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Research Article

DEMARCATION OF GROUNDWATER POTENTIALITY ZONES USING ANALYTICAL HIERARCHY PROCESS (AHP) MODEL WITH RS & GIS TECHNIQUES OF PASCHIM MEDINIPUR DISTRICT IN WEST BENGAL, INDIA

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ABSTRACT

In recent years, delineation of ground water potentiality zones plays an increasingly important role in sustainable management of groundwater resource throughout the world. Now it is very useful to demarcate ground water potentiality zones through the application of advance techniques of remote sensing and GIS based on multi criteria evaluation approach. In Paschim Medinipur District, more than 90% of rural and 60% of urban population are dependent on ground water for domestic, agriculture as well as industrial purposes. More than 80% people are of rural background and 60% of which are poor and mostly dependent on groundwater for their daily livelihood.

In the present study ground water potential mapping of Paschim Medinipore District has been delineated by using Analytical Hierarchy Process (AHP) or Pairwise Comparison Matrix (PCM) model in the arena of GIS. Ten useful criteria were selected for this mapping of the study area. These are slope (degree), geology, soil, land use and land cover (LULC), drainage density, relative relief, NDVI, rainfall and geomorphology. The resultant ground water potential index has been classified into five groups using natural break classification scheme of very high (15.19 %), high (23.55 %), moderate (29.79%), low (24.92%) and very low (6.55%). Result of this research could be helpful for better management of ground water resource in the study area and opportunity to prepare appropriate groundwater investment plain.

INTRODUCTION

Over the past few decades, over exploitation of groundwater as well contamination have become one of the most serious environmental problems due to increasing industrial and agricultural activities. Groundwater recharge refers to the downward movement of water from the unsaturated zone into the saturated zone below the water table surface, together with the associated flow away from the water table within the saturated zone (Freeze and Cherry 1979). Groundwater is one of the most important natural resources for multi purpose uses. Although it is more dynamic renewable natural resource yet availability with good quality and quantity in appropriate time and space is more important (Chowdhury, A., Jha, M.K., Chowdary, V.M. 2010). PaschimMedinipur district is a tribal dominated relatively drought prone and poor district in West Bengal. Rivers are mostly non-perennial. Agriculture and industrial activities are mostly dependent on groundwater.

Thus, groundwater is emerging as a formidable poverty reduction tool in this district. It should be supplied to poor communities far more cheaply, quickly and easily than the conventional canal irrigation water (IWMI, 2001). Dependence on groundwater has recently increased due to the introduction of high yielding varieties of crops and adoption of multi-cropping patterns, both of which require a timely, assured water supply. (Tiwari *et al*. 2009; Naik and Awasthi, 2003). Increasing population and agricultural activities are not only creating over exploitation of ground water resources but also polluting by releasing untreated wastes. Groundwater studies have become crucial not only to delineate groundwater potential zone, but also to find the way of proper management and conservation of this vital resources .As remote sensing techniques cannot detect groundwater directly, the presence of groundwater is inferred from different surface features derived from satellite imagery such as geology, landforms, soils, land use/ land cover, surface water bodies, etc., which act as indicators of groundwater existence (Todd, 1980; Jha and Peiffer, 2006). Many factors affect the occurrence and movement of groundwater in a region including topography, lithology, geological structures, and intensity of weathering, extent of fractures, primary porosity, secondary porosity,

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slope, drainage patterns, landform, land use/land cover, and climate (Mukherjee 1996; Jaiswal *et al*. 2003). Remote sensing techniques not only provide a wide range scale of the space–time distribution of observations, but also save time and money (Murthy 2000; Leblanc *et al*. 2003; Tweed *et al*. 2007). Sener *et al*. (2005) pointed out that remote sensing can effectively identify the characteristics of the surface of the earth (such as lineaments and geology) and can also be used to examine groundwater recharge. Bierwirth and Welsh (2000) applied remote sensing to determine the preferential path of groundwater recharge in an area.

Integration of remote sensing with GIS for preparing various thematic layers that has direct or indirect control over groundwater occurrence with assigned weightage in a spatial domain will support the identification of potential groundwater zones. Therefore, the present study focuses on the identification and delineation of groundwater potential zones in Paschim Medinipore District, West Bengal using the advance technology of remote sensing and GIS for the planning, sustainable management of groundwater resources.

Objective

The objectives of this study area are:

1. To create integrated GIS based geographic database for Paschim Medinipore District.
2. To generate land use / land cover map through digital processing of remote sensing data of LANDSAT ETM
3. To assign weight to all thematic maps prepared by Analytical Hierarchy Process (AHP)
4. To integrate all thematic maps using GIS and demarcate groundwater potentiality zones for sustainable management of this valuable renewable resource.

METHODOLOGY

This research work consists of two parts; first one deals with the collection and preparation of geospatial data using GIS and Remote Sensing techniques. Different layers of mapping have been prepared considering the determining factors of ground water storage such as geology, geomorphology, soil, NDVI, drainage density, slope, elevation, relative relief and land use and land cover. These layers are necessary for predicting ground water potentiality in many stages.

