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Delineation of Ground Water Prospect Zone in hard rock terrine part of Purulia District of West Bengal-India using Remote Sensing & GIS Approach

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ABSTRACT

In the field of ground water resource uses of Remote Sensing and Geographic Information System (GIS) assume a crucial part in ground water investigation. Using Remote Sensing data (satellite image) and the Geographic Information System we can undoubtedly get to, observing, preserving and economically dealing with the ground water resource. In this work utilizing Remote Sensing and GIS system, different ground water prospect zones depicted of ground water accessibility in Purulia district. Different thematic layers viz. Topography, soil, hydro geomorphology, land use, slope, drainage density, lineament density and water level depth were prepared utilizing Survey of India (SOI) Toposheets, satellite image (IRS-1C, LISS-III and Cartosat-1, DEM), National Bureau of Soil Survey (NBSS), and Geological Survey of India (GSI) maps in GIS environment. The multi influence factor (MIF) technique used to process a weighted score of each raster class. Additionally, each weighted thematic layer statistically compute to get the ground water prospect zones utilizing the weighted overlay analysis tool in Arc GIS software. Five classes (Restricted, Not Suitable, Suitable, Moderate and Highly Suitable) of ground water prospect zones found in the study area, the restricted zone covers 1412.35 sq km around 22.57 %, not suitable zone covers 151.75 sq km around 2.42 %, suitable zone covers 1333.97 sq km around 21.31 %, moderate zone covers 2912.47 sq km around 46.53 and high suitable zone covers 448.47 sq km around 7.17 % of the total study area. The result delineate the ground water prospect zones in the study area and observed to be useful in better planning, management and sustainable development of ground water resource in future.

Keywords : Remote Sensing & GIS, SOI, GSI, NBSS, LISS-III, DEM, MIF, Hydro-Geomorphology, Drainage Density, Lineament Density, Weighted Overlay, Ground Water Prospects.

I. INTRODUCTION

Groundwater is a vital natural resource on the earth surface; consequently, it assumes a principal part in human prosperity, and additionally that of some aquatic and earthbound biological systems (Magesh et al., 2012). 90% of the rural and about 30% of the urban population depend on ground water to meet their drinking and residential necessities in India (Reddy and Adams, 1996; Pani et al., 2016). Ground water is the part of fresh water resource, in present's day ground water contributing 34% of the total annual water supply. The assessment of this resource Remote Sensing & GIS are widely utilized for sustainable management of ground water and others natural resources (Dar et al., 2010; Krishna Kumar et al., 2011; Magesh et al., 2011a, b). The remote sensing & GIS is an effective tool for delineation the ground water prospect zone mapping. It is simpler to establish baseline information of ground water prospect zone using satellite image, conventional map and field truth information (Tiwari and Rai, 1996; Das et al., 1997; Thomas et al., 1999; Harinarayana et al., 2000; Muralidhar et al., 2000; Chowdhury et al., 2010). Remote sensing not only provides a wide-range scale of the space-time distribution of observation but also saves time and money (Murthy, 2000; Leblanc et al., 2003; Tweed et al., 2007). Likewise, it is generally used to describe the world's surface, (for example, lineaments, drainage pattern, and lithology) and in addition to looking at the groundwater recharge zones (Sener et al., 2005). Coordination of remote sensing and GIS, the different thematic layer, such as, geology, soil, drainage density, lineament density, hydro geomorphology, land use, slope and water level depth assigning weighted an encouragement in a unique area for getting ready to ground water prospect zones mapping. Already, numerous researchers utilized the remote sensing and GIS method to characterize the spatial dissemination of groundwater potential zones on the premise of geomorphology and other related parameters (Krishnamurty and Srinivas, 1996; Ravindran and Jayaram, 1997; Sree Devi et al. 2001; Sankar, 2002; Jagadeeseara et al., 2004). Hence, the present examination concentrated on ground water prospect zone mapping utilizing advance remote sensing, MIF and GIS technique for future sustainable ground water management.

