwater from suitable sites is possible. That's why the present study has been carried out to evaluate the potential zones for groundwater targeting in Khoyrasol block of Birbhum district using remote sensing data, Survey of India (SOI) topographical sheets, other collateral data and field verification (Ghosh et al. 2015).



**Figure 1:** Location map of Khoyrasol block

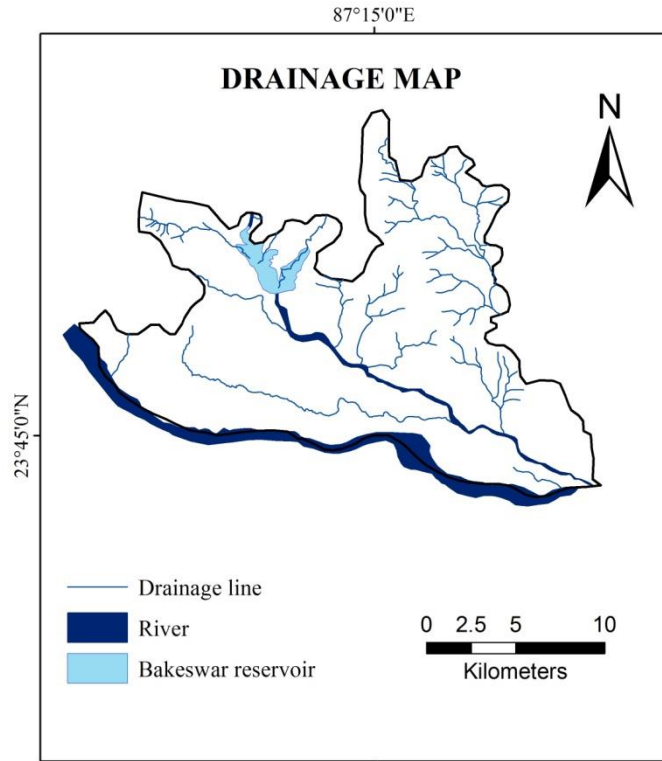


Figure 2: Drainage map of Khoyrasol block

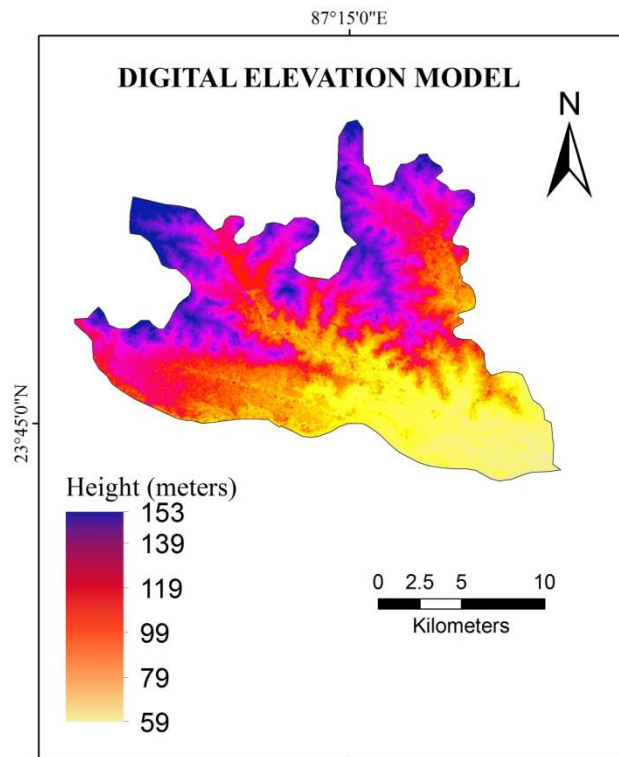
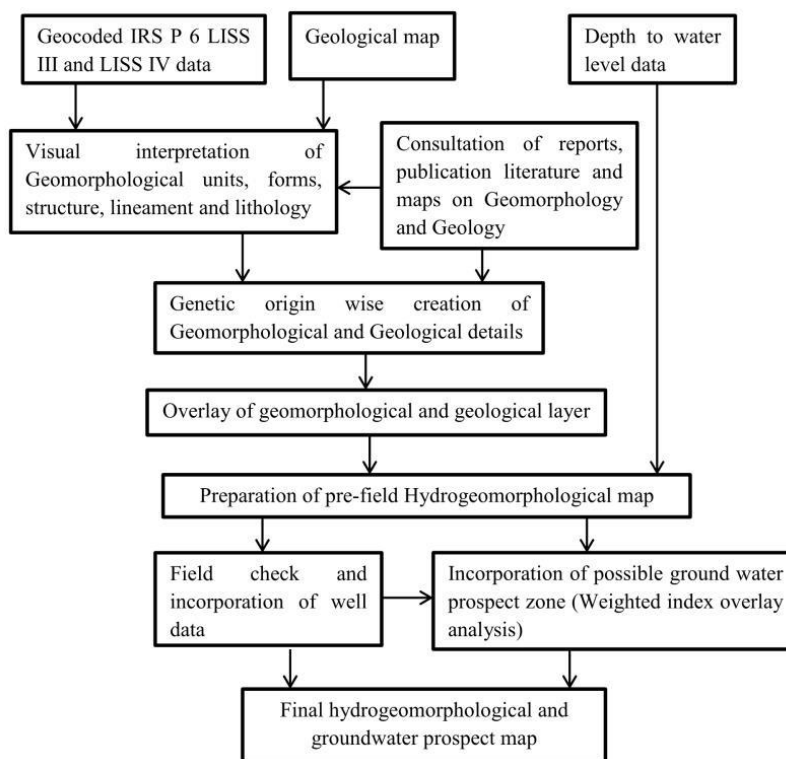


