Hydro Geomorphological Characteristics and Delineation of Ground Water Potential Zone - A Case Study of Rushikulya and Bahuda Basin, Ganjam Odisha

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Abstract The present study attempts to delineate different groundwater potential zones using remote sensing and geographic information system (GIS) in Rushikulya Bahuada Basin of Ganjam district, Orissa. Thematic maps of Geology, Hydrology, geomorphology, land use and land cover, drainage density, were prepared using the Landsat Thematic Mapper data. Relationship of each layer to the groundwater regime has been evaluated. The major hydro geomorphic units identified in the area are, weathered denudation hills, residual hills, Pediments, spit, Valley Fills, beach ridges, Alluvial Palin, flood plain. Most part of the study area is occupied by alluvial plains with various thicknesses and the ground water potential is directly related to thickness of alluvial plain. Field observations showed that ground water occurs under unconfined conditions with water table at shallow to deep depth. From the lineament map, the lineament density and lineament intersection maps prepared to understand the impacts on groundwater percolation. Finally, the hydrogeomorphology and Lineament maps are overlaid following the weighted index overlay method, which delineates groundwater potential zones. An integrated remote sensing and Geographic Information System (GIS) based approach has been used for demarcating groundwater potential zones in the study area.

Keywords Geomorphology; Ground water; Remote sensing

1. Introduction

Ground water is a vital natural resources for the reliable and economic provision of potable water supply in both urban and rural environment. It plays significant role in human well beings, as well as some the aquatic and terrestrial ecosystem. At present, ground water contributes 34% of the total annual water supply and is an importance to fresh water resources; so it as an urgent need to study the ground water assessment using the recent technologies such as Remote sensing and GIS. In the recent years it has been observed that extensive use of satellite remote sensing has made easier to define the spatial distribution of different ground water potential zones based on geomorphology, and its associated features. Remote sensing techniques are also useful for ground water exploration, especially delineation Hydrogeomorphological units. Complex geology and geomorphic set up, skewed distribution of rainfall result in diverse hydrogeological conditions in an area. Ground water occurrence being subsurface phenomenon, its identification and location is based on indirect analysis of some
directly observable terrain features like geological structures, geomorphic features and their hydrologic characters (Das et al., 1997). GIS and satellite remote sensing have credibility to obtain various features related to land and water. GIS techniques also facilitate integrated and conjunctive analysis of large volumes of multi-disciplinary data sets include spatial and non-spatial, with the same georeferencing scheme. To obtain the ground water potential zone, it is necessary to integrate data from the various terrain characteristics such as topography, lithology, geological structures, and geomorphology, weathering depth, slope characteristics and drainage pattern using geographical information system techniques (Jones, 1986; Sinha et al., 1990; Chi and Lee, 1994; Bahuguna et al., 2003; Kumar et al. 2007). The present study focused delineation of ground water potential zone based on integrated study using all the controlling parameters such as geomorphology, drainage, slope characteristics, geological structure.

1.1. Study Area

The study area, a Coastal tract is situated on the eastern margin of Ganjam District (Figure 1). It lies between latitudes of 19°05’ - 19°30’ N and longitudes of 84°35’ - 85°05’ E and cover all area of 350 sq. km. The width of the coastal tract varies from 4 to 6 km and extends for a length of about 45 km. It is bound by Rushikula River on north and Bahuda Estuary on south and Bay of Bengal on the east.

1.2. Geology

Major parts of study area are underlain by hard crystalline rocks of Archaean age. Rushikulya Bahuda River occupies recent to sub recent sediments along the coast track. It has been observed sometimes laterites occur as a capping over khondalites. The Archaean crystalline of the Eastern Ghat Group comprises of Granite and Granite gneiss, Khondalite suite, Charnockite suite, Pegmatites and Quartz vein. Figure 2 shows Geology map the study area.
1.3. Geomorphology

The study area presents a unique geomorphological setting with highly rugged mountains region in the West, North, Central, and northern part and with dense forest covered and gently undulating plains and some isolated hillocks in the eastern part. The altitude in the hilly terrain ranges between 300m to 700m above the mean sea level. The low laying area which includes the flood plain of the river Rushikulya and the intermountain valleys are characterised by undulating topography, scattered hill. The major geomorphic units are classified as Structural hills, Denudational hills, Residual Hills, Inselberg, pediment, buried pediplain, flood plain, coastal plain and sandiness (Tripathy et al., 1996).

