Development of different hydrogeological influencing thematic layers and groundwater potential zones of Deo river watershed of Mayurbhanj district, Odisha, India

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Abstract: Water is one of the most abundant renewable resources, and it is essential to all living things. Groundwater is one of the major sources of Water in the planet Earth. Continuous uses of water without any conservation cause lowering of Ground water level and thus living forms are facing many problems now-a-days. Due to increase in industrialisation in the state of Odisha water problem is rising its head. Using Remote Sensing and Geographic information system (GIS) methods, this research aids in the delineation of water potential zones in the Deo river watershed in Mayurbhanj district, odisha. For this, different thematic layers have been prepared and interpreted. This study may be helpful to monitor and conserve groundwater in near future.

Keywords: Groundwater, Remote sensing, GIS, Deo watershed

1. Introduction:

India is the world's largest consumer of groundwater. More than 60% of agricultural operations rely on groundwater, and more about 85% of people rely on it for potable water. Groundwater removal has caused water levels to rise and shallow groundwater harvesting structures to dry up eventually. The survey's goal is to delineate subsurface water for improved planning of the aquifer system in Mayurbhanj district, Odisha. Where groundwater deterioration has risen rapidly in recent decades. Groundwater levels have been lowered, with a long-term dropping trend and even wells drying up as a result of this persistent groundwater removal for diverse sectors (irrigation, household, and industrial)[14]. For calculating the groundwater resources, remote sensing techniques occupy a broad and inaccessible portion of the earth's surface in a short amount of time. For groundwater management and planning, detailed understanding of aquifers, replenishment, and potentiality is essential. Groundwater flow and distribution are governed by a number of elements, including rock types and geological qualities, elevation, , landform patterns, land use/land coverage patterns, drainage networks
and climatic conditions. A GIS overlay analysis based on drainage density, lineament, slope, Land use / land cover (LULC), and geology was used to create the groundwater potential zone [1].

To generate thematic layers of the research region utilising satellite data from various thematic layers such as geology, landform, LULC, gradient, drainage network, precipitation, water level, lineament, and lithology [12]. To delineate the ground water potential zone of Deo watershed.

2. Research area:

The Deo river watershed (Figure 1) is located in Odisha’s Mayurbhanj district. The catchment covers a total area of 456.07 km2 and includes one of Odisha’s most hilly regions like similipal national park, Iron mines and agricultural lands. According to Survey of India (SOI) Toposheets No. 73 J/18, Latitude 21°40’0” to 21°50’0” and Longitude 86°0’0” to 8°20’0”. This region falls under tropical climatic areas, which supports the area with average rainfall of 1681.7 mm and mean temp 27.3°C. The southwest monsoon is the area’s key source of precipitation [9].

Fig.1. Research area location map
3. Data used:

The GIS software used to make all the thematic layers are ArcGIS and QGIS. Satellite data Used: Shuttle Radar Topography Mission (SRTM), Digital elevation model (DEM) imagery was used for the preparation of drainage and slope map. Sentinel-2 imagery was used to make LULC map of the study area. Bhukosh site data were used to prepare geology, geomorphology and lithology map [11]. India Water Resources Information System (India-WRIS) data were used for the precipitation and groundwater level maps. The source of data is described below (Table-1).

| SL. No. | Layer Name                  | Source        | Sites                                      |
|--------|-----------------------------|---------------|--------------------------------------------|
| 1      | Geology                     | Bhukosh       | www.bhukosh.gsi.gov.in                     |
| 2      | Geomorphology- Landforms    | Bhukosh       | www.bhukosh.gsi.gov.in                     |
| 3      | Geomorphology- Units        | Bhukosh       | www.bhukosh.gsi.gov.in                     |
| 4      | Lithology                   | Bhukosh       | www.bhukosh.gsi.gov.in                     |
| 5      | Drainage pattern            | DEM           | www.earthexplorer.usgs.gov                 |
| 6      | Lineament Density           | Bhuvan        | www.bhuvan.nrsc.gov.in                     |
| 7      | Precipitation               | India-WRIS    | www.indiawris.gov.in                       |
| 8      | Groundwater level           | India-WRIS    | www.indiawris.gov.in                       |
| 9      | Land Use and Land Cover     | Sentinel-2    | www.earthexplorer.usgs.gov                 |
| 10     | Slope                       | DEM           | www.earthexplorer.usgs.gov                 |

