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VIDYASAGAR UNIVERSITY
Dept. of Geo. and Env. Mang.

An Integrated GIS Approach for Assessment of Ground Water Potential Zone: A case Study on the Upper Catchment Area of Subarnarekha River

*Amrit Kamila[1], Abhinanda Bal[2], Tuli Sarkar Sen[2], Jasmin Parvin[2], Farhin Sultana[1], Asutosh Goswami[2] & Ashis Kr. Paul[2]

[1]Dept. of Remote Sensing and GIS, Vidyasagar University, Midnapore-721102, West Bengal
[2]Dept. of Geography and E.M., Vidyasagar University, Midnapore-721102, West Bengal

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ABSTRACT

In the present study, Remote Sensing and GIS techniques have been used to perceive the Ground water Prospect sites in the upper catchment area of Subarnarekha River, Jharkhand. The studied area is the part of the Chota Nagpur Plateau and mainly named as Ranchi Plateau. A GIS integrated method is considered to delineate the ground water potential zone in this plateau region. This study is a systematic application and it has been considered five major controlling factors such as land use / land cover, geological structure, soil taxonomy, drainage density and surface steepness to detect the ground water potentiality.The weighted overlay method has been stimulated to demarcate the final ground water potential zone on the basis of weighted value. Each scheming factors are reclassified based on their assigning weighted value which are as certained from the prioritization of each class from all thematic layers according to their influence on ground water recharge. The result shows that more than 88% of the study area is under moderate to high potential zone of ground water. Among which 45% of area is under moderate potential zone, 38% under high potential zone and 4% is very high potential zone.

Introduction:

Human health, economic development and ecological diversity are laid down for the inflow of ground water. In India, more than 90% of the urban populations rely on ground water for meeting their drinking and domestic requirements (Yammani, 2007). Groundwater is the declension of water which inhabits all the voids within a geological stratum. The groundwater occurrence in a geological formation and the scope for its exploitation primarily depends on the formation of porosity. High relief and steep slopes impart higher runoff, while topographical depressions increase infiltration. An area of high drainage density also increases surface runoff compared to a low drainage density area. Surface water bodies like rivers, ponds can act as recharge zones (Murugesan et al., 2012). Currently groundwater is gaining more attention due to drought problem, rural water supply, irrigation project and low cost of development. Despite the extensive research and technological advancement, the study of groundwater has remained more risky, as there is no direct method to facilitate observation of water below the surface (Mukherjee etal., 2012). Its presence or absence can only be inferred indirectly by studying the geological and surface parameters. For the analysis of potential zones of the above study area totally five parameters have been considered. Presently the remote sensing and Geographic information system (GIS) tool can open new path in water resource studies (Preeja et al., 2011).

2. Study Area

The upper catchment of the Subarnarekha river basin mainly occupies the major portion of the south-eastern

Correspondence to Amrit Kamila
Dept. of Remote Sensing and GIS, Vidyasagar University, Midnapore-721102, West Bengal
E-mail address : amritkamila90@gmail.com

segment of the Chota Nagpur Plateau. This area is underlined by three basic geological formations such as Pre-Cambrian, Achaean and Tertiary (Nag & Chakraborty, 2003). The river originates near Nagri Village in Ranchi District of Jharkhand State at an altitude of 600 m from the MSL. The main tributaries of the river are Kanchi, Kharkai, Damra and Raru (Sarkar et al., 2001). The study area covers several administrative boundaries. Mainly the study area is bounded with some parts of the Ranchi, Ramghar and Khunti Districts of the Jharkhand State and a fragment of the western part of the Purulia District of West Bengal State in India (Fig. 1). The upper part of the Subarnarekha River Basin is located in between latitude 22°48'04.02" N to 23°32'44.17" N and longitude 85°08'19.07"E to 86°08' 32.01"E.The Chota Nagpur Plateau has an attractive climate. The basin is generally influenced by the South-West monsoon, which starts in the month of June and extends up to October.

3. Materials and Methods

Integrated remote sensing and GIS is a very useful tool for assessing the Ground Water potential zones

