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A Geo-Spatial analysis and assessment of groundwater potential zones by using remote sensing and GIS techniques-A micro level study of Bhagwanpur-I CD Block in Purba Medinipur District, West Bengal, India

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Abstract

The important resource of groundwater is a contributing significantly in total annual supply. However, over exploitation has depleted groundwater availability considerably and also led to land subsidence at some places. The integrated approach based on advanced applications of remote sensing and GIS lends itself to evaluate the groundwater prospective zone based on multi-criteria evaluation approach (e.g., Seasonal land use/land cover, geology, soil, drainage density and Slope), for assessment of groundwater availability in Bhagwanpur-I, CD Block (Purba Medinipur District, West Bengal) shows various groundwater potential zones. The groundwater availability at the block was roughly divided into different classes (i.e., very good, good, moderate, and poor) based on its hydro-geomorphological condition. Toposheet by Survey of India and Landsat-8 satellite (Oli sensor) imageries of 16 February, 2017 are used for preparing various thematic maps viz. Geology, slope, land-use/ Land-cover, drainage density, and soil map. Those maps transformed to raster class data using the feature to raster converter tool in Arc GIS were All the raster maps were allocated to a fixed percentage of influence and weighted their after weighted overlay tool or technique was used. For getting the groundwater potential zones, each weighted thematic layer was computed statistically. The results obtained were integrated with the different thematic maps on a GIS platform which yielded a good match with the obtained resistivity test result. The result shows the groundwater potentiality of Bhagwanpur-I, CD Block (Purba Medinipur District, West Bengal) is stretched along the eastern part and in small pockets in Northern and Southern part. The hydrologic parameters-based groundwater potential zone map also indicated 8.08% of the study areas were classified as having very high potential, 11.99% high potential and 17.72% moderate potential. The groundwater abstraction structures feasible in each of the various potential zones have also been suggested. This study also provides a methodological approach for an evaluation of the water resources in hard rock terrain and enables an opening of the scope for further development and management practices.

Keywords: GIS, groundwater, remote sensing, resistivity survey.

Introduction

Groundwater and surface water is one of the most important natural resource that is vital for the reliable and Economic provision of potable water supply in both urban and rural environments. Hence it plays a fundamental role in human wellbeing, as well as that of some aquatic and terrestrial ecosystems. Groundwater represents the second-most abundant available freshwater resources and constitutes about 30% of fresh water resources of the globe (Subramanya, 2008). More than 1.5 billion people in the world are known to depend on the groundwater for their drinking water requirements. However, the Remote Sensing and GIS is playing a rapidly increasing role in the field of hydrology and water resources development. Remote sensing provides multi-spectral, multi-temporal and multi-sensor data of the earth's surface (Choudhury et al., 2003). One of the greatest advantages of using remote sensing data for hydrological investigations and monitoring is its ability to generate information on spatial and temporal domain, which is very crucial for successful analysis, prediction and validation (Sarma & Saraf, 2002). Integration of remote sensing with GIS for preparing various thematic layers, such as drainage density, geology, land use/land cover, Soil type, slope and mean annual rainfall with assigned weighted in a spatial domain will support the identification of potential groundwater zones. Therefore, the present study focuses on the identification of groundwater potential zones in Bhawanpur-I Block using the advanced technology of remote sensing, and GIS for the planning, utilization, and management of groundwater resources which consists of 354 villages. A groundwater potential map can be incorporated to formulate effective management strategies for groundwater conservation in the area. The present study focused on the identification of groundwater abstraction structures feasible in each of the various potential zones in and around the Bhagwanpur-I block (Purba Medinipur district) using RS and GIS techniques.

Study area

Bhagwanpur-I, CD Block mainly situated in the West Bengal (Purba Medinipur District) in the Bhawanpur –I, CD blocks contain of 354 Villages and this block represented by survey of India topographical map number F45 & J16 and the imageries Landsat-8, Path and Raw is 139, 045 & extant is 22°0'16.455"N to 22°10'40.706"N and 87°40'19.758"E to 87°50'18.311"E. The total area is about 182.48 Sq.km.

Objectives of the study

The specific aims of the present study are:

1. To estimate the groundwater potential Area in Bhagwanpur-I Block of the Purba Medinipur District.
2. Delineate surface features like Land use/ Land cover, Geology, Soil, and Drainage Pattern etc. for estimating Groundwater Potential Zone by Remote Sensing & GIS Techniques.
3. Accuracy Assessment for Post Classify and Field survey to access the groundwater potential zone in Bhagalpur –I Block using Resistivity Method.
4. Estimation of GP wise water potentiality.
5. Integration of different above techniques to developed groundwater potential map.

Drainage

Hooghly is the main River, which are located the side of the Study area and in many cases the canals are drainage canals which get the back flow of river water at times of high tide or the rainy season. This river flows from the Northeast direction in the Southeastern direction respectfully the study area. During the rainy season the river carries a huge amount of water and in the dry season it carries a low quantity of water.

