International Journal of Pure and Applied Mathematics
Volume 119 No. 17 2018, 3195-3210
ISSN: 1314-3395 (on-line version)
url: http://www.acadpubl.eu/hub/
Special Issue
http://www.acadpubl.eu/hub/

IDENTIFICATION OF GROUNDWATER POTENTIAL ZONES USING GIS AND REMOTE SENSING

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ABSTRACT

Nowadays ground water is decreasing and therefore there is an increase in demand of water. Ground water is one of the major source that contributes to the total annual supply. The objective of this paper is to review techniques and methodologies applied for identifying groundwater potential zones using GIS and remote sensing. Several methods are used for mapping of ground water zones. The parameters that are used for controlling groundwater zones are soil, drainage density, land use\land cover, geology, geomorphology, rainfall, slope, and contour. Groundwater mapping techniques are described and derived from satellite remote sensing and additional data sources. These techniques includes both conventional methods and advanced methods. The thematic layers are used for mapping and identification of groundwater potential analysis. The importance of each thematic layer and its weight is discussed for the location groundwater potential zones using groundwater conditions. This groundwater potential information will be useful for effective identification of appropriate locations for extraction of water.

1. INTRODUCTION

Groundwater is the one of the most natural resource that supports human health and ecological diversity (Waikar & Nilawar, 2014). Protecting it from contamination and carefully managing its use will ensure its future as an important part of ecosystems and human activity. The rate of groundwater flow is controlled by two properties of the rock: porosity and permeability. The main sources of groundwater recharge are precipitation and flow and of discharge include effluent seepage into the streams and lakes, springs, evaporation and pumping.

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It is estimated that approximately one third of the world's population use groundwater for drinking (Jose, Jayasree, Kumar, & Rajendran, 2012). Groundwater is the source for irrigation and domestic purpose. In which 80% of the rural areas are use groundwater for domestic purpose and 50% of the urban areas use the groundwater for domestic purpose. Due to more dependent on usage of groundwater for domestic purpose and irrigation and for other sectors may results in exploitation of groundwater resources (Shakak, 2015). Groundwater is dynamic and replenishable resource. The exploitation and exploration of groundwater resources needs to understanding geology, geomorphology of that area. The data and thematic maps such as satellite images, soil data, geology data, drainage data and rainfall data, are helpful for mapping of groundwater potential zones(Giri & Bharadwaj, 2012).

Remote sensing data combined with Geographical Information System (GIS) technique is very efficient in identification of groundwater potential of any region. The study results that the integration of thematic maps prepared from conventional and remote sensing techniques using GIS gives more and accurate results (Jose et al., 2012). Groundwater is available when water infiltrates below the earth surface and soil beneath the earth surface is porous (Sayeed, Hasan, Hasnat, & Kumar, 2017). Groundwater table reduces when pumping rate is more than the rate of usage. Hence, it can be concluded that areas of high withdrawal rates may lead to reduction of groundwater zones. This may lead to reduced water level in wells, lakes and streams (Senanayake, Dissanayake, Mayadunna, & Weerasekera, 2016).

Remote sensing is one of the major source for surface feature information of groundwater such as land use, land forms and drainage density. These data can be easily input in GIS to identify the groundwater zones (Oh, Kim, Choi, Park, & Lee, 2011). According to World Bank report, India may be in water stress zone by 2025 and water scarce zone by 2050 [give reference]. This is due to improper education in groundwater exploitation, improper maintenance of water, failure of government schemes for rural areas may lead to groundwater and drinking water problems in India. The advantage of GIS and remote sensing of spatial, spectral and manipulation of earth surface and subsurface data cover with a short time having a great groundwater potential for accessing, processing and monitoring the groundwater resources. The conventional methods such as geophysical resistivity surveys, field based hydrogeological are

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time consuming methods and very cost effective (Ahmed, 2016). Ground water is the subsurface water which fills the pore space and geological formation under the water table. The water flows through the aquifer towards the point of discharge that includes wells, oceans, lakes etc. In the world scenario there may be 60% of groundwater in which there may be 0.6% of fresh water. The use of remote sensing and GIS techniques increases for identifying groundwater zones gives with accurate results. Many methods are available for mapping of potential zones such as Weighted Linear Combination (WLC) (Vijith 2007;Madrucci et al. 2008; Dar et al. 2011), Analytical Hierarchical Process (AHP) (Chowdhury et al. 2009; Pradhan 2009), and Index Overlay Method (Muthikrishnan and Manjunatha 2008).