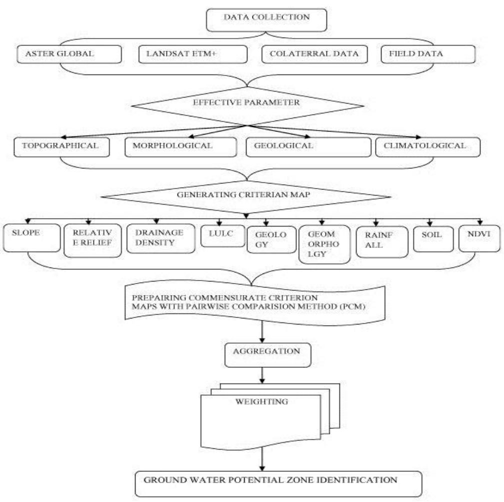

Fig 1 Flowchart of the methodology of the study

The second part deals with the comparison of these layers and a specific weightage is given to each determining factors according to their impact on ground water storage. The weights have been calculated according to the experienced judgment of the hydro- geological situation of this study area and in-situ investigations and also the field observations. A simple model of the methodology of this study is given in the following.

Study Area

Paschim Medinipur District of West Bengal in India lies between 21°46´ N to 22° 57´N latitudes and 86°33´ E to 87°44´ E longitude, covers with an area of 8999.4258 sq km. The district enjoys with tropical climate and the physiography of the district is characterized by hard rock uplands, lateritic plateau fringe, and narrow flat alluvial and deltaic plains. Extremely rugged topography is seen in the western part of the district and rolling topography is experienced consisting of lateritic soil. These rolling plains gradually merge into flat alluvial and deltaic plains to the east and south east of the district. The soil is fairly fertile and a great group of the Taxonomic classification system as paleustalfs and haplaquents. Average temperature of the district varies widely across seasons, varying between maximum 43°C to minimum 7°C with an annual average rainfall of 1428 mm.

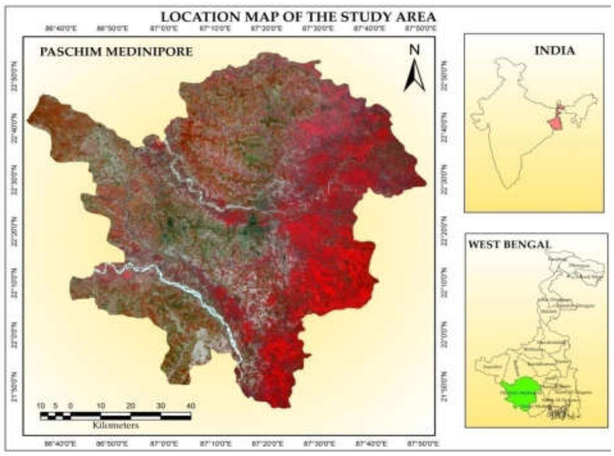

Fig 2 Study Area

Data Source

Table 1 To achieve the objectives of the study the following data have been used

Data	Year	Resolution/scale	Source
LANDSAT 8	2013	30m	GLOVIS.USGS.GOV
LANDSAT ETM+	2013	30m	GLOVIS.USGS.GOV
District map	2015	NOT TO SCALE	www.mapsofindia.com
Soil map		1:500000	NBSS&LUP(ICAR)
Geology map	1999	1:2000000	G.S.I.
Morphology Map		1:2100000	NBSS&LUP(ICAR)
Rainfall Map		1:2100000	I.M.D.

The Analytical Hierarchy Process (AHP) and the Prioritized Factor Rating Value (PFRV)

The Analytic Hierarchy Process developed by T. L. Saaty (1971) is one of the relevant applied techniques of *the hierarchical additive weighting methods* for multicriteria decision problems. AHP is a decision-making and semi-quantitative value judgment approach that serves the objectives of the decision makers. This process is employed in this study to support the decision on the instability rank of the factors by estimating the prioritized factor rating value (PFRV) (Maiti R. & Mondal S. 2013). AHP also uses a weighted average approach idea, but it uses a method for assigning ratings and weights that are considered more reliable and consistent. To mitigate the complexity of the structure a gradual steps has been taken from the large to the small, or from the general to the particular, so we can relate them with greater accuracy according to our understanding. AHP is a learning tool rather than a means to discover the TRUTH because truth is relative and changing. In the AHP different factor preferences and their conversation into numerical values are accomplished with the help of comparative judgment based on the interview taken to the local people and finally select the priorities (table 1). A pairwise comparison matrix has been prepared on the basis of preferences factor with the other factor and ground water potential triggering factors hierarchically. The prioritized factor rating value/eigenvector (PFRV) with reasonable consistency ratio (CR), based on Saaty (1977, 1980) and Saaty and Vargas (2000).

Phases in AHP

Phase 1: Decompose the problem into a hierarchy

AHP starts with an identification of the criteria to be used in evaluating different alternatives which are organized in a tree-like hierarchy

Phase 2: Collect input data by pairwise comparisons of criteria at each level of the hierarchy and alternatives

Phase 3: Estimate the relative importance (weights) of criteria and alternatives and check the consistency in the pairwise comparisons

Phase 4: Aggregate the relative weights of criteria and alternatives to obtain a global ranking of each alternative with regards to the goal

Now to calculate the consistency vectors, it is necessary to compute values for two more terms, *lambda* (λmax) and the consistency index (CI). The value for *lambda* is simply the average value of consistency vector.

Lambda (λmax) = sum of consistency vector / n…………Eq 1

Where RI is the average of the resulting consistency index depending on the order of the matrix given by Saaty and CI is the consistency index that is expressed in Eq. 3. If the value of CR is smaller or equal to 10 percent, the inconsistency is acceptable, but if the CR is greater than 10 percent, the subjective judgment needs to be revised (Saaty 1977)

CI = λmax – n/n – 1 ……………….Eq 2

Saaty and Vargas (2000) randomly produced reciprocal matrices using scales 1/9, 1/8, 1/7…1…8, 9 to evaluate a so-called random consistency index (RI).

