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Groundwater Prospective Zone Mapping using Remote Sensing and Gis Techniques: A Case Study from the Gadilam River Basin, Tamil Nadu, India

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ABSTRACT

The objective of this study is to explore the groundwater availability in the Gadilam River basin mainly for agriculture. Remote sensing data and geographic information system were used to locate Prospective zones of groundwater in the Gadilam River basin. Various maps (i.e., Base, Hydrogeomorphology, Lithology, Drainage, Drainage density, Lineament, Lineament density, Slope and Land Use/Land Cover) were prepared using the Remote sensing data along with the existing maps. The groundwater availability of the Gadilam River basin is quantitatively classified into different classes based on its Hydrogeomorphological conditions. The land use/land cover map was prepared using IRC-1C LISS III, PAN satellite data and other collateral information. Using a digital classification technique with the limited ground truth verification for irrigated area in the Gadilam river basin. The alluvial plain, filled valley, flood plain and deeply buried pediplain were successfully delineated. It demarcates highly prospective Zones of groundwater accumulation in the study area. The overall results demonstrate that the use of remote sensing and GIS techniques provide powerful tools for groundwater development and the design of a suitable exploration plan of the study area.

1.Introduction

Groundwater is a form of water occupying all the voids within a geological stratum. Water bearing formation of the earth's crust acts as conduits for transmission and as reservoirs for storing water. The occurrence of groundwater in a geological formation and the scope for its exploitation primarily depend on the formation porosity. In the presence of interconnected fractures, cracks, joints, crushed zones (such as faults zones or shear zones) or solution cavities, rainwater can easily percolate through them and contribute to accumulate groundwater storage. The conventional methods used to prepare groundwater potential zones are mainly based on ground surveys. With the advent of remote sensing and Geographic Information System (GIS) technologies, the mapping of groundwater prospective zones within each geological unit has become an easy procedure. The groundwater conditions vary significantly depending upon the slope, depth of weathering, presence of fractures, surface water bodies, canals, irrigated fields etcetera. These factors can be interpreted or analyzed in GIS using remote sensing data. Demonstrated the use of Hydrogeomorphological map by using satellite imaging data. The topographic maps to indicate the groundwater prospective zones in qualitative terms (i.e., Excellent to good, moderate to good and poor). The integrated use of remote sensing data and GIS technique, with field ground surveys, are well known as powerful techniques for groundwater mapping and exploration particularly in the arid environment. Over the last few decades, the international scientific community has shown great interest in this topic and thus, many authors have used remote sensing and GIS techniques for groundwater prospective zones (Gustafsson, 1993; Minor et al., 1994; Krishnamurthy and Venkatesesa, 1996; Sabins, 1997; Sander, 1997; Teevw, 1999; Singh and Prakash, 2003; Sikdar et al., 2004; Kuskyand Gad, 2006; Sultan et al., 2008; Dineshkumar et al., 2007;Jasrotia et al., 2007; Sreedharet al., 2009; Chowdhury et al., 2009; Chowdhury et al., 2010; Jha et al., 2010; Mohammed-Aslam et al., 2010). Sankar, 2002; Jagadeeseara et al., 2004. Remote sensing (RS) data is used for qualitative evaluation of groundwater resources by extracting and analyzing geological structures, surface morphology and their hydrologic characteristics. Moreover, it provides a better observation and more systematic analysis of various geomorphic units, landforms and lineament features which govern the sub-surface water conditions (Singhal and Gupta, 1999; Das et al., 1997). Gustafsson (1993) used GIS techniques for the analysis of the lineaments data derived from high resolution imagery for groundwater prospective zones mapping. Krishnamurthy and Venkatesesa (1996) used remote sensing data and GIS techniques to prepare and to analyze different thematic maps. They used lithology, landforms, lineaments, drainage density, slope map and land use/land cover maps.

The employed remote sensing and GIS techniques to locate prospective zones for groundwater with the Gadilam river basin.Groundwater conditions vary significantly depending upon the slope, depth of porous sediments, presence of fractures, surface water bodies and irrigated fields (Sreedhar et al., 2009) and are also influenced by climate, physiography, drainage and geology (Pradeep, 1998). These various data are prepared in the form of thematic map using geographical information system (GIS) software tool.

