A geospatial technique for demarcating ground water recharge potential zones: A study of Mahi - Narmada Inter stream region, Gujarat

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ABSTRACT

With the current pace of development and utilization of resources at various levels of human development, the demand for water is ever increasing. But the fact remains the same i.e. natural resources are limited and especially water resource are depleting at an alarming rate. This includes both quality and quantity aspects which to a large extent depends upon the geologic/geographic location of the resource. The conventional approach for groundwater recharge assessment has some limitations in spite of its simplicity and wide applicability in varied hydro-geological setup. Whereas in case of remote sensing and Geographic Information System (GIS) application, spatial distribution of the variables are taken into account, thus preparing an information layer for an area under consideration. In the present study, weighted indexing method has been used to identify and demarcate the potential zones for groundwater recharge which can also be used as sites for artificial recharge. Thus, multiple thematic layers of influencing parameters like geology, soil, slope, drainage density and land use are prepared and assigned on a scale of 1 to 5 based on their influence on the groundwater recharge process. The final map suitable for ground water recharge thus obtained categorizes study area into three zones, viz., poor, moderate and good according to their suitability for ground water recharge. Present study deals with the efficiency of RS and GIS techniques to identify groundwater recharge sites. It further envisages generating a regional model for development and management of water resources with a view to apply at local level.

Keywords: Geospatial, Ground water, Recharge Zone, Suitability, Weighted Analysis.

1 Introduction

Developmental planning for any area is a complex process of decision-making based on information about the status of resources and socio-economic conditions. Reliability of the database, both spatial and non-spatial is therefore crucial to the success of the developmental planning. Geological methods, involving field studies and interpretation of geologic data are undoubtedly, a foremost important step in ground water prospecting. The use of remote sensing data from aircraft or satellite has become an acceptable valuable tool for understanding subsurface water conditions (Todd, 1980). Blending of remote sensing and GIS techniques has been proved to be an efficient tool in groundwater studies (Gustafsson, 1993; Saraf and Jain, 1994; Krishnamurthy and Srinivas 1995, Krishnamurthy et. al. 1996).
Remote sensing data provide accurate spatial information that can be economically utilized over conventional techniques of groundwater investigation.

2. The study area
The study area constitutes a part of Mahi - Narmada interstream region. It has a distinct physiographic boundary and is bordered by the Gulf of Cambay in the West, the rocky uplands in the East, Mahi River in the North and Narmada River in the South and sprawl in an area of about 11,000 sq km. The area lies between 72° 30’ E and 73° 43’ E longitudes and 21° 40’ N and 22° 53’ N latitudes (Figure 1). (Dabral Sumit, 2009).

3. Methodology
For this purpose, criteria for the analysis are defined and each parameter is assigned weightage based on its importance (Saraf and Choudhury, 1997 and Saraf and Choudhury, 1998). Determination of weightage of each class is the most crucial in integrated analysis, as the output is largely dependent on the assignment of appropriate weightage. Consideration of relative importance leads to a better representation of the actual ground situation (Choudhury, 1999).

In the present study, weighted overlay method has been used to identify and demarcate the potential zones for groundwater recharge which can also be used as sites for artificial recharge. Thus, multiple thematic layers of influencing parameters like Geology, Soil, Slope, Drainage density and Land use were prepared and assigned weights as per the importance in the selection of recharge sites. (Dabral Sumit, 2009). Each input raster can be weighted and the total influence for all raster equals 100 percent. (Table 1) (Dabral Sumit and Sharma N. 2013). Moreover, individual thematic layers and their classes are assigned weightage on the basis of their relative contribution towards the output. Using this suitability modeling,
suitable areas were identified wherein the classes with higher values indicate the most favorable zones for natural recharge and also for artificial recharge structures.

### Table 1: Showing the Percentage Influence on Layer

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Major Unit</th>
<th>Raster layer</th>
<th>% influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hydrogeology</td>
<td>Geology</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Drainage Density</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Landform</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>Hydrogeomorphology</td>
<td>Slope</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Soil</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Land use</td>
<td>5</td>
</tr>
</tbody>
</table>

#### 3.1 Thematic Layers

**3.1.1 Geology:** The study area constitutes a part of central Gujarat and its geology is represented by Precambrian crystalline, sedimentary rocks of Mesozoic (Cretaceous), Deccan traps of Tertiary and soft sediments deposits of Quaternary periods (Merh, 1995) A major part of the main landform within the alluvium tectonics domains of Cambay and Narmada rift systems. The alluvial tract being part of “Gujarat alluvial plains” comprises huge thickness of marine, fluvial and aeolian sediments deposited during the Quaternary period (Merh and Chamyal, 1997). Based on the hydrogeological characteristics of different rock types, weightage was assigned to various groundwater potential categories and based on the weightage various lithologies in the study area have been reclassified in terms of their groundwater potential suitability.

**3.1.2 Hydro-geomorphology:** The study area is cropped with varieties of landforms shaped by the various processes of fluvial, aeolian and marine environments. The western part of the study area is characterized by pedeplains of sedimentaries and metasedimentaries, Deccan
plateau, eroded land, dissected plateau, hills, residual hills etc. while central part is monotonous formed by a vast stretch of alluvial plains. (Dabral Sumit, 2009) The eastern part is characterized by coastal alluvial plains which have been developed due to tectonics and climate. Based on the hydrological characteristic of these geomorphic features weightages are assigned.

**3.1.3 Slope:** Slope has a direct control on the surface runoff and infiltration processes. Infiltration is inversely related to slope, gentle slopes coupled with vegetative cover will have higher infiltration and less runoff. Slope map has been generated using SoI maps. The topographic maps were scanned and geo-referenced to the specific coordinates. The slope analysis was carried out to further classify the area into five classes according to groundwater holding capacity.