2. REMOTE SENSING AND GIS TECHNIQUES

Remote sensing and GIS plays a vital role in developing of water and land resources management. The advantage of using remote sensing is to develop information on spatial technology which is useful for analysis and evaluation (A. Sciences, 2017).Remote Sensing is the science of acquiring information about the earth surface without being contact with it. This is done by sensing, recording, analyzing and applying the information. GIS is a collection of computer hardware, software and geographic data for capturing, storing, analyzing, and manipulating data for geographical information (Tiwari & Shukla, 2015). For getting the soil, land use and land cover, geology, geomorphology, rainfall, drainage density data high resolution satellite images are taken for mapping of groundwater zones (E. Sciences, 2013). National Remote Sensing Agency (NRSA) was first identify the remote sensing and GIS information for mapping of groundwater potential zones. GIS technique is used to classify the results of remote sensing, assign the appropriate weights to the related maps. These maps are used to identify the groundwater flow, and recharge zones (Æ & Chang, 2009). Remote Sensing and GIS plays a vital role in delineation of groundwater potential zones. From the satellite data we can identify the water holding capacity for different geomorphological and structural units. From the land use, slope and rainfall data we can identify the groundwater quality of the study area (Singh, Kumar, & Chakarvarti, 2015). Remote Sensing and GIS technique has proved that it is time saving process and low cost for obtaining slope, drainage density, geology, geomorphology maps (Sharma, 2016).

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3. Methods for identification of groundwater potential zones

There are several methods that can be used to explore groundwater but can be grouped into two major categories:

1. Conventional methods
2. Advanced methods

3.1 Conventional methods

The conventional methods used to prepare groundwater potential zones are mainly based on Ground surveys:

1. Sensitivity Analysis Method such as resistivity, and ground penetrating radar.
2. Probabilistic Models such as Logistic Regression Method.

Conventional methods of exploration may not be highly reliable due to assessment of diverse factors which affects the presence of groundwater (Biswajeet&Saro et al. 2012). Similarly, GIS is an efficient tool for calculating and storing large volumes of data, integrating spatial and non-spatial information in a single system, offering a consistent framework for analyzing the spatial variation, allowing manipulation of geographical information, and allowing connection between entities based on geographical proximity (Pradhan 2010a, 2010b, 2011; Pradhan et al. 2010a,b,c). Jha et al. (2007) categorized six major areas of remote sensing and GIS applications in groundwater hydrology: (1) exploration and assessment of groundwater resources, (2) selection of artificial recharge sites, (3) GIS-based subsurface flow and pollution modelling, (4) groundwater pollution hazard assessment and protection planning, (5) estimation of natural recharge distribution, and (6) hydrogeological data analysis and process monitoring.

3.2 Remote-sensing based methods:

1. Analytical hierarchical process (AHP)
2. Weighted overlay method (WOM)
3. Frequency ratio model (FRM)
4. weighted aggregation method (WAM)

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3.1.1 ANALYTICAL HIERARCHICAL PROCESS

Analytical Hierarchical Process (AHP) is a multi-criteria decision making method developed by Prof Thomas L Satty in 1980. It is a strategy to get proportion scales from paired difference. The information has been taken from actual measurements such as weights, price and from subjective conclusions.

