GROUNDWATER POTENTIAL ZONE IDENTIFICATION BY ANALYTICAL HIERARCHY PROCESS (AHP) WEIGHTED OVERLAY IN GIS ENVIRONMENT ─ A CASE STUDY OF JHARGRAM BLOCK, PASCHIM MEDINIPUR

Santanu Pani[1], Abhisek Chakrabarty[2], Sandhya Bhadury[3]
[1]Research Scholar, Dept. of Remote Sensing & GIS, Vidyasagar University, West Bengal, India
[2]Assistant Professor, Dept. of Remote Sensing & GIS, Vidyasagar University, West Bengal, India
[3] Former Deputy Director, NATMO, Kolkata, West Bengal, India

Abstract

It is very important to reasonably develop and utilize groundwater resources in an area because groundwater resource is linked mainly with drinking purpose and different sectors like agriculture. And Jhargram is the township and only developing area in Jhargram subdivision. Shallow groundwater level is an essential factor related to the eco-environmental problems such as oasis degeneration and land salinification. GIS integration tool is proposed to demarcate the groundwater potential zone in a soft rock area using eight themes: geology, geomorphology, lineament, soil, drainage density, slope, land use/ land cover and the potentiality around stream channels. Except for net recharge and slope, the other five themes are derived from remote sensing data (LISS-IV). The potentiality around the major streams found from the primary field survey. Each feature of all the thematic maps was evaluated according to its relative importance in the prediction of groundwater potentiality. Finally, the weighted overlay analysis rank value assigned for each class for all the thematic layers according to their influence on ground water hydrology and factor weighted values are assigned according to analytical hierarchy process (AHP). The result shows the high potentiality areas are mainly north-eastern part around Kangsabati River and some valley fills areas near to Dulong Nala. Groundwater potentiality is very poor in the Jhargram township area and some parts of upland plains. The Remote Sensing and GIS plays the key role to explore the groundwater monitoring and open new paths to take needful guideline and proper management of the water resource.

Keywords: GIS, thematic layers, weighted overlay, groundwater potentiality

1. Introduction:

In India, more than 90% of the rural and nearly 30% of the urban populations depend on ground water for meeting their drinking and domestic requirements (Reddy et al. 1996). Remote sensing and GIS technology have opened new paths in groundwater studies. In the present study, an attempt has been made to identify the Groundwater Prospect sites in the Paschim Medinipur district area, West Bengal based on Remote Sensing and GIS techniques. The groundwater prospect map is a systematic effort and has been prepared considering major controlling factors, which influence the water yield and quality of ground water. The map depicts hydro-geo-morphological aspects, which are essential as basis for planning and execution of groundwater exploration. However, integrated studies using conventional surveys along with satellite image data, and geographical information system (GIS) tools, are useful not only to increase the accuracy results, but also to reduce the bias on any single theme. Previously, many researchers used the remote sensing and GIS technique to define the spatial distribution of groundwater potential zones on the basis of geomorphology and other associated parameters (Krishnamurty and Srinivas, 1996; Ravindran and Jeyaram, 1997; Sree Devi et al. 2001; Sankar, 2002; Jagadeeseara et al. 2004). In the present study, an empirical model is developed using GIS for the qualitative assessment of groundwater potential in the soft rock area of Paschim Medinipur District, West Bengal, India.

2. Background of the study:

Agriculture is the main occupation of the rural inhabitants. Groundwater plays an important role in drinking, agricultural and industrial needs as a timely assured source due to non-availability of surface water in time. In the summer, the sun heats up sidewalks, parking lots and streets. Rain falls on these areas, warms up, and runs into the river. Factories and stations that generate electricity to cool their processes also use water. (S. Pani, 2014)

The district is unique in geomorphic settings, in the sense that hard rock upland, laterite covered fringe areas and flat alluvial are found. Extremely rugged-topography is seen in the western part of the district. The district form west to east presents a gradually slopping topography; the land is highest near Silda (132 mts. Above MSL) and only around 3 mts. to 4 mts. near the coast where that land gradually dips into Bay of Bengal. The heterogeneous nature of terrain condition of the district makes it difficult for systematic development of groundwater. The area which is being hard massive rocks with shallow depth groundwater occurring within restricted zone of weathering and within fracture zone.

Both groundwater and surface water are being harnessed from implementation of minor irrigation schemes in various parts of the district. The district id reflecting widely varied geo-morphological agro climate conditions. The eastern and south-eastern parts of the district are underlain by recent alluvium except Garbeta, Salboni and some parts of Chandrakona and Kespur block. A comparative study in the blocks done by SWID shows variation in groundwater. It appears that 10 years average of groundwater varies from 8.91 mbgl. To 3.76 mbgl. during pre-monsoon (April-May) and post-monsoon (Nov-Dec) respectively and in 2004 average ground varies from 9.76 mbgl. to 3.49 mbgl. From comparative study it reveals that in pre-monsoon groundwater is decreasing by (-) 0.85 mbgl and post-monsoon it is increasing by 0.27 mbgl. Overall the groundwater potential is decreasing in the district and in different blocks under Midnapore, Kharagpur and Jhargram sub-division it is alarming condition.