**3.1.4 Drainage density:** In general, high drainage density reflects high runoff and low infiltration while low drainage density denotes low runoff and high infiltration (Chow, 1964). Three west flowing rivers along with their tributaries drain the area. Among the three,
the centrally flowing Dhadharriver along with five tributaries debouch into Gulf of Cambay. The major part of the study area is covered by the watershed basin of Dhadhar river which forms large elongated basin, gently sloping south-westerly. Study area was divided into square grids of 10 x10 km and streams in each grid were calculated in order to determine the drainage density values. These values were regrouped to produce a drainage density map that was classified into five categories (Table 2) and accordingly reclassified drainage map has been prepared.

![Figure 5: Reclassified Drainage Density as per suitability](image)

3.1.5 Landuse: The term land use refers to man’s activities on land which are directly related to land. Satellite image of Landsat ETM+, 2001 for the post monsoon was used for visual classification.

![Figure 6: Reclassified landuse class as per suitability](image)

The study area was classified into eight major land use classes i.e. agriculture, water body, forest, fallow land, wasteland, saline land as per USGS classification level I. It is observed that the eastern part of the study area comprises of dense and open forests and waste land while the central and western part is predominantly agriculture based. The extreme west
closer to coastal area is saline hence minimum one weight value has been assigned. Based on above reclassified land use map has been prepared and details of weightage assigned are given in Table 2.

3.1.6 Soils: The soils have varying degree of average water capacity from low to high depending upon textural variation. While the soil occurring on the coastal plains are dominantly very deep, imperfectly to poorly drained and fine textured soils are slightly to moderately alkaline and calcareous and salt affected. The eastern part of the study area characterized by highland and piedmont zone display wide variation in soil types attributed to varied rock types. The soils in rocky outcrops are shallow. In other areas it is shallow to deep and at places very deep, well drained, and calcareous to clayey fine soils associated with slight to moderate erosion. (NBSSandLUP, 1994).

**Table 2: Weightage assigned to thematic layers in study area**

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Landform</th>
<th>Slope (Degree)</th>
<th>Drainage Density</th>
<th>Land use</th>
<th>Soil</th>
<th>Weighted Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>Alluvial Plain, Palaeo channels, Flood Plains, Old Meanders</td>
<td>0-3º</td>
<td>0 – 0.38</td>
<td>Agriculture and Water Body, Dense Forest,</td>
<td>Coarse Loamy</td>
<td>5</td>
</tr>
<tr>
<td>Alluvium Central Plains</td>
<td>Valley fills, Vegetation Anomalies, Sedimentary Pediplains</td>
<td>3-9º</td>
<td>0.38 – 0.77</td>
<td>Open Forest</td>
<td>Calcareous, coarse Loamy</td>
<td>4</td>
</tr>
<tr>
<td>Deccan Trap, Quartzite</td>
<td>Deccan Plateau, River Dissected hills (Meta),</td>
<td>9-12º</td>
<td>0.77 – 1.16</td>
<td>Fallow Land</td>
<td>Fine Loamy</td>
<td>3</td>
</tr>
<tr>
<td>Dolomite and Limestone, Sandstone, Green Marble, Gneiss and Granite</td>
<td>Eroded land</td>
<td>12-24º</td>
<td>1.16 – 1.55</td>
<td>Settlement</td>
<td>Fine soil</td>
<td>2</td>
</tr>
<tr>
<td>-</td>
<td>Plains, Pediplains (Meta), Dissected Plateau (mod/highly), Old Mud Flats, Sand Dunes</td>
<td>Above 24º</td>
<td>1.55 – 1.94</td>
<td>Waste Land, Saline land</td>
<td>Clayey</td>
<td>1</td>
</tr>
<tr>
<td>-</td>
<td>Dissected hills (Sedimentary ), Residual hills Mud flats</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
</tbody>
</table>
4. Result and conclusions

4.1 Groundwater resource evaluation: Interpretation and modelling

As depicted in Weighted Overlay map (Figure 8), (DabralSumit, 2009), it can be visualized that the eastern highlands shows poor to moderate zone of recharge, this is mainly due to the fact that in hard rock although primary porosity and permeability is low, but fractures and joints facilitate movement of water which in turns helps in flushing of salts.
side. These highlands also act as a zone of recharge for aquifers at downstream. Groundwater after monsoonal recharge flows downstream towards west under the effect of gravity/slope. In alluvial plains although the groundwater prospects are better however, its poor quality is contrary to eastern highlands. The vast stretches of plains having gentle slope and consisting of material having high porosity and permeability are the most suitable site for recharge. In alluvial plain the water fluctuation is not high and the effect of rainfall is not seen immediately. In the coastal track, groundwater flow appear minimum to non-existent as a result of no effective flushing mechanism exists therefore, groundwater is saline in most part. The study exhibit that the areas with agricultural land, alluvium soil, gentle slope and relatively low drainage density contributes to the suitable sites for recharge. The recharge sites are in conformity with the land use pattern of the area. The suitable sites, based on geological considerations, are to be located in flood plain of rivers, alluvial fans, bajadasandpiedmont plains, sand dunes and weathered zones. Overall categorization of the study area based on various adopted approach concludes that a poor recharge zone constitutes 26.3%, moderate zone 37.0% and good recharge zone is 36.5% of the total study area.Finally, it is concluded that the remote sensing technology has great potential to revolutionize groundwater monitoring and management in the future by providing unique data to complement the conventional field data. Integrating RS- and GIS based groundwater research is also necessary in conjunction with field investigations to successfully exploit the expanding potential of these technologies.

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5. References


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