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EVALUATION OF SUBSURFACE WATER RESOURCE FOR UPGRADING LANDCAPABILITY OF KHAYRASOLE BLOCK, BIRBHUM DISTRICT, WEST BENGAL

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ABSTRACT

The amount of subsurface water resource and its fluctuation is the outcome of interaction among geolithological factors, climatic factors and anthropogenic factors. About 51% of the Khayrasole block is covered by weathered residuum of consolidated or semi-consolidated formation comprising of Archean Crystalline rocks with aquifers yielding capacity ranges 1-10m^3/day in general. The narrow elongated tract of the western and southeastern portion and some isolated patches in the eastern part are covered by older and recent Alluvium with aquifer yielding capacity ranges 100-200m^3/hr in general. At the same time availability of surface water resource in the study area is restricted by the presence of some rain fed rivers, ponds, lakes and other small water bodies. Thus, agriculture, the main stay of economy of the study area is constrained by the poor availability of water resources. Only the adequate supply of water resources can enhance the land capability of the study area to many folds.

Against this backdrop the present study aims to analyze the subsurface water potentiality of the area concerned. The study considers six parameters to delineate the subsurface water potential zones such as geology, hydrogeology, drainage density, soil texture, landuse and land cover and slope. Weighted overlay methods have been applied to identify the subsurface water potential zones. In this method all the thematic maps are used to analyze in overlay and weights and ranks are assigned to each thematic layer. The main objectives of the present study are to analyze the method related to determination of sub-surface water potential, classify Khayrasole block into different sub-surface water potential zones and to analyze the implication of sub-surface water potential zones in the context of agricultural efficiency of the study area.

Keywords: Sub-surface water potential, aquifer, agricultural efficiency, land capability

I. INTRODUCTION

Spatial disparity of mineral resources (e.g. coal, iron ore etc.) can be accomplished through siphoning of resources from surplus to deficit region. Similarly, imbalances in surface water can be materialized through river linking mechanism. However, the in-situ properties of ground water restricted its use only within the area of occurrence. Groundwater is considered as one of the most valuable natural resources and dependable source of water supply in all climatic region of all over the world (Todds and Mays, 2005). Therefore, categorization of space in terms of prevalence of subsurface water can become an inventory for effective future planning. Groundwater is considered as more dynamic renewable natural resource and plays important role in drinking, agricultural and industrial needs (Fashae, Tijani et. al., 2013).

In subtropical monsoon climatic regime of India rainfall is mainly concentrated during summer months. Very little or sometimes hardly any rainfall is occurred during winter months due to the powerful anti-cyclonic and katabatic winds from Central Asia. As a consequence the farmer communities in rural India have to confront with the constraint of water scarcity during winter period. The situation becomes worst in those areas where surface water resource is also inadequate. In such areas conjunctive use of surface and subsurface water can help to break the interruption in agricultural activity. Therefore, to eliminate water scarcity proper development and utilization of ground water resources is essential (Rao, 2006). However, indiscriminate exploitation can lead to decrease in groundwater potential by lowering the water table. Therefore, adequate characterization of basement aquifer and demarcation of ground water potential zone is necessary (Fashae, Tijani et. al., 2013). Application of Remote Sensing and GIS tools are very efficient for successful delineation of ground water potential zones (Chowdhury et al., 2009). Systematic integration of individual thematic layers like geology, geomorphology, lineaments, slope, landuse and land cover under RS and GIS environment can successfully explore different ground water potential zones (Prasad et al., 2008).

A plethora of research articles have been published all over the world centering on the theme of identification of ground water potential zone. Globally the area of concern hovering from Malaysia (Manap et al. 2011), Iran (Zeinolabedini et al., 2015), Nigeria (Fashae et al., 2014), Greece (Oikonomidis et al., 2015), Sultan mountain, Turkey (Ozdemir, 2011) to Brazil (Madrucci, 2008) and so on. At national level ground water potentiality have been identified for Jammu district (Jasrotia et al, 2007), Cauvery river basin (Muthukrishnan et al, 2008), Jharia and Raniganj coalfield region (Rai et al, 2008), Salboni block of West Medinipur district (Jha et al, 2010). In the present work the author has focused her attention at Khayrasole block, Birbhum District, West Bengal.

II. STUDY AREA

To determine the ground water potential zone, Kayrasole block of southwest Birbhum District has been selected as a study area. The area is extended from $23^{o}42^{/}49^{//}$ N to $23^{o}54^{/}40^{//}$N and $87^{o}05^{/}20^{//}$ E to $87^{o}21^{/}56^{//}$ E. The area is bounded by the District of Dumka and Jamtara of the State of Jharkhand in the West and North. The eastern part is bounded by the C.D. Block Dubrajpur. River Ajay forms the southern boundary of the study area. The study area covers 271.12 sq.km. area. Altogether 171 *mouzas* under 10 *Gram Panchayets* constitute the Khayrasole C.D. block (Fig. 1).

The area of concern is entirely a rural area with agriculture as the main stay of economy. About 67% of the total population of the block is dependent on agriculture and allied activities. Except some isolated patches, agriculture is mainly dominated by mono-cropping system with rain fed paddy cultivation. Entire irrigation system of the block is dependent on surface water resources. Conjunctive use of surface water and subsurface water in agriculture may enhance the land capability of the study area to many folds by changing the cropping system from mono-crop to multi crop one.