Kangsabati, Subarnarekha, Dulongs, Keleghai and their tributaries are the main rivers of the district. Irrigation is provided to both kharif and rabi crops. Kangsabati canal system is the main irrigation scheme. Ground water supports supplementary irrigation. 63% of net cultivable area irrigated and exploitation of ground water potential only 27% of the utilizable recharge. The groundwater development and judicious management of the surface water are the vital factors for promoting modern agriculture through high yielding and remunerative crops, particularly in the western parts of the district that is Jhargram Sub-division area as known as "**Junglemahal**" area. And Jhargram block is the most important area in the socio-economical & agricultural perspective. It is better to say, Jhargram is the capital of Junglemahal area.

Fig-1: Irrigation through groundwater in Jhargram block

3. Location of the study area:

Jhargram police station serves this block. It extends from 86º 54′ 16.174″ to 87º 15′ 34.651″ (longitudinal extension) and 22º 15′ 21.793″ to 22º 30′ 7.598″ Headquarters of this block is at Jhargram. Total geographical area of this block is 554.07 Sq. km. The maximum and minimum temperature varies from 45º C to 10º C and the average normal rainfall 1570 mm.

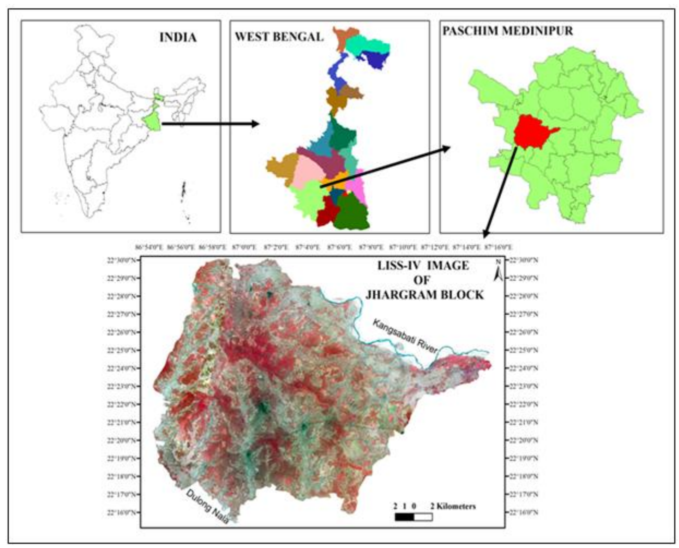


Fig-2: Location of the study area

4. Objectives:

1. Identification and delineation of groundwater potential zones through integration of various thematic maps with GIS techniques.

2. To prepare various thematic maps of the area such as lithology, lineaments, slope steepness from remotely sensed data and other data sources like DEM.

3. Recommendations for future work and provide guidelines for groundwater prospecting & sustainable use of groundwater with reference to excessive withdrawal in that area.

4. How LISS-IV satellite data is useful for Groundwater potential zones mapping to assess groundwater controlling features by combining remote sensing, field studies and DEM.

5. Data Used and Methodology:

Various types of data used for identification of groundwater potential zones in Jhargram block.

1. LISS-IV multispectral satellite data used of November 2010

2. One of the most essential used for this study Digital Elevation Model (DEM) data sources is the elevation information provided by ASTER 30-meter extension.

3. There are three Topographic map sheets at a scale of 1:50,000 cover the entire Jhargram block. Besides, the block map was collected at the same scale to delineate the block area.

4. Other data such as Soil map, Geological map,Geomorphological Map were collected from the different registered govt. organizations.

5.1 Image processing and Interpretation:

All the images were mosaicking and subset to the boundary of Jhargram block. Image processing was completed using ERDAS IMAGINE 2011 environment. It has been adjusted by suitable color balancing and data scaling technique.

Land use/ land cover map was prepared based on the visual interpretation technique on LISS-IV data and verified with spectral signatures for each class, District Planning map, topographic maps and ground truth points. The block was classified into eight land use/ land cover classes which are agricultural land, forest, scrub land, social forestry, river, ponds/lakes, mixed settlement and urban area.

The drainage lines were mapped through this 5.8-meter resolution imagery and topographic maps and DEM data will help to check the accuracy.

Where the lineaments are extracted from the drainage pattern of this study area. In that hard rock topography the drainage pattern helps to identify the lineament structure.