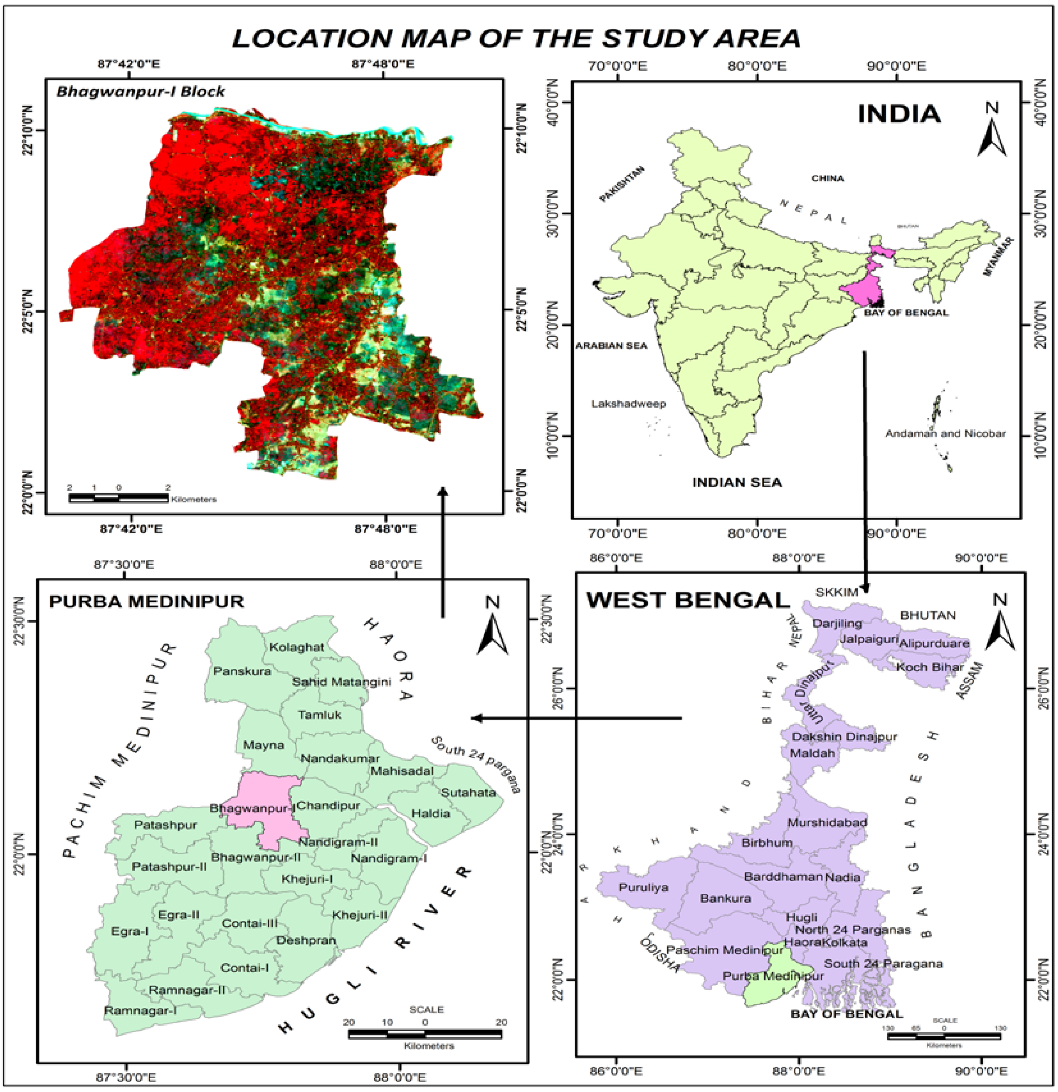

Fig. 1. Location Map

The major land-use/Land Cover type of the study area is road network, Cannel/water bodies, settlement area, vegetation Cover land and agricultural cropland shown in Fig. 03. Bhagwanpur-I Block is extensively agricultural land with the seasonal single crop and double crops. This region is also extensively drained by a number of 1st orders, 2nd order and 3rd order streams from source to mouth.

The remaining areas of newer alluvium tracts were potential for cultivation and settlement with available surface and groundwater resource. Almost 89.17 km^2 area is a rural area and Agriculture (Single Crop) is 37.29 km^2. Other areas of this area are mostly altered by water body (3.54 km^2), Agriculture (Double Crops) is 52.34 km^2, Brick kilk (0.14km^2) (Fig. 03). On the basis of the alteration of land cover areas, some rural area is coming up on the margin of the roadways of the Bhagwanpur-I block.