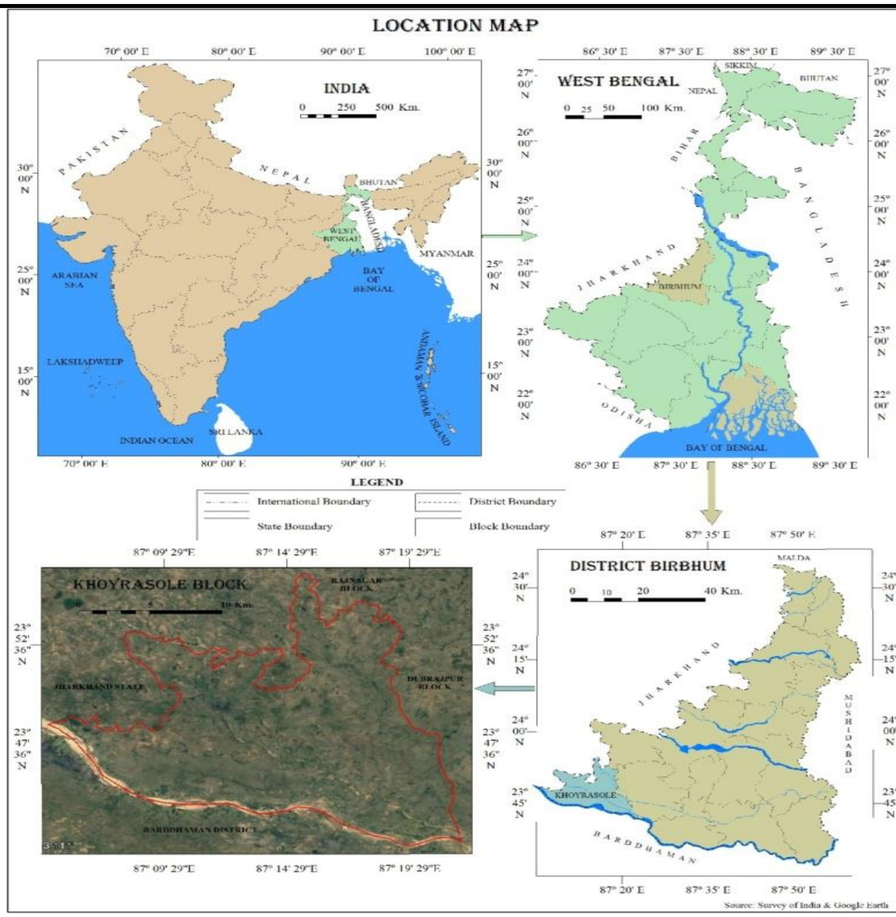


Fig. 1

III. OBJECTIVES

Main objectives of the present study are:

- To identify and assess the status of the ground water storage controlling parameters specific to the area concerned
- To regionalize the survey area in terms of ground water potential zones by integrating different thematic layers through weighted overlay analysis method.
- To analyse the relation between subsurface water potentiality and agricultural efficiency

IV. DATABASE & METHODS

To classify the block into sub-surface water potential zones following data have been collected from various organizations:

- Survey of India Topographical maps on 1:50000 scale (73M/1, 73M/2, 73M/5 & 73M/6)
- Sentinel II Satellite imagery acquired on 22.02.2020 from usgs website (https://earthexplorer.usgs.gov/) of 10 m resolution

- SRTM Data, February, 2014 with 30m resolution downloaded from usgs website (https://earthexplorer.usgs.gov/) for preparing the slope map
- The layer of geology was digitized from District resource map, Birbhum District, published by the Geological Survey of India, Kolkata
- Soil layer has been prepared by digitizing the Soil map published by the National Bureau of Soil Survey and Landuse Planning, Kolkata and All India Soil Survey and Landuse Planning, Baishnabghata, Kolkata
- Thematic layer of hydrogeology and Ground Water information was extracted from published map and data provided by State Water Investigation Directorate (SWID), Kolkata

Integrated remote sensing and GIS based approach have been adopted for assessing the sub-surface water potential zones based on which suitable location for ground water withdrawal can be identified. Methodology for delineation of ground water potential zones involve following steps:

- At first the study area has been delineated by georeferencing and mosaicing the P.S. map of Khayrasole block and 4 Survey of India Toposheets on 1:50000 scale (73M/1, 73M/2, 73M/5 & 73M/6) by using GIS software.
- Different thematic layers (Geology, Hydrogeology, Drainage Density, Soil texture, Landuse Land cover, Slope) have been prepared by using Arc GIS software
- Field observations have been incorporated in various thematic maps
- Multi-criterion Evaluation techniques have been used for assigning weightages, ranks and scores to different themes and sub-themes according to their influence in determining ground water occurrence
- After assigning the weightages, ranks and scores to the themes and subthemes, all the themes are converted to raster format using spatial analysis tool in Arc GIS 10.6 software.
- Finally, integrated ground water potential zone map has been prepared by overlaying the different thematic maps through weighted overlay method using Arc GIS 10. 6 Software. “Raster Calculator” option of ‘Spatial Analysts’ extension of Arc GIS Software was used to prepare ground water potential zone map by using following formula:

GP = GGwGGr+HGwHGr+DDwDDr+STwSTr+LCwLCr+SGwSGr

Where,

GP= Ground water Potential

GG= Geology index

HG= Hydrogeology index

DD= Drainage Density index

ST= Soil Texture index

LC= Landuse Land Cover index

SG= Slope gradient index

After overlapping the layers the final sub-surface water potential map divided into 4 potential zones, namely very high, high, medium and low ground water potential zones.