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These thematic maps are then integrated using ''Spatial Analyst'' tool. The ''Spatial Analyst'' tool operators is then used to develop model depending on objective of the problem at hand, such as of the groundwater Prospective zone. S. Venkateswaran and R.Ayyandurai (2015). The main objective of the present study is to apply innovative approach to assess the groundwater controlling features to identify groundwater prospective zones and finally build up a groundwater prospect map. This objective is achieved by preparation of thematic maps for the most important contributing parameters that indicate groundwater potential such as lithology, lineaments, drainage, and slopes through GIS module. Field observations and investigations are applied to test the validity of the resulting GIS module for locating groundwater prospective zones. The advantage of such methods is to conduct regional and cost-effective investigations over large areas as is the case with the study area.

2.Data and methodology

2.1Description of study area:

The Gadilam River basin is the most important agricultural production area. The fast growing population and increasing urbanization, consequently increasing water demand in the cities and industries. There is a growing awareness of the need for adequate water resources to maintain environmental requirements. In contrast to land resources, there is a high interdependency among water users due to the movement of water in the hydrologic cycle. The study area covered 1428 Sq.km. The Gadilam river flows both in Vizhupuram and cuddalore districts of Tamil Nadu. In Gadilam river basin originates from mayanur garudan spring of garudan rock and traverses via pasar hill and damal village before reaching the sedimentary contact near Thirunavalur, Sesha Nadi is an ephemeral stream which is found almost to be dry throughout the year, excepting for surface water flow for few days in a year during rainy season. Hard rock area falls under semi-arid climatic conditions with numerous surface water tanks and lakes with unseasonable, erratic and almost failure in monsoon. The study area lies between North Latitudes 11°40' to 11° 58' N and Longitudes 78° 58' to 79° 26' 35'' E. The drainage pattern in the area is dendritic to sub dendritic and at tor complex as trellis type. National Highway (NH-45) passes in eastern part of the study area in the NE-SW profile. fig.1 the study area is characterized by gently undulating topography with low relief hills.

2.3 Data products used in the study

Remotely sensing data are composed of Shuttle Radar Topographic Mission-Digital Elevation Model (SRTM-DEM) data and Landsat, LISS III satellite data. Maps used to analysis using Survey of India Toposheet –1:50,000; geology maps – 1:50,000.

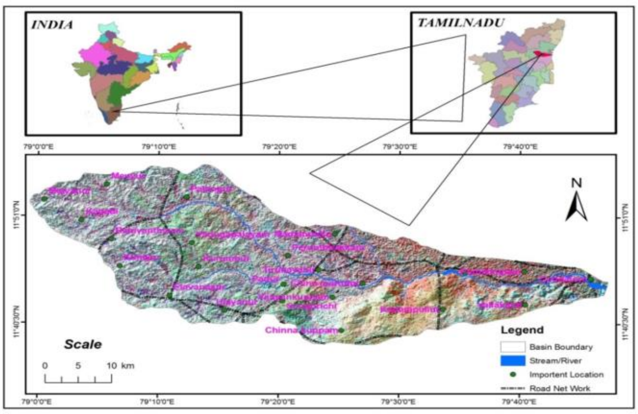

Fig 1. Study Area Map.

3.Lithology

The Gadilam river basin is characterized by different geological formations, reflecting the various geological eras. There are mainly three types of formations in the Gadilam river basin fig. 2.

They are as follows

- The western part comprises the hard rock and its weathered pediments.
- The southern part comprises the Cuddalore sandstone and lateritic cap rock.
- The northern part comprises the recent alluvium and older flood plain pediments including the recent coastal alluvium

The areas subtended between east of Kundathur and west of Tirunamanallur are covered with weathered pediments derived from the Achaean rocks. Further west of these area shallow pediments occur. The pediments of both younger and older flood pain encompassing the recent alluvium occur from north of the villupuram.

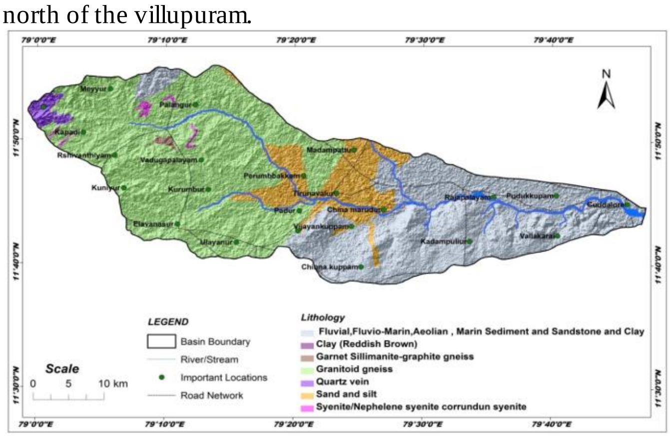

Fig 2. Lithology Map.