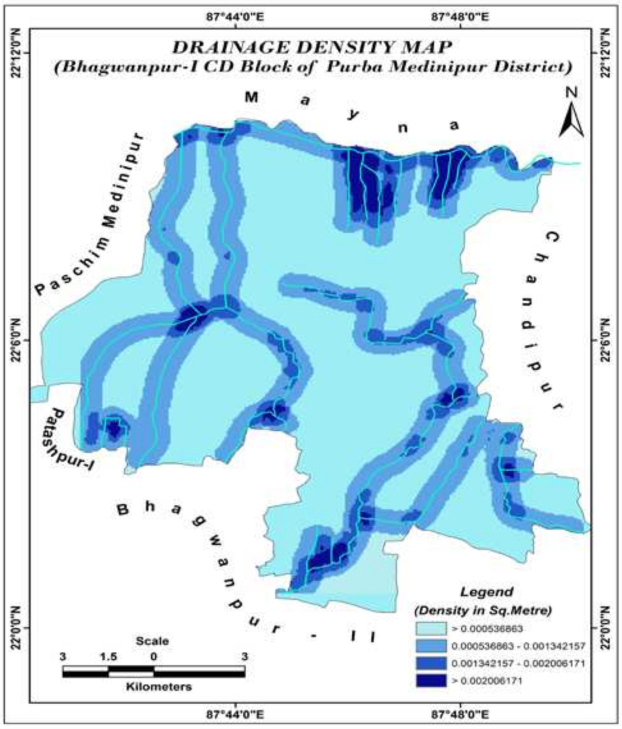

Fig. 2. Drainage Density Map.

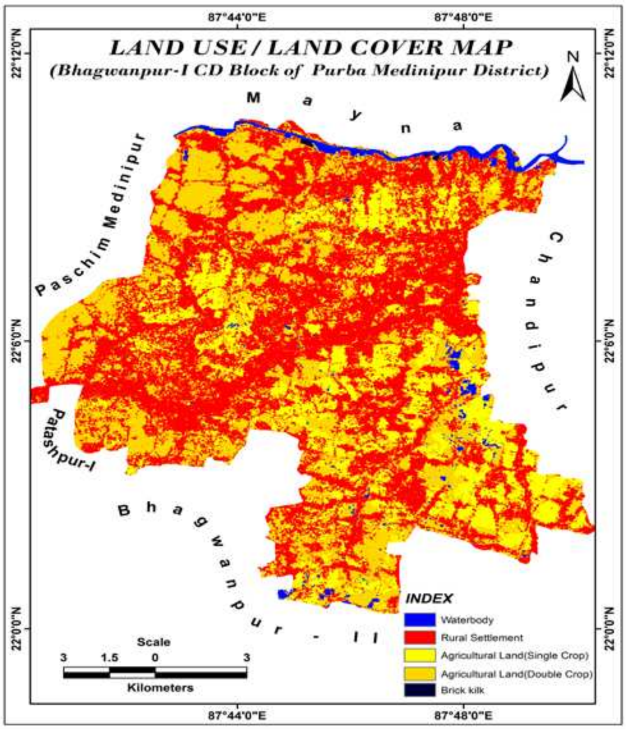

Fig. 3. LULC Map.

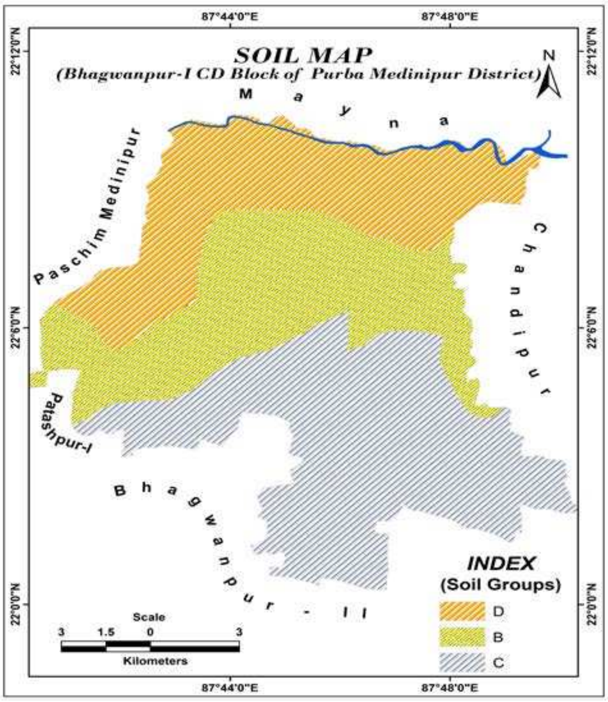

Fig. 4. Soil Map.

