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Original Article

Application of Remote Sensing and GIS for Groundwater Potential Zonation: A Case Study of Bori-Chikli Watershed, Maharashtra, India

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ABSTRACT

Groundwater is important fresh water resource. It plays vital role in drinking as well as irrigation practices. In study area, majority of people doing agricultural practices and it's directly reflected on groundwater draft. Geological features, landforms, drainage morphometry and landuse/landcover of any area control groundwater potential. Geologically, area is composed of massive and/or fractured and weathered basaltic flows (simple and compound) and small patches of sand, gravel and silt along major nallas with E-W, NW-SE and N-S trending dykes. Present research paper shows demarcation of groundwater potential zones using weighted overlay analysis in Bori-Chikli watershed of the Jalgaon district, Maharashtra state. The groundwater potential map is generated by integrating and overlaying of thematic layers/data (lithology, geomorphology, land used and land cover, slope, drainage etc.) using GIS platform