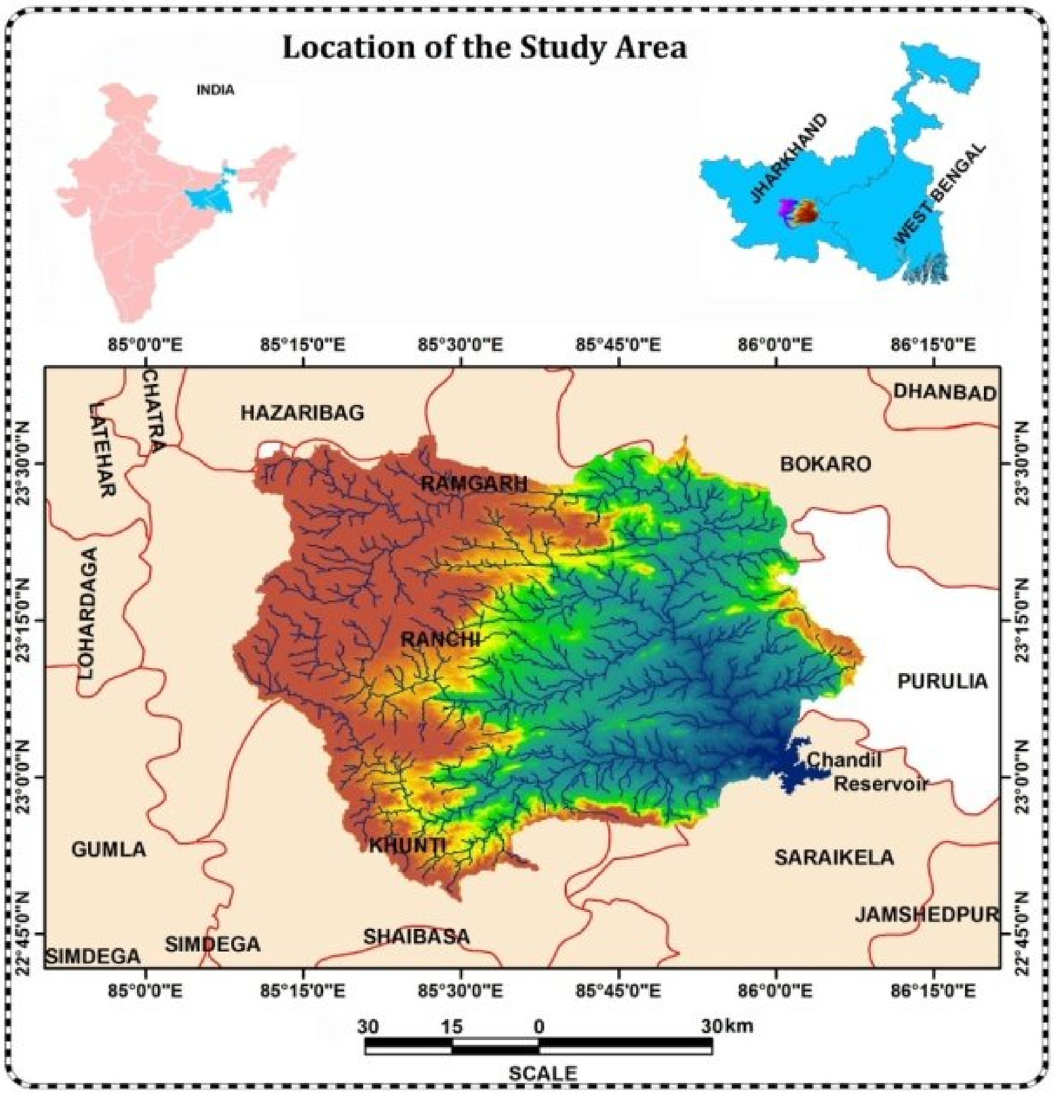

Fig. 1 : Location Map of the Study Area

Table 1. Details of Setellite Data

	Bands	Wavelength (μ)	SpatialResolution (m)
Landsat 8, Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	Band 1 (Coastal aerosol)	0.43 - 0.45	30
	Band 2 – Blue	0.45 - 0.51	30
	Band 3 - Green	0.53 - 0.59	30
	Band 4 – Red	0.64 - 0.67	30
	Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
	Band 6 - SWIR 1	1.57 - 1.65	30
	Band 7 - SWIR 2	2.11 - 2.29	30
	Band 8 - Panchromatic	0.50 - 0.68	15
	Band 9 - Cirrus	1.36 - 1.38	30
Imagery Date 15. 03. 2017	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)

TIRS bands are acquired at 100 metre resolution, but these are re-sampled to 30 meters in delivering data product.

SRTM DEM: 1 Arc-Second Global (30 m) Downloaded from USGS

Soil Map: NBSS & LUP

Geological Map: Dept. of Information & Technology (JSAC)

using different hydrological models (Bahuguna et al., 2003). For this study Landsat 8 OLI and TIRS data have been used and taken from USGS on 15.03.2017. This data is processed in ERDAS Imagine 9.0. The Spectral Angle Mapping (SAM) classification techniques have been consumed for land use / land cover classification. The Digital Elevation Model (DEM) can play a significant role to compute the digital slope and drainage network of this study area. The categorization of different parameters such as, Land use / land cover, Drainage density, soil taxonomy, slope and geology are reclassified in a specific weighted value for each class. After assigning the weighted value, it is converted to raster format using cubic convolution resampling method to renovate the pixel size using GIS software (Fig. 2). The weighted overlay method allows the calculation of a multi criteria analysis between several rasters. Every parameter is used to specify the rasters criteria and their respective properties. Finally, the groundwater potential zones