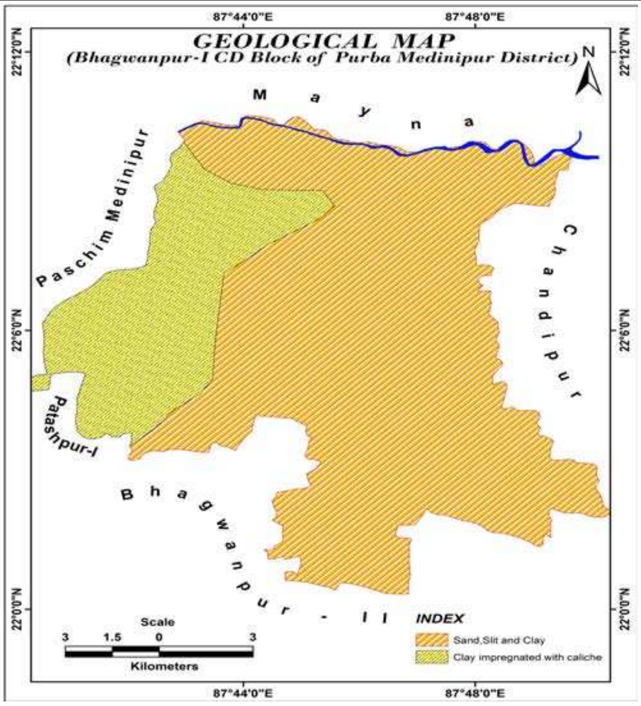

Fig. 5. Geological Map.

Soil

Soil characteristics also of an important input in mapping groundwater potential zones, coarse textured soil are generally permeable while fine textured soils indicate less permeability. Highly permeable soil permits relatively rapid rate of infiltration wherein much of the rainwater can reach the ground water table. Soil type Bhagwanpur-I, CD block can be divided into three categories as well as three groups, represented as-

a) Very deep, poorly drained, fine cracking soil occurring on level to nearly level low laying alluvial plain with clay surface and moderate flooding (B).
b) Very deep, poorly drained, fine cracking soil occurring on nearly level to very gently sloping coastal plain with clayey surface, moderate flooding and moderate salinity(C).
c) Very deep, poorly drained, fine soil occurring on level to nearly level low laying alluvial plain with clay surface and severe flooding (D).

Geology / Geomorphology

Lithological structure is generally identified of two types in the study area. These are (Fig. 05)-

a) Alternating layer of Sand, Slit and Clay: Found in South and North Eastern part in the areas.

b) Clay impregnated with caliche: This type of lithology is located western portion in the area.

A large part of the area rocks similar to the Panskura formation (Q2P) of are found in South and North Eastern part and Western portion of Sijua formation (Q1S) are represented by of most horizontal lava flows of basaltic composition.

Slope

Slope plays a key role in the ground water occurrence as infiltration is inversely related to slope. A break in the slope (that is steep slope followed by gentle slope) generally promotes and applicable ground water infiltration. Steep slope is generally found in the study area where poor ground water prospects due to high slope gradient and high ground water prospects due to very gentle or gentle slope gradient. From the figure of virtual GIS slope steepness is clearly visible (Fig. 06).

Methodology

Satellite data of Landsat-8 (Oli sensor) 16 February-2017, Path Row 139/045 Geo-coded FCC of the study area was used and it has a spatial resolution of 30 m. to demarcate the groundwater potential-zones, the weightage of individual theme and future score ware fixed and added to the layer depending upon their suitability to hold ground water. A probabilistic weighted approach has been applied during overlay analysis in Arc Map GIS environment. The maximum is being to the lowest potential feature. Spatial analyst extension of Arc GIS 10.1 was used for converting the feature to raster and also for final analysis in this method the total weightage of the final map was derived as the sum or product of the weightage assigned to the different layers according to their suitability.

Geology *15 + Slope*10 + Drainage Density*20 + Geology*10 + Soil*15 + Land use/Cover*30

Data input

Land use and the divisional map of the study area were digitized as separate themes using ERDAS IMAGIN 9.2 and map composed by Arc GIS 10.1. Then these coverage's are projected. Attributes of the respected themes such as the type of Land use, Geology, Slope, Drainage Density and the field observation of a particular division have been added separately.

Data analysis

Different thematic maps were prepared conventional survey (Land use/Land cover, geology, drainage and contour maps) and remotely sensed data (hydro geomorphology, lineament map and land use).The movement and storage of groundwater and each unit in every theme map were assigned a knowledge-based ranking depending on its significance to groundwater occurrence. In this terrain geomorphology plays a vital role in groundwater storage followed by a slope, geology, lineament density, drainage density, land use. All the themes were overlaid in Arc/Info; two at a time and the resultant composite coverage was classified into four groundwater prospect categories such as (i) Very well (ii) Good (iii) Moderate and (iv) Poor.

Result and Discussion

Assessment of ground water potential zones

The ground water potential zones were obtained by overlaying all the thematic maps in terms of weighted overlay methods using the spatial analysis tool in are G.I.S 10.1 during the weighted overlay analysis the ranking has been given for such individual parameter of each thematic map and weighted were assigned according of the influence of the different parameters.

Preparation of the thematic maps to overlay

The following maps were scanned; dereference subsisted and digitized the study area using arc GIS-10.1 and ERDAS-9.2.DEM and slope map, Geology map ,Soil map ,Drainage density map, Land use/land cover map. All the thematic maps were changed into raster format and superimposed by weighted overlay method (weightage wise thematic maps) for the ground water potential zone.