The eigenvalues enable the quantification of a consistency measure that is an indicator of the inconsistencies or intransivities in a set of pairwise ratings. Saaty and Vargas (2000) stated that for a consistent reciprocal matrix, the largest eigenvalues λ_{max} is equal to the number of comparisons n. An index of consistency, known as the CR (Consistency Ratio), is used to indicate the probability that the matrix judgments were randomly generated (Saaty 1977).

CR = CI / RI ……………..Eq 3

In practice, a CR of 0.1 or below is considered acceptable. Any higher value at any level indicates that the judgments warrant re-examination.

Table 2 Scale of preference between two parameters

Scale	Degree of Preference	Explanation
1	Equally	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly to moderately favor one activity over another
5	Strongly	Experience and judgment strongly or essentially favor one activity over another
7	Very Strongly	An activity is strongly favored over another and its dominance is showed in practice
9	Extremely	The evidence of favoring one activity over another is of the highest degree possible of an affirmation
2,4,6 and 8	Intermediate values	Used to represent compromises between the references in weight 1,3,5,7, and 9
Reciprocals	Opposites	Used for inverse comparison

Table 3 Ground water potential triggering factors and prioritized factor rating values (weights) in the Paschim Medinipore district, West Bengal, India.

Factors	1	2	3	4	5	6	7	8	9	Prioritized rating(PFRV)
(1)Geomorphology	1	2	3	4	5	6	7	8	9	0.304
(2)Slope	1/2	1	2	3	4	5	6	7	8	0.216
(3)Geology	1/3	1/2	1	2	3	4	5	6	7	0.153
(4)Drainage Density	1/4	1/3	1/2	1	2	3	4	5	6	0.107
(5)Rainfall	1/5	1/4	1/3	1/2	1	2	3	4	5	0.075
(6)LULC	1/6	1/5	1/4	1/3	1/2	1	2	3	4	0.053
(7)NDVI	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	0.036
(8)Soil	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	0.025
(9)Relative Relief	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	0.018

CI (consistency index) = 0.043; RI (random inconsistency index) = 1.45; and CR (consistency ratio) = 0.029 (consistent) LULC = land use and land cover

Table 4 Random Inconsistency Index (RI)

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: Adapted from Saaty (1980).

Analysis

The analytical part of this work is divided into four steps. Firstly the ground water potential triggering factors have been vividly discussed. Secondly, the potential factors rating value have been calculated. Thirdly, the relation between these triggering factors with ground water potentiality have been evaluated and finally, the ground water potentiality zones have been demarcated through the compilation of the above techniques.

Analysis of Geology

Geology is also an important factor of ground water vernablity identification. Geology is the science of rocks. The type of rock exposed to the surface significantly affects groundwater recharge (Shaban *et al.* 2006). Lithology affects the groundwater recharge by controlling the percolation of water flow (El-Baz and Himida 1995).

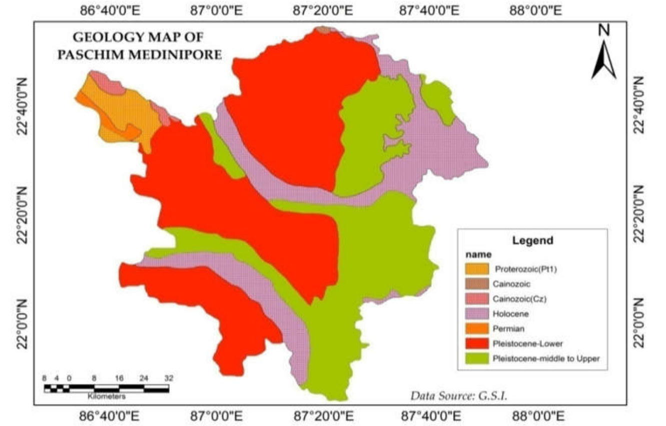

Fig 3 Geology map of the study area.

The undergroundwater moves from areas of recharge to areas of discharge under the influence of hydraulic gradients depending on the hydraulic conductivity or permeability (Manikandan.J *et al.* 2014) which also depends on the nature of rock types and structure.

Analysis of Geomorphology:

Geomorphology is the science that studies the nature and history of landforms and the processes of weathering, erosion, and deposition that created them (Bocco *et al*., 2005). Geomorphological maps help to identify various geomorphic units and groundwater occurrence in each unit (Bahuguna *et al*., 2003; Rao *et al*., 2004). It is a branch of earth science, which has grown after the advent of aerial photographs and satellite data. Geomorphology, along with information on soil, water and vegetation has become one of the essential inputs in planning for various developmental activities. Geomorphology of the study area has been classified into eight categories i.e. Residual hills with pediments, Pediplain, Residual hills hillocks and mounds, Lower alluvial plain, Coastal plain, Valley bottom, Undulating upper alluvial plain and Marshy area. Ground water storage is also depend on the nature of landform. Flat areas have higher water recharge capacity than sloppy areas.