V. CONTROLLING FACTORS:

Underground water system implies a relentless process of manifesting the balance between recharge and discharge. Apart from the existence of natural spring, the discharge of subterranean water is mainly guided by anthropogenic factors. Similarly in addition to natural recharge process in terms of infiltration and percolation of rainwater some human activities (e.g. irrigation, waste water disposal, injection of water into the underground through injection well) are also act as an ancillary factors in recharge process. Thus the availability of ground water as a water source is controlled by several factors: climate, geology (lithology, lineament density), topography (relief, slope), vegetation cover, soil properties, drainage pattern, and landuse practices.

Very limited areal extent (271.12 sq.km) in the survey area does not create any remarkable variation in climatic parameters. Rainfalls are more or less equally distributed all over the area. Thus more or less homogeneous pattern of rainfall distribution hardly creates any spatial variability in ground water system. However, for present study six ground water storage controlling factors have been selected as input for generating the model of ground water potential zone.

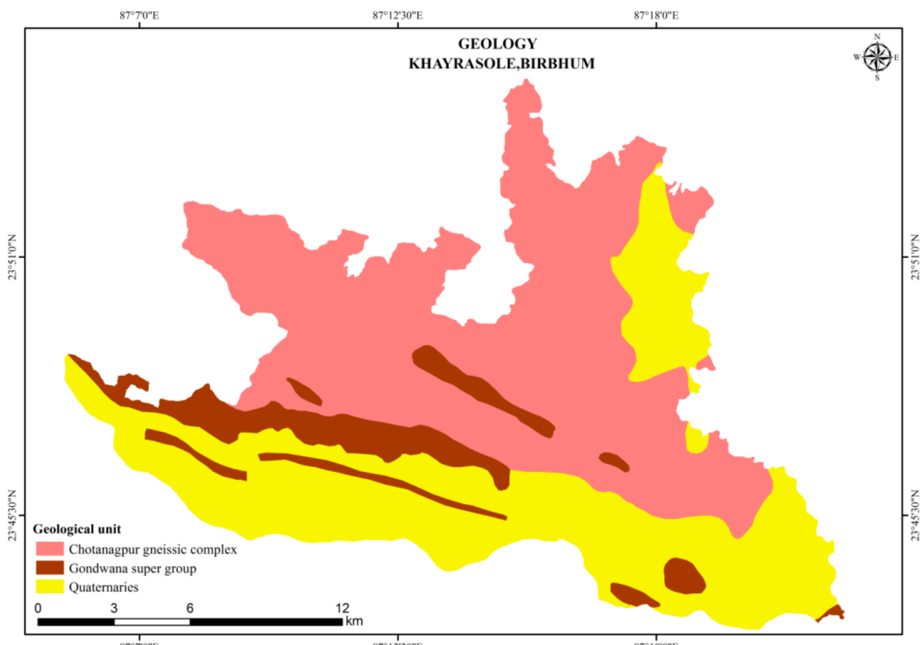
1. Geology:

The geological formation in the study area belongs to Archean to Pliestocene in age. The area comprises of three geological units such as Chotanagpur gneissic complex, Gondwana supergroup and Quaternary. More than half (52%) of the study area is covered by Chotanagpur gneissic complex. These rocks are primarily hard, compact and lack of primary porosity. Ground water movement is difficult in this rock type. The southern part and small isolated patch in the northern part are covered by Quaternary formation. These portions of the study area are composed of newer alluvium with alternate layer of sand, silt and clay. Thus, primary porosity of this layer is relatively higher. (Table 1, Fig.2)

Table 1: Geology

Geological era	**Geological unit**	**Area coverage (sq.km.)**	**% to total area**
Pleistocene to Holocene	Quaternary	25.99	9.59
Permian	Gondwana Super group	104.68	38.61
Archean to Proterozoic	Chotanagpur gneissic complex	140.45	51.80
Total		271.12	100