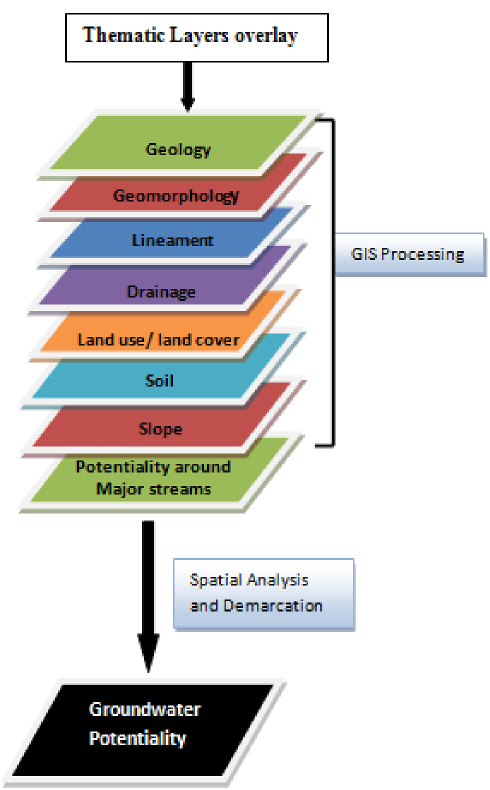
5.2 Digital Elevation Model:

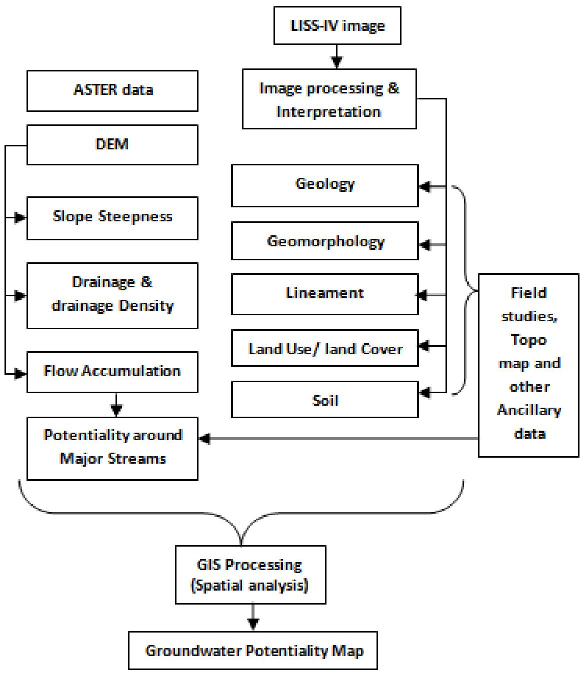
Geo-referenced ASTER GLOBAL elevation data from a 30-meter tiles (1 arc second) digital elevation model of the study sites were collected from USGS Earth Explorer (http://earthexplorer.usgs.gov/) and the data were overlaid throughout the model.Advanced Spaceborne Thermal Emission and Reflection (ASTER) elevation data was used to generate the slope map, flow accumulation map and stream ordering. The different types of DEM analysis and processes for generating different types of thematic maps are done on ARC GIS 10.1 environment.

5.3 Database generation:

The thematic layers (drainage density, soil, geology, geomorphology, land use/ land cover etc.) were prepared with the help of Arc GIS 10.1 environment. After reclassifying these have been merged through assigning weighted values for each and every class of the layers. Finally, the groundwater potential zones were identified using overlay analysis method. The highest values point towards the higher groundwater potentiality.

5.4 Methodology Flow Chart:





6. Result and discussion:

In this study, the following factors were considered as controlling/influencing the groundwater storage potential of the area.

6.1 Geology and its relation to Groundwater potentiality:

It is a well established fact that geological setup of an area plays a vital role in the distribution and occurrence of groundwater (Krishnamurthy and Srinivas, 1995). The geology of this area depicts the geological units, the underlying structure, lithology and the geological process and its relation to groundwater. Laterite is the major formation of this area. There are two major geological units; The *Lalgarh formation* is a part of older alluvium in the Paschim Medinipur district which contains the fragments of quartz, granite pebbles, phyllite but occasionally lateralitized.

Another one is Sijua formation which is soft unconsolidated sediments, low slopes, flood proneness and it confined to flood prone areas. And the landforms of Sijua formation are on higher ground and devoid of any flood or waterlogging hazard. Recent or younger alluvium have been deposited along the floodplains of the river.

The Geological settings define the underlying structures and prospects of groundwater. The geological map has been prepared through the help of Geological survey of India data and current satellite imagery (Fig-3). At first we need to rectify the Geological map of Medinipur district and match the area of interest with the satellite imagery. In case of satellite imagery visual interpretation must be needed.

Table No. 1: Geological descriptions which cover the study area

Code	Description
Q1	Fluvio-deltaic sediment overlained by secondary laterite (Fragments of Quartz, phyllite, granite, pebbles and gravels occasionally lateritised)
Q1-2	Younger alluvium (Greenish grey clay, impregnated with caliche nodules)
Q2a	Sands with silts, clays, associated with Fe-nodules

6.2 Geomorphology and its relation to Groundwater potentiality:

Geomorphologic maps help to identify various geomorphic units and groundwater occurrence in each unit (Bahuguna et al., 2003; Rao et al., 2004). LISS-IV satellite data is the most useful tool to understand the geomorphological settings of this area (shows in Fig-4). The secondary data collected from GSI map of Medinipur district. It helps to verify the geomorphological features messed up with the interpretation of the satellite image. The *flood plains* are manly based on two rivers in the block. The Kangsabati flood plain is in the North side and in south part of the block it is along the Dulong Nala. The flood plains appear as greenish and pinkish tones in the satellite image. Actually pinkish tone represents the double crop areas in flood plains. It comprises mainly of sands and slits with minor inter clarified of clays and they act as good aquifers. The ground water potential of flood plain is very high. These surfaces are underlain by deposits of older alluvium bearing rolling plains.