In this study, a total of nine parameters were used to delineate the ground water potential zones such as drainage, elevation, density, geology, geomorphology, land use and land cover, lineament and dykes, rainfall pattern, slope and soil texture. DEM data has been used to create aspect map, slope map and flow accumulation. The LANDSAT ETM images were used to classify the land use image. Drainage density map is created using QGIS software and weights are calculated. These parameters are prepared in GIS environment and weights are assigned for each classes are assigned using analytical process(Ramu & Vinay, 2014). For mapping of ground water potential zones totally seven parameters are used such as geology, geomorphology, drainage density, slope, soil, land use map. Then the DEM data is used to prepare the slope, aspect, map and contour map. Digitizing is done in QGIS into vector format and convert into the raster format. The analytical hierarchical process is used to create thematic layers and weights are calculated and assigned. The ground water potential zones are classified into five categories are very poor, poor, moderate, good, excellent(Waikar & Nilawar, 2014).

Analytical hierarchical process analysis different datasets into a pairwise matrix which is used to calculate geometric mean and normalized weight of parameters (Chowdhury et al. 2010).

Geometric mean

The geometric mean is calculated from different parameters based on defined score (0.5-1 scale). The geometric mean is derived from the total score weight divided by the total number of parameters (Rhoad et al. 1991).

Geometric mean = total score weight/total number of parameters

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Normalized weight

It is the indicator of multi parameter analysis of groundwater mapping. Normalized weight is calculated by assigned weight of parameter feature class to the geometric mean (Yu et al. 2002)

Normalized weight = Assigned weight of parameter feature class/geometric mean

3.1.2 WEIGHTED OVERLAY METHOD

In this method firstly the spatial data base has been developed using Survey of India topo sheet on a 1:50000 scale and IRS P6 LISS IV MX satellite data. Various thematic maps such as drainage density, contour and stream length are prepared by using GIS and remote sensing. Then the DEM data is used to obtain slope, aspect, contour and flow accumulation map. The image processing of satellite data is used for geo referencing and geometric correction. The attribute data from the collected data are used to create buffer for agriculture and settlement area. The DEM data may be used to prepare the land use/cover classification map and lineament map. Therefore all the thematic maps are used to analyze in overlay and weights are assigned for each thematic layer and ranks are assigned to evaluate the groundwater potential zone (Waikar & Nilawar, 2014). For identifying ground water potential zones for an area following equation is used

Pr = RFwRFr + LGwLGr + GGwGGr + SGwSGr + LDwLDr + DDwDDr + LCwLCr + SCwSCr

Where Pr is Groundwater potential index, RF is Rainfall index, LG is lithology index, GG is Geomorphology index, SG is Slope Gradient index, LD is Lineament density index, DD is Drainage density index, LC is Land use and Land cover index, SC is Soil cover index. W is weight and r is rank (Senanayake, Dissanayake et.al 2016)

3.1.3 FREQUENCY RATIO MODEL

In this method a spatial data base with groundwater factors and designed and applied. All the data such as topography, soil map, land use, geology and lineament map are taken from different government of Malaysia with different GIS data type with different scales. The input layers are used in GIS software are in vector format. The DEM data is used to calculate aspect map, slope map and contour map. These contour lines are in the scale of 1:25000 topo sheets

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with spatial resolution of 20m. The lineament map is prepared from ArcGIS spatial analysis. Finally all these factors such as lineament map, slope map, geology map and land use map are converted into raster grid form with 20*20m cells. The ground water data such as well number, topography, depth are collected from web data base systems. Finally the weights are assigned for each thematic maps and evaluate the ranks for mapping of potential zones(Manap et al., 2014).