Figure 3: DEM of Khoyrasol block

## Materials and methods

The delineation of groundwater prospect zone of the area under investigation has been carried out on 1: 50,000 scale of Survey of India's topographical sheets (73M/1, 73M/5 and 73M/6), satellite data and other collateral data. The geological map is generated using geological map and quadrangle map of Birbhum district. The hydro-geomorphological, LULC and lineament density map have been prepared from IRS LISS-III data by using visual interpretation techniques and supervised classification techniques. All the thematic layers viz., hydro-geomorphological, slope, geology, land use/land cover, drainage, depth to water level and soil maps have been incorporated and analyzed by 'Spatial Analyst' tool to find out different ground water prospect zones (Fig. 4). Well discharge data (dug cum bore well and tube well) covering different geomorphic units have been incorporated to validate the result. Then hydro-geomorphic unit's wise groundwater prospect information has been assigned in the map.



**Figure 4:** Flowchart of methodology

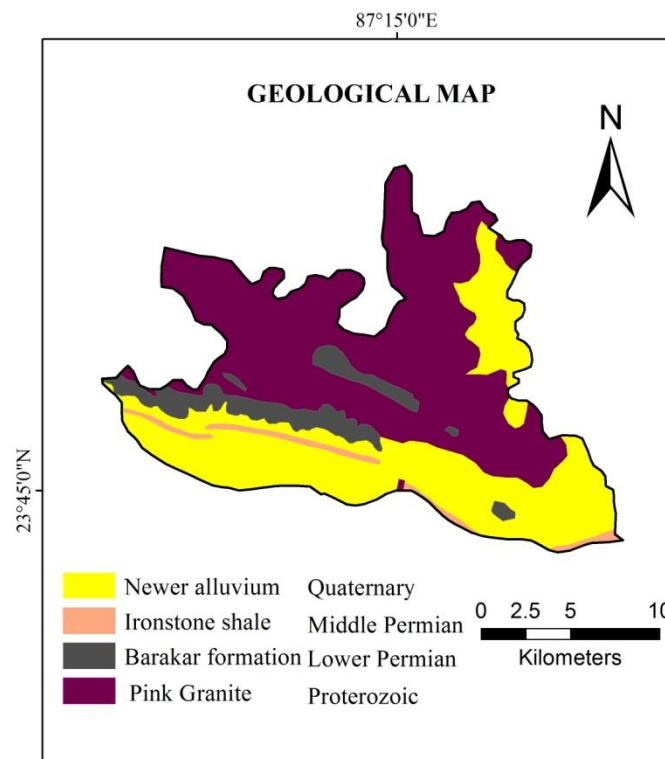
## Results and discussion

In order to demarcate the groundwater potential zones in the study area different thematic maps have been prepared from topographical maps, remote sensing data, geological map and other existing data as well as maps. The thematic layers of geology, lineament, slope, hydro-

geomorphology, land use land cover (LULC), soil texture and depth to water level have been used for the delineation of groundwater potential zones.

