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RESEARCH PAPER

Geospatial technology for delineating groundwater potential zones in Doddahalla watershed of Chitradurga district, India

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Abstract Groundwater is one of the valuable natural resources which determines the health of a human being in an area. The present research investigated the hydrogeological determinants to assess the sensitivity of each factor to the infiltration pattern and to map the regional groundwater potential zone for the semi-arid watershed in Karnataka, India using a geographic information system (GIS) and satellite remote sensing. It was one of the driest and water scarcest regions in the country. Groundwater potential zones are demarcated by integrating the highly impacting thematic layers such as land use, soil texture and depth, rainfall, slope, drainage density, lineament and geomorphology. The thematic layers are prepared from the remote sensing satellite images, ground truth data and available secondary data. Cartosat-1 CartoDEM (30 m), IRS P6 LISS III (24 m) and Landsat 8 (30 m), SOI toposheet (57 B/7, 57 B/8, 57 B/11, 57 B/12, 57 B/15 and57 B/16) and high resolution satellite images from Google Earth were used for the preparation of thematic maps. ArcGIS software was utilized to manipulate these data sets. Weight is assigned to each class for each thematic map according to their characteristic and interrelationship with groundwater. All the thematic layers are integrated into a GIS domain, and assigned weight values are added for each polygon in the attribute table. Then each polygon is classified a groundwater zone into five different subclasses according to the gained weight value. Only 15% of the total land area is rich with groundwater resources. More than 70% of the total land area is moderate to poor with groundwater resources.

1. Introduction

Groundwater, or subsurface water, is a term used to denote all the waters found beneath the ground surface (Bear and Verruijt, 1987). It is one of the most significant natural resources worldwide serving as a primary source of water for communities for domestic purpose, industries, agricultural

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productions (Ayazi et al., 2010; Manap et al., 2012; Neshat et al., 2013; Pradhan, 2009), and for tourist developments (Jaturon et al., 2014). Groundwater is naturally replenished by rain or snow melts which seep down through the soil and/or through pore spaces of underlying rocks (Nampak et al., 2014). Hence, its occurrence and distribution depends on the climate and regional setting of the region, surface and subsurface characteristics such as fractures in the underlying rock, land use type, geomorphic features, structural features and their interrelationships with the hydrological characteristics (Edet et al., 1998; Greenbaum, 1992; Jaturon et al., 2014; Kumar et al., 2007; Saud, 2010; Senthil Kumar and Shankar, 2014). Groundwater accounts for 26% of global renewable fresh water resources (FAO, 2003). Salt water (mainly in oceans) represents about 97.2% of the global water resources with only 2.8% available as fresh water. Surface water represents about 2.2% out of the 2.8% and 0.6% as groundwater. Groundwater contributes to about 80% of the drinking water requirements in the rural areas, 50% of the urban water demands and more than 50% of the irrigation needs of the nation (National Remote Sensing Agency, 2008). Groundwater demand is drastically increasing due to the immense pressure on population and urbanization, global impact due to climate and weather change, repetitive drought condition and lack of rainfall. Over exploitation of the groundwater resource caused a sudden decline in the groundwater table and an excess in the sustainability of groundwater resources (Jaturon et al., 2014; Rahman, 2001). Especially the agrarian states like Karnataka, the groundwater dependence is high. Recent studies indicate that 26% of the area of Karnataka state is under overexploited category and numbers of villages are under the critical category (Central Ground Water Board, 2013). According to a World Bank report, India will be in water stress zone by the year 2025 and water scarce zone by 2050. Insufficient education on groundwater exploitation and conservation, improper balance in exploitation and recharge, failure of government schemes in rural areas where poor access to the groundwater, etc. are some of the major groundwater and drinking water problems in India.