4. Factors affecting ground water potential zones

The potential zones for groundwater recharge were explored by analyzing the different parameters such as geology, geomorphology, slope, land use and land cover, lineament density, drainage density, Transmissivity of Aquifer, soil permeability and rainfall through integrated AHP method and geospatial technology. Factors influencing ground water are:

4.1 DRAINAGE DENSITY

Drainage pattern means formation of surface and subsurface characteristic. If drainage density is more than the runoff will be more. Therefore the water will be less infiltrated in that area. If drainage density is less than infiltration will be more. So there may be groundwater potential zone. In this study the drainage flows from granitic hills which is in northern part of basin. Here the drainage pattern is like dendritic (Venkateswaran et al 2015). Drainage density is closeness of the spacing of the channels. The drainage networks are prepared from carto DEM with help of Arc Hydro tool 9.3 of ArcGIS. These extracted networks are taken from google earth images and Landsat 8 image data (Ahmed, 2016). The drainage density is categorized into five categories such as very low, low, moderate, high, very high. Under the area 0- 1.2 km/km2 the ground water prospect is very low, the area 1.2- 2.4km/km2 the ground water prospect is low, the area 2.4- 3.6km/km2 the ground water prospect is moderate, the area 3.6- 4.8 km/km2 the ground water prospect is high, the area 4.8-6 km/km2 the ground water prospect is very high. The high ranks are given to low drainage density due to more infiltration rate (Waikar & Nilawar, 2014).

4.2 GEOLOGY

Groundwater may be available under water table conditions in weathered zones of chitravati rocks. Due to the present of joints and fractures in the rock types the water may be available in the wells. The basal and quartzite are the good aquifers in the shallow water table.

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Here the water is alkaline in nature and which is suitable and useful for irrigation and drinking facilities. The water in that area is saline due to unhygienic conditions (Nagaraju, Arveti Sreedhar et al, 2016). Geology is the important for occurrence of groundwater. The area is normally formed with igneous rocks. The rocks available in that area with ground water quality are Limestone and Dolomite with very high water quality, Migmatities and Granodiorite with high groundwater quality, Amphibolotic with moderate water quality, Chamundi granite with less water quality and pink gray granite with very less groundwater quality (Ramu, Mahalingam et al, 2014). Geology consists of both porosity and permeability in aquifer rocks. The geology map has been created by digitizing the geological map of scale 1: 00000. The rocks available in that area are quaternary alluvial rock, diorite rock, diorite gabbro rock. Due to the hardness and low fractures the movement of ground water is difficult in diorite and diorite gabbro rocks. Therefore it may be result in poor groundwater potential(Rahmati, Nazari Samani, Mahdavi, Pourghasemi, & Zeinivand, 2015).

4.3 GEOMORPHOLOGY

Geomorphology is the study of earth structures and landforms. It is mainly depend on geological formation (Waikar & Nilawar, 2014). The map shows five geomorphological features in order to know about the water resources areas. (1) Denudational hills: most the of area is covered with forest and slope is moderate with moderate flow. The entire area is fully covered with few fractures with drainage pattern which may results in moderate to good recharge of groundwater. (2) Pediment: Here the area is covered with cultivate land. The slope is very steep. Drainage pattern is Dendritic and having well to very good recharge of groundwater prospect.

(3) Undulating upland: the slope is very steep with moderate runoff and having poor groundwater recharge. (4) Pediment Inselberg complex: the area is full of barren land with poor drainage pattern. The barren land is of sandy soil with poor slope may results in erosion. The ground water prospect is also poor. (5) Peneplain: the area is of flat rocks with uneven land. The drainage pattern is sub parallel to sub dendritic with poor groundwater prospect (Giri & Bharadwaj, 2012). The geomorphological features of the area has been identified from satellite images and used as the inputs of geomorphological map. The geomorphological features of the area is classified into five categories. (1) Denudational hill: These are characterized by high surface runoff and high topography. (2) Denudational hills with moderate slope. (3) Dykes. (4)

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Water bodies: water bodies are lakes, ponds, streams can act as recharging zones. (5) flood plains (Manap, Sulaiman, Ramli, Pradhan, & Surip, 2013).