### Geology

The geological setting is an important parameter for identification of groundwater potential zone. Geologically Khoyrasol block is a part of diverse groups of rocks from various ages including Chhotanagpur gneissic complex, sediments of Gondwana and Quaternary ages (GSI 1985). Major part of the study area (northern, central and western) is mainly characterized by weathered material of Precambrian granite gneiss which is gradually merged with Barakar formation, lateritic terrain and alluvial plains (Fig. 5). From hydro-geologic point of view, weathered basement granite rocks contains negligible groundwater; so this zone given less weightage than alluvial plains for groundwater potential zone.



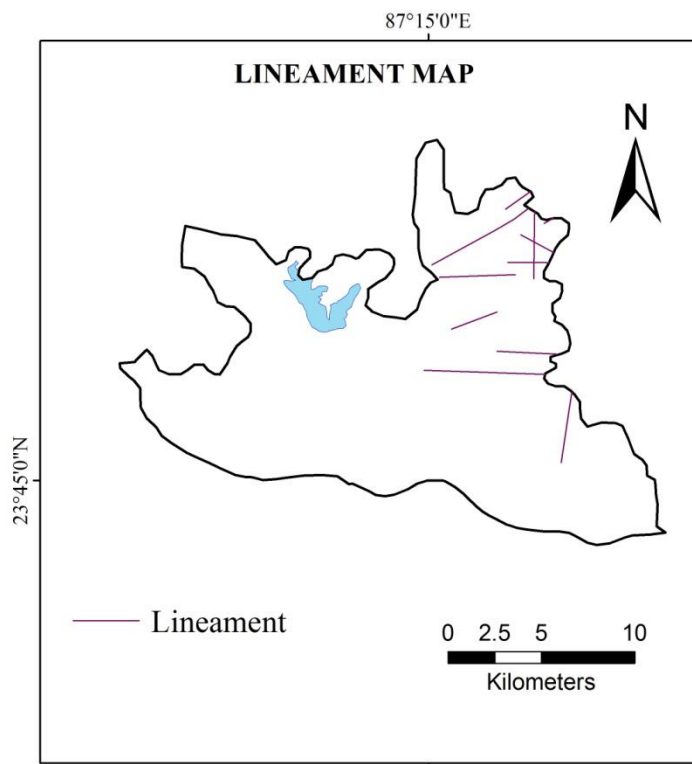
**Figure 5:** Geological map of Khoyrasol block

### Lineament map

In present study area lineaments are extracted from satellite imagery (IRS LISS-III) and quadrangle map. The major and minor lineaments area mainly concentrated in the northern and eastern part of the study area (Fig. 6). In this area hard rock terrain (granite rocks), intersection of lineaments can also play important role groundwater accumulation. Lineaments play a very



important role in recharging groundwater in the hard terrains rock (Koch and Mather 1997). The area with low lineament is given lower weightage, having poor groundwater potential.