Reclassified drainage density

The drainage map creates from the survey of India, top sheet and then updated with the help of cartosat DEM (Fig. 10). It noted from the map that the flow direction of the canal is from North- East to South-West. The source of water of this canal is rain water. The total area of the area is 182.48 Sq.km and length of the canal is around 114.44 kilometers. The drainage density map is prepared by Arc GIS software and then the put weightage value drainage density map is reclassified. It is observed from the map red zone (1st class) is the high ground water potential zone, whereas blue zone (4th class) lowest potential zone.

Reclassified geology

In this area there are two types of lithology like Alternating layer of Sand, Slit and Clay and Clay impregnated with caliche etc. is observed (Fig. 09). According to geological structures, highest weightage value is given to Sand, Slit and Clay and Clay and lowest weightage value is given Clay impregnated with caliche. In this study area undulating plain (Clay impregnated with caliche) is Bibhisanpore, Mahamadpore-I & Mahamadpore-II GP and pediments and planes (alternating layer of Sand, Slit and Clay) is Gurgram, Bhagwanpur, Benudia, Kakra, Simulia & Kajlagarh GP. Low weightage value is given to undulating planes, whereas high weightage value to pediments and planes.

Reclassified slope map

Digital elevation model (DEM) is derived using contour information from the topographical map for estimation of slope in degree. Weightage value is assigned to the different slope according to the recharge potential of Ground Water. Steeper the slope lower will be the potentiality of ground water recharge. Highest weightage value is assigned to the very high potentiality of ground water recharge. Four types of slope are found using the slope weightage value (Table 1). Those are very low, low, moderate, high and very high (Fig. 10).

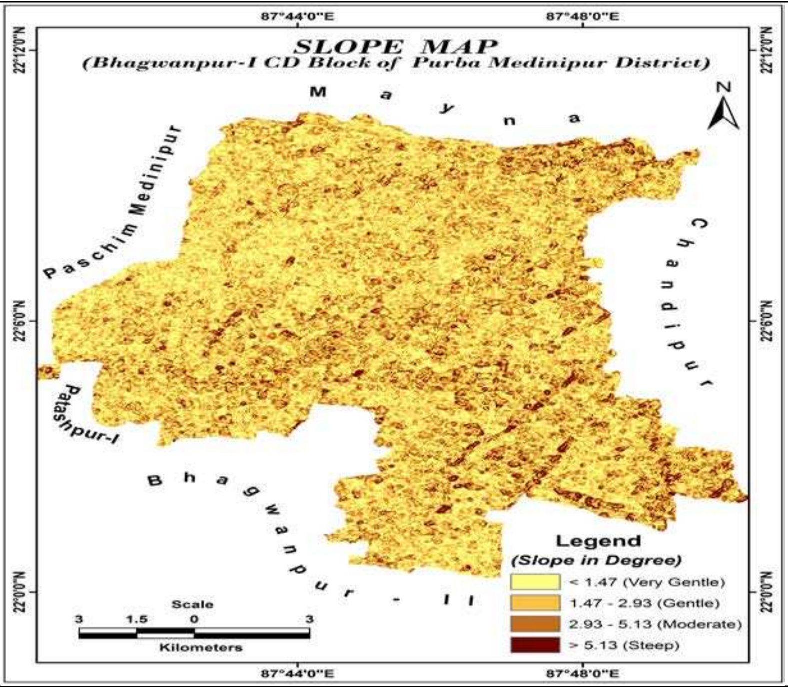

Fig. 6. Slope Map.

Table 1. Weightage of different parameters for Ground Water potential.

Drainage Density		
Class Name		**Weightage**
Very low		2
Low		3
Moderate		4
High		5
Land use map		
Class Name		**Weightage**
Brick kilk		1
Rural settlement		2
Agricultural Land (Double cop)		4
Agricultural Land (Single cop)		6
Water Body		10
Soil		
Code	**Group**	**Weightage**
WO44	B	5
WO78	C	4
WO47	D	3
Geology		
Class Name	**Code**	**Weightage**
Alternating of sand, slit & clay	Q2P	10
Clay impregnated with caliche	Q1S	4