Due to some rugged landforms groundwater is found in *valley fill* areas and sometimes valley fill covered with laterite. Valley fills are identified in between the upland ranges and are filled with pebbles, cobbles, gravel, sand and silt. These units are found to have a good groundwater potential due to underlying weathered rocks. The hard rock terrain with extremely rugged topography is found in the north western of the block which is occasionally covered by laterites.

The more or less flat alluvium terrain is generally from west to towards south west portion of this block as well as the district.

But The maximum percentage of area covered by *Upland lateritic plains* where the groundwater prospect described as poor to moderate. And very small potion covers by Plantation surfaces which mean pediplains and peneplain landforms. The potentiality of groundwater is poor in those areas.

6.3 Lineament and its relation to groundwater potentiality:

The lineament and lineament density map shown in Fig-7 and Fig-8. It is well known that fracture traces and lineaments are important in rocks where secondary permeability and porosity dominate and where inter-granular characteristics combine with secondary openings influencing weathering and groundwater movement (Carlo Travaglia and Niccolo Dainelli, 2003). Groundwater occurrence and movements are controlled by secondary porosity and permeability resulting from folding, faulting, fracturing, etc (Dar et al., 2010). The lineaments which are mapped in valley fill sediments, are considered as a high potential zones.Groundwater prospect in this region is gooddue to the intersection of the above lineaments were the first to adopt a lineaments map to exploit groundwater. Thereafter, many scholars have applied this approach in complicated geological regions (Solomon and Quiel, 2006).

6.4 Slope and its relation to groundwater potentiality:

The slope amount map (Fig-10) has been prepared using contours produced from ASTER 30-meter Digital Elevation Model data (shows in Fig- 9). In relation to groundwater flat areas where the slope amount is low are capable of holding rainfall, which in turn facilitates recharge whereas in elevated areas where the slope amount is high, there will be high run-off and low infiltration. Generally, the elevation declines from north-west to eastern and south eastern direction. The slope amounts have shown that elevation is low in eastern and south-eastern part. The ground water reservoir is in the form of a low relief, water table aquifer to nearly uniform gradient (Parizek *et al.*, 1967). The method of producing the slope amount map is described below.

Methods: Steps followed to prepare the slope amount of the project area are described below:

1. Derive DEM from ASTER data.
2. Importing in to ARC GIS
3. Derivation of Slope Amount using Spatial Analysis and reclassification in to appropriate classes.

6.5 Soil characteristics and its relation to groundwater potentiality:

The soil act as a natural filter to screen out many substances that mixes with water (Donahue *et al.*, 1983). Generally, it is a lateritic area, besides alluvial and red soil are dominating in the entire block. This area divided into five soil categories (shows in Fig-6). Most of the upland area covered by *fine loamy ultic paleustalfs* soil which is very deep imperfectly drained and fine loamy type. In the uplands of the area, soil formation mainly by physical weathering is a very important process. It is occurring on very gently sloping to undulating dissected upland with loamy surface and moderate erosion (associated with very deep, moderately well drained fine loamy soils). Valley fill areas covered by *fine loamy, aericochraqualfs* soils which is good for groundwater percolation. The Kansabati Irrigation area covers *fine loamy typic ustifluvents* soil type. The another major soil type is Coarse loamy, typichaplustalfs which is found in the forest part of that area. A very small portion of the north western side of that block is under *fine, aeric ochraqualfs* which is very deep but very poorly drained. Soil ranking was indicated on the basis of its infiltration capability.

6.6 Land use / Land cover and its relation to groundwater potentiality:

Jhargram block area is classified into major eight Land use pattern i.e. Agricultural land, Scrub land, Forest, Social forestry, River, Ponds, Mixed settlement and Urban area. The maximum area is dominated by dense forest and Agricultural land (shows in Fig-5). Extreme Eastern and south Eastern part of the area is experienced as the land of Dry crops, Scrub forest, mixed forest and wetlands. North-western part is attributed as the diversified land use pattern. In terms of Groundwater hydrology, the area of crop land, Scrub forest are related with good and excellent ground water prospect on the other hand, Urban area, Dense forest, are closely associated with the poor ground water Potentiality. Human settlements and constructions are the major factors which influence to prevent infiltration and groundwater storage. Accordingly, for vegetation cover, the higher the vegetation cover, the higher the evapotranspiration rate and this imply less chance for percolation to the subsurface layers (Darwichetal., 2003).