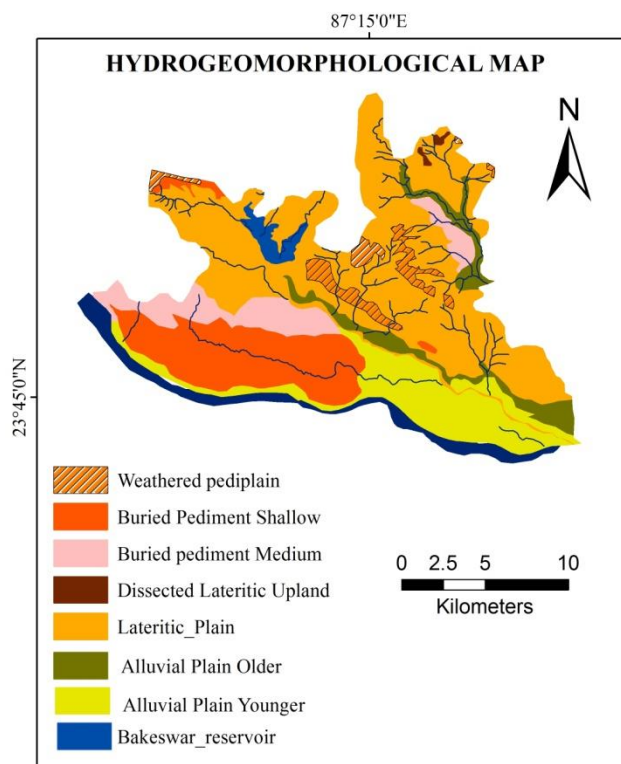


**Figure 6:** Lineament map

### Hydro-geomorphology

The hydro-geomorphological map is prepared from IRS P6 LISS III image and geohydrological characters of the study area. The major geomorphic units of the basin are –alluvial plain older, alluvial plain younger, lateritic plain, dissected lateritic upland, buried pediment medium (BPM), buried pediment shallow (BPS), weathered pediments and valley fills (Fig. 7). The alluvial plain (older and younger) and valley fill are given maximum weightage since these zone are very good potential site for groundwater recharge. Surface water can easily percolate in this zone throughout the all season, as valley fills are the drainage line (Das 2016). Due to low permeability of lateritic formation, lateritic plain as well as dissected lateritic upland given less weightage as these zones are mainly runoff area. Buried pediments shallow is less potential site for groundwater recharge than buried pediments medium (BPM). Buried pediment medium has been given the higher weighted than BPS because this zone mainly consists of unconsolidated weathered material overburden by thick alluvium or gravels which acts as a high groundwater recharge source in the study area (table 1). Weathered pediments are mainly composed of

erosional bed rocks, minor gully channels and less intergranular space, so groundwater recharge is very poor.



**Figure 7:** Hydro-geomorphological map of Khoyrasol block

**Table 1:** Score and Weightage of different classes for identification of groundwater prospect zone

Theme	Score	Classes	Weightage
<b>Hydro-geomorphology</b>	30	Alluvial Plain	5
		Lateritic plain	3
		Pediment (BPS, BPM)	2
		Weathered pediplain	1
<b>Slope</b>	20	$< 1^0$	5
		$1 - 2^0$	3
		$> 2^0$	1
<b>Geology</b>	20	Alluvium	5
		Ironstone shale	3
		Granite Gneiss	1
		$> 2 \text{ km/km}^2$	1
<b>Land use/ Land</b>	10	Water bodies	5
		Deciduous forest	4

<b>cover</b>		Agricultural land	3
		Scrub land	3
		Built-upland	1
<b>Depth to water level</b>	10	< 3 m.	5
		3 - 6 m.	4
		> 6 m.	3
<b>Lineament Density</b>	5	>2	3
		1 - 2 km/km <sup>2</sup>	2
		< 1 km/km <sup>2</sup>	1
<b>Soil texture</b>	5	Coarse loam	5
		Fine loam	3
		Loamy skeletal	1

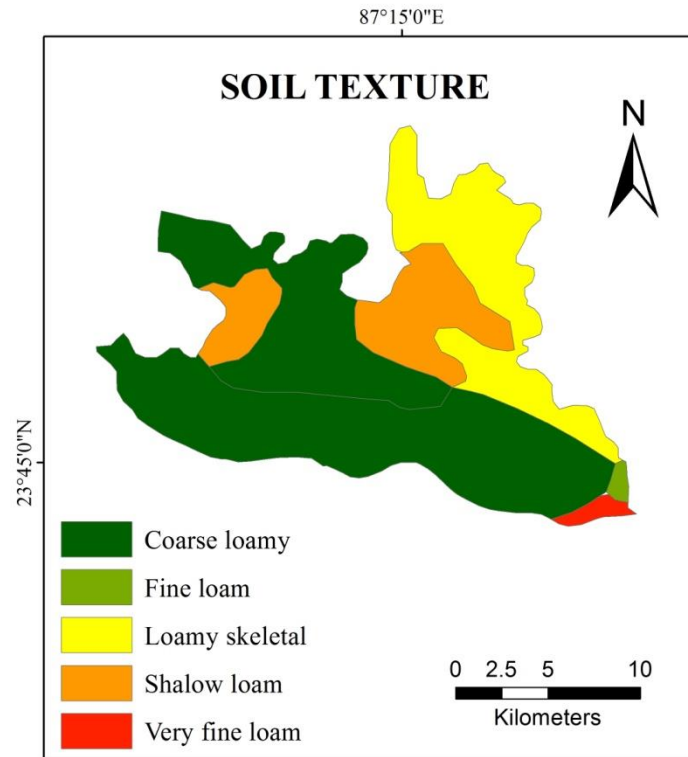
Source: Extracted from different maps.

### Slope

The slope map of the study area has been prepared from SRTM DEM data using ArcGIS software. The general slope of the block is from west to east direction. Major part of the study area is gentle slope (1-2 degrees). Low or gentle slope is favorable for groundwater recharge zone.