1.4. Hydrogeology

With respect to water bearing properties of different geological formations play an important role in the occurrence and movement of ground water. In the present study area the crystalline rock of Archean age which is occupies more than 90% of the total area. The patches of recent to sub recent alluvium along the river courses occupy 374 sq.km areas. As per hydrology is concerned the weathered and fractured zones of the crystalline and porous alluvium and costal deposits contains ground water in the district depending upon the water yielding properties of various formation, it can be grouped into 3 hydrological units such as Consolidated formation, Semi consolidated formation and Unconsolidated formation.

1.5. Structure

The study area falls in the parts of the Eastern Ghats. These rocks have undergone poly phase deformation revealed by structural features like Joints, floods, fault and foliation etc. Foliations are well developed in khondalites and granitic rocks, crude foliations are also common in charnockite. From the structural analysis it has been observed that Landsat imagery revealed five major tectonic events represented by NE-SW, ENE-WSW, N-W, NW-SE, and NNE-SSW tectonic pattern in chronological order (Krishan, 1992). The major NE-SW, NE-SE, N-S and E-W lineaments are closely related to the fold movements.
2. Material and Methods

2.1. Data Collection

The landsat thematic mapper TM data has been used for the present study. Survey of India toposheet (No.74E/3, 74A/15 and 74A/16) at 1:50,000 scales have been used. Hydrology and ground water well data has been collected from Central Ground Water Board, Bhubaneswar and supporting field data collected through VGIS. ARC GIS and ERDAS have been used for interpretation, analysis and mapping of the individual layers.

2.2. Satellite Data Analysis

In order to produce the thematic map a step by step procedure has been followed to do analysis and interpretation from the satellite data. The processing has been done the various digital images processing such as Enhancement, filtering, classification and followed by GIS analysis. (ESRI-ArcView GIS, 1996). Subsequently, Selective field checking was carried out.

2.3. Spatial Database Building

All the primary and secondary data brought in to the GIS data base. Digitization of all maps and collateral data followed by the transformation and conversion from raster to vector, gridding, buffer analysis interpolation and analysis were done in GIS. In this stage the layers has been created such as Geomorphology, Drainage, Drainage density, lithology, surface water body, lineament and lineament density and slope etc.

2.4. Satellite Data Interpretation

The final stage involved combining all thematic layers using the method that are modified from DRASTIC model. This model is used to assess ground water pollution vulnerability by Environmental Protection Agency of the United State of America (Aller et al., 1985). The output has been classified into five groups such as very high, high, moderate, low and very low using the quintile classification method (ESRI-ArcView GIS, 1996). Groundwater potential index (GWPI) in the present study has been determined by the formula as shown below (Nath et al., 2000):

\[
GWPI = \frac{(GgwGgr + DgwDgr + DdwDdr + LhwLhr + LtwLtr + LdwLdr + WwwWwr + SswSsr)}{\text{Total Weight}}
\]

Where: Gg: geomorphology, Dg: drainage, Dd: drainage density, Lh: lithology, Lt: lineament, Ld: lineament density, Ww: surface water body, Ss: slope. With “w” representing weight of a theme and “r” the rank of a feature in the theme. GWPI is a dimensionless quantity that helps in indexing the probable groundwater potential zones in an area. It is classified as Excellent GP (>7.1), Very good GP (5.8-7.1), Good GP (4.4-5.8), Moderate GP (3.0-4.4) and Poor GP (<3.0).

3. Results and Discussion

3.1. Generation of Thematic Maps

Lineaments have been identified from Landsat TM and also water bodies interpreted. SRTM digital elevation model is also used preparing the slope map along with the Survey of India toposheet. These
mentioned above, there data sets are useful for delegation of the ground water potential zones coupled with limited field study.

Figure 3: Slope map (%) of the study area (Biswa Arkoprovo et al., 2012)

3.2. Lithology Map

Geology or lithology is a very important aspect to identify and predict ground water potential zones. From the visual interpretation skill extraction of geological information from satellite data depends on the identification of different patterns on an image resulting from the spectral arrangement of different tones and textures. Depending on the rock reflectance properties, satellite images are used and they play important role in rock identifications. A lithology map is prepared using the IRS IC and Landsat TM Digital Data and simultaneously ground check verification is done in field (Biswa Arkoprovo et al., 2012) (Figure 4).