4.Material and Methods

4.1 Data Collection

Survey of India (SOI) Toposheet (No.58M/1, 2, 5, 6, 9, 13, 10 and 14) at 1:50,000 scales have also used. Mapping is done with the help of field verification. The Landsat TM data LISS-III Digital data, images and SRTM data have used in the present study. Geographic Information System and Image Processing (Arc VIEW, Arc GIS and ERDAS IMAGINE software) used for analysis and mapping of the individual layers as described in the flow chart (fig.3).

4.2 Satellite Data Analysis

The main task in this stage was to carry out analysis and interpretation of satellite data, in order to produce thematic maps, such as lithology, Hydrogeomorphological and Land use/land cover class. Initially, all the images were rectified using the SOI Toposheet. This was followed by processing the digital images using the various processing techniques, viz., enhancement, filtering, classification and other GIS processes. Subsequently, selective field checking was carried out.

4.3 Spatial Database Building:

The main task was to bring all the appropriate data and other collateral data together into a GIS database. All the available spatial data was assembled in the digital form and properly registered to make sure the spatial component overlaps correctly. Digitizing of all the maps and collateral data, followed by transformation and conversion from raster to vector, gridding, buffer analysis, box calculation, interpolation and other GIS processes were undertaken. This stage produced derived layers such as Geomorphology, Drainage, Drainage density, Lithology, Lineament density, Slope etc.

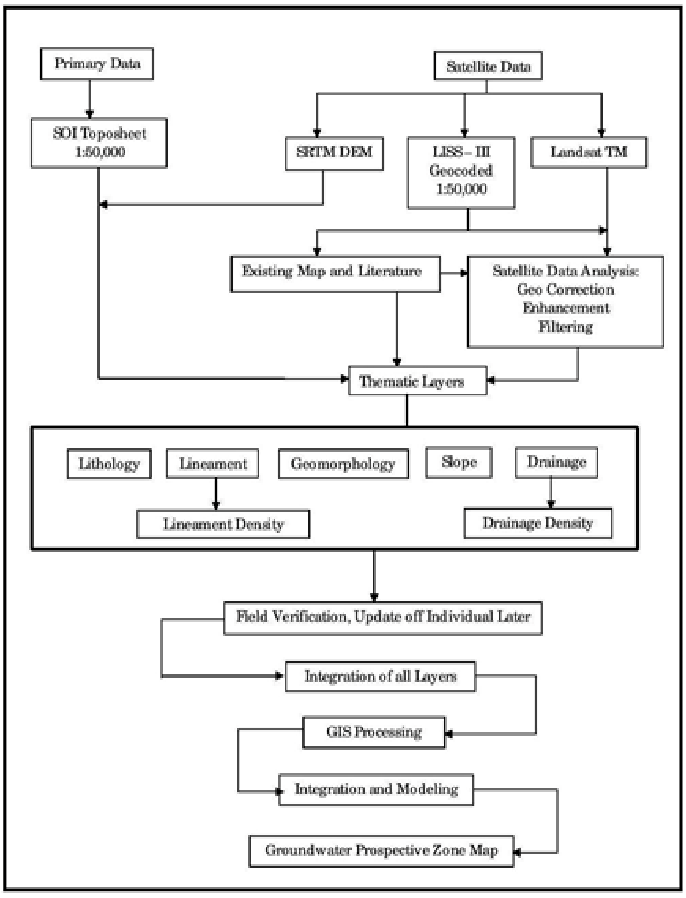

Fig 3. Flowchart.

5.Results and discussion:

In order to delineate the location of the groundwater prospect zones in the study area, different thematic maps (such as slope, Drainage network, lineaments and lithology) were prepared from topographic and geological maps. The methodology followed for preparing groundwater prospective zones is based on determining the most important contributing parameters that controlling groundwater storage. These parameters includes: (1) slope, which controls the runoff of water or remain on the ground surface for long enough to infiltrate, (2) Drainage Density, which influences the distribution of runoff and groundwater recharge (3) lineament, which enhance significantly the permeability by inducing secondary porosity and thus hence vertical water percolation to recharge the aquifers, (4) lithologic or rock type, which determine the soil and exposed rocks infiltration capabilities and govern the flow and storage of water.