II. Study Area

The investigation area bounded by 22° 36' 0" N to 23° 30' 0" N latitudes and 85° 45' 0" E to 86° 39' 0" E longitudes, the total area covers 6259 sq.km (Fig. 1). Topographically the area originates from undulating plain, Ajodhya hill run in the southwestern site, the relief of the area varies 29 – 632 meter above mean sea level. Purulia is drought prone district of West Bengal, part of subtropical atmosphere and is characterized by high evaporation and low precipitation. Temperature is high in the summer (52^{0}C) and low in winter (2.8^{0}C), average annual precipitation fluctuates between 1100 mm to 1500 mm. Kangsabati, Kumari, Silabati (silai), Dwarakeswar, Subarnarekha, and Damodar are the important river in the study area.

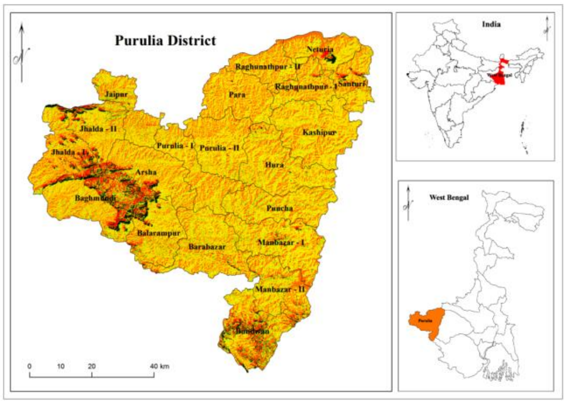


Figure-1: Location Map of the Study Area

III. Methodology

The methodology utilized for this present examination is appeared in (Fig-2). The investigation zone map prepared utilizing Indian administrative maps, the drainage map of the study area produced utilizing Cartosat-1, DEM data and Survey of India Toposheets (73 E/15,16, 73 I/2, 3, 4, 6, 7, 8, 10, 11, 12, 14, 15, 16 and 73 J/5, 6, 9, 10 on a scale 1:50000). The slope map generated from a Cartosat-1 DEM image using Arc GIS spatial analysis tool. Satellite image from IRS-1C, LISS-III sensor, on a scale of 1:50,000 (Geo-coded, with UTM projection, spheroid, and datum WGS 84, Zone 45 North) have been utilized for prepared of thematic layers, such as, lineament, and land use type. Geological map prepared using Geological Survey of India (GSI) map and soil map prepared using ICAR-NBSSLUP soil map and hydro-geomorphology and water level map generated using different thematic maps. These thematic layers were converted into a raster format (30 m resolution) before they were brought into the GIS environment. The monthly precipitation data collected from Indian meteorology department (http://www.imd.gov.in) of the year 2016. The groundwater prospects zones were gotten by overlaying all the thematic layers in the terms of weighted overlay analysis method utilizing the spatial analysis tool in Arc GIS 10.1 software. During weighted overlay analysis, the ranking was given for every individual parameter of each thematic layer, and weights were assigning as per the multi influence factor (MIF) of that specific component on the hydrogeological condition of the study area (Shaban et al., 2006).

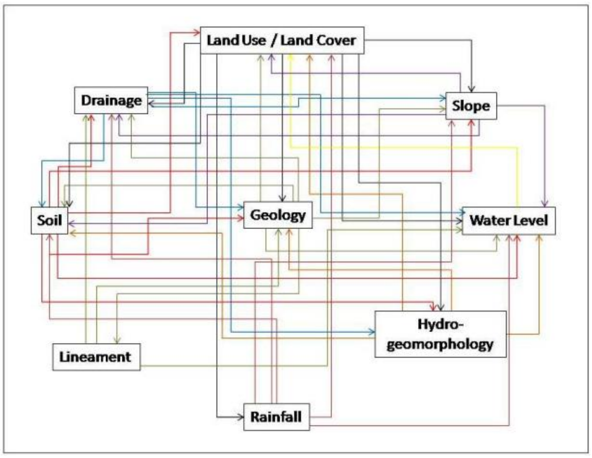


Figure-2 : Methodological Flow Chart

3.1. Multi Influence Factor (MIF) for ground water prospect zones:

Eight influencing factor s, such as, soil, geology, land use, drainage density, slope, hydro geomorphology, lineament, and water level have been distinguished to depict the groundwater prospect zones. An interrelationship between these variables and their impact is appeared in (Fig. 3). Every relationship is weighted by its strength. The representative weight by a factor of the prospect zones is the sum of all weights from each factor. A factor to higher weight value represented a high impact and a factor with a lower weight value represented to a less impact on groundwater prospect zones. Incorporation of these variables with their potential weights is computed through weighted overlay analysis in Arc GIS 10.1.