Source: Birbhum District resource map, Prepared by Geological Survey of India



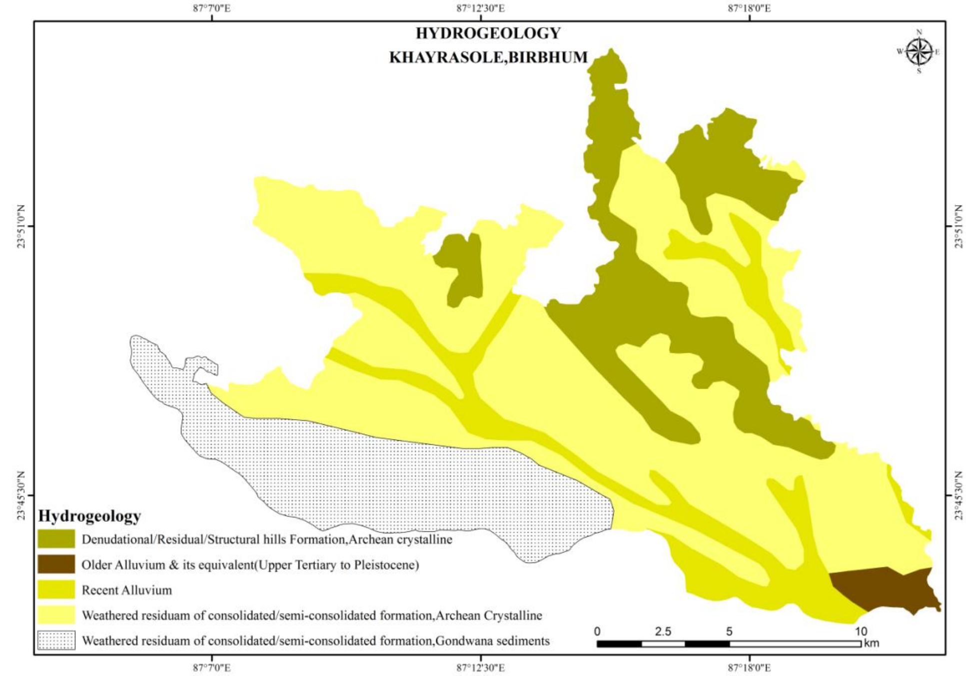
Source: District Resource Map, published by Geological Survey of India **Fig.2**

2. Hydrogeology:

Hydrogeological condition of an area determines the movement and distribution of underground water in the rocks and soil (Table 2, Fig. 3).

Table: 2 Hydrogeological unit

Hydrogeological unit	**Area coverage (sq.km.)**	**% to total area**	**Rock type & occurrence**	**Hydrological conditions**
Recent alluvium	32.55	12.00	Present day river & flood plain deposits under fluvial conditions comprising clay, silt, sand, gravel etc.	Medium to high yielding aquifer depth is 35m bgl; yield of aquifer ranges 100-200m^3/h in general
Older alluvium and its equivalent	3.41	1.26	Generally occurs in elevated terraces outstriking Chotanagpur plateau. The formation comprises of clay, silt, sand and kankar.	Moderate to low yielding aquifers. LDTW/DW are feasible on suitable geomorphic sites; yield of aquifer ranges 18-100m^3/h in general.
Weathered residuum of consolidated/semi-consolidated formation, Gondwana sediments	48.86	18.02	Thin to thick weathered residuum comprising of Gondwana sediments gradually merges into older alluvium/ recent alluvium.	Low yielding secondary aquifers; DW/Bore wells are feasible for domestic uses; yield of aquifer ranges 1-10 m^3/day in general.
Weathered residuum of consolidated/semi-consolidated formation, Archean crystalline	137.81	50.83	Thin to thick weathered residuum comprising of underlying Archean crystalline gradually merges into older alluvium/ recent alluvium.	Low yielding secondary aquifers; DW/Bore wells are feasible for domestic uses; yield of aquifer ranges 1-10 m^3/day in general.
Denudational /Residual/ Structural Hill formation, Archean crystalline	48.49	17.89	Mainly comprises of Archean crystalline Chotanagpur granite-gneisses with thin soil cover having high surface runoff.	Poor yielding secondary aquifer.
Total	271.12	100		
Source: State Water Investigation Directorate, Kolkata				



Source: State Water Investigation Directorate, Kolkata **Fig. 3**

3. Drainage density:

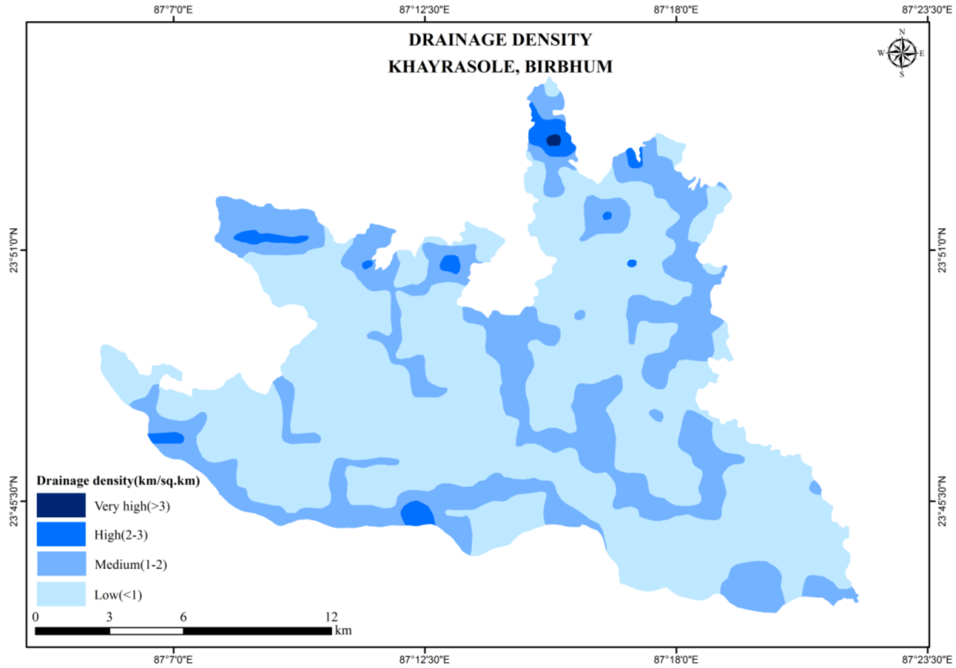
The drainage density map has been prepared from Survey of India Topographical map at 1:50000 scale. The general drainage pattern of the study area is dendritic to sub-dendritic. Drainage density of the study area has been categorized into four groups. Very high and high drainage density together constitutes only 2.11% of the study area and is concentrated in small isolated patches in extreme northern and southern part of the study area. Most part of the study area (67.98%) is under low drainage density zone along with some narrow elongated patches of moderate density zones (29.91%) (Table 3, Fig. 4).