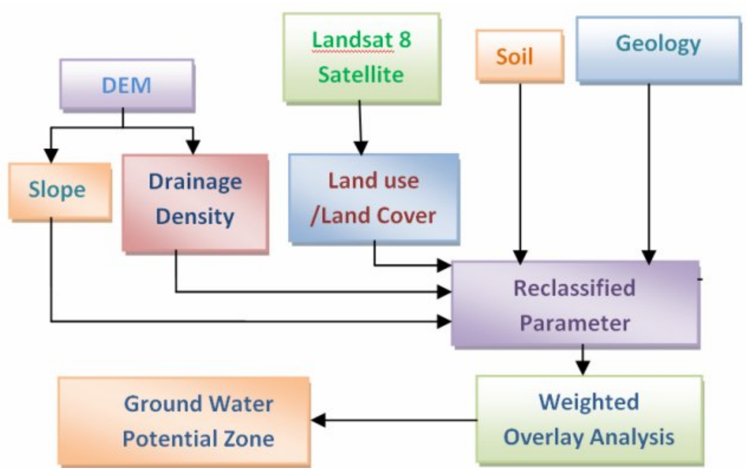

Fig. 2 : Methodological Flow Chart

have been identified using weighted overlay analysis method (Pani et al., 2016).

4. Results and Discussions

4.1 Land Use / Land Cover

Land use plays a significant role in controlling various hydrogeological processes in the completion of a water cycle. Different types of land use pattern determine variability of infiltration, evapotranspiration and surface runoff of a particular region. In the study area, having six types of land use land cover, maximum coverage area is found under mixed vegetation with grass land which is a good groundwater potential area because forest areas act as site of more infiltration and less runoff (Fig. 3). But the highest ground water potential zone can be found under the water bodies and dense vegetation, where as hard rock or built up area has the lowest chance of having recharge of ground water.

4.2 Geomorphology

From the Digital Elevation Model three types of broad geomorphological features are visible like- moderately dissected plateau, escarpment with pediment and pediplain (Fig. 4). It is evident that the pediplain surface in the east has the maximum scope for groundwater recharge rather than the pediment surface at the middle if slope factor is also considered with it (Basavaraj et al., 2016). On the other hand plateau being upland helps in higher runoff so retarding water infiltration.