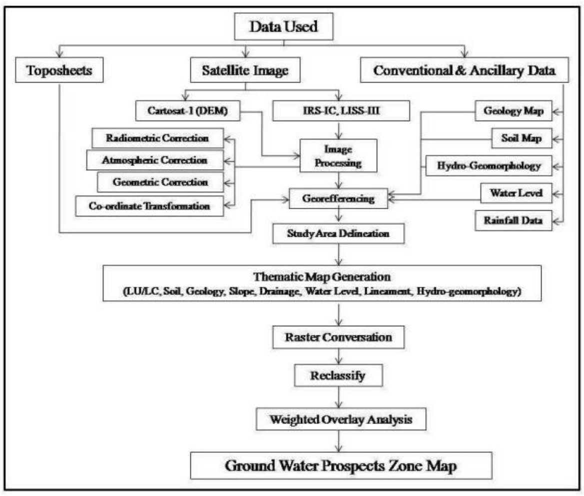


Fig-3: Interrelationship between the Multi Influencing Factors.

In the weighted overlay method, the map class's occurring in each input layer assigning by different scores, although the layer themselves getting weights. The average score is then defining by utilizing the formula is given underneath; (Borham Carter, 1994; Bhunia et al., 2012).

$$S = \Sigma\, SijWi/\Sigma Wi$$

Where, S is the weight score of an area object (polygon, pixel), Wi is the weight for the ith input layer and Sij is the rating score of the jth class of the ith layer.

IV. Result and Discussion

4.1. Weighted calculation:

The multi impacting factors associated with groundwater prospect zone mapping, to be specific soil, geology, land use, drainage density, slope, hydro geomorphology, lineament and water level were analyzed and assigned a suitable weight and are appeared in (Table 1). The impact of each influencing factor may contribute to portray the groundwater prospect zones. In addition, these factors are independent. The effect of each major and minor factor is assigned a weighted of 1.0 and 0.5 separately (Fig. 3). The cumulative weighted of both major and minor effect is considered for calculating the relative rates. This rate is additionally used to calculate the score of each influencing factor. The proposed score for each influencing factor is calculated by utilizing the formula (Magesh et al., 2011a);

$$\left[\frac{(A+B)}{\sum(A+B)} \times 100\right]$$

Where; A will be a major interrelationship between two components and B is a minor interrelationship between two elements. The concerned score for each influencing factor was separated similarly and assigned to each reclassified factor (Table 2).

Table-1: Effects of influence factor, relative rates and score for each potential factor				
Factors	**Major Effects (A)**	**Minor Effect (B)**	**Proposed Relative Rates (A + B)**	**Proposed Score of each influence factor**
Soil	1+1	0.5	2.5	10
Geology	1+1	0.5+0.5+0.5	3.5	15
Land Use	1+1+1	0.5+0.5+0.5	4.5	19
Drainage Density	1+1	0.5+0.5	3	12
Slope	1+1	0.5+0.5+0.5+0.5	4	16
Hydro-geomorphology	1	0.5+0.5	2	8
Lineament	1+1	0.5+0.5	3	12
Water Level	1	0.5+0.5	2	8
Total Value			**∑ 24.5**	**∑ 100**

Table-2: Classification of Weighed factor influencing ground water prospect zones			
Factors	**Domain of effects**	**Weightage**	**Cumulative Weightage**
Soil	Fine, Fine Loamy, Fine Loamy – Coarse Loamy	3	10
	Coarse Loamy, Gravelly Loam, Gravelly Loam - Loam	5	
Geology	Amphibolite and Horblendi Schist, Volcanics, Calc Granulite and Calc Schist, Intrusive Granite, Phyllite / Schiest	1	15
	Gabro & Anorthosite	5	
	Gondwana	2	
	Quartzite quartz schist, Granite Gneiss, Migmatite, Mica Schist, Meta Basic	3	
	Pleistocene Sediments	4	
Land Use	Forest & Vegetation	4	19
	Settlement	1	
	River & Surface Waterbody	3	
	Sediment	2	
	Barren land	3	
	Agricultural Land	6	
Drainage Density	0 – 0.55	6	12
	0.55-0.85	3	
	0.85-1.11	2	
	1.11-1.64	1	
Slope	0-5.96	7	16
	5.96-17.22	5	