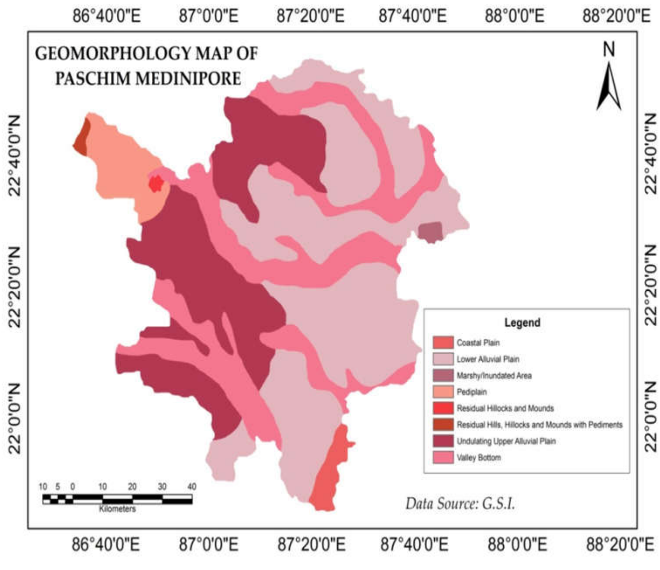

Fig 4 Geomorphology map of the study area.

Analysis of Relative Relief

Relative Relief is an useful morphometric techniques for understanding the surface variation of the slope. Relief played an important role in determining the infiltration rate. Relative relief is the ratio of horizontal and vertical curvature. Five relative relief zones have been found out in this study area such as (1) 0.03- 26.38 m of 49.19% land cover, (2) 26.38-39.40m of 36.29% coverage,(3)39.40-64.33m with 12.46% area,(4)64.33-113.13m of 1.89% land area and (5)113.13-234.93m of only 0.25% land cover. Here the highest relative relief is 234.93m and the lowest relative relief is 0.03m. This land coverage under 113.13 – 234.93 m relative relief is only 0.25 % and the 0.03 – 26.38 m relative relief is 49.19 %. So this area is already plain.

The Relative Relief calculation of this formula-

Relative Relief (RR) = $H_x - H_n$ (smith 1935) Eq6

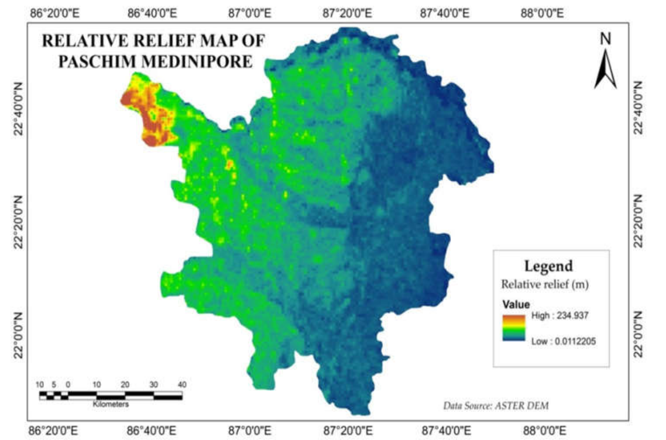

Fig 5 Relative Relief of the study area

Analysis of slope

Slope is an important factor for the identification of groundwater potential zones and it is also one of a factor controlling infiltration of groundwater from surface into subsurface. Hence it is an important indicator for the suitability for groundwater prospect. The slope calculates the maximum rate of change in value from that cell to its neighbors. Basically, the maximum change in elevation over the distance between the cell and its eight neighbors identifies the steepest downhill descent from the cell. The rates of change (delta) of the surface in the horizontal (dz/dx) and vertical (dz/dy) directions from the center cell determine the slope. The basic algorithm used to calculate the slope is:

slope_radians = ATAN ($\sqrt{([dz/dx]^2 + [dz/dy]^2)}$) Eq4

Slope is commonly measured in units of degrees, which uses the algorithm:

slope_degrees = ATAN ($\sqrt{([dz/dx]^2 + [dz/dy]^2)}$) * 57.29578.....Eq5

The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain. Here the slope is classified into five groups. Highest slope is 49.39^0. The higher the slope value, steeper the terrain means high run-off and low percolation. The lower the slope value, the flatter the terrain indicate low run-off and high percolation .So generally, in the lowest slope area ground water potentiality is always high. This region consists of hilly area in north west part, plateau area in northern part and plain area in southern and south eastern part. The south eastern portion is basically flood prone with very low amount of slope (0 to 2.32 degree)