Drainage density is inversely correlated with permeability. The less permeable a rock is, the less the infiltration of rainfall, which conversely tends to be concentrated in surface runoff (Chowdhury et al. 2009). It means areas having high density are not suitable for ground water development because of the greater surface runoff (Dinesh Kumar et al. 2007).

Table 3: Drainage Density

Drainage density (km./sq.km.)	**Area coverage (sq.km.)**	**% to total area**
Low (<1)	184.30	67.98
Medium (1-2)	81.10	29.91
High (2-3)	5.52	2.04
Very high (>3)	0.20	0.07
Total	271.12	100

Source: SOI Toposheets, 1972 (1:50000)



Source: Survey of India, Toposheets (1:50000) **Fig.4**

4. Soil texture:

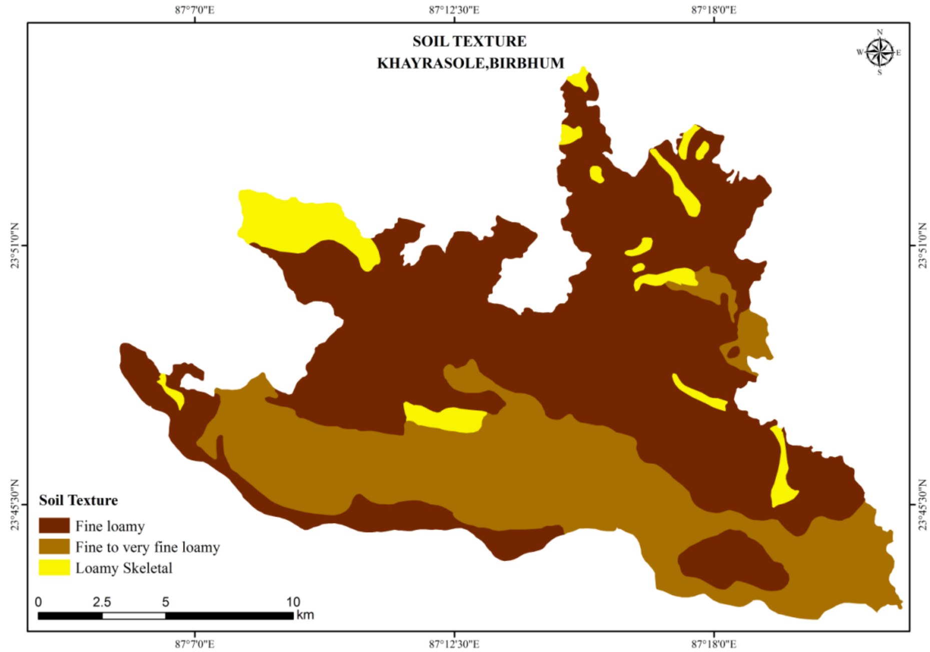
The soil map of the study area has been prepared from the published soil map derived from National Bureau of Soil Survey and Landuse Planning, Kolkata. Entire study area has been grouped into three soil textural classes (Table 4, Fig. 4). Majority of the study area (62%) is covered by fine loamy soil. The southern portion of the study area is dominated by fine to very fine loamy soil (33%). Very small proportion of loamy skeletal soil (6%) is sporadically distributed in small isolated patches over the study area (Table 4, Fig. 5).

Soil is one of the most important determinants of infiltration capacity of a region. Coarse grained soil is relatively more permeable as compared to fine grained soil thus providing more potential for ground water storage.