	17.22-44.05	3	
	44.05-84.47	1	
Hydro-Geomorphology	Buried Pediment Medium & Shallow	1	8
	Valley Fill	3	
	Waterbody	4	
Lineament	0-0.19	2	12
	0.19-0.35	4	
	0.35-0.74	6	
Water Level	0-2	5	8
	2-5	2	
	5-20	1	

4.2. Soil:

The soil is a vital factor for depicting the ground water prospect zones. The analysis of the soil type it is revealed that the study area is prevalently covered by Coarse Loamy, Fine and Gravelly Loam-Loam and others. Fine Loamy – Coarse Loamy is found in Ajodhya hill region, Fine loamy and Gravelly Loam exhibits in another portion of the study area (Fig. 4). The ground water recharge rate is high in coarse loamy and gravelly loamy soil, so, ground water prospects is high in this soil group according to others soil group.

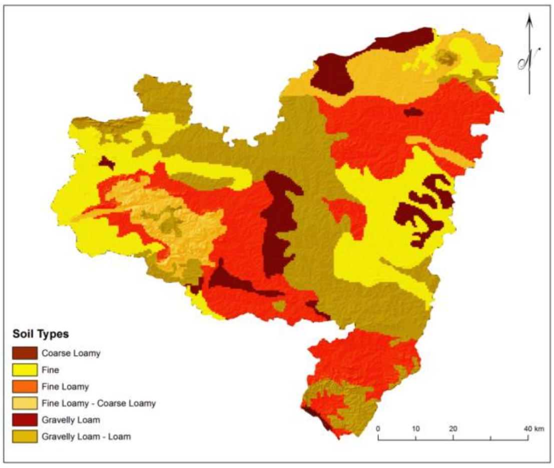
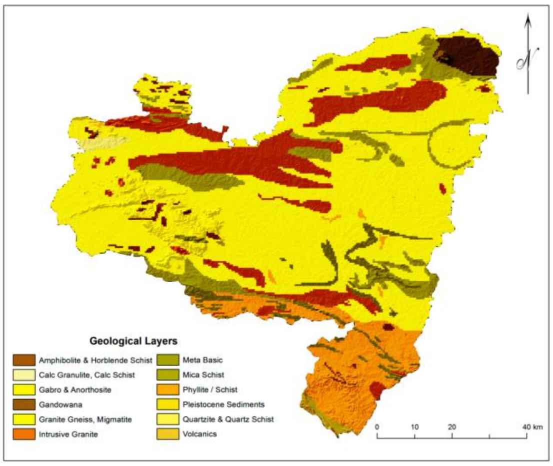


Figure-4: Soil map of Purulia District

4.3. Geology:

Purulia district is underlain by granite gneiss, migmatite, phyllite/schist, gabro and anorthosite, quartz and quartz schist, mica schist, amphibolite and hornblende schist, metabolism, intrusive granite, volcanic, Gondwana and Pleistocene sediment (Fig. 5). The quartzite and quartz schist presence overall portion of the Purulia district and its favorable for the ground water recharge.



4.4. Land Use:

The major land use in the study area is forest and vegetation, barren land, and agriculture land. These land use classes are portrayed from IRS-1C, LISS-III satellite data and extraordinary field check (Fig. 6). Around 43.24 % of the total area under forest and vegetation, 32.04 % are under barren land, 14.53 % zone under agriculture land and 10.19 % are under others features (Table. 3). The forest land presence in hill area with high slope region and agriculture land presence in low lying area of the study and its favorable for ground water recharge.