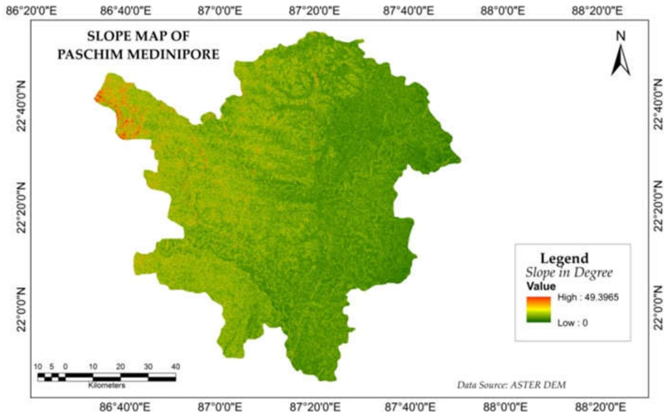

Fig 6 slope of the study area

Analysis of drainage density

Density analysis takes known quantities of some phenomenon and spreads them across the landscape based on the quantity that is measured at each location and the spatial relationship of the locations of the measured quantities. The drainage Density calculates the density of linear features in the neighborhood of each output raster cell. Density is calculated in units of length per unit of area. A drainage basin is a natural unit draining runoff water to a common point. Drainage density is one of the important parameters to understand the ground water potential of a watershed. Drainage density has an inverse relation to permeability. Drainage pattern reflects the major characteristic of surface as well as subsurface formation. Generally, lower the drainage density higher the ground water potential and vice-versa. Drainage pattern reflects surface characteristics as well as subsurface formation (Horton, 1945). In this study, drainage network was extracted directly from topographic maps (1:250,000) and LANDSAT ETM+ image, each class represents an interval of the number of drainage segments per 1x1 sq. km grid area. The drainage system of the study area mainly controlled by Kansai River on the south, Subarnarekha River on the SW and Silai River on the north and intersecting numerous Khals. Different drainage pattern such as, dendritic, sub-dendritic and radial are predominantly seen within the study area. The highest drainage density is 1.104 per/sqkm .The entire study area have five drainage density zones. High drainage density is found in the western and northern part, whereas, moderate to low drainage density is found in the southern and eastern part. Average density also provides the indications of the type of aquifers, the magnitude of the recharge area and the direction of ground water flow. The drainage density characterizes the runoff in an area or in other words, the quantum of relative rainwater that could have infiltrated. Hence the lesser the drainage density, the higher is the probability to recharge the ground water.

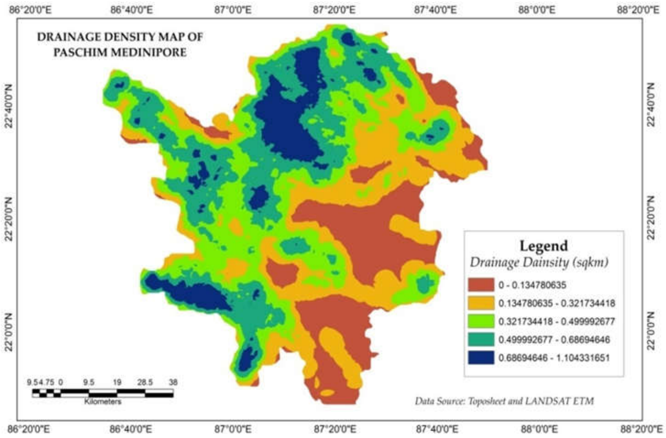

Fig 7 Drainage Density of the study area

Analysis of Rainfall

The annual average rainfall is around 1400 mm. The intensity and distribution of rainfall along with the slope gradient directly affect the run-off and infiltration rate. This study area have been classified three rainfall classes (I) >1300 mm rainfall (II) 1301 mm to 1400 mm and (III) 1401 mm to 1600 mm. The ground water potentiality is directly related to the rate of infiltration and adversely related to run off rate. Here the highest rainfall zone (1600 mm) is found in the southern portion and lowest rainfall zone (>1300 mm) in northern portion. The southern part of the study area is plain land with highest rainfall. It is easily assumed that this area enjoys higher rate of infiltration than run off .The slope is gradually higher in south to northern part and have lower infiltration rate and higher run off. Therefore, the ground water potentiality is obviously higher in southern part than the northern.

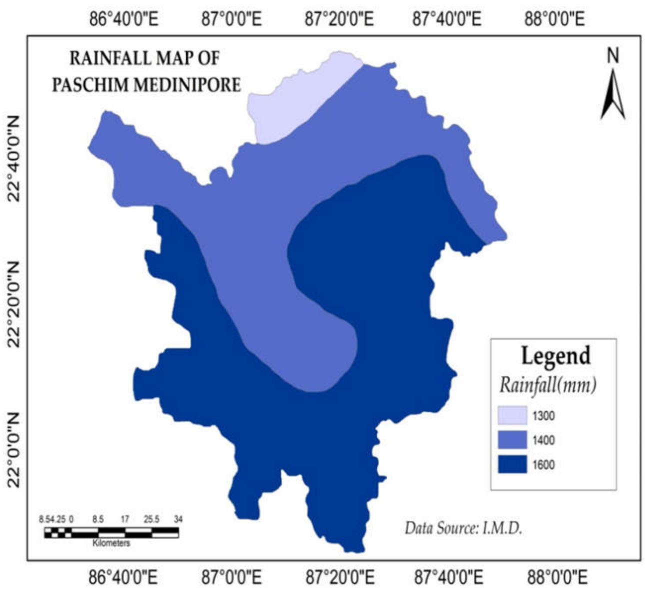

Fig 8 Rainfall of the study area

Analysis of Soil

Soil is important factor for ground water potentiality e.g. coarse textured soil are generally permeable while fine textured soils have less permeability. Soil is unconsolidated material on the surface of the earth that serves as a natural medium for growing plants. Plant roots reside within this material and extract water and nutrients (Jensen R. 2009). According to the ground water prospect the soil plays an important role in the ground water percolation and holding capacity. In this study area soil type in Paschim Medinipur district can be divided into sixteen categories, represented as coarse loamy typic haplustalfs, coarse loamy typic ustifluvents, fine aeric ochraqualfs, fine loamy aeric ochraqualfs, fine loamy typic paleustalfs, fine loamy typic ustifluvents, fine loamy typic ustochreptas, fine loamy ulti paleustalfs, fine vertic haplaquaepts, fine vertic ochraqualfs, loamy lithic ustochrepts, loamy skeletal lithic ustochreprs, residential area, rocky outcrops, and very fine vertic haplaquepts. The soil act as a natural filter to screen out many substances that mixes with water (Donahue *et al.,* 1983). In the eastern part of the district very fine vertic haplaquepts and sandy loam soil are found with high specific yield (19-30%) and porosity value (32-38%), which indicates that recharge from precipitation should pass easily form the surface to the zone of saturation (Holt Jr., 1965). On the other hand, crystalline rocks of the north-west part of the district has low porosity and low permeability due to small grain sizes with large surface areas, which resulted in increased friction, because it contains very few openings, so water cannot pass through (Donahue *et al.,*1983).