6.7 Drainage density and its relation to groundwater potentiality:

Drainage lines extracted mainly from ASTER Digital Elevation Model data and validate it with November 2010 LISS-IV image. According to the density in per square kilometer grid area it has been classified into five classes, very high to very low which shows below in Fig-11. Drainage and drainage density are one of the major factors of groundwater occurrence. Wherever the density is high then surface runoff will be more on contrary and in low density areas infiltration will be more. Drainage pattern reflects surface characteristics as well as subsurface formation (Horton, 1945).

6.8 Groundwater potentiality around the Major streams:

A flow accumulation map prepared using ASTER DEM data step by step technique Fill – flow direction- flow accumulation. The flow accumulation map (Fig-12) shows stream weight and the major influencing streams in that area. It is indicated that low accumulation values represent ridge tops whereas higher accumulation values represent valleys and stream channels. (Sreedhar Ganapuram, G.T. Vijaya Kumar, Murali Krishna, Ercan Kahya, M. Cüneyd Demirel)

In this context the field survey was conducted around the major streams including Dulong Nala and Kangsabati River. It helps to understand when the distances from the stream increases, the potentiality of the groundwater decreases. The buffer analysis along the river (shown in Fig-13) says so.

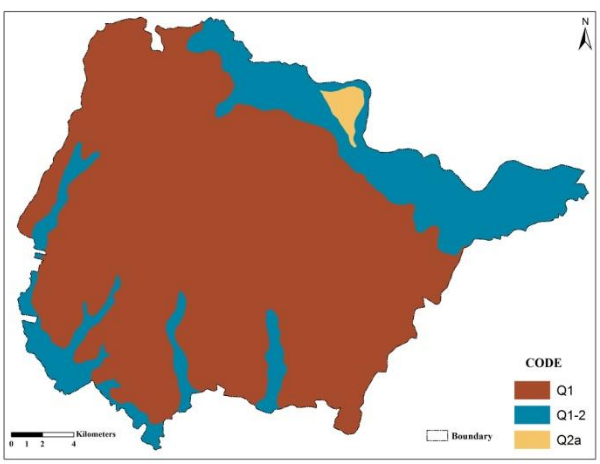


Fig-3: Geology Map

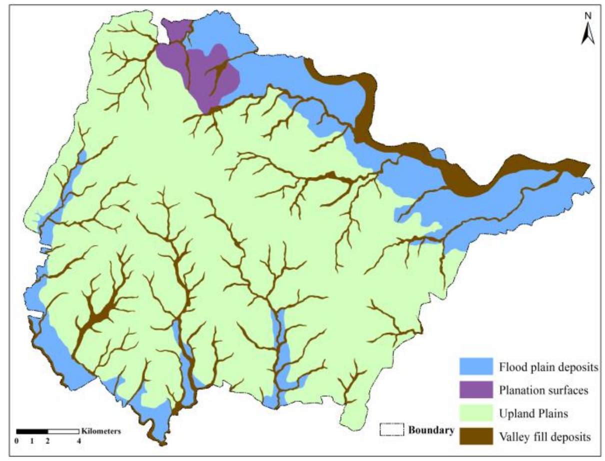


Fig-4: Geomorphology Map

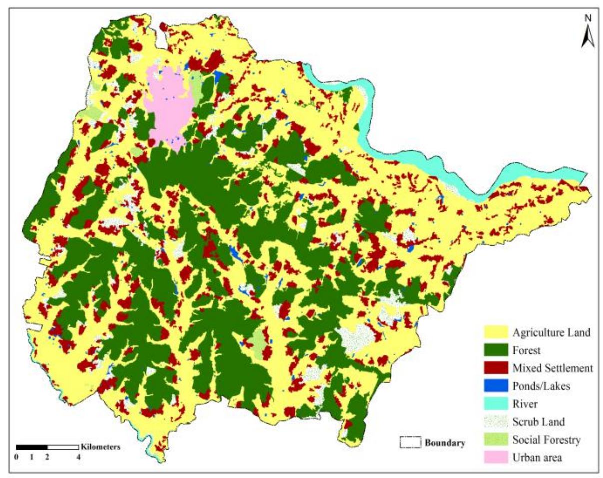


Fig-5: Land use/ land cover Map

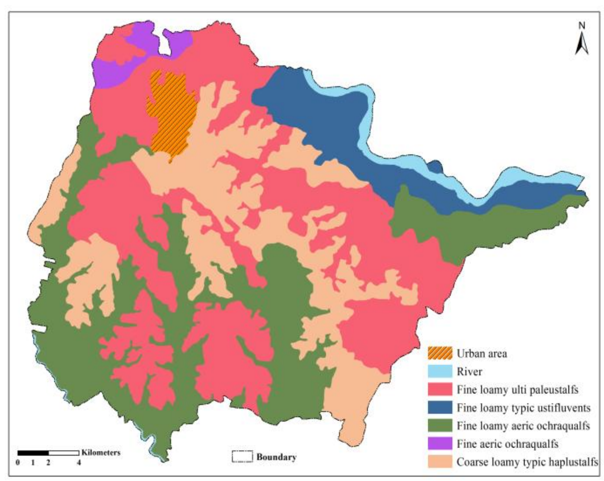


Fig-6: Soil Map

Fig-7: Lineament Map