Table: 4 Soil Texture

Soil Texture	Area coverage (sq.km.)	% to total area
Fine to very fine loamy	88.46	32.63
Fine loamy	166.79	61.52
Loamy Skeletal	15.87	5.85
Total	271.12	100

Source: All India Soil Survey and Landuse Planning, Kolkata



Source: All India Soil Survey and Landuse Planning, Kolkata **Fig. 5**

5. Landuse Land cover:

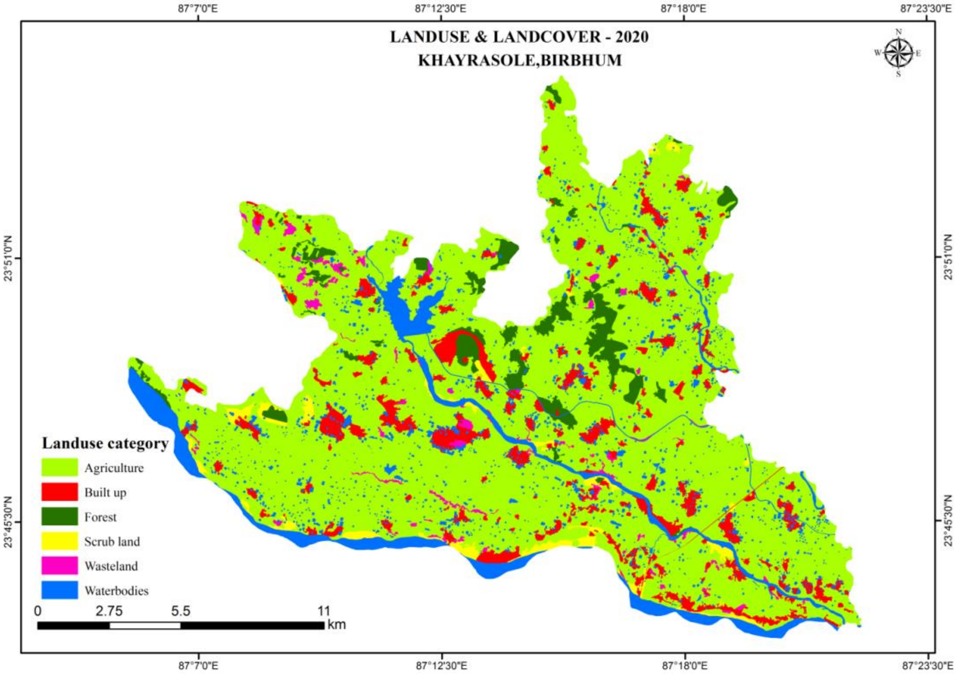
Landuse map has been prepared from Sentinel II satellite image (2020) with 10 m resolution downloaded from USGS website. Five categories of landuse have been identified in the study area (Table 5, Fig.5). Being entirely a rural area, agriculture constitutes the prime landuse category with 75.15% of its share, followed by water bodies (10.34%), built up area (7.86%), forest (3.89%), wasteland (1.73%) and scrubland (1.03%) (Table 5, Fig. 6). .

Landuse and land cover map is one of the most important anthropogenic determinants of ground water system. Vegetation and agricultural land have cracks and loosen the soil and increases the infiltration rate in the soil (Ahmed, 2016). The nature of surface materials and the landuse pattern control the infiltration and runoff (Dinesh Kumar et al. 2007). However, very low percentage of built-up area (7.86%) in Khayrasole block significantly lessens the adverse impact of recharge process in the study area.

Table 5: Landuse Land Cover

Landuse Category	**Area coverage (sq.km.)**	**% to total area**
Agriculture	203.75	75.15
Built up	21.32	7.86
Forest	10.54	3.89
Scrub land	2.80	1.03
Wasteland	4.68	1.73
Water bodies	28.03	10.34
Total	271.12	100.00

Source: Sentinel II Satellite Image (2020)



Source: Sentinel II Satellite Image (2020) **Fig. 6**

6. Slope:

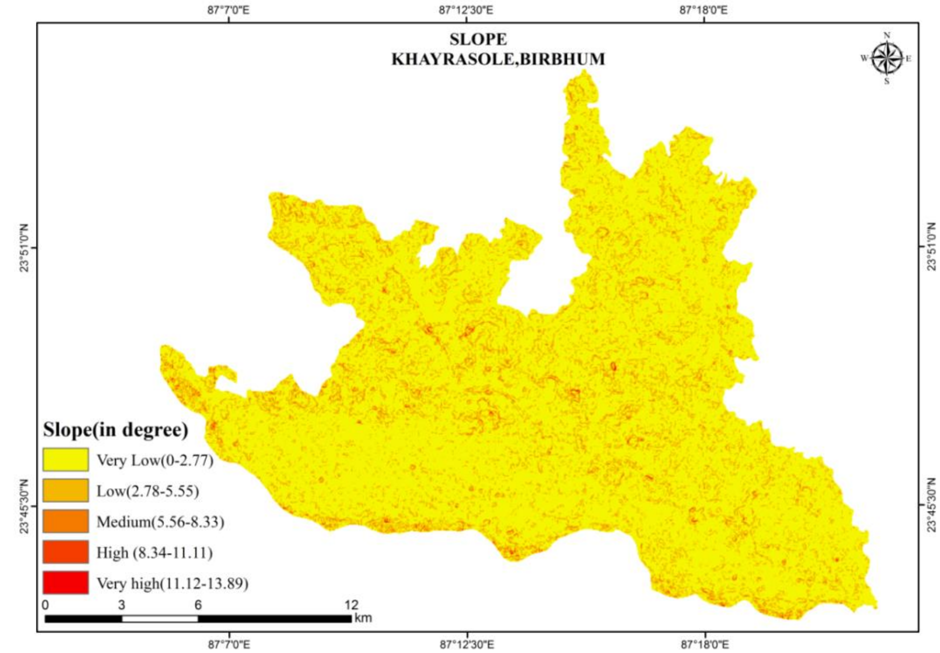
Slope map for the present study has been prepared from SRTM data with 30 m resolution. Except very few isolated patches (less than 2%), about 82% of the study area falls under very low (0-2.77 degree) slope category (Table 6, Fig.7).