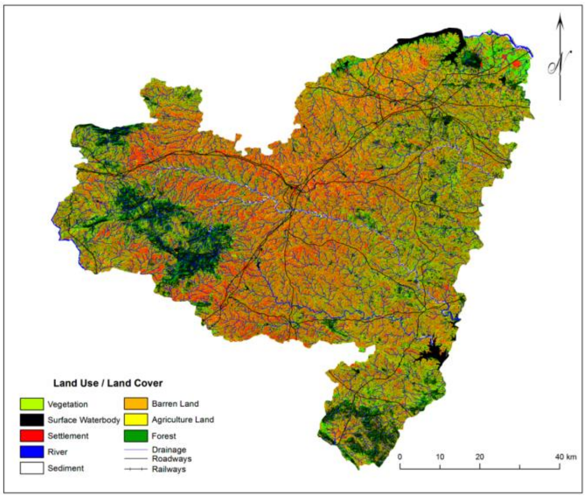


Figure-6: Land Use / Land Cover map of Purulia District

Table-3: Land Use / Land Cover Area			
Class Name	Area in (Hectare)	Area in (sq km)	% of Area in Total Area
Surface Waterbody	13685.68	136.86	2.19
Forest	94154.94	941.55	15.04
Vegetation	176519.60	1765.20	28.20
River	585.12	5.85	0.09
Settlement	48405.32	484.05	7.73
Agricultural Land	90960.01	909.60	14.53
Barren Land	200552.26	2005.52	32.04
Sediment	1037.07	10.37	0.17
Total Area	**625900**	**6259**	**100**

4.5. Drainage Density:

Drainage density is defined as the closeness of dividing of stream channels. It is a measure of the total length of the stream segment of all order per unit area. The drainage density is an function of permeability. The less permeability of a rock is, the less infiltration of precipitation, which alternately has a tendency to be amassed in surface overflow (Magesh et al., 2011a). Drainage density of the study area is calculated using line density analysis tool in Arc GIS software. The study area has been gathered into five classes. These classes have been assigned to 'very good' (1.11-1.64 km/km^2), "good" (0.85-1.11 km/km^2), "moderate" (0.55-0.85 km/km^2), "poor" (0.19-0.55 km/km^2), and 'very poor' (0-0.19 km/km^2) respectively. High drainage density (1.64 km/km^2) is recorded in the southwestern part (Ajodhya hill region) of the study area (Fig. 7). The suitability of groundwater potential zones is indirectly related to drainage density because of its relation with surface runoff and permeability. The high drainage density is high surface runoff, low infiltration rate due to high surface slope and low drainage is low surface runoff and high rate of infiltration.

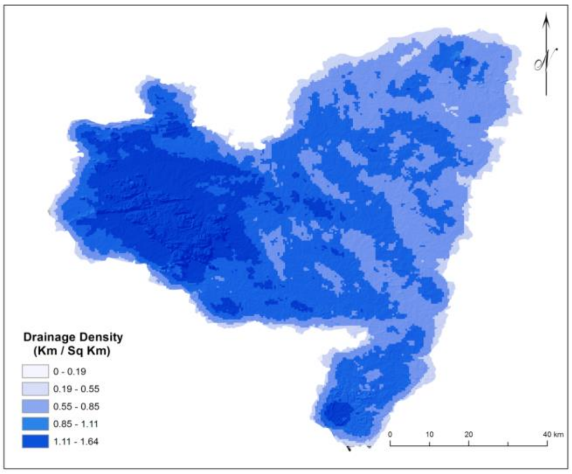


Figure 7: Drainage Density of the Study Area

4.6. Slope:

The slope is an essential factor in the distinguishing proof of groundwater potential zones. The Higher degree of slope brings about rapid runoff and increased erosion rate with feeble recharge potential (Magesh et al., 2011a, b). The slope map of the study area was prepared based on Cartosat-1, DEM data using the spatial analysis tool in Arc Info 10.1. slope grid is distinguished as the maximum rate of change in value from each cell to its neighbors (Burrough, 1986). Based on the slope, the study area can be divided into five slope classes. The areas having 0-0.99^0 slope fall into the 'very good' category because of the nearly flat terrain and relatively high infiltration rate and low surface runoff. The areas with 0.99^0-5.96^0 slope are considered as 'good' for groundwater storage due to slightly undulating topography with low runoff. The areas with 5.96 ^{0}-17.22^0 slopes are considered as 'moderate' for groundwater storage due to low undulating topography with low runoff. The areas under of 17.22^0-44.05^0 slopes cause relatively high runoff and low infiltration, and hence are categorized as 'poor' and the areas under of >84.46^0 slopes are considered as 'very poor' due to higher slope and high runoff (Fig. 8). The Ajodhya hill region found the high slope of the study area.