5.1Hydrogeomorphology Unit

Geomorphology of an area is one of the most important features in evaluating the groundwater potential and prospect. The integrated use of landsat images and field survey were used to distinguish various geomorphic units in the study area (fig. 4). The area is characterized by a number of erosional and depositional geomorphic features, viz. Brackishwater creeks (young coastal plain), Buried Channel (Flood plain), Channel bar (Flood plain), coastal plain Deep, Inselberg, Moderately weather/ Moderately buried pediplain, Older coastal plain Deep, pediment Inselberg Complex, pediment Valley Floor, Shallow Flood plain, Shallow alluvial plain younger / Lower, Shallow Weathered /Shallow buried Pediplain, and Upland. The described as nearly flat terrain with gentle slope. The area is covered with relatively thick weathered material. This is a dominant geomorphological unit in the study area covering an area of Shallow Weathered/ Shallow Buried Pediplain 535.26 sq.km.

5.2 Soil

Soil map was prepared by visual image interpretation. Climate, geology and physiography characterize soils and play an important role in groundwater recharge and runoff. The water-holding capacity of an area depends upon the soil types and their permeability. The initial infiltration and transmission of surface water into an aquifer system is a function of soil type and its texture. Five types of soils are found in the study area, viz. Alfisols, Entisols, Inceptisols, Reserve Forest, vertisols and outcrops (fig. 5). The delineation was based on differential manifestations on the imagery in the form of color, tone, texture and association. Field checks in the identified soil units were conducted and confirmed. The type of soil, specific yield and its water-holding capacity shows high in the study area. (fig.5)

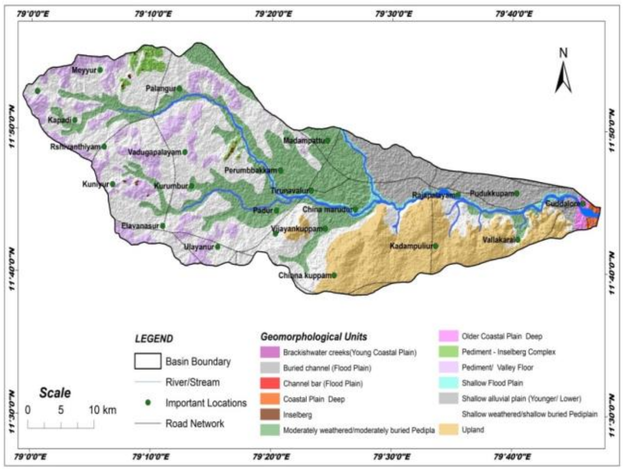

Fig 4. Hydrogeomorphology Unit map.

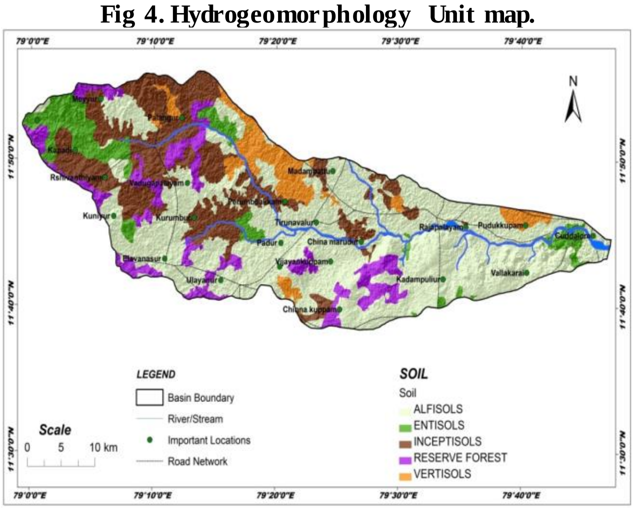

Fig 5. Soil Map.

5.3 Lineaments

Lineament represents features such as fracture, joints, faults, bedding etc. Lineaments are the linear, rectilinear, curvilinear features of tectonic origin observed in satellite data. These lineaments normally show tone, textural, soil tonal, relief, drainage and vegetation linearity and curvilinear in satellite data. Lineaments are mainly linear features that can be picked out as lines (appearing as such or evident because of contrasts in terrain or ground cover on either side) in aerial or space imagery. In geology, these are usually faults, joints, or boundaries between stratigraphic formations. Lineaments represent areas and zones of faulting and fracturing resulting in increased secondary porosity and permeability and are good indicators of groundwater.

Lineaments are defined as naturally occurring linearor curvilinear features. Lineaments were delineated from shaded relief map generated from SRTM Digital Elevation Map and Satellite images with ERDAS 9.3.1 (fig. 6). A surface lineament map is prepared from the data. The study area is characterized by gently undulating topography with low relief hills. The areas have much low altitude hilly structures which are linearly aligned Lineaments play an important role in groundwater recharge. The groundwater prospective zone is high near lineament zones.