Figure 4: Geology map of study area
3.3. Geomorphology Map

Geomorphological features have been identified using visual interpretation from Landsat TM on scale of 50,000 and hydrogeological characteristics have been identified. The different geomorphological elements (Figure 5) such as Flood plain, pediment, coastal plain, beach ridges and sandiness identified (Biswas Arkoprovo et al., 2012)

Figure 5: Geomorphology map of the study area

Figure 6: Surface water body map (Biswas Arkoprovo et al., 2012)
3.4. Slope Map

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. Slope always plays a crucial role in groundwater potential mapping. 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 (Biswas Arkoprovo et al., 2012) (Figure 3).

3.5. Surface Water Body Map

Surface water body map is prepared from Landsat TM Satellite data. The supervised maximum likelihood classification is used to delineate the surface water body present in different parts of the area. The study area is covered by many water logged bodies, ponds, lakes and rivers (Figure 6).
3.6. Drainage and Drainage Density Map

A surface drainage map is prepared from SOI Toposheet at 1:50,000 scale and satellite data. The study area is covered by Rushikulya and Bahuda River. Mostly the drainage pattern is dendritic in nature but locally it exhibits structurally controlled area (Figure 7). From the above Drainage map, a density map is generated. In this density map, the values have been assigned depending on the density of the drainage pattern (Figure 8).

Figure 9: Lineament map of the study area (Biswa Arkoprovo et al., 2012)

Figure 10: Lineament density map (Biswa Arkoprovo et al., 2012)
3.7. Lineament and Lineament Density Map

A surface lineament map is prepared from the SRTM DEM data. The study area exhibits a structurally controlled region. The areas have much high altitude hilly structures which are linearly aligned (Figure 9). From the above Lineament map, a lineament density map is generated. The lineament density map shows a low density in most of the area comparatively to other parts of the study area (Biswas Arkoprovo et al., 2012) (Figure 10).

![Figure 10: Lineament Density Map](image)

3.8. Integration of Thematic Layers and Modelling through GIS

Weighted Index Overlay Model

Depending on the groundwater potentiality, each class of the main eight thematic layers (geomorphology, lithology, slope, drainage density, lineament density and surface water body) are qualitatively placed into one of the following categories viz., i.e. Excellent, ii. Very good, iii. Good, iv. Moderate, v. Poor. Suitable weightage on a scale of ‘Six’ has been given to each class of a particular thematic layer based on their contribution towards ground water potentiality. The rank of each thematic map is scaled by the weight of that theme. All the thematic maps are then registered with one another through ground control points and integrated step by step using normalized aggregation method in GIS for computing groundwater potential Index of each feature. All the thematic maps have been integrated using GWPI formula in GIS. A final groundwater potential map (Figure 11) is prepared based on the above technique. In the present study, the groundwater potential zones have been categorized into five types’ viz., excellent, very good, good, moderate and poor (Biswas Arkoprovo et al., 2012).

![Figure 11: Ground water potential map](image)

4. Conclusion

From the above study it has been observed that that remote sensing and GIS can provide the appropriate platform for convergent analysis of large volume of multi-disciplinary data and decision making for groundwater studies. The Weighted index overlay model has been found very useful in the mapping of groundwater prospective zones. Mainly IRS IC was used for preparing the thematic maps viz., lithology, geomorphology, drainage. Landsat TM was useful in demarcating the water bodies and also in identifying numerous lineaments. SRTM was also used in preparing DEM from which slope
map is prepared. In this study area, five categories of groundwater potential zones have been
delineated based on remote sensing and GIS technique. The five categories are: excellent, very good,
good, moderate and poor. The groundwater potential map (Figure 11) near the coast line and in some
parts of the north-eastern and north-western region shows excellent potential whereas greater part of
the area shows good groundwater potential. Poor groundwater potentials are confined mostly in the
hilly terrain and in settlement area. The quantitative amount of groundwater potential zones can be
carried out if geophysical resistivity data is available.

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