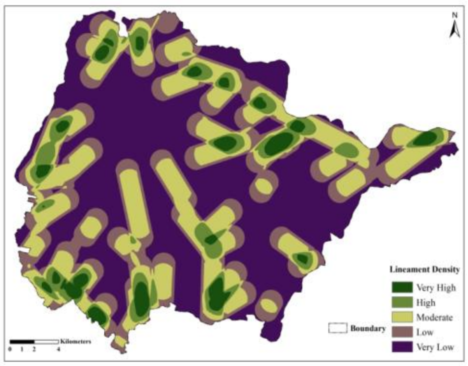


Fig-8: Lineament Density Map

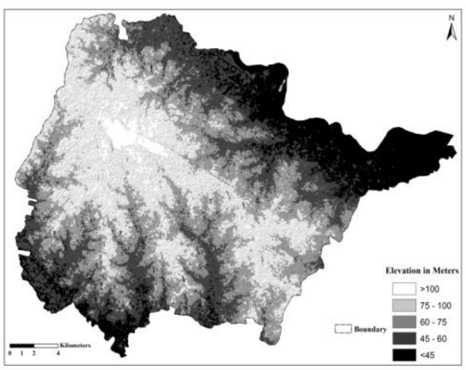


Fig-9: ASTER DEM

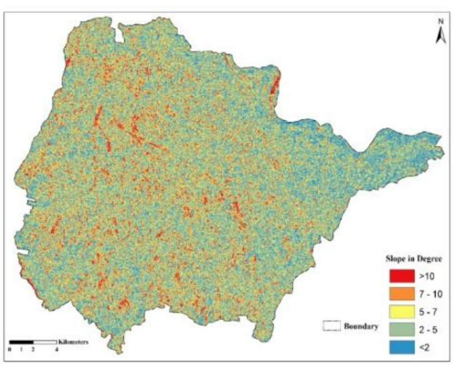


Fig-10: Slope Map

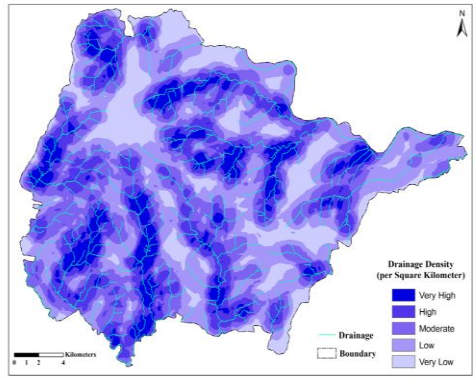


Fig-11: Drainage and Drainage Density Map

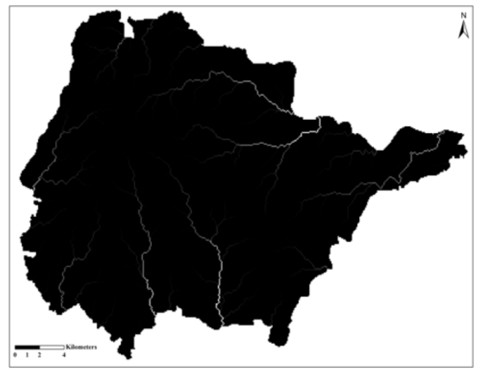


Fig-12: Flow Accumulation Map

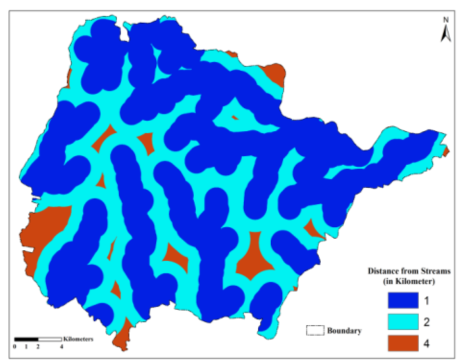


Fig-13: Groundwater potentiality around major streams

TableNo. 2: Weights assigned for different classes of different layer

Thematic layers	Map weights (%)	Classes	Rank	Groundwater potentiality
Geology	10	Fluvio-deltaic sediment overlaid by secondary laterite	4	Poor
		Younger alluvium	7	Excellent
		Sands with silts, clays, associated with Fe-nodules	6	Moderate
Geomorphology	15	Flood plain deposits	8	Excellent
		Valley fill deposits	7	Good
		Upland plains	4	Moderate
		Planation surfaces	3	Poor
Lineaments (km/km^2)	10	Very High	5	Excellent
		High	4	Good
		Moderate	3	Moderate
		Low	2	Poor
		Very Low	1	Very Poor
Soil	15	Fine loamy ulti paleustalfs	3	Very Poor
		Fine loamy typic ustifluvents	8	Excellent
		Fine loamy aeric ochraqualfs	6	Good
		Fine aeric ochraqualfs	4	Poor
		Coarse loamy typic haplustalfs	5	Moderate
Drainage Density (km/km^2)	10	Very High	3	Very Poor
		High	4	Poor
		Moderate	5	Moderate
		Low	6	Good
		Very Low	7	Excellent
Slope (in degree)	10	>10	2	Very Poor
		7 - 10	3	Poor
		5 - 7	4	Moderate
		2 - 5	5	Good
		<2	6	Excellent
Land use/ land cover	20	Agriculture land	7	Very Good
		Forest	4	Poor
		Urban Area	3	Very Poor
		Mixed Settlement	5	Moderate
		Ponds/Lakes	8	Excellent
		River	8	Excellent
		Scrub land	6	Good
		Social forestry	5	Moderate
Potentiality around the major streams (distances from main stream)	10	1 Km	7	Excellent
		2 Km	5	Good
		4 Km	3	Poor