5.4 Lineament Density

Lineament density map has been prepared with the help lineament map using ArcGIS software the densities were classified as five categories as Very High, High, Moderate, Low and very Low. In the study area, lineament density is high in the Northern, Western, Southern region and low Lineament Density is concentrated in the Eastern part of study area. The central portion of study area, occupies moderate lineament density. Lineament density values then obtained were interpolated by inverse distance weighted (IDW) interpolation method (fig. 7).

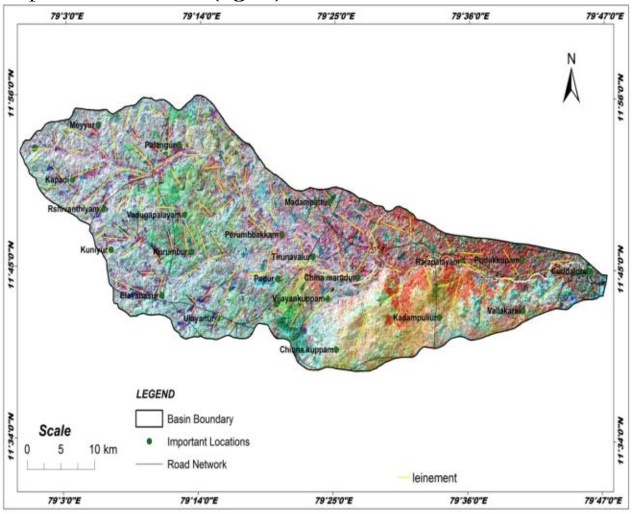

Fig 6. Lineament Map

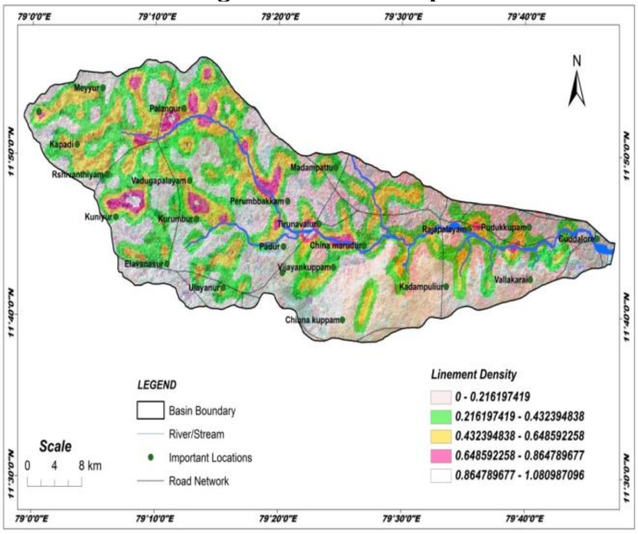

Fig 7. Lineament Density Map

5.5 Drainage Map

A surface drainage map is prepared from SOI Toposheet at 1:50,000 scale and satellite data and SRTM data derived from using ArcGIS 9.3.1. All the rivers, streams were digitized. gadilam River are the major rivers flowing in the area. It has different kinds of drainage patterns such as dentritic, parallel, sub parallel, and trellis. The main gadilam River is formed from the confluence of 2 streams, which flow directly opposite direction that is NE-SW. The drainage architecture indicates that the development of drainage is fully controlled by geological structures and Lithology. At some of the places, it is possible to see the compressed meandering of the river, which is a significant signature of tectonic activity. (fig. 8).

5.6 Drainage density

Drainage density map has been prepared with the help of Drainage map using ArcGIS Software, the densities were classified. Drainage density is an inverse function of permeability. The less permeable of rock is, the less the infiltration of rainfall which conversely tends to be concentrated in surface runoff. This gives origin to a well-developed and fine drainage system. High drainage density indicates less infiltration and hence acts as poor groundwater prospect compared to low drainage implying an inverse relation betweenthe two. Low network of drainage course indicates presence of highly resistant and permeable rock, while a high drainage course indicates highly weak and impermeable rocks. (fig.9).