4.4 SOIL

Soil is most important factor that determines the infiltration capacity of the region. The different types of soils available in that area are silt clay loamy, clay loamy, loamy sand, loamy fine sand, coarse sandy loam. Silt clay loam covers 74% of the area and sandy clay loam cover 1.34% and coarse granule loam covers 6.28% of the area. The results are in loamy sand permeability is very high, silt clay loam permeability is medium to moderate. In clay loam permeability is poor, in sandy clay loam permeability is moderate to high. In coarse granule loam it is high and rapid flow. In coarse sandy loam permeability is medium (Kaliraj, Chandrasekar, & Magesh, 2014) . The soil is taken from the National Institute of Agriculture Science and Technology with a scale of 1: 25000. The different features available in the soil map are forest, grass land, silt, sandy loam, clay silty loam, gravel silt loam (Oh et al., 2011).

4.5 LAND USE AND LAND COVER

Land use map tells the information about soil moisture, infiltration, groundwater and surface water. Landsat 8 images are taken for classification of land use map. Then the converted reflectance values obtained for red is band 4 and for near infrared is band 5. These band values are used for Normalized different vegetation index (NDVI). The values obtained from NDVI measurement are ranges from -1 to +1 and for vegetation the value is between 0.1 and 0.6. If the value is more than 0.4 it indicates as dense vegetation. If the value is less than 0.15 then there is no vegetation i.e, barren land. If the value is 0 then it may be water bodies, wet areas. The Normalized different vegetation index is calculated by using formula

$$NDVI = NIR – RED/ NIR + RED$$

Therefore vegetation and agricultural land have cracks and loosen the soil and increases the infiltration rate in the soil (Ahmed, 2016). Land use and land cover map is the main factor for controlling the groundwater recharge process. In general land use means the land which is used for agriculture, mining purposes. Land cover means removing the upper layer of the soil and used for construction like buildings, lakes etc (Prabhu & Venkateswaran, 2015). The different features available in soil map are crop land, barren land, hill, medium dense forest, and dense

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forest. The dense forest mainly covers the plantation and these types of lands are not suitable for groundwater recharge due to heavy rainfall. Firstly the barren land, crop land are prioritized for recharge of ground water due to less availability of groundwater and surface water for domestic and irrigation purpose (Kaliraj et al., 2014). The land use map was created from the satellite imaginary with different field verifications (Srivastava and Battacharya 2006). The characteristics of the surface materials and land use pattern control the infiltration and runoff (Dinesh Kumar et al. 2007).

4.6 RAINFALL

Rainfall is main source for recharging the groundwater and also for all hydrological process. The annual rainfall data is taken from the Indian Meteorological Department (IMD) for annual rainfall measurements from rain gauge stations in the study region. The rainfall map has be categorized into four categories of rainfall zones each of 250mm interval. The zone which gives low rainfall may results in not useful for groundwater zones (Manap et al., 2013). Rainfall is the source of recharging groundwater (Musa et al. 2000). The monthly rainfall data is collected from different rain gauge stations for period of 15 years from Iranian Meteorological organization. From the rainfall map the results were concluded that the annual rainfall in elevation regions is more when compared to low elevation (Rahmati et al., 2015). Rainfall is the major source of groundwater availability. If the rainfall is more than groundwater is available, if rainfall is less than groundwater will be less. Rainfall may be varies from one region to another region. From that the annual rainfall data is taken from the rain gauge stations for past 33years and interpolation method has been used to find amount of rainfall has been appeared in the study area. Then zones are classified with equal intervals and weights are assigned to each zone (Ramu & Vinay, 2014).

4.7 TRANSMISSIVITY OF AQUIFER

Groundwater is normally taken from unconfined and semi confined aquifers to confines aquifers. The tube wells and dug wells are used to drawn the groundwater for usage of domestic purpose, irrigation purpose. Sometimes the water drawn from dug wells requires cleaning. The depth of water table data has been prepared from field work. As noted that the water table is at depth of 5m from the ground level and 35m from the unconfined aquifer. This may results that water table is deeper from the ground level and the movement of the groundwater is through