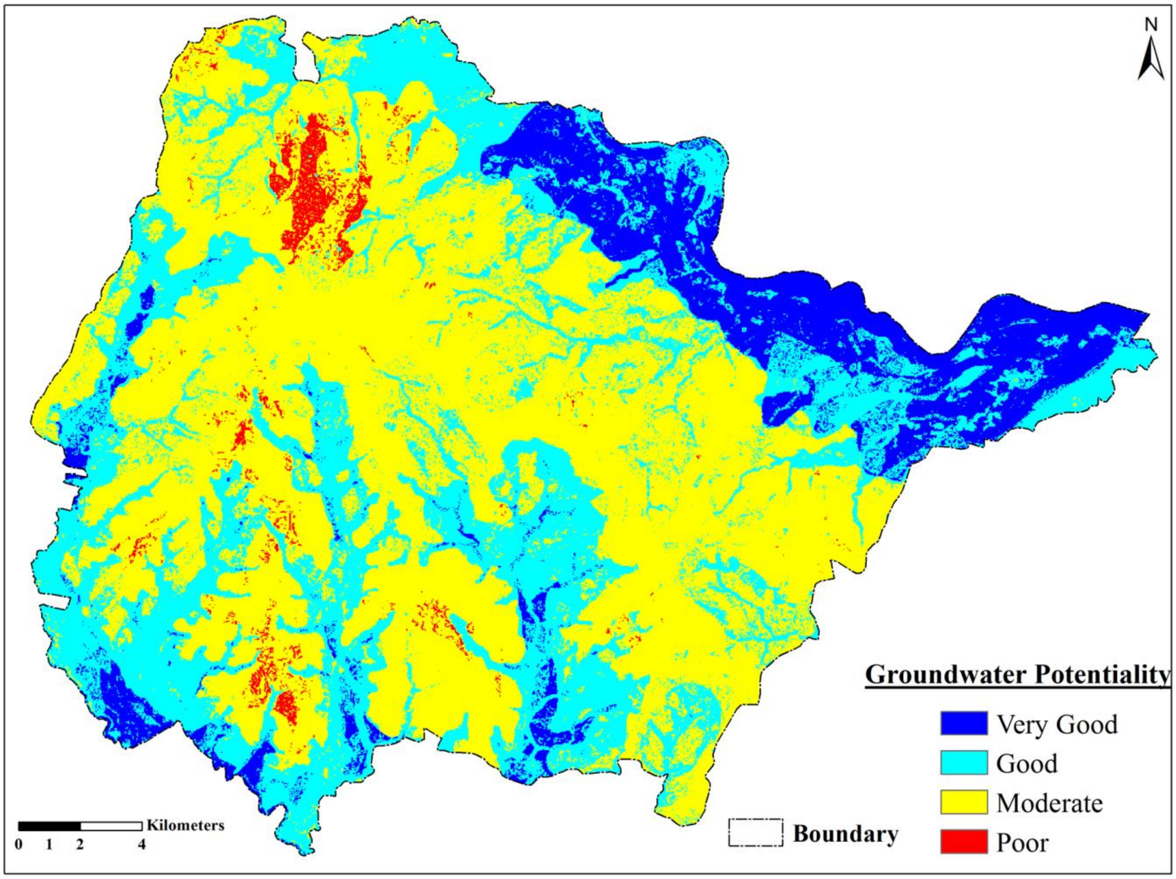


Fig-14: Groundwater Potential Zones of Jhargram Block

Table No. 3: Area under Groundwater potentiality

Classes	Area (Sq. km.)
Poor	9.26
Moderate	297.96
Good	179.98
Excellent	67.20

7. Conclusion:

The remotely sense data helps in accurate hydro-geomorphological analysis and identification and delineation of land features as well as one of the most important factor for this study. IRS-P6 Resourcesat data (LISS-IV multispectral) can be used successfully to interpret, classify the different land use/ land cover, drainage extraction and ASTER DEM also very useful for classified slope maps and different hydrological themes like flow accumulation. The main objective was to show the spatial distribution of groundwater potential areas, and it has been developed that final result (groundwater potential zones) has been produced using eight thematic layers. The result is classified into four categories, very good, good, moderate and poor. The high potentiality areas are mainly north-eastern part around Kangsabati River and some valley fills areas near to Dulong Nala. Groundwater potentiality is very poor in the Jhargram township area and some parts of upland plains which showed in the Fig-14.