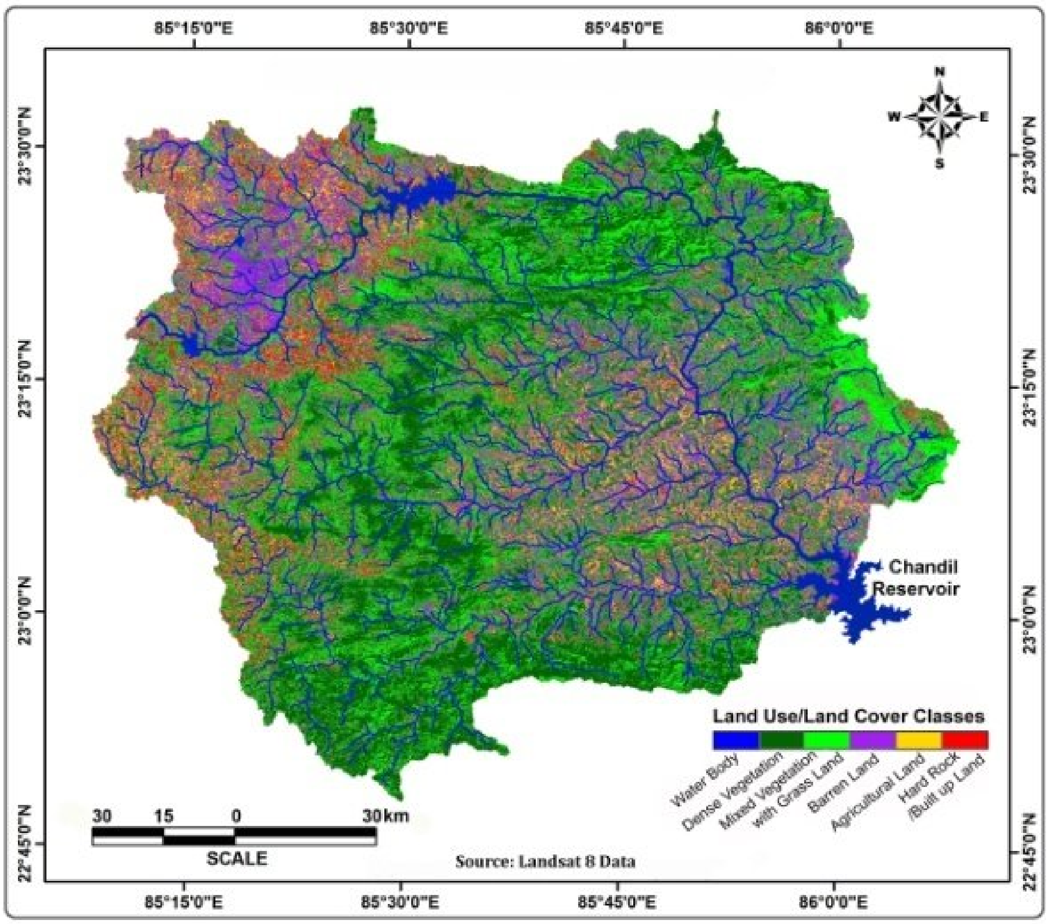

Fig. 3 : Land Use/Land Cover of the Study Area

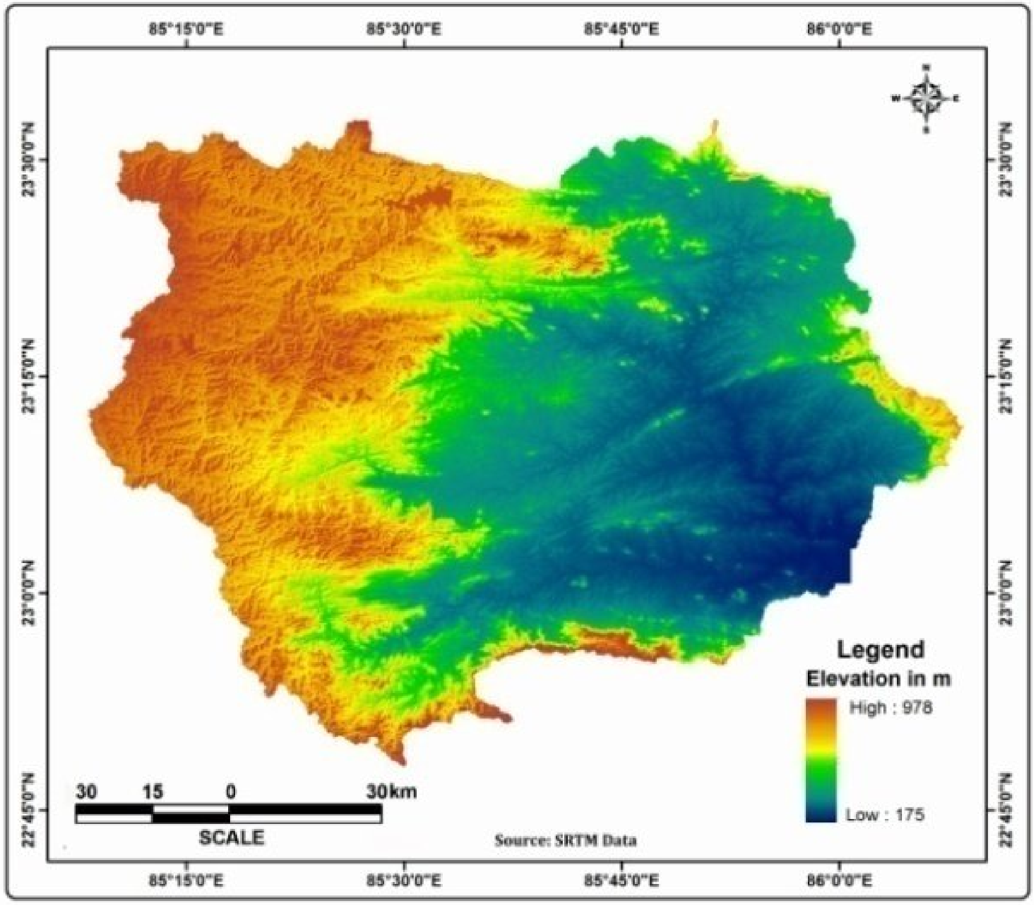

Fig. 4 : Digital Elevation Model (DEM)

4.3 Drainage Density

From the Drainage Map it has been seen that the upper catchment area of Subarnarekha River is a fourth order stream and the whole runoff and discharge of water of this drainage basin is collected at a common point, at the Chandil Reservoir (Fig. 5). The study area with mostly dendritic drainage pattern shows a homogenous rock structure but in the western and north-western part few trellis and parallel drainage pattern provides an evidence of lithological and structural control.

From the drainage density map, a clear picture about the runoff, infiltration and permeability of rocks can be established. A greater portion of the drainage basin has a coarse drainage texture (Waikar M. L. et. al., 2014) with porous and permeable rocks and also in those particular areas the drainage density is low with higher resistance from vegetation and agricultural field and also with lower relief, mainly the eastern part. This shows a situation of less runoff and more infiltration with high groundwater recharge capacity. The remaining areas with high drainage density comprise of the highest order streams which accelerates a quick and more runoff situation. In total drainage density map is depicted with five sub-classes (Fig. 6).