Remote sensing and geographical information system with their advantages of spatial, spectral and temporal availability and manipulation of Earth surface and subsurface data covering vast and inaccessible areas within a short time have a great potentiality in groundwater hydrology for accessing, monitoring and conserving groundwater resources (Dar et al., 2010). The complexity of conventional exploration methods such as field-based hydrogeological, geophysical resistivity surveys, exploratory drilling which is more time-consuming and very expensive, supports the application of satellite-based Geospatial Science (Gumma and Pavelic, 2013; Nampak et al., 2014; Singh and Prakash, 2002). Hydrologists are now familiar with the integration of multi-thematic maps of the Earth surface and subsurface through the application of remote sensing (RS) and geographical information system (GIS) techniques for delineating the groundwater prospective zones for exploration, development and sustainable management of groundwater resources (Gumma and Pavelic, 2013; Murthy, 2000; Rashid et al., 2011; Senthil Kumar and Shankar, 2014). Researchers have utilized the Geospatial technology for the groundwater mapping by integrating thematic maps such as geomorphology, drainage pattern, lineament, soil (Preeja et al., 2011; Rassam et al., 2008; Saraf and Choudhary, 1998), rainfall intensity and soil texture (Magesh et al., 2012), resistivity, aquifer thickness, or fault maps (Senthil Kumar and Shankar, 2014). In the present work groundwater prospective zone mapping was carried out for Doddahalla watershed in the drought prone district of Karnataka state, India by integrating the thematic maps such land use land cover, geomorphology, soil texture and depth, slope, lineament, drainage and rainfall maps in a spatial domain of GIS environment.

2. Study area

The Doddahalla watershed is part of the lower Tungabhadra catchment of Krishna basin. The watershed covers an area of 1082 km^2 lying in between Chitradurga, Hiriyur and Challakere taluk of Chitradurga district of Karnataka (Fig. 1). Geographically the area extends from 76°21′10″E to 76°50′30″E longitude and 14°4′9.42″N to 14°25′00″N latitude. Physiographically the watershed can be called a dry and thirsty land with broken hills ranges and huge undulating plains (Ibrahim-bathis and Ahmed, 2014a). The average rainfall in the area is 578 mm. Fifty percent of the annual rainfall is received during the southwest monsoon season (Ibrahim-bathis and Ahmed, 2014b). The quality of vegetation is poor because of poor rains. However, small groves of the trees are to be seen in rural villages. The agricultural seasons in the district highly depend on the rainfall and the climate (Ibrahim-bathis and Ahmed, 2013). The region experienced severe drought in the year 2002, 2003, 2004 and 2006 (Central Ground Water Board, 2013) resulted in the failure of agriculture. Due to the scarcity of abundant surface water farmers have to turn groundwater resources for irrigation. Groundwater contributes to more than 70% for irrigation. Hence, the present research contributes and delineates the potential groundwater prospective zones for the sustainable development of the agriculture and to fulfill the domestic water needs.

3. Materials and methodology

In the present study, the groundwater prospective zone mapping is carried out by integrating satellite derived multi thematic maps using GIS techniques. Cartosat-1 DEM (30 m), Landsat 8 Operational Land Imager (OLI −30 m), Survey of India (SOI) toposheets (57 B/7, 57 B/8, 57 B/11, 57 B/12, 57 B/15 and 57 B/16) and high resolution satellite images from Google Earth (Digital Globe, Astrium and SPOT) were used for preparation of thematic maps. Seasonal Landsat 8 images are used to prepare the thematic map and the date and month of each images are shown in the Table 1. All data are georectified and projected to Geographic Coordinate System-World Geodetic System 1984 (GCS WGS) Universal Transverse Mercator (UTM) zone 43 North for the easy handling in a GIS environment (Ibrahim-bathis and Ahmed, 2016). Satellites data are enhanced and processed in Erdas Imagine 9.2 for the better visualization. SOI toposheets are used as reference maps for the preparation of thematic maps. Individual maps are updated from the recent available images in Google Earth through the color pattern and their appearance in the image. Weight is assigned to the individual classes for each thematic map according to their characteristics and interrelationships