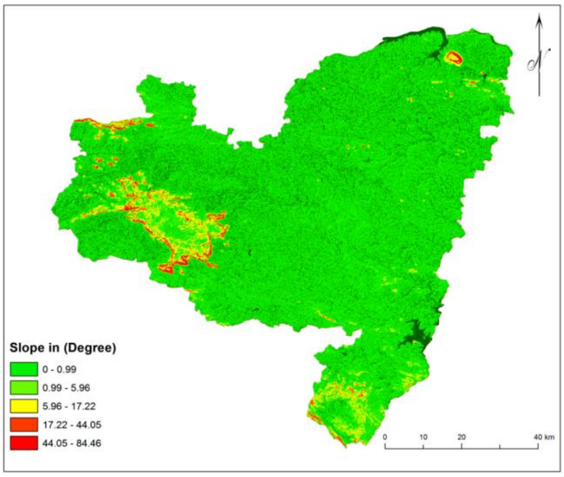


Figure-8: Slope map of Purulia District

4.7. Hydro-Geomorphology:

Hydro-geo morphologically the area under the four classes buried pediment medium covers northern and north-eastern part of the Purulia district, buried pediment shallow, covers northern, western, northwestern and southwestern (Ajodhya slope) region, valley fill covers all around the study area and water body found northern part of the Purulia district (Fig. 9).

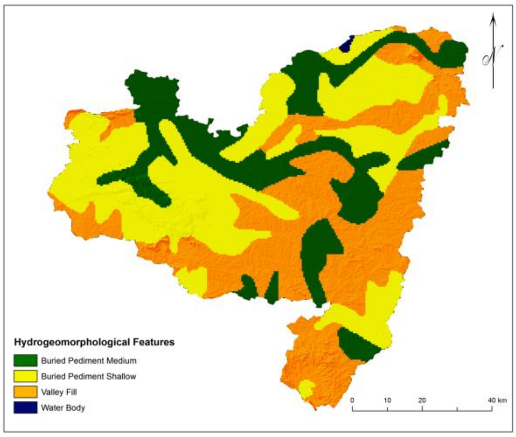


Figure-9: Hydro-Geomorphology of the Study Area

4.8. Lineament Density:

Lineaments are structurally controlled linear or curvilinear components, which are recognized from the satellite imagery. These features express the surface topography of the underlying structural features. Lineaments represent the zones of faulting and fracturing resulting in increased secondary porosity and permeability. These elements are hydro-geographically imperative as they give the pathways to groundwater movement. Lineament density of an area can indirectly reveal the groundwater prospects since the presence of lineaments usually denotes a permeable zone. Areas with high lineament density are useful for groundwater prospect zones (Haridas et al., 1998). The lineament density map of the study area is shown in (Fig. 10), and it reveals that the high lineament density is observed in the northeastern, western & middle part of the study area with a value ranging from 0 to 0.74 km/km^{2}.

Figure-10: Lineament Density map of Purulia District

4.9. Water Level:

The ground water level is dividing into four classes; it's fluctuated between 0-20 m bgl of the post-monsoon season. 0-2 m bgl is very good for the ground water prospect found in center and north-eastern part, 2-5 m bgl is good for the ground water prospect found in northern, southern and southwestern part, 5-10m bgl is poor and it's found in western and southeastern part and 10-20m bgl is very poor for ground water prospects it's found in the eastern part of the study area (Fig. 11).