4. Methodology:

Groundwater potential zones in and around the Deo basin were identified using a GIS technology that included satellite-derived multiple themed images. The following layers were created and utilised to identify the groundwater potential zone in this investigation. SRTM data is process in ArcGIS and used to create the drainage density along with slope map was created [15]. Bhuvan.gov.in provided the geomorphology theme map which data is also process in ArcGIS. The GSI provide the geology map. For ease of use in GIS settings, all of these datasets were geo-rectified and projected in the WGS 1984 using Universal Transverse Mercator (UTM) Zone 45’N after that False colour composite (FCC) is generated by considering the band no. 8, 3 and 2 from 12 band data then pixel processing then LULC map is prepared. From IWRIS site we found rainfall and post monsoon waterlevel data from different station in my research area then IDW interpolation process provide the rainfall and water level map. The flow chart depicts the approach used in this paper. Geology, geomorphology, LULC, slope, drainage
system and water level are combining to give the best site for groundwater potential. Spatial analysis integration utilizing an index overlay approach in a GIS context was used to determine groundwater potential. Eight layers were combined in this design by giving relative weight to each theme map on a level of 1–10 and subcategories on a range of 1–5. The map was then classified as follows: very high, high, moderate, very poor, and poor [14]. As a result we found GW potential boundaries.

5. Thematic layers

Thematic layers that play significant role for GW occurrence and management of aquifer system in research area are as follows;

5.1. Geology:

The study area comes under Singhbhum supergroup which is Proterozoic in age. Singhbhum supergroup divided into three groups. The study area comes under Singhbhum group and similipal group. Age of the study area is Meso-proterozoic to Neoproterozoic.
5.2. Lithology

The study has a variable lithology which plays a crucial role to control the presence of groundwater [5]. As it represents a delta type environment here more sediment accumulates rather than rock mass. Granite, gabbro, quartzite, slate, phyllite, spilitic lava and lateritic soil cover most of the portion in the study area. These weathered zones can also hold a huge amount of groundwater. Towards the West part of my study area granitic rocks are dominant, but these have some linear features. So the regions may be categorized under medium recharge zones but in the central part covered with spilitic lava so this region is categorized under least recharge zone. The regions like dolerite dyke, Spilitic lava, quartzite, basic and ultra basic and ultramafic rocks have no porosity and permeability condition and Laterite acts as a good recharge zone. Hence these zones can be categorized under low recharge zones.

5.3. Geomorphology:

Recognition of various geomorphological feature are critical in assessing groundwater possibilities. Geomorphological variables such as gradient, degradation extent, and landform type all serve a part in defining a region's groundwater potency. The research region is split among thirteen primary landforms (according to the Bhukosh-Geological Survey of India categorization systems), with low-to-high dissected hills and valleys, as well as alluvial plain, pediment, and Pediplain being some of the most prominent characteristics. Dissected hills are generated by differential erosion and weathering processes and are made up of jointed and fractured granites and gneisses. Percolation of groundwater is possible due to the existence of fractures, joints, and topographic cuts, however as the slope rises, so does the probability of runoff, restricting the groundwater recharge process. As a result, low-dissected
hills recharge groundwater greater efficiently than high-dissected hills. Pediplain in western part creates excellent recharging and buffer zones.

5.4. Slope:
Any terrain's slope is critical for permitting water to infiltrate the subsurface system. Runoff will be slower in areas with gentle slopes, giving rainfall more time to percolate, whereas rapid runoff occurs near steep slopes, allowing rainwater to enter for a shorter length of time. A medium to mild slope covers nearly half of the research area, indicating that moderate recharging is possible in these places. As per characteristics impacting groundwater recharge, holding, and recurrence, the grades were allocated to the relevant slope classes.