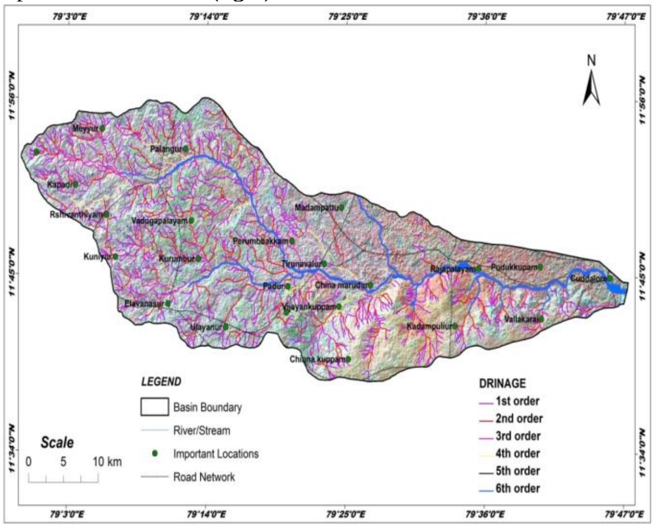

Fig 8. Drainage Map.

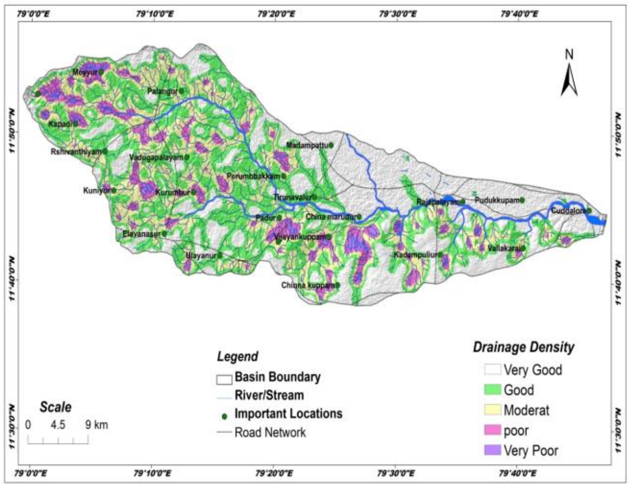

Fig 9. Drainage Density Map.

5.7 Slope

The occurrence and movement of groundwater are governed strongly by slope; therefore slope can be considered an important factor in runoff flows and infiltration. The slope layer was used to determine groundwater prospecting areas (Sreedhar et al., 2009). Surface runoff is typically slow in areas of gentle slope; however, in the north-eastern part of the study area, there is an increase in slope.

Despite of this very gentle slope, a slope map has been prepared according to the following class interval allowing more time for rain water percolation and promotes appreciable groundwater recharge.Slope always plays a crucial role in groundwater potential mapping. Using the SOI Toposheet and SRTM data of the area, a slope map of the area is prepared. The area, in general is very gentle slope. However, in the north-eastern part of the study area, there is an increase in slope. Despite of this very gentle slope, a slope map has been prepared according to the following class interval (fig.10).

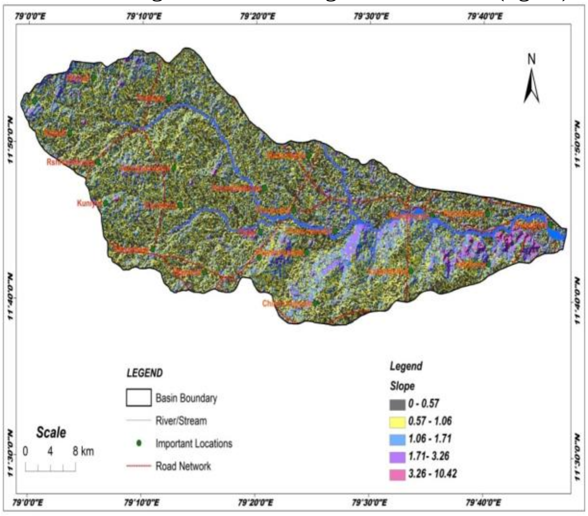

Fig 10. Slope map.

5.8 Land use / land cover

Landsat and LISS III imagery of 2012 was used for preparing Land use / Land cover map on 1:50,000 scale by visual interpretation method. In the study area 1428. Sq. km land surface has used and occupied by different features such as Back water, buildup, kharif only, rabi only, zaid only, double/triple, current fallow, plantation/orchard, evergreen forest, scrub/deg.forest, littoral swamp, grassland, other wasteland, Gullied, scrub land, water bodies. The land use and land cover pattern are classified based on the NRSA (1996) nomenclature. The Land use / Land cover patterns of the study area is classified from the satellite imagery and image interpretation techniques by using the tonal variations, texture, pattern, size, shape and association etc., and digitized through ArcGIS software.TheAnalysis has been done with the help of two years of satellite data and the changes in the features from 2012 was calculated and shown in the following descriptions. (fig.11)

