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Research Paper

Hydrogeological delineation of groundwater vulnerability to droughts in semi-arid areas of western Ahmednagar district

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ABSTRACT

Groundwater, a renewable and finite natural resource, is a vital source of sustenance for humans and different ecosystems in the semi-arid regions. Rapid population growth in the last three decades has caused a rise in water demand which has inadvertently posed a stress on its availability. Occurrence of groundwater in the Deccan Volcanic Province is governed by the subsurface hydrogeological heterogeneity of basaltic lava flows and by the presence of geological structures like dykes, sills and fractures that influence spatial & vertical groundwater flow. The main objective of this paper is to map and assess areas that are naturally most susceptible to groundwater scarcity and at risk of depletion due to over extraction. The current study involves a field hydrogeological mapping that was integrated with remote sensing and GIS to delineate areas. This technique was based on using different thematic layers *viz.* lithology, slope, land-use and land cover, lineament, drainage, soil type, depth to groundwater and annual rainfall. Additionally, pumping tests were carried out to classify the study area into different hydrogeological typologies to help delineate communities that are most vulnerable to subsurface heterogeneity. This paper attempts to underline the groundwater scarcity zones based on different influencing thematic layers and provide a robust methodology to prioritize areas vulnerable to groundwater unavailability, by categorizing the study area into different vulnerable class types – extreme, high, moderate and low.

1. Introduction

Groundwater is a vital resource for communities and ecosystems in the semi-arid agro-climatic zone of Sangamner and Akole blocks of Ahmednagar district, Maharashtra, India. In the past few decades, groundwater withdrawal for public supplies, agriculture, industry and other uses has increased by a manifold. Agriculture intensification has resulted in expansion of groundwater irrigated area in India (Shah, 2008). Tian et al. (2014) studied large scale land transformations in India for the period of 130 years ranging from 1880–2010. The study indicated a dramatic shift in cropping patterns from rain-fed cereal crops to more water intensive cash crops; a significant loss of forest cover and an increase in cropland. These changes further pressurized the groundwater resources. Therefore its over-exploitation or indiscriminate extraction tends to deplete the shallow and deep aquifer water table. In mountainous areas, it also causes a reduction in the flow of springs (Thomas, 2011; Buono et al., 2015); a subsequent reduction in the base flows of streams and availability of water in open wells and lakes. Successive droughts and excessive extraction have induced a stress on the current aquifer regimes, which threatens the flow of many springs that emerge from this region (refer Fig. 1).

In the Deccan Trap Province, the occurrence of groundwater in basalts depends on differing hydrological properties of the rock types (compact, vesicular, amygdaloidal, inter-basaltic clay), degree of weathering and their intrinsic jointing patterns and fractures (Kulkarni et al., 2000). Rainfall plays a significant role regarding how water is distributed and is available for recharge in these regions. The underlying geology and deficiency in rains has seriously crippled the agrarian livelihood and could threaten the future of farmers who are dependent on irrigated agriculture (Shah, 2009; Udmale et al., 2014). Rampant well drilling due to groundwater unavailability for irrigation has pushed many of the farmers into a spiraling debt and ultimately to a suicide (Taylor, 2013). Knowledge of subsurface hydrogeology, hence, plays a vital role in regulation of drilling boreholes and aiding the communities to manage the underlying aquifers.

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Figure 1. Many remote communities are dependent on natural springs for drinking purposes, which ooze out through the basalt flow contacts (sheet pahoehoe flow units). (Location: *Kandobachiwadi, Pimpaldhari*).