4.4Slope

This slope map is calculated in degree which shows a range of 0^{o} to 63^{o} from east to west and divided into five sub-types. In the west and north-west lies the plateau area and to the east lies the level land or the pediplain surface. As the plateau area is moderately dissected so the top surface of the plateau has a lower slope. On the other hand the middle part of the map with maximum dissection of plateau and zone of change in elevation shows the highest slope values

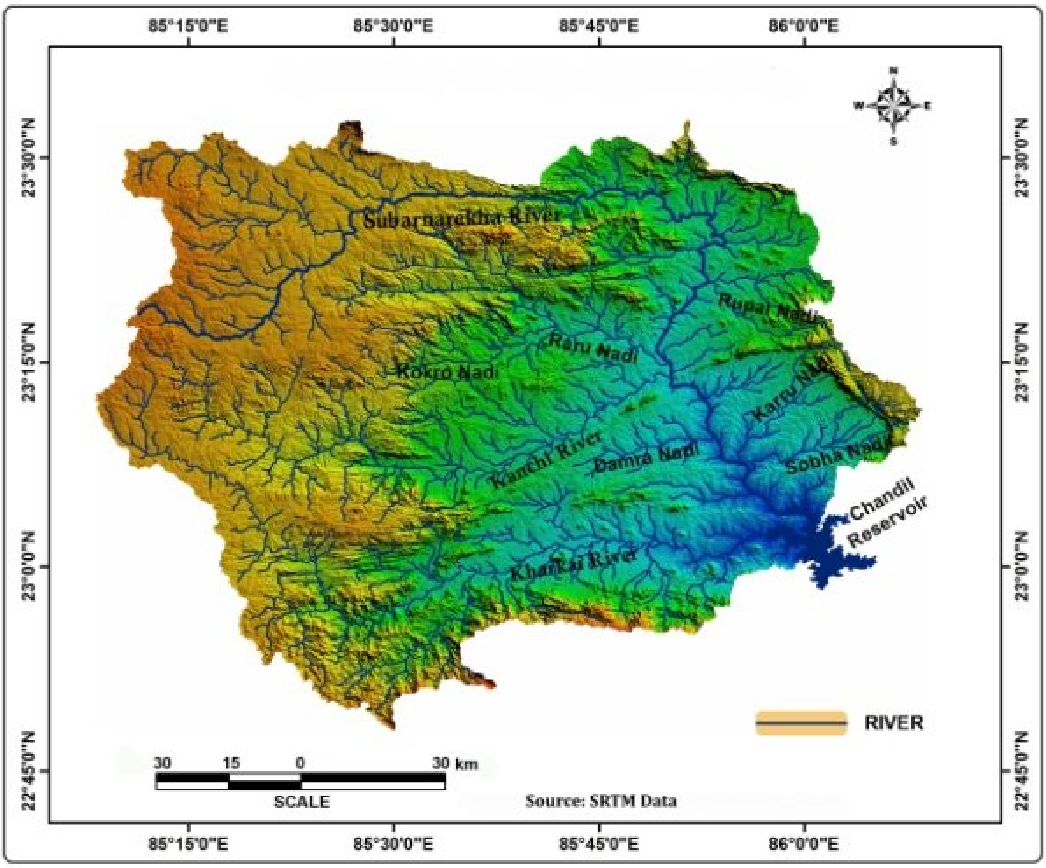

Fig. 5 : Drainage Network of this Area

(Fig. 7). The eastern riverine pediplain surface has also a lower slope value. So the highest potentiality of the groundwater recharge can be the plains in the east and top surface of the plateau in the west (Nagarajan M., 2009).

4.5 Geology

The geological map depicts the lithological structure as mainly of igneous origin. Five variations of rock formations are delineated among which the predominance is on gneiss and granophyre and volcanogenic metasediment and metasedimentary rock. The southern part of the map has the sedimentary structure with igneous origin due to the depositional process by the large streams carrying sediments from the igneous plateau structure (Fig. 8).

4.6 Soil

The eleven types of soil class have been found in this area but for the convenience of the weighted overlay mechanism four main subdivisions are done. The region is mainly predominated by loamy soil which retards runoff and aggravates infiltration. So according to soil taxonomy this region is a good groundwater potential zone (Fig. 9).

4.7 Assigning Weighted Value and Estimation of Groundwater Potential Zone

This study carried out the linear combination of weighted value for assessing the zonation. The individual ranks are given for sub variables of each thematic maps (Table: 2) of land use land cover, drainage density, geological features, slope and soil taxonomy and analysis on groundwater potential zone are carried out accordingly (Basavaraj et. al., 2011).