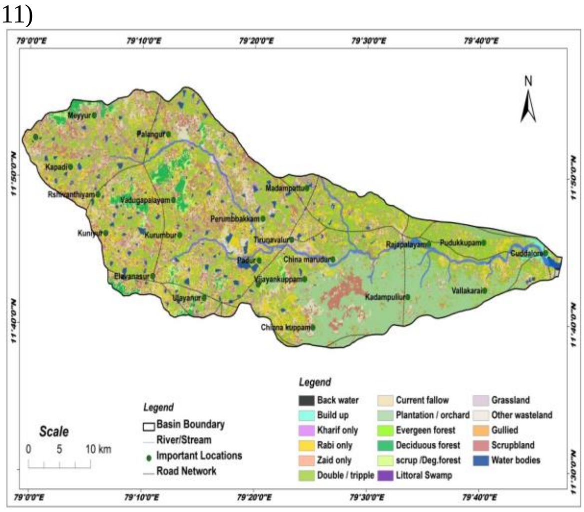

Fig 11. Land use/land cover map

6.Integration of Thematic Layers and Modeling through GIS: Weighted Index Overlay Model

Preparation of groundwater prospective zone map is seen as a prerequisite for creating and planning any agricultural and industrial development in this area. Depending on the groundwater potentiality, each class of the main eight thematic layers (Hydrogeomorphological, lithology, slope, drainage density, lineament density and Land use/Land cover) is qualitatively placed into one of the following categories. In order to obtain a final groundwater prospective zone map of the area, it is essential to integrate these layers in GIS model. As a result the final prospect map describing the groundwater occurrence in the study area was calculated. (fig.12)

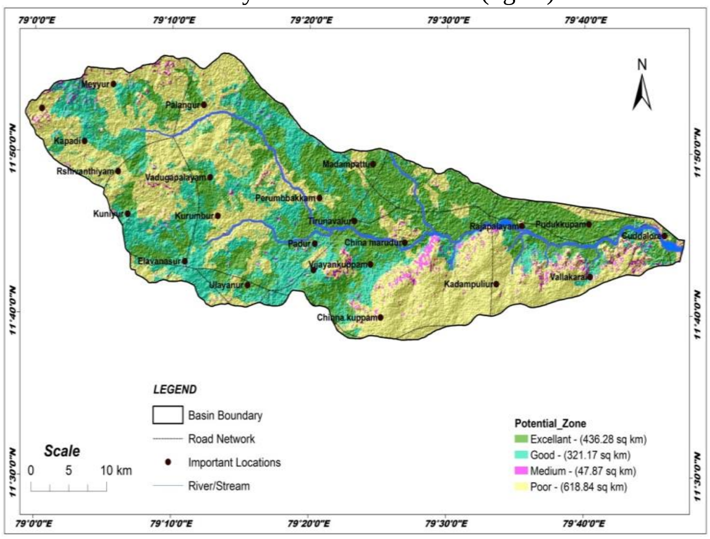

Fig 12. Groundwater Prospective Zones Map.

7. Conclusion

Remote sensing data and geographic information system were used to delineate favorable areas for well establishment in the study area. Various geo-informative thematic maps (i.e., Base, Hydrogeomorphological, Geological, Structural, Drainage, Slope, Land Use/Land Cover and groundwater prospect zones) which play major role in storing and transmit groundwater were prepared The delineation of groundwater prospect zones was made by grouping the grids of the integrated layers, using GIS technique into four categories defined as, Excellent- 436.28 sq.km, good- 321.17 sq.km, moderate- 47.87 sq.km and Poor- 618.84 sq.km a general conclusion is that around 53% of the study area constitutes zones of Excellent to good groundwater Prospective Zones. These zones are terrain with highly porosity rocks, dense lineaments and very gentle to gentle slope (<5), implying that considerable amount of precipitated water is allowed to percolate to the subsurface. The spatial distribution of the areas classified as ‘‘highly prospective’’ is correlated with those that have thick water bearing formation and the locations of the existing wells. This demonstrates the capabilities of Remote Sensing and GIS for demarcation of different groundwater prospective zones for groundwater development and management program. The generated prospective zone map shows that there are a lot of unexplored areas that have a good prospective zone of groundwater exploration. The model presented in this manuscript should be further tested by carrying out pumping tests to determine the yield of the wells in different.

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Reference:

Chowdhury, A., Jha, M.K., Chowdary, V.M., 2010. Delineation of groundwater recharge zones and identification of artificial recharge sites in West Medinipur

District, West Bengal using RS, GIS and MCDM techniques. Environmental Earth Sciences 59 (6), 1209–1222.