Slope	
Class Name	**Weightage**
Very gentle	1
Gentle	2
Moderate	5
Steep	7

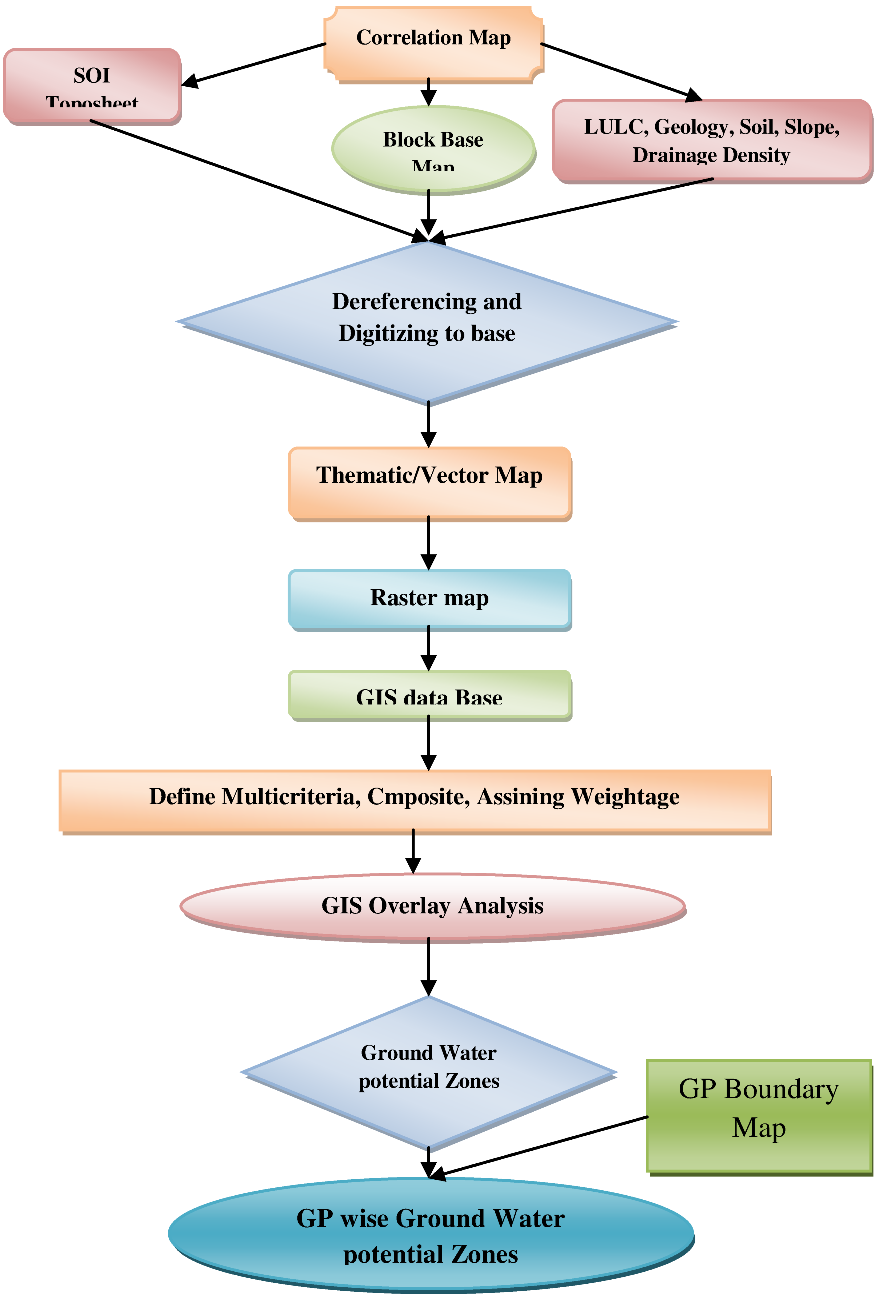

Fig. 7. Flow Diagram.

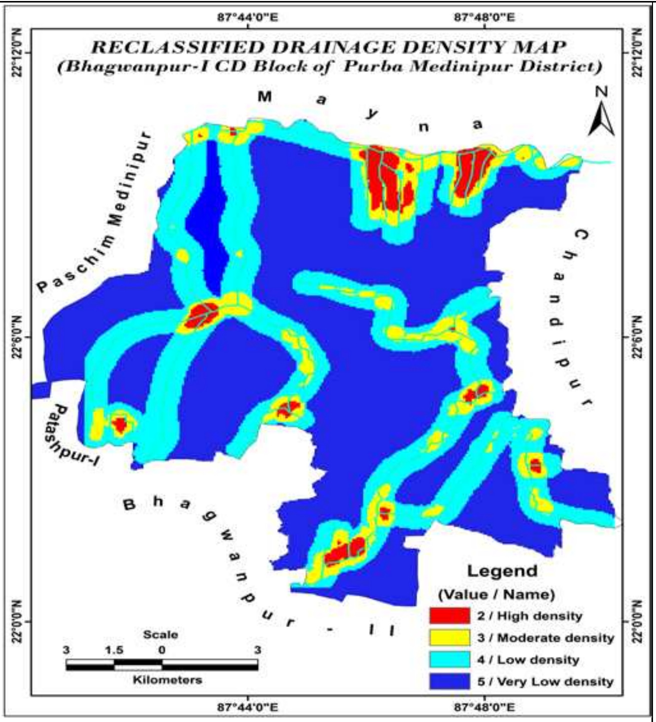

Fig. 8. Reclassified Drainage Density Map.