The maximum value is given to the feature with highest groundwater potentiality and the minimum given to the lowest potential feature. The water bodies

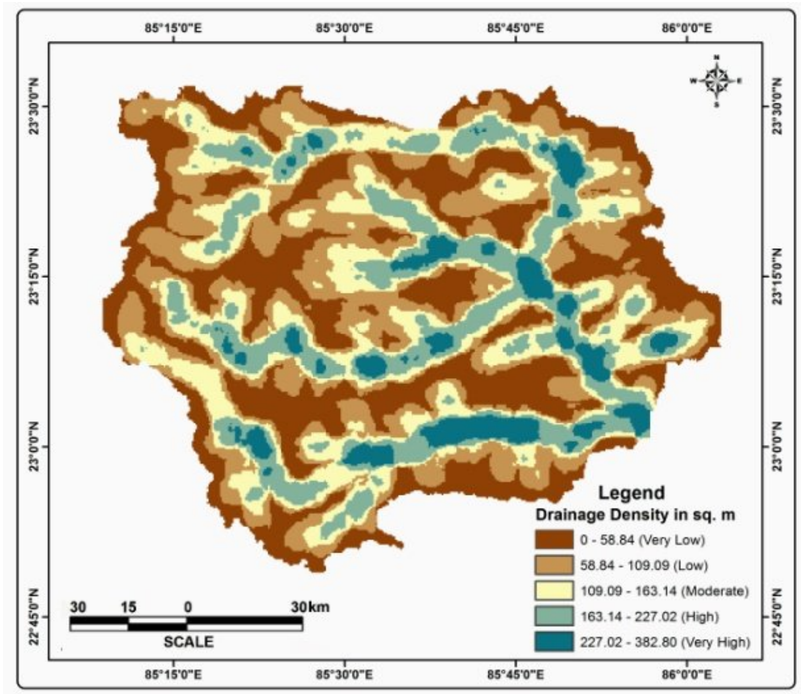

Fig. 6 : Drainage Density Map

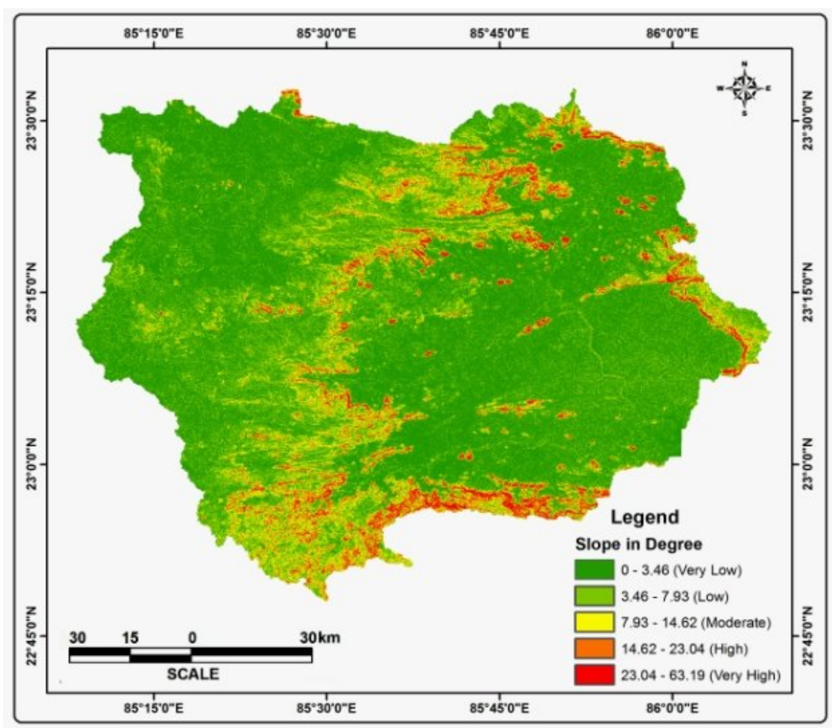

Fig. 7 : Slope Map (in Degree)