Chowdhury, A., Jha, M.K., Chowdary, V.M., Mal, B.C., 2009. Integrated remote sensing and GIS-based approach for assessing groundwater potential in WestMedinipur district, West Bengal, India. International Journal of Remote Sensing30, 231–250.

Dineshkumar, P.K., Gopinath, G., Seralathan, P., 2007. Application of remote sensing and GIS for the demarcation of groundwater potential zones of a river basin in Kerala, southwest coast of India. International Journal of Remote Sensing 28, 5583–5601.

District, West Bengal using RS, GIS and MCDM techniques. Environmental Earth Sciences 59 (6), 1209–1222.

Evaluating groundwater potential of a hard-rock aquifer using remote sensing

Gustafsson, P., 1993. High resolution satellite data and GIS as a tool for assessment of groundwater potential of semi-arid area. In: IXth Thematic Conference on Geologic Remote Sensing, vol. 1, Pasadena, CA, pp. 609–619.

Jasrotia, A.S., Kumar, R., Saraf, A.K., 2007. Delineation of groundwater recharge sites using integrated remote sensing and GIS in Jammu district, India. International Journal of Remote Sensing 28, 5019–5036.

Jha, M.K., Chowdary, V.M., Chowdhury, A., 2010. Groundwater assessment inSalboni Block, West Bengal (India) using remote sensing, GIS and multi-criteriadecision analysis techniques. Hydrogeology Journal 18, 1713–1728.

Krishnamurthy, J., Venkatesesa, K.N., 1996. An approach to demarcate ground water potential maps through remote sensing and GIS. International Journal of

Kusky, T., Gad, S., 2006. Lithological mapping in the Eastern Desert of Egypt, the Barramiya area, using Landsat thematic mapper (TM). Journal of African Earth Sciences 44, 196–202.

Minor, T., Carter, J., Chesley, M., Knowles, B., Gustafsson, P., 1994. The use of GIS and remote sensing in groundwater exploration for developing countries. In: Proceedings of the 10th Environmental Research Institute of Michigan ERIM Thematic Conference on Geologic Remote Sensing held in San Antonio, USA, pp. 168–179.

Mohammed-Aslam, M.A., Kondoh, A., Rafeekh, P.M., Manoharan, A.N., 2010.

recharge zones and identification of artificial recharge sites in West Medinipur Remote Sensing 7, 1867–1884.

Sankar, K. (2002), "Evaluation of groundwater potential zones using remote sensing data in upper Vaigai river basin, Tamilnadu, India", J. Indian Soc. Remote Sensing 30(3), 119–130.

Sabins, F.,1997. Remote Sensing Principles and Interpretation, third ed. W.H. Freeman Company, 494p.

Sander, P., (1997), Water well siting in hard rock areas: identifying promising targets using a probabilistic approach. Hydrogeol journal, 5(3), pp 32–43.

Sikdar, P.K., Chakraborty, S., Adhya, E. and Paul, P.K., (2004): Land use/land cover changes and groundwater potential zoning in and around Raniganj coal mining area, Bardhaman District, West Bengal: A GIS and remote sensing approach. Journal of Spatial Hydrology, 4, pp 1–24.

Singh AK, Prakash SR (2003) An integrated approach of remote sensing, geophysics and GIS to evaluation of groundwater potentiality of Ojhala sub-watershed, Mirjapur district, U. P., India,

Singhalbbs and Gupta rp. 1999. Applied Hydrogeoly of Fractured Rocks. Netherlands: Kluwer Academic Publishers, 400 p

Sreedhar, G., Vijaya Kumar, G.T., Murali Krishna, I.V., Ercan, K., Cüneyd, D.M., 2009. Mapping of groundwater potential zones in the Musi basin using remote Sensing data and GIS. Advances in Engineering Software 40, 506–518.

Sultan, S.A., Mekhemer, H.M., Santos, F.A.M., AbdAlla, M .2008.Geophysical Measurements For Subsurface Mapping And Groundwater Exploration At The Centarl Part of Sinai Egypt, TheArabian Journal For Science And Engineering, Vol 134, No 1A, pp103-119

Teevw, R.M.1999 Ground water exploration using Remote Sensing and A low cost GIS Hydrogeology Journal, 3(3), 21-30.

Venkateswaran, S. Ayyandurai, R., 2015. Groundwater Potential Zoning in Upper Gadilam River Basin Tamil Nadu, Aquatic Procedia, V. 4, pp.1275-1282.