### Soil texture

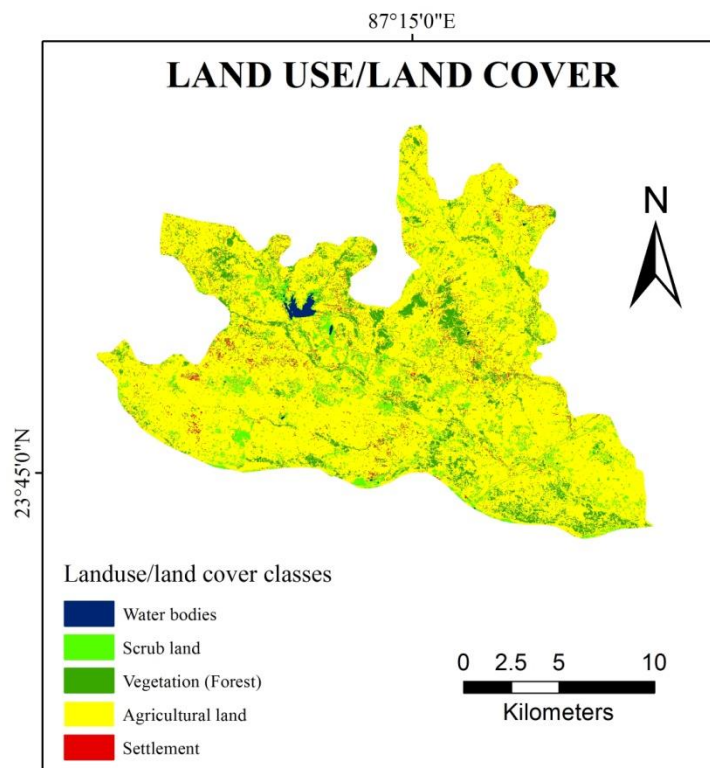
Groundwater recharge is mainly influenced by the type of soil texture. Various types of soil texture are present in the study area i.e., coarse loamy, fine loam, very fine loam, shallow loam and loamy skeletal. Coarse loamy soil covers mainly eastern and southern parts whereas fine loam to very fine loam covers about 5.2% of the study area (Fig. 8). Loamy skeletal and shallow loam soil covers in the southern part of the study area where basement terrain is mainly Gneiss rock. Porosity and permeability of groundwater are low in loamy skeletal soil but in coarse loam to fine loam it is very much high.



**Figure 8:** Soil texture map of Khoyrasol block

### Land use land cover analysis

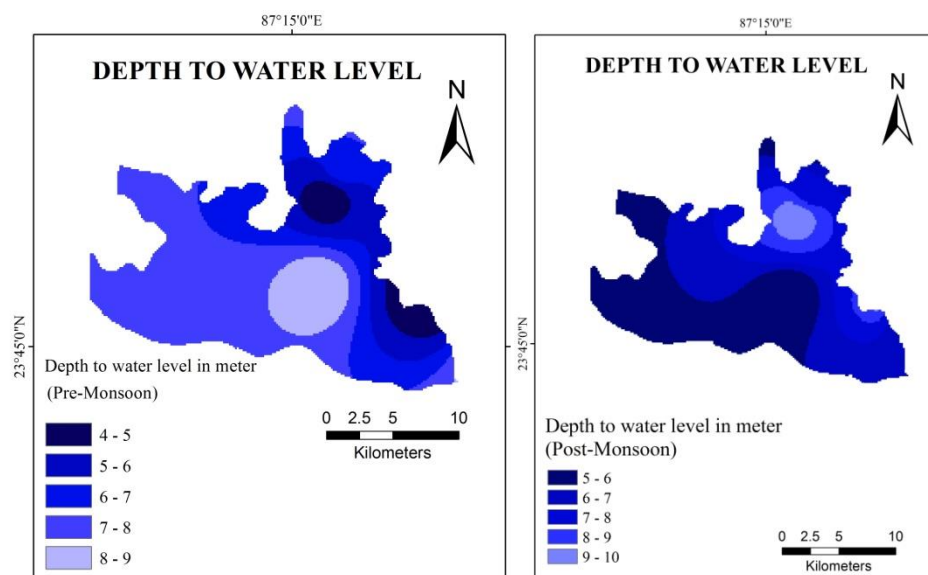
The vegetation cover as well as agricultural land influences the groundwater recharge by preventing water loss by absorbing water (Shaban et al. 2006). For identification of groundwater prospect zone, land use/ land cover (lulc) plays a significant role and following land use land cover classes have been prepared i.e., water bodies, scrub land, deciduous forest, agricultural land and built upland in the study area (Fig. 9). Land use and land cover classification maps have been prepared using cartosat images in the two different seasons. Major part of the study area is under single and double crop agricultural lands so groundwater recharge is good. The deciduous forest and scrub land scattered all over the study area.