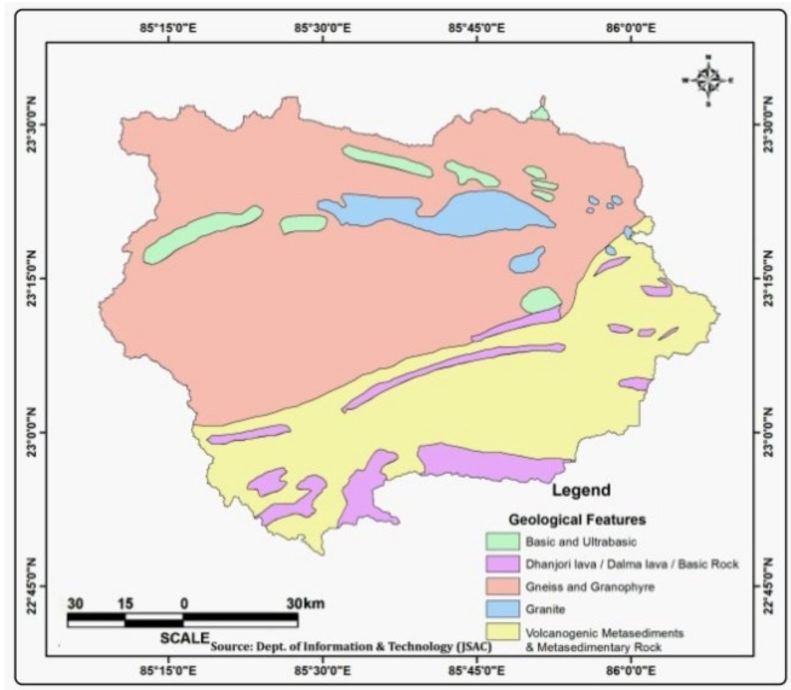

Fig. 8 : Geological Features

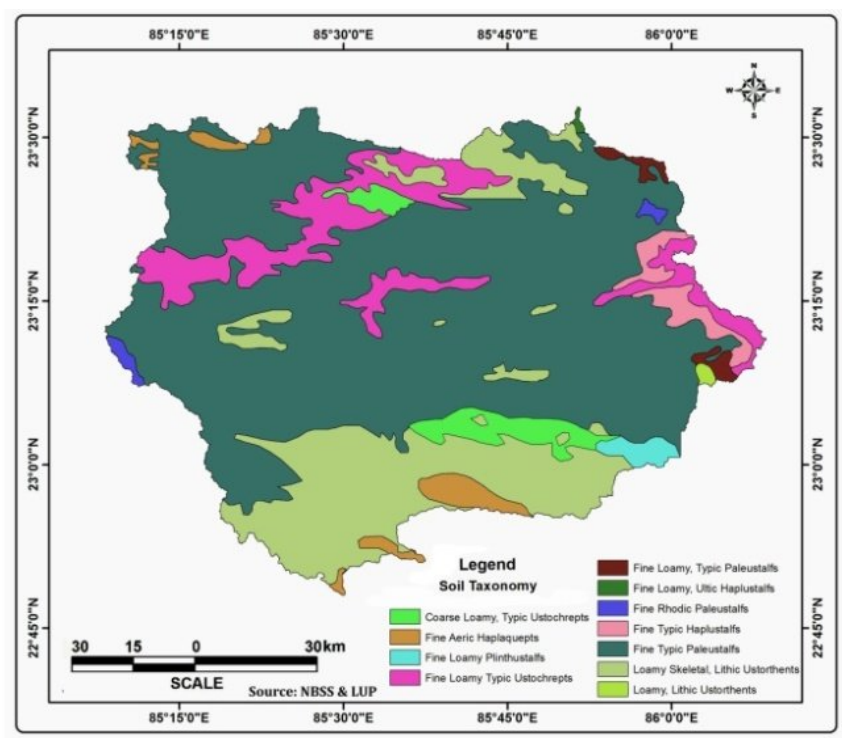

Fig. 9 : Soil Taxonomy Categorization

Table 2. Changing natures of different micro-

Land Use/Land Cover	Theme Weight	Weighted Value
Water Body		9
Dense Vegetation		3
Mixed vegetation with Grasses	10	8
Barren Land		4
Agricultural Land		7
Hard Rock / Built up Land		1
Drainage Density	**Theme Weight**	**Weighted Value**
Very High		1
High		2
Moderate	5	3
Low		4
Very Low		5
Slope in Degree	**Theme Weight**	**Weighted Value**
Very High		1
High		2
Moderate	5	3
Low		4
Very Low		5
Geological Features	**Theme Weight**	**Weighted Value**
Volcanic Metasediments & Metasedimentary Rock		7
Gneiss and Granopphyre		5
Dhanjhori Lava / Dalma Lava / Basic Rock	10	3
Basic and Ultra Basic		2
Granite		1
Soil Taxonomy	**Theme Weight**	**Weighted Value**
Fine Rhodic Paleustalfs		2
Loamy Skeletal, Lithic Ustorthents; Fine Loamy, Ultic Haplustalfs; Fine Loamy Typic Ustochrepts; Fine Typic Haplustalfs; Fine Loamy Plinthustalfs; Fine Typic Paleustalfs	10	3
Fine Aeric Haplaquepts; Loamy, Lithic Ustorthents; Fine Loamy, Typic Paleustalfs;		4
Coarse Loamy, Typic Ustochrepts		6

get the highest weighted value and hard rock or built up land get the lowest in the land use land cover map. The higher rank factors are assigned to low drainage density because the low drainage density factor favours more infiltration than surface runoff. Lower value followed by higher drainage density. As far as slope is concerned, the highest rank value is assigned for gentle slope and low rank value is assigned to higher slope. The volcanic metasediments & metasedimentary rock is given the highest value among the geological features and granite receives the least. Among the soil variations fine rhodic paleustalfs are assigned the least weight and coarse loamy and typic ustochrepts the highest because of the porosity and permeability of the soil (Magesh et al. 2012).