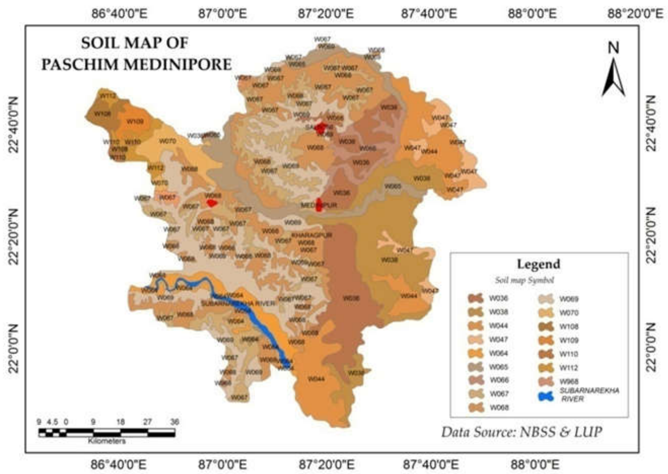

Fig 9 Soil map of the study area

Analysis of Normalize Difference Vegetation Index (NDVI)

The parameters derived from remotely sensed observations are being directly used in various studies relating NDVI (Normalized Difference Vegetation Index) and hydrological processes (Sellers, 1987; Gamon *et al*., 1995; Kondoh and Higuchi, 2001). In this study area highest NDVI values is 0.45 and the lowest values is – 0.34.This NDVI values are derived from LANDSAT 8 image data (November 2014). However NDVI analyses have to matched with other outputs of groundwater modeling criteria before final outlining the groundwater potential zones. The NDVI was controlled by the shallow ground water levels around low topographic lands which form the pathways of water flow in monsoon from the good zone of ground water potential. In this study area maximum percentage (66.38%) of area is under 0.225 – 0.32 NDVI values. This highest NDVI value cover the entire southern portion. Higher NDVI values implied availability of sufficient shallow groundwater and surface which stimulate vegetation growth and support local water needs .It is because of presence of extensive agricultural land with standing crop.

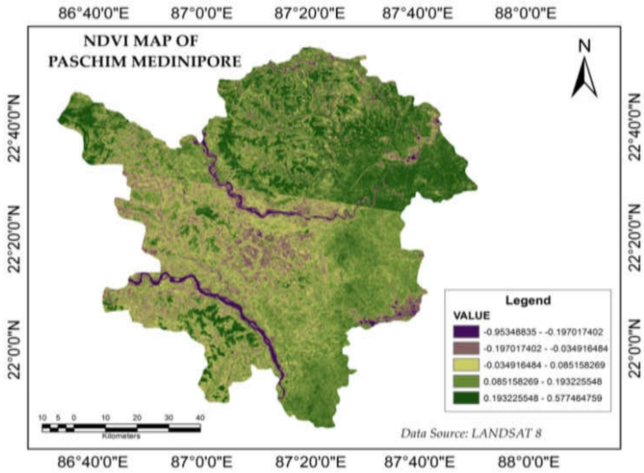

Fig 10 NDVI map of the study area.

Analysis of Landuse Landcover (LULC)

The analysis of land use land cover (LULC) is the most important application part of remote sensing. Land use land cover play significant role in ground water potentiality. It controls many hydrgeological processes in the water cycle viz., infiltration, evapotranspiration, surface runoff, condensation etc. Surface cover provides roughness to the surface, reduce discharge thereby increases the infiltration and decreases the surface run-off. Remote sensing provides excellent information with regard to spatial distribution of vegetation type and land use in less time and low cost in comparison to conventional data. LULC of the study area has been analyzed through the LNDSAT ETM image. The various land use classes are water bodies, sandy tract, lateritic land, dry fallow, moist land, dense forest, degraded forest, agricultural land, agricultural fallow, and settlement. The agricultural land is highest land cover of the study area (2627.8533 sq km) lowest land cover is sandy tract(71.6769 sq km). Land use land cover has an important role in ground water potentiality because the dense forest covers (17.10%) resist the water and decrease the run-off and increase the infiltration .On the other settlement area (1.28%) experiences high run-off and low infiltration. The presence of vegetative coverage in southern part facilitates the more ground water potentialities of this area.