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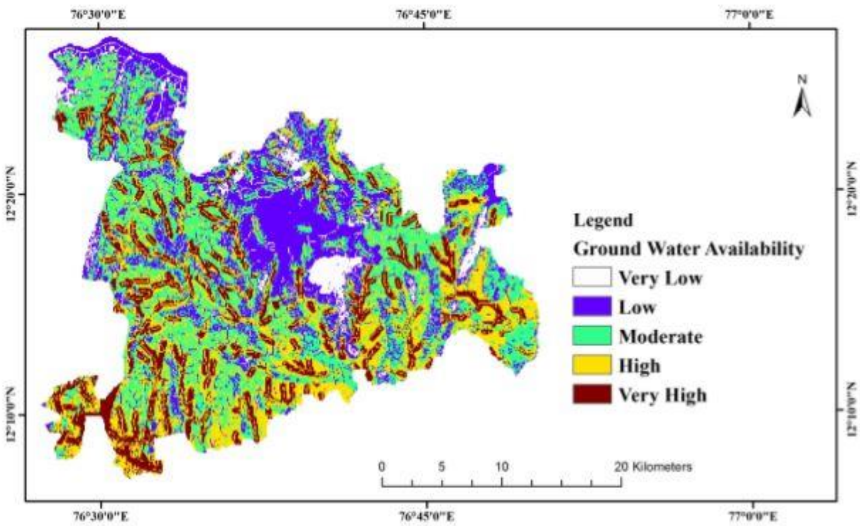
west to east direction (Study, Bata, & District, n.d.). Aquifers are the unconsolidated layer of the geological area. Aquifer transmissivity is the groundwater discharge of unit area with unit time (Kaliraj et al., 2014).

4.8 GROUND WATER QUALITY

Groundwater quality is mainly based on geological formation, climate, pollution and drainage conditions. Normally the groundwater is in neutral to alkaline. If the contaminants present in the groundwater then it is not suitable for daily purposes and for irrigation. Data interpretation may compares the water quality standards, relation between water quality and environmental data.(Nagaraju, Sreedhar, Thejaswi, & Dash, 2016). The groundwater samples are collected from different regions of the study area. The water samples are placed in cleaned bottles. The samples are taken to water quality laboratory and laboratory tests are conducted for the samples like TDS, CL, EC, SO4, NO3, Ca, Mg, Na. The obtained results are compared with World Health Organization (WHO) standards. Ranks are assigned for each parameters and identify the amount of water gets polluted (Nagaraju et al., 2016). Table 1 shows the International and National standards of Water Quality.



Groundwater potential zones

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S No	Parameter	Drinking Water							Irrigation FAO
		BIS		ICMR		WHO	NSDWR		
		Desirable limit	Admissible limit	Highest limit	Maximum Desirable limit	Guide line permissible value			Maximum trace conc. of elements
1	Alkalinity	200	600	-	-	-	-		-
2	TDS	500	2000	500	1500-3000	1000	500		-
3	Hardness	300	600	300	600	500	-		-
4	Chloride	250	1000	200	200	250	250		4
5	Arsenic	0.01	0.05	-	0.05	0.05	-		0.1
6	Lead	0.05	NR	-	0.05	0.05	-		-
7	Mercury	0.001	NR	-	0.001	0.05	-		-
8	pH	6.5-8.5	NR	7.5-8.5	6.5-9.2	6.5-8.5	6.5-8.5		-
9	Copper	0.05	1.5	-	-	-	1.0		0.2

Table 1: National and International standards for Water Quality

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5. CONCLUSION

This review has shown that remote sensing and GIS is useful to identify the Groundwater potential zones in many ways. Several methodologies are used to mapping of potential zones. Some methods are very easy and gives accurate results. Some of the methods requires more data and time consuming process. Each technique having their advantages and their disadvantages in doing process. Satellite images are useful for mapping of groundwater potential zones using different parameters like geology, geomorphology, drainage density, soil, rainfall data, transmissivity of aquifer and land use & land cover. The discussion on each parameters are also given for mapping of potential zones.

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