Thus the overlay method for extraction of groundwater potential zone reveals the most important fact about the study area that this region is a good source of recharge for groundwater. The map (Fig. 10) and the final tabulated figure (Table: 3) explores the fact that more than 88% of the study area is under moderate to high potential zone of groundwater.

5. Conclusion

The study reveals that integration of five thematic layers such as drainage density, slope, geology, soil taxonomy and land use / land cover have been reclassified on the basis of weighted value. The weighted overlay analysis methods have been exploited to determine the ground water potential zone. Then the ground water potential zones have

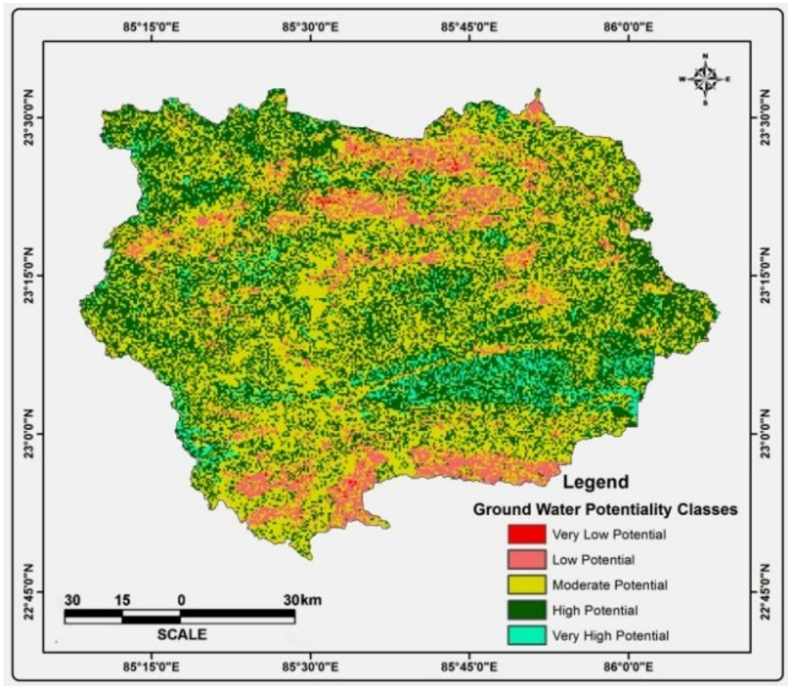

Fig. 10 : Grownd Water Potential Zone

Table 3. Area of Ground Water Potential Categorization

Ground Water Potential Classes	Area in sq. km	Area in Percentage (%)
Very Low Potential Zone	21.46	0.39
Low Potential Zone	617.86	11.52
Moderate Potential Zone	2462.18	45.91
High Potential Zone	2038.61	38.00
Very High Potential Zone	223.35	4.16
Total	**5363.46**	**99.98**

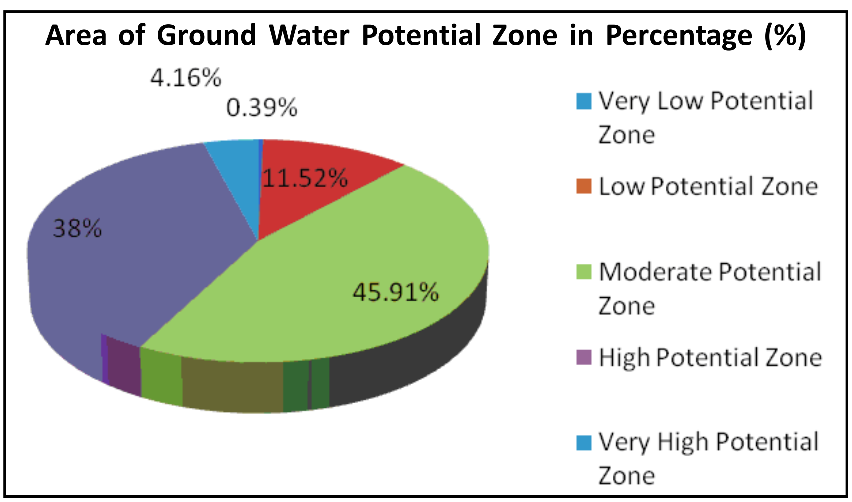

Fig. 11 : Area of Ground Water Potential Zone in Percentage

been derived for the upper catchment area of Subarnarekha River. The result highlights that about 38% (2038.61 sq km) of the study area is designated as high potential for ground water recharge. Moderate, low and very low potential covers 45.91 (2462.18 sq km), 11.52 (617.86 sq km) and 0.39 (21.46 sq km) respectively. It is recommended that the high potential zones are well places for getting the ground water using tube wells and artificial recharged and provides a quick perspective about ground water exploitation in sustainableway for betterment of the society.

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