**Figure 9:** Land use land cover of Khoyrasol block

### Depth to water level

Depth to water level map helps to identify the groundwater prospect zone. The pre-monsoon depth to water level varies from 4 to 9 m below ground level. Depth to water level map of pre-monsoon reveals that south and south-eastern part have 7 to 9 meter water level (Fig. 10a). On the other hand 4 to 6 meter dwt have been found in the central part of the study area. The post-monsoon depth to water level varies from 5 to 10 meter below ground level (Fig. 10b). High groundwater fluctuation is observed in the southern part of the study area which indicates the good potentiality of groundwater.



**Figure 10 a;b:** Depth to water level (Pre-monsoon and post-monsoon) Source: Central Ground Water Board (CGWB)

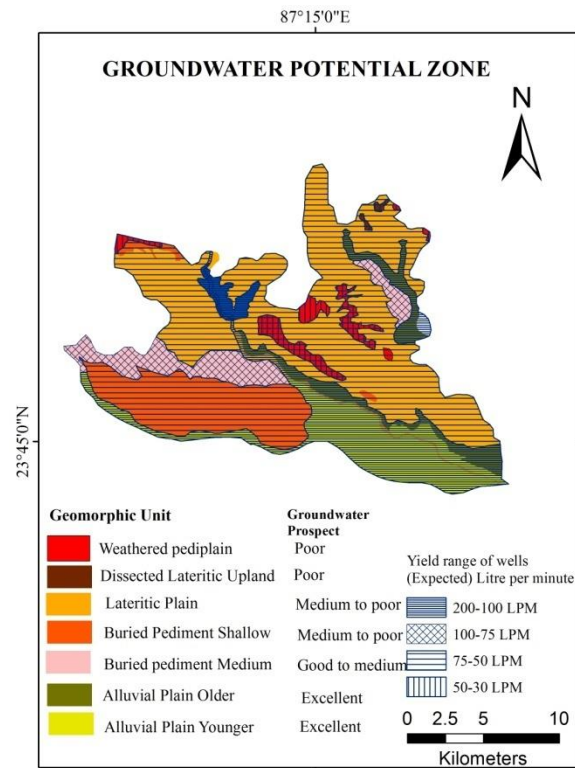
### Groundwater potential zoning

All the thematic maps (geological, hydro-geomorphological map, lineament, slope, drainage, land use/ land cover map, depth to water level and soil texture map) in the study area have been analyzed and projected to a common co-ordinate system through GIS software and reclassified the entire thematic maps by spatial analysis tool (weighted index overlay method).

### Validation with bore well data

In order to validate the groundwater potential map, it is essential that the evaluation criterion chosen meets imperatively the concern for the reality of the ground, the principles of independence of the criterion, and its conformity (Morjani et al. 2002; Benjmel et al. 2020). The groundwater potential map has been further validated with the data related to bore wells/ tube well (SWID 2014) located different part of the study area. There is good correlation between expected yield of wells and groundwater potential zone. The alluvial plain older and younger geomorphic units shows excellent groundwater prospect and expected yield of water 200-100 liter per minute (LPM). The medium yielding wells (100-75 lpm) are located in buried pediment medium which is characterized by unconsolidated thick alluvium or weathered materials and coarse loamy soil. Medium to poor potential zone spreads over the northern part of the study area, in lateritic plain land which experiences 75 to 50 lpm yield of groundwater. But in the

weathered pediplain and dissected lateritic upland regions lineaments are in less, so groundwater potentiality is very low and this area is not suitable for groundwater withdraw (Das 2017).



**Figure 12:** Groundwater potential zone map

## Conclusion

In the present research work, the delineation of groundwater potential zone has been done through weighted overlay method by integration of different thematic layers. The mainstay of economy of the study area is agricultural practice but major part is mainly single crop agricultural land due to decline in groundwater level and drying of river bed. The study reveals that 22% of the study area is under excellent, 49% under good to moderate, 21% medium to poor and 8% under poor groundwater potentials zone. The result of the present study can give detailed guidelines for planning of investigation, development and management of groundwater utilization. The delineation of groundwater potential zone can be widely applied to the same climate and hydrogeological settings to improve the sustainable groundwater management and efficient utilization of this resource.

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