5.5. Drainage density:
Western part of research area is covered by high drainage density due to a deltaic environment. High drainage density indicates the underlying strata is more saturated hence more surface runoff occurs rather than percolation. In the low drainage density area (Southeast side) more infiltration occurs. The line density analysis technique was used to create the drainage density map. So the area with high drainage density more ground water potential and law recharge area [2].
5.6. LULC:
LULC is a significant indicator of anthropogenic impact on groundwater resources. Groundwater absorption, preservation, and release are all influenced by land use patterns. Water bodies (rivers/canals/reservoirs), thick woods, vegetation, scrubland, towns, and river sand are the six forms of LULC in this area.

5.7. Lineament buffer:
The occurrence of lineaments implies favorable groundwater potential since they operate as possible channels for groundwater circulation. The zone of enhanced pore size distribution underpins lineament-controlled landscapes in general. As a result, lineament intensity mapping from lineament maps is closely linked to groundwater occurrence.

5.8. Water Level:
The water levels map was created using static water levels from pre-monsoon drilled wells (source: India WRIS) (figure-9). The water level is at its highest in the eastern half of the research area. Viz. 12.44-15.31m and in northern part water level is minimum viz. 0.97-3.84m. Moderate water level occurs in central, western and southern of the study area viz. 3.84-6.70m, 6.70-9.57m and 9.57-12.44m.
5.9. Rainfall:
The primary component of groundwater recharge is rainfall. On this study, a thematic map of rainfall was created using the Inverse Distance Weighted (IDW) approach in the ArcGIS software using multiple area points of data. The research region is classified into different rainfall zones. The rainfall total of 1533-1568.58 mm falls into the moderate groundwater storage category. The area with rainfall between 1624.74 and 1656.32 mm are classified as Good. The groundwater potential of locations with rainfall ranging from 1656.32 to 1685.9 mm is rated as Very excellent. This is shown in the Fig.11.
### Table 2: Weightage Table

| Influencing Factors | Category (Classes) | Groundwater Potentiality | Rating | Weightage |
|---------------------|--------------------|--------------------------|--------|-----------|
| Geology             | Granite/Granitic gneiss | Moderate                 | 3      | 1         |
|                     | Gabbro/Anorthosite    | Very Poor                | 1      | 9         |
|                     | Laterite              | Good                     | 4      |           |
|                     | Arkasani Granophyre   | Very Poor                | 2      |           |
|                     | Slate, Phyllite       | Poor                     | 2      |           |
|                     | Newer Dolerite        | Very Poor                | 1      |           |
|                     | Spilitic Lava         | Very Poor                | 1      |           |
|                     | Quartzite, Conglomerate| Very Poor                | 1      |           |
| Geomorphology       | Dyke/ sill ridge      | Very Poor                | 1      |           |
|                     | Highly Dissected Hills and Valleys | Very Poor | 1 | |
|                     | Low Dissected Hills and Valley | Poor | 2 | |
|                     | Intermontane valley   | Very Good                | 5      |           |
|                     | Pediment              | Moderate                 | 3      |           |
|                     | Pediplain             | Good                     | 4      |           |
|                     | Residual hill valley  | Moderate                 | 3      | 8         |
|                     | Pediment              | Moderate                 | 3      |           |
|                     | Pediplain             | Good                     | 4      |           |
|                     | Residual hill         | Very Good                | 5      |           |
|                     | Lateritic Upland      | Moderate                 | 3      |           |
|                     | Valley Fill           | Good                     | 4      |           |
|                     | Water Body            | Very Good                | 5      |           |
| Lineament Density   | 0-0.05 km/km²         | Very Poor                | 1      |           |
|                     | 0.05-0.1 km/km²       | Poor                     | 2      |           |
|                     | 0.1-0.15 km/km²       | Moderate                 | 3      | 7         |
|                     | 0.15-0.2 km/km²       | Good                     | 4      |           |
|                     | >0.2 km/km²           | Very Good                | 5      |           |
| Slope               | 0-2%                  | Very Good                | 5      |           |
|                     | 2-8%                  | Good                     | 4      |           |
|                     | 8-15%                 | Moderate                 | 3      | 5         |
|                     | 15-30%                | Poor                     | 2      |           |
|                     | >30%                  | Very Poor                | 1      |           |
| Groundwater Depth   | 0.97-3.84m            | Very Good                | 5      |           |
|                     | 3.84-6.70m            | Good                     | 4      |           |
|                     | 6.70-9.57m            | Moderate                 | 3      | 7         |
|                     | 9.57-12.44m           | Poor                     | 2      |           |
|                     | 12.44-15.31m          | Very Poor                | 1      |           |
| Rainfall            | 1533-1563.58mm        | Moderate                 | 3      |           |
|                     | 1563.58-1594.16mm     | Moderate                 | 3      |           |
|                     | 1594.16-1624.74mm     | Good                     | 4      | 9         |
|                     | 1624.14-1655.32mm     | Good                     | 4      |           |
|                     | 1655.32-1685.9mm      | Very Good                | 5      |           |
6. Groundwater potential zone:

Based on above 8 thematic maps groundwater potential map is made according to the GW potential it is divided into one of 5 groups: Very Good, Good, Moderate, Poor, and Very Poor [6]. The weights and ranks were determined using groundwater potentiality map - based features. All thematic maps are converted to raster format before being stacked using the weighted overlay method. Geomorphology and geology were given larger weights in the weighting process, whereas drainage density and lineaments were given lesser weights. Individual ranks for sub variables were assigned after weights were assigned to various factors. The characteristic of the high groundwater potentiality receives the maximum value, while the characteristic of the lowest groundwater potentiality receives the minimum. The greatest rank values are attributed to water bodies, while the lowest rank values are attributed to the built-up area in LULC. Sandstone and laterite have the greatest values in geology, whereas Granite, Gneiss, and volcanic rocks have the lowest. The extremely high lineament density groups are given higher rank values among the other lineament density groups because they have a higher possibility of groundwater penetration. Alluvial plain and valley has the maximum score of 5 in landforms, whereas hill has the lowest rank of 1. Table 2 summarises the overlay analysis. Using the Groundwater Potential Index (GWPI) algorithm in GIS, all of the theme maps were combined. The abovementioned approach is used to produce a complete groundwater potential map (Fig.12). In this paper, the groundwater potential zones were split into five categories: The five degrees of performance are Very Good, Good, Moderate, Poor, and Very Poor.

| LULC                  | Water body                  | Very Good | 5 |
|-----------------------|-----------------------------|-----------|---|
| Dense Forest vegetation| Very Good                   | 5         |   |
| Scrubland             | Poor                        | 1         |   |
| Sand settlement       | Good                        | 4         |   |
|                       | Very Poor                   | 1         |   |
| Drainage Density      | 0.004- 2.083 km/km²         | Very Good | 5 |
|                       | 2.083-4.167 km/km²          | Good      | 4 |
|                       | 4.167- 6.242 km/km²         | Moderate  | 3 |
|                       | 6.242- 8.321 km/km²         | Poor      | 2 |
|                       | 8.321- 10.4 km/km²          | Very Poor | 1 |

Fig.12.Groundwater potential map of Deo watershed
7. Conclusion:

This study revealed that GIS technology may be an incredible tool for analysing large volumes of cross-disciplinary data and making decisions in groundwater explorations. Several approaches have been proven useful and demonstrated for the monitoring of groundwater potential. For the delineation of potential zones, the weightage rating overlay methodology has shown to be quite beneficial. This groundwater potential data will be valuable in determining a good location for water extraction. This study found that remote sensing and GIS techniques are used efficiently to define groundwater resources map, which can be used to improve future groundwater studies in that region, as well as for other purposes such as identifying the locations of artificial recharge structures, tube well locations, and cost effective groundwater management for the benefit of society.

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