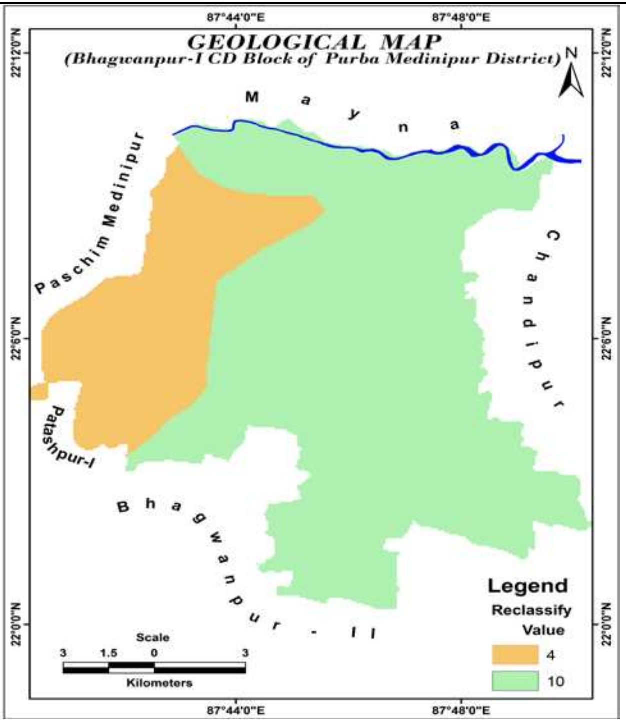

Fig. 9. Reclassified Geological Map.

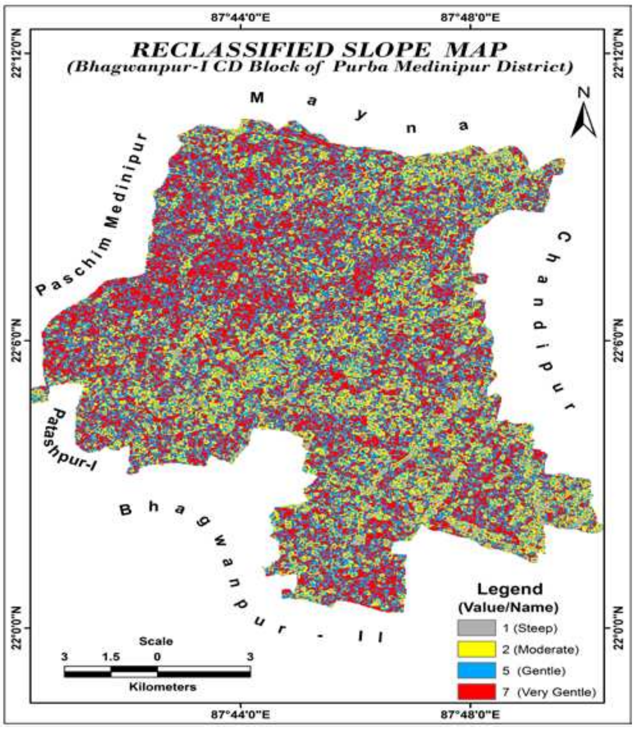

Fig. 10. Reclassified Slope Map.

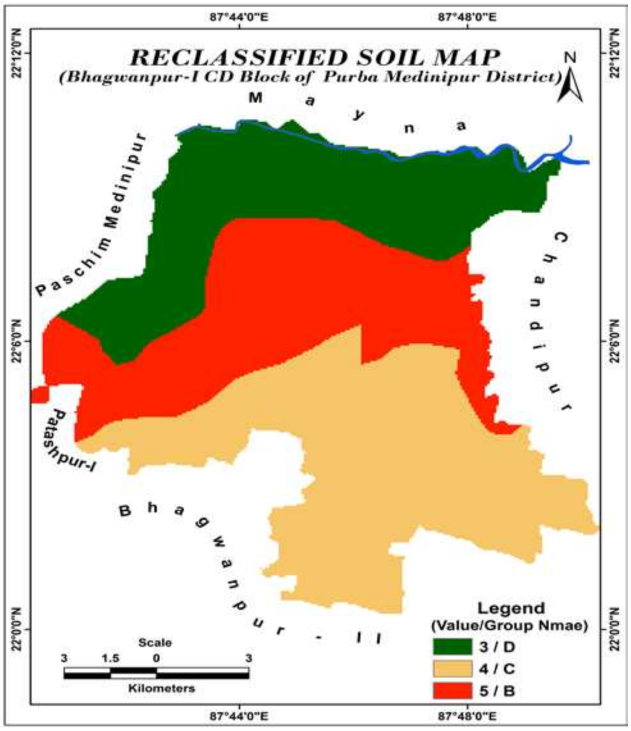

Fig. 11. Reclassified Soil Map.