Therefore, it is demonstrating that an integration of remote sensing and GIS can be used in predicting and identifying sites of groundwater accumulation and groundwater salinity in arid regions. In this context the Remote Sensing and GIS technologies evolve new approaches to explore the groundwater monitoring and management for the future by providing new guidelines and unique method to supplement conventional field data which will help for proper management and development of the poor groundwater potentiality areas.

Acknowledgements:

It is my pleasure to introduce to this research work on an important and problematic issue. For modification and completion of this research work, I would like to express my gratitude to my guide Dr. Abhisek Chakrabarty, Assistant Professor, Vidyasagar University. His scholarly opinion about this research topic is as kind as informative.
I am also grateful to Dr. Sandhya Bhadury, Former Deputy Director, NATMO for her initial help.
And I am very much thankful my friend Mr. Amit Ghosh, Research Scholar at Jadavpur University, Kolkata and Miss Saptadwipa Sen, Project Scientist at Dept. of Science & Technology, Kolkata for providing their knowledge and for helping to complete some parts in this study.

References:

[1] Reddy, K.R., & Adams, J.A. (1996), “In situ air sparging: a new approach for ground water remediation”, Geotech News, 14(4), 27-32.
[2] Jagadeeswara, R.P., Harikrishna, P., & Rao, B.S. (2004), “An integrated study on groundwater resources of PeddaGedda Watershed”, J. Indian Soc. Remote Sensing, 32, 307-311.
[3] Dar MA, Sankar K, Dar IA (2010). GW prospects evaluation-based on hydrogeomorphological mapping: A case study in Kancheepuram district, Tamil Nadu. Indian J. Rem. Sens. 38(2):333-343.
[4] Krishnamurty, J., & Srinivas. (1996), “Demarcation of geological and geomorphological features of parts ofDharwar Craton, Karnataka using IRS LISS-II data”, Int. J. Remote Sensing, 17, 3271-3288.
[5] Ravindran, K.V., Jeyaram, A. (1997), “Groundwater prospectus of ShahbaTeshil, Baran district, easternRajasthan: A remote sensing approach”, J. Indian Soc. Remote Sensing, 25, 239-246.
[6] Sree Devi, P. D., Srinivasulu, S. & Raju, K. K. (2001), “Hydrogeomorphological and groundwater prospects ofthePageru river basin by using remote sensing data”, Environ. Geol. 40, 1088–1094.
[7] Sankar, K. (2002), “Evaluation of groundwater potential zones using remote sensing data in upper Vaigairiverbasin, Tamilnadu, India”, J. Indian Soc. Remote Sensing 30(3), 119–130.
[8] Donahue, R., Miller, R., &Shickluna, J. (1983), “Soils: An Introduction to Soils and PlantGrowth”, Englewood Cliffs, NJ: Prentice-Hall, Inc.
[9] Darwich, T., Kawlie, M., Faour, G., Masri, T., Haddad, T., Awad, M., BouKheir, R., Shaban, A., Jomaa, I.,Abdallah, C.(2003), “Dynamic factors of land degradation in Lebanon”, Workshop on: Ecosystem-basedassessment of soil degradation to facilitate land user’s and land owners’ prompt action. Adana, Turkey, 2-7/6/2003, p66-68.
[10] Bahuguna, I.M., Nayak, S., Tamilarsan, V. & Moses, J. (2003), “Ground water prospective zones in Basalticterrain using Remote Sensing”. J.Ind Soc. Remote Sensing, 31(2), 107-118.
[11] Travaglia and Dainelli (2003), “Groundwater search by remote sensing: A methodological approach”. Food and Agriculture Organization of the United Nations, Rome. P-17
[12] Horton, R.E., “Erosional development of streams and their drainage density: hydrophysical approach to quantitative geomorphology”. Geol. Soc. Amer. Bull., no.56, pp.275-370,1945.
[13] SreedharGanapuram, G.T. Vijaya Kumar, Murali Krishna, ErcanKahya, M. CüneydDemirel (2008), Mapping of groundwater potential zones in the Musi basin using remote sensing data and GIS , Elsevier Ltd. http://www.journals.elsevier.com/advances-in-engineering-software
[14] Santanu Pani, Dr. Abhisek Chakrabarty, Dr. Sandhya Bhadury (2014), “Water Quality Monitoring and Mapping of Hooghly and Haldi River near Haldia Industrial Belt" on Journal of Centre for Ground Water Studies, Indian Groundwater: VOL-II, January 2014.
[15] Parizek, R. R., Kardos, L. T., Sopper, W. E., Myers, E. A., Davis, D. E., Farrell, M. A., and Nesbitt, J. B. (1967). “Penn State Studies 23: Waste Water Renovation and Conservation. Administrative Committed on Research”, The Pennsylvania State University, American journal of public health 65, 71 pp.