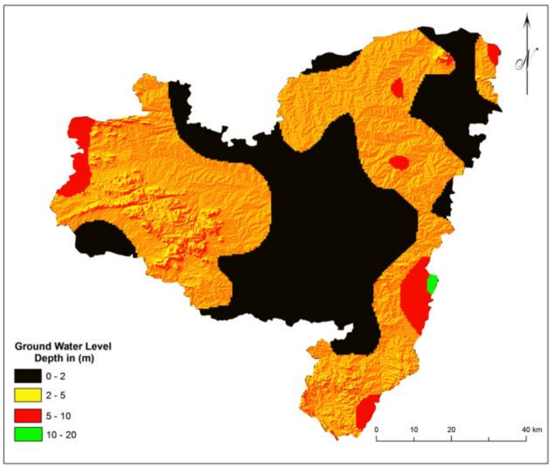


Figure-11: Water Level map of Purulia District

4.10. Delineating the ground water prospect zones:

The groundwater prospect zones in the investigation area were created through the integration of different thematic maps viz., geology, soil, hydro geomorphology, land use, slope, drainage density, lineament density and water level depth using remote sensing and GIS technique. The edge of groundwater prospect zones in the study area was made by a grouping of the interpreted layers through weighted multi influencing factor and lastly allocated diverse prospect zones. The groundwater prospect zones of this study can be divided into five classes, in particular restricted, not suitable, suitable, moderate and high. The groundwater prospect map (Fig. 12) exhibits that the high groundwater potential zone is packed in the center, north and north-eastern region of the study area due to the (Shankar and Mohan, 2006; Prasad et al, 2008) circulation of gravelly loam-loam soil, agriculture land, low slope and scrub vegetation with high infiltration capacity. This demonstrates soil type and slope assumes a crucial part in groundwater expansion. In addition, the centralization of drainage density and lineament density additionally helps the infiltration capacity of the groundwater framework. The restricted zone covers 1412.35 sq km (22.57 %), not suitable zone covers 151.75 sq km (2.42%), suitable zone covers 1333.97 sq km (21.31 %), moderate zone covers 2912.47 sq km (46.53 %) and high zone covers 448.47 sq km (7.17%) of the total study area (Table-4). Finally, the combined impact of the weighted multi influencing factors through overlay analysis in a GIS platform reveled the mapping of groundwater prospect zones in the Purulia district.

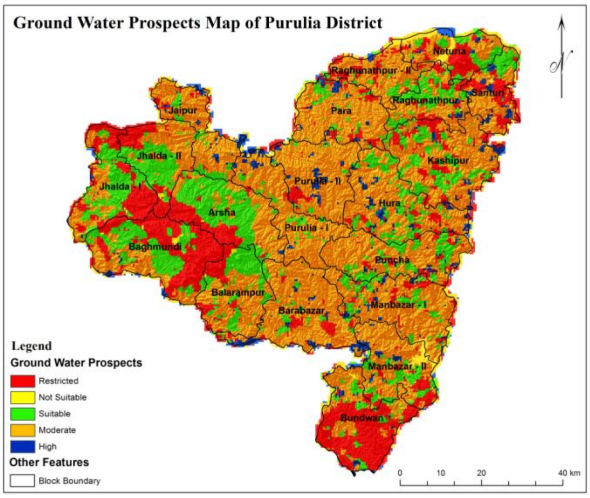


Figure-12: Ground water Prospects map of Purulia District

Table-4: Ground Water Prospect Zones Area

Ground Water Prospect Zone	Area in (Hectare)	Area in (sq km)	% of Area in Total Area
Restricted	141234.5	1412.35	22.57
Not Suitable	15174.5	151.75	2.42
Suitable	133397	1333.97	21.31
Moderate	291247	2912.47	46.53
High	44847	448.47	7.17
Total Area	**625900**	**6259**	**100**

V. Conclusion

Remote Sensing & GIS techniques used to delineate groundwater prospect zones in Purulia district of West Bengal. In sustainable groundwater resource management, advance GIS technique found efficiently to minimize the time, labor and money and thereby enables quick decision-making. Satellite imageries, topographic maps and conventional data were used to prepare the thematic layers of geology, soil, lineament density, drainage density, slope, hydro geomorphology, land-use and water level depth. The various thematic layers are assigned proper wattage through MIF technique and then integrated into the GIS environment to prepare the groundwater prospect zones map of the study area. According to the groundwater prospect zone map, Purulia district is categorized into five different zones, namely 'high', 'moderate', 'suitable', 'not suitable', and 'restricted'. The results of the present study can serve as guidelines for planning future artificial groundwater recharge projects of the study area in order to ensure sustainable groundwater managements. This is an empirical method for the exploration of groundwater prospect zones using remote sensing and GIS, and it succeeds in proposing ground water use in different purpose. This method can be widely applied to a vast area with rugged topography for the groundwater exploration.

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