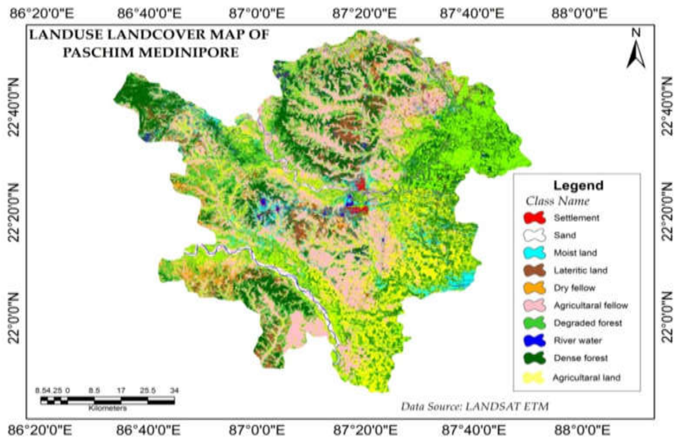

Fig 11 LULC map of the study area

Table 5 Class area and percentage (%) in particular parameter

Class name	Sl. No.	Slope in Degree	Area in sqkm	Area in (%)
Slope	1	$0^0 - 2.32^0$	2989.1943	33.22
	2	$2.32^0 - 4.65^0$	3573.8469	39.71
	3	$4.65^0 - 7.75^0$	1818.7272	20.21
	4	$7.75^0 - 13.17^0$	540.9792	6.01
	5	$13.17^0 - 49.39^0$	76.6782	0.85
Rainfall	**Sl. No.**	**Rainfall (mm)**	**Area in sqkm**	**Area in (%)**
	1	>1300	383.2064	4.26
	2	1301 – 1400	3597.6551	39.97
	3	1401 – 1600	5018.5463	55.77
Relative Relief	**Sl. No.**	**Relative Relief (m)**	**Area in sqkm**	**Area in (%)**
	1	0.03 – 26.38	4427.3709	49.19
	2	26.38 – 39.40	3257.5644	36.29
	3	39.40 – 64.33	1121.9697	12.46
	4	64.33 – 113.13	170.0755	1.89
	5	113.13 – 234.93	22.4433	0.25
NDVI	**Sl. No.**	**NDVI Value**	**Area in sqkm**	**Area in (%)**
	1	-0.34 – 0.225	1131.6474	12.57
	2	0.225 – 0.27	3160.6164	35.12
	3	0.27 – 0.32	2813.4558	31.26
	4	0.32 – 0.37	1184.0220	13.17
	5	0.37 – 0.45	709.6851	7.88
LULC	**Sl. No.**	**Class Name**	**Area in sqkm**	**Area in (%)**
	1	River water	185.1786	2.05
	2	Sand	71.6769	0.79
	3	Settlement	114.6141	1.28
	4	Moist Land	395.0901	4.39
	5	Dry Fallow	280.5795	3.12
	6	Lateritic Land	538.8498	5.98
	7	Dense Forest	1539.3384	17.10
	8	Degraded Forest	1166.0958	12.96
	9	Agricultural land	2627.8533	29.20
	10	Agricultural Fallow	2080.1493	23.12

Ground Water Potential (GWP) zone identification:

Remotely sensed satellite image data from LANDSAT ETM and LANDSAT 8 provided information used to identify landscape characteristics, vegetation condition, and outline geomorphological properties. Accordingly, SRTM data and TOPOSHEET offer the elevation of the surface as well as to delineate the drainage characteristics. Remote sensing satellite imagery (LANDSAT ETM and LANDSAT 8), SOI topographic maps and conventional data were used to prepare the thematic layers of nine parameters, namely geomorphology, geology, slope, soil, drainage density, relative relief, NDVI and rainfall. The thematic layers and their corresponding features were assigned weights after deciding the relative importance of different themes in causing groundwater occurrence on a 1–9 scale, and the normalized weights were obtained using Saaty's Analytical Hierarchy Process (AHP) or Pairwise Comparison Matrix (PCM).

The groundwater potential zones for the study area have been also generated through the integration of various thematic maps viz., classified maps of land use/land cover, NDVI, geology, geomorphology, soil, elevation, relative relief, and drainage density, slope and rainfall map generated by using remote sensing and GIS techniques. The identification of groundwater potential zones for the study area is generated generated by grouping of the above interpreted layers through Analytical Hierarchy Process (AHP) or Pairwise Comparison Matrix (PCM) and creates the weighted multi influencing factors and finally assigned different potential zones. From the analysis, the study area has been classified into five ground water potentiality zones such as very high potential, high potential, moderate potential, low potential and very low potential. Very high potential zone is found in eastern and south eastern part with the area of 1367.112sq km (15.19%).

Table 6 Distribution of area and percentage (%) under different Ground Water Potential (GWP) zones of the Paschim Medinipore district.

Sl. No.	Class Name	Area in sqkm	Area in (%)
1	Very high	1367.1128	15.19
2	High	2119.9124	23.55
3	Moderate	2681.2135	29.79
4	Low	2241.9067	24.92
5	Very low	589.2804	6.55

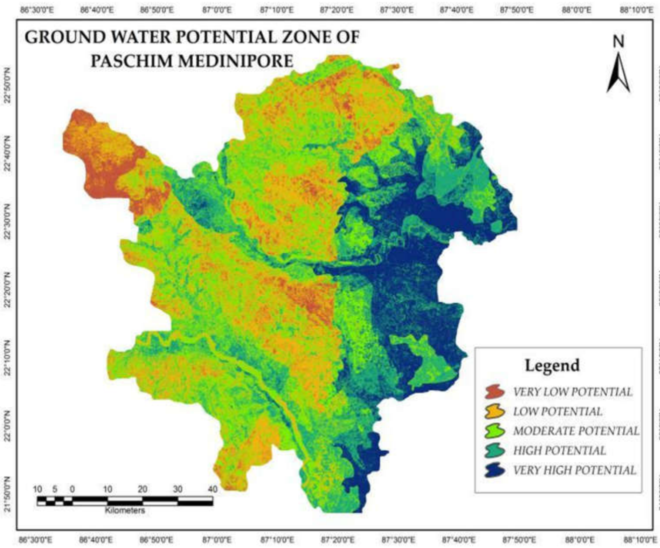

Fig 12 Ground water potential zone of Paschim Medinipore

This area is mostly flood prone due to basin like landform and poor drainage system. High potential area is covered 2119.9124 sq km (23.55 %) land area, moderate potential zone covers 2681.2135 (29.79 %), low potential zone covers 2241.9067 (24.92 %) and very low potential area is covered 589.2804 (6.55 %). The very low potential area is found in few patches in northern portion, middle portion and south western portion. Very high and high potential zone are located at the place of less drainage density, low slope, lower elevation and older alluvium and as well as the flood plain.