Slope is inversely related with ground water potential of a region. Gentle slope hinders rapid surface runoff which in turn increases the time span of water contact with the ground surface and thus facilitates more infiltration. Thus, in Khayrasole block slope does not act as a detrimental factor from the point of view of ground water potential.

Table 6: Slope category

Slope (in degree)	**Area coverage (sq.km.)**	**% to total area**
Very low (0-2.77)	222.55	82.09
Low (2.78-5.55)	45.16	16.66
Medium (5.56-8.33)	3.16	1.17
High (8.34-11.11)	0.23	0.08
Very high ?(11.12-13.89)	0.02	0.01
Total	271.12	100.00

Source: SRTM data , 2014



Source: SRTM data, 2014 **Fig. 7**

VI. RESULT & DISCUSSION

To regionalize the study area into different ground water potential zone at first the individual thematic layers and their subclasses were assigned into different weightages and ranks according to their influence in determining the ground water storage. By considering the relative importance of the parameters in influencing ground water storage, geology and hydrogeology was given highest weightage value of 25. Being entirely a rural area the study area contains only about 8% built up area. At the same time about 75% of the area in under agricultural landuse. Thus from the point of view of infiltration and recharge, the study area occupies safer position. Three soil textural classes are distributed in the study area in a disproportionate manner with 61% fine loamy soil, 33% fine to very fine loamy soil and the rest 6% loamy skeletal soil. Except very minimal percentages of very high (0.07%) and high (2.04%), the rest of the area of the study area is under low (68%) and medium (30%) category drainage density. Thus, drainage density is not a detrimental factor from the point of view of ground water storage in the study area. Now, as the influence of these three parameters (Landuse & Land cover, Soil texture and Drainage density) in determining ground water storage in the study area is more or less same, these three parameters were given same weightage i.e. 15 each. More than 80% of the study area in under very low (0-2.77 degree) category of slope. Thus, influence of slope is more or less same throughout the area under consideration which, in turn, lessens its significance in favourability evaluation. This is why slope received a lowest weightage score of 5 (Table 7).

Table 7: Weights and ranks assigned to individual themes and feature classes

Sl. No.	Theme	Weight (%)	Feature class	Rank	Weighting method
1.	Geology	25	Quaternaries	5	According to Age the area is divided into three sub-regions. The more age, the more density and the lower coefficient
			Gondwana super group	4	
			Chotanagpur gneissic complex	2	
2.	Hydrogeology	25	Older Alluvium & its equivalent	5	
			Recent Alluvium	5	
			Weathered residuam of consolidated/semi-consolidated formation,Gondwana sediments	3	
			Weathered residuam of consolidated/semi-consolidated formation,Archean Crystaline	2	
			Denudational/Residual/Structural hills Formation,Archean crystaline	1	
3.	Landuse & Land cover	15	Waterbodies	5	The more fertility and infiltration, the more coefficients.
			Agriculture	4	
			Forest	3	
			Scrub land	3	
			Wasteland	2	
			Built up	1	
4.	Soil texture	15	Loamy Skeletal	5	The more compactness of soil the lower the coefficients
			Fine loamy	4	
			Fine to very fine loamy	3	
5.	Drainage density	15	Low	5	The lower the drainage density the higher the coefficients
			Medium	4	
			Very high	3	
			High	2	
6.	Slope	05	Very low	5	The lower the slope the higher the coefficient
			Low	4	
			Medium	3	
			High	2	
			Very high	1	

Now, in Arc GIS weighted overlay analysis was performed to generate ground water potential map. In order to prepare potentiality map all weights and ranks are put into following formula:

GP = 0.25*RG+0.25*RH+0.15*RD+0.15*RST+0.15*RC+0.05*RS

Where,

GP= Ground water Potential

RR= Raster-Geology map

RH= Raster-Hydrogeology map

Rd= Raster- Drainage Density map

RST= Raster- Soil Texture map

RC= Raster- Landuse Land Cover map

RS= Raster- Slope map

After overlapping the layers the final potential map has been divided into four potential zones (Fig.8). Analysis of ground water potential zone represents that very small proportion of area (3.07%) falls under very high potential zone which is concentrated in small isolated patches in the north eastern and southern-middle and southeastern parts of the study area. High potential zone is distributed in an elongated manner throughout the southern part of the study area along the main river system (Ajay river). Another small patch of high potential zone is found in the north eastern part surrounding the very high potential zone. This category constitutes 34.46% of the total area. The share of moderate potential zone is highest (40.10%) among the four categories. This zone is distributed in a more or less continuous manner in the western and southeastern part. Another patch of this zone is found in the north eastern part. The middle portion and the extreme northern part of the study area falls under low ground water potential zone (22.37%). Percentages of each ground water potential zones are shown in fig 9.