The expanse of hard basaltic rocky terrain, also known as the Deccan Volcanic Province (DVP) or Deccan Traps, covers an area of more than 500,000 km^2 in the western central region of the country and exceeds more than1.5 $\times$ 10^6 km^2 of total flow, which makes it one of the largest, among other known continental flood basalt provinces namely Siberian and Paraná-Etendeka traps. The lava pile in DVP is thicker towards the Western Ghats and wanes down gradually towards the east. *Sangamner* and *Akole* region of Ahmednagar district, situated towards the western region, are underlined by massive lava pile consisting of flow units of varied thickness and belong to different flow types (Bondre et al., 2000, 2004). The flows are composed of compound pahoehoe (Duraiswami et al., 2001; Bondre et al., 2004), slabby pahoehoe (Duraiswami et al., 2003), rubbly pahoehoe (Duraiswami et al., 2008) and aa' types (Brown et al., 2011). The flow units are a result of volcanic eruptions which erupted through a series of long fissures that occurred approximately 65 million years ago (Chenet et al., 2007). The massiveness of these units presents itself as an impervious stratum which provides very little possibility for water to be recharged. Access to groundwater in such units is dependent on the availability of inherent structures like cooling joints, fractures and presence of intrusive features like dykes and sills. The region is cluttered with dyke swarms and fracture lineaments (Bondre et al., 2006) that are potential groundwater reservoirs (Duraiswami, 2005; Mège and Rango, 2010) and act as conduits for groundwater flow (Lie and Gudmundsson, 2002; Larsen and Gudmundsson, 2010) in the hard rock terrain (Deolankar et al., 1980; Peshwa et al., 1987; Babiker and Gudmundsson, 2004).

The failure of boreholes in the hard rock areas in Deccan Traps is a common phenomenon and has been happening more frequently than before. This can be attributed to over exploitation and incorrect site selection. Groundwater mainly exists in shallow weathered rock, vesicular and amygdaloidal rock, fractures and joints (refer to Fig. 2) (Kale and Kulkarni, 1993; Kulkarni et al., 2000). Locating groundwater productive zones and predicting the subsurface flow processes needs rigorous scientific survey. Recurring crop failures, due to insufficient rainfall and depleting groundwater in shallow aquifers, has resulted in a growing need for tapping deeper aquifers.

For spatial mapping of groundwater zones different methods like the overlay and index methods, process-based methods consisting of mathematical modelling and empirically based statistical methods (Eslamian, 2014) are available, but the overlay and index method was found to be suitable to delineate areas that are generally vulnerable to groundwater unavailability. Many studies based on integration of thematic layers have been geared towards identification of groundwater potential zones (Murthy, 2000; Dar et al., 2011; Magesh et al., 2012; Nag and Ray, 2014; Ibrahim-Bathis and Ahmed, 2016.) and recharge zones (Shaban et al., 2006; Duraiswami et al., 2009), however efforts to identify and delineate areas that face groundwater unavailability needs to be ascertained in order to increase knowledge at the village level. The multi influencing factor technique takes into consideration different thematic layers and its independent influences on each other. Hence this method is quite novel in spatial mapping of the vulnerable zones.

In lieu of vagaries of climate, this study aids in delineating vulnerable areas based on different influencing factors, which are at a serious risk from rainfall limitations and drought like conditions. It will also enable in strengthening the communities for sustainable management of their resources. Additionally it will aid in better formulation of adaptation strategies that requires to be adopted, given the current scenario of successive climatic drought conditions prevalent in this region.

2. Study area

The present study conducted in the year 2015–2016, comprised of seventeen villages from Sangamner and Akole block of Ahmednagar district as shown in Fig. 3 (*Jawalebaleshwar, Warudi Pathar, Gunjalwadi, Karjule Pathar, Mahalwadi, Sawargoan Ghule, Sarole Pathar, Dolasane, Malegoan Pathar, Khandgedara, Kuthe Khurd (kh), Kothe Budruk (Bk), Borban, Pemrewadi, Wankute, Bhojdari and Pimpaldhari*). These villages fall in the semi-arid region, with a mean annual precipitation being around 450 mm, and with a minimum and maximum average daily temperature of 12 °C and 42 °C respectively.

2.1. Geomorphology of the area

The study area depicts alluvial plains, undulating lands with mesas and buttes to dissected hills with escarpments and narrow valleys. The highest elevation in this area accounts to 1163 m