Relation between Slope and Ground Water Potentiality (GWP)

Where the height is very high, the ground water potential becomes very low because these is always inverse relation between slope and ground water storage. On the other hand the ground water storage is in good condition in the plain areas. In the first case the relation is negative and is positive in second case.

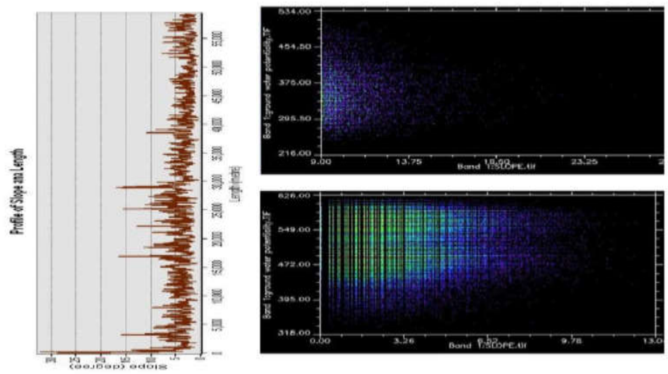

Fig 13 Relation between Slope and GWP

Relation between digital elevation model (DEM) and Ground Water Potentiality (GWP)

Here at the first place height is very high and ground water potential is very low because the slope is always inverse relation to ground water storage. Secondly in plain land, the height is very low and ground water potential is very high. First condition possess negative relation and second condition has positive relation.

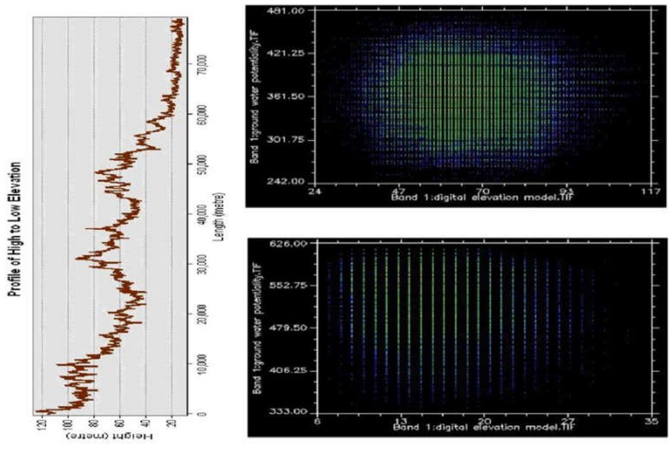

Fig 14 Relation between DEM and GWP

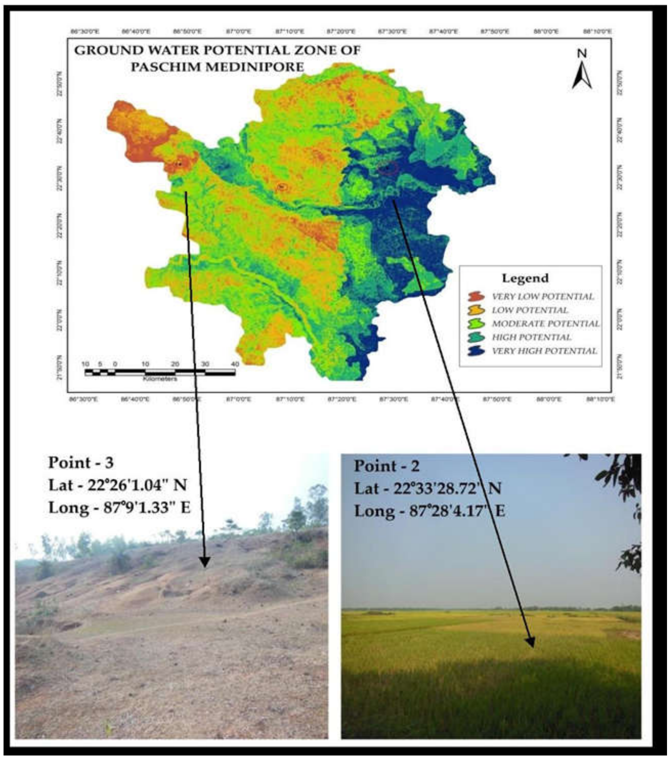

Fig 15 Ground truth verification

CONCLUDING REMARKS

Demarcation of groundwater potential zones of an area plays an increasingly significant role for sustainable management of groundwater resource across the world. Paschim Medinipore district located in the West Bengal, India is suffering from growing water shortages for both irrigation and domestic purposes. The results indicate that the most effective ground water potential zone is located at south and south eastern portion. Here the growing population and increasing agriculture production and erratic climate are too much effective for ground water level. These is no restriction in administrative level on permission to bore deep wells and submarsibles.This impose threat to the ground water storage level, which is decreasing at an alarming rate. Northern part of this district has already threatened to low water potentiality. The people of this area are more vulnerable for their agricultural and other activities so far as ground water availability is concerned. Administration should provide them water of alternative sources .Otherwise they will become more poor.

Overall, the results of this study demonstrated that the Geoinformatics technology is a powerful tool for assessing groundwater potential zone, based on which sustainable use of water resources should be taken. This groundwater potential information will be useful for effective identification of suitable locations for extraction of water. Result of this study is helpful for better management of groundwater reserve in the study area and give planners and decision makers an opportunity to prepare appropriate groundwater investment plans.

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