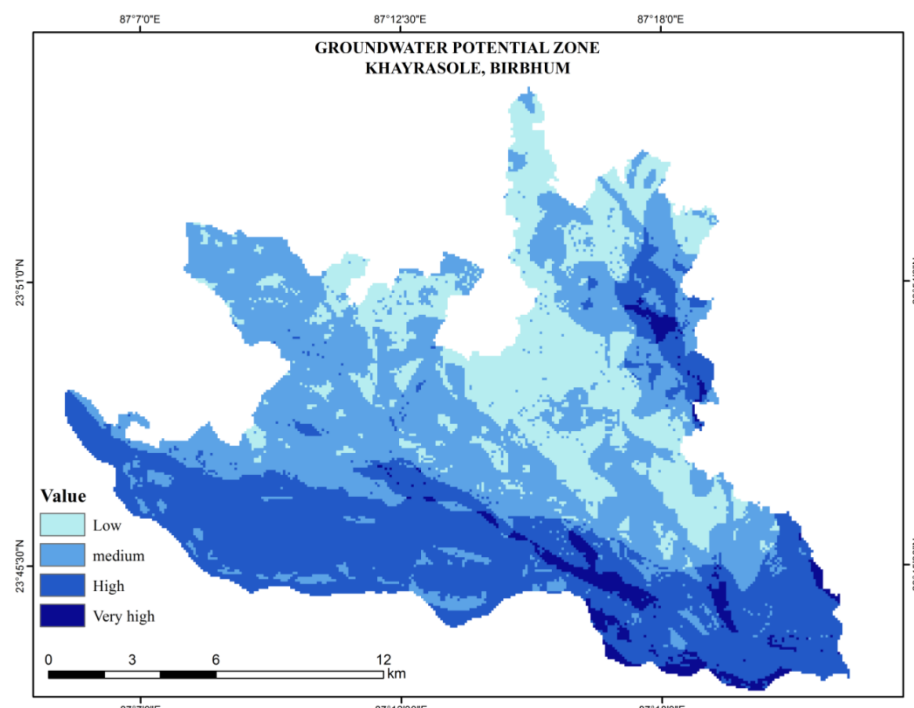


Fig. 8

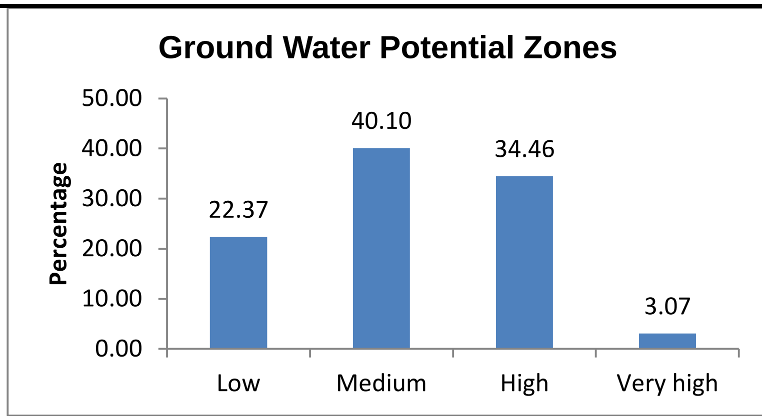


Fig. 9

VII. CONCLUDING REMARKS:

In terms of overall subsurface water potentiality Khayrasole block does not exhibit any futuristic inclination. More than 60% of the concerned area falls under medium to low category of subsurface water potential zone. However, area specific conjunctive use of subsurface water along with surface water can enhance the land capability by combating with the prime agricultural constraint of water scarcity of the study area. Table 8 shows the G.P. wise potentiality of subsurface water resource and the percentage distribution of irrigated area.

Table 8: G.P. wise irrigated area and subsurface water potentiality (2018-19)

Gram Panchayet (G.P.)	**Area of standing Kharif crops & others crops (ha)**	**Area irrigated(ha)**	**% of area irrigated**	**Subsurface water potentiality**
Lokpur	1568	707	45.0	Low to medium
Hazratpur	1076	607	56.41	High
Rupuspur	1538	897	58.94	Medium to high, small patch of very high
Khayrasole	1154	701	60.74	Low to medium
Nakrakonda	1337	727	54.38	Low
Babuijore	2301	646	28.07	Medium to low
Kendragoria	2052	1301	63.40	High to very high
Parsundi	2431	675	27.77	High
Panchra	2618	1915	73.15	High to medium and low
Barhra	1291	619	47.95	High

Source: Raw data obtained from agricultural Office, Khayrasole block and compiled by the author

Subsurface water can supplement the water requirement in Parsundi, Hazratpur and Rupuspur G.P. which fall under the category of high subsurface water potential zone. Contrary to this, in terms of area coverage of agricultural land, Babuijore G.P. falls under 3rd rank (2301 ha) followed by Parsundi (2431ha) and Panchra G.P. Only 28% of total cropped area of Babuijore G.P. is under irrigation. However, subsurface water irrigation cannot be recommended for Babuijore G.P. as the G.P. is located under medium to low subsurface water potential zone.

Similarly, to enhance the land capability or agricultural efficiency of Babuijore, Nakrakonda or Khayrasole G.P. emphasis must be given on surface water resources instead of subsurface water resource.

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