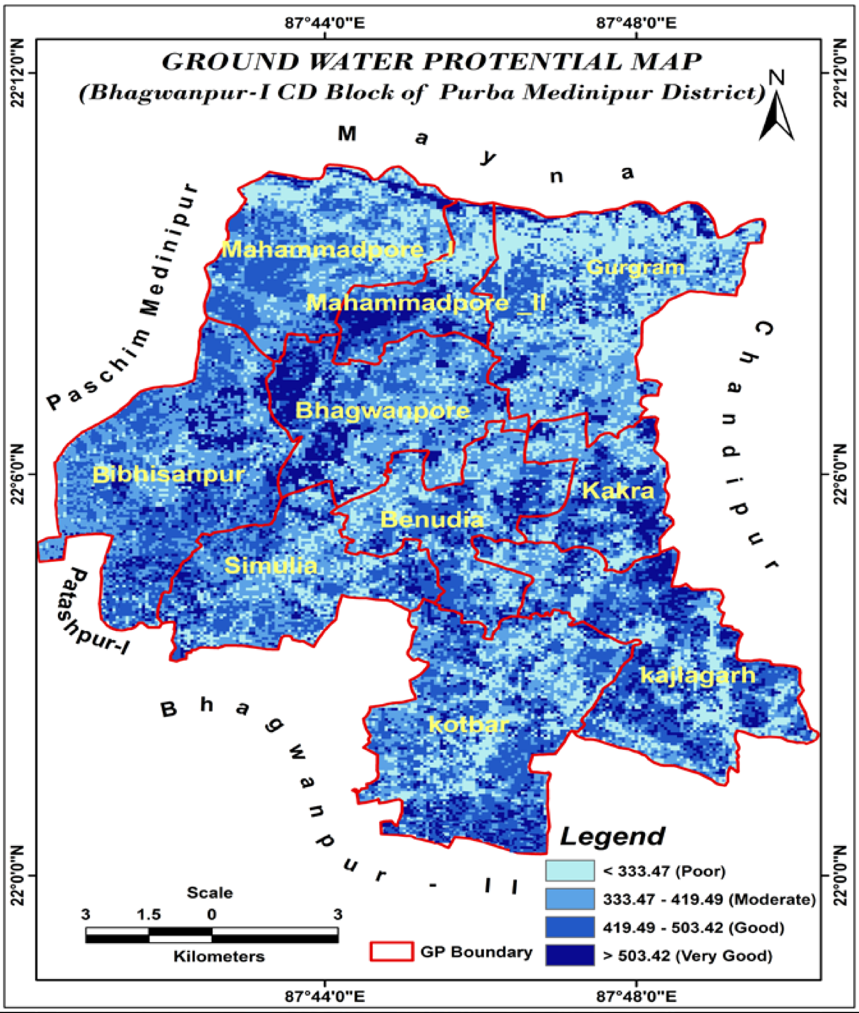

Fig. 12. Ground Water Potential Map.

Reclassified soil map

In Gurgram, Mahamadpore-I, Mahamadpore-II & some part of Bibhisanpore GP have soil is very deep, poorly drained, fine soil occurring on level to nearly level low laying alluvial plain with clay surface and severe flooding (W047) have occurring gentle sloping, very deep and Bhagwanpur, some part of Kakra & Bibhisanpur GP have soil is poorly drained, fine cracking soil occurring on level to nearly level low laying alluvial plain with clay surface and moderate flooding low gentle slope (W044) and Simulia, Benudia, Kajlagarh, Kotbar & some part of the Kakra GP have soil is Very deep, poorly drained, fine cracking soil occurring on nearly level to very gently sloping coastal plain with clayey surface, moderate flooding and moderate salinity (W078) occurring steep slope. Using weightage value from the Table no-01/B soil map is reclassified (Fig: 08). It is observed from the reclassified map that the highest potential zone is 3rd class; medium is 2nd class and lowest is the 1st class.

Ground water potential zone

The objective investigation in the area to find out which are good ground water potential in the hard rock terrain of the present study. The factor geology, geomorphology, land use, land cover, drainage density, soil is influenced the ground water potentiality (Das & Kader, 1996). These factors are good for water potentiality and have higher ground water. The groundwater potential zone using weightage index is prepared (Fig. 11). It is observed during the case study and also from the, the area, South Western part of Bhagwanpore, Goursahi, Southern part of Mahammadpore-II, Kakra & North-eastern part of Kajlagarh Gram Panchayet etc. have good water potentiality. Because of low slope, high drainage density, infiltrated soil, porous lithology. On the other hand North-East-west part of Gurgram, some part of Bibhisanpur, Mahammadpore-I & South-Eastern part of Simulia GP etc. has low water potentiality because of high slope, low drainage density, hard lithology, non porous soil etc.

Conclusion

The ground water potential zones have been derived of the Bhagwanpur-I, CD block and it has been divided into mainly four categories, namely very good, good, Moderate and poor recharge potential zone.

- Rain water is mainly responsible for the ground water recharging for the study area.
- The limitation of this study is as follows-
  - Much of the information can only be confirmed by the use of well records, bore hole and other sampling methods.
  - Due to the unavailability of temperature data to the ground water potential zones measurement does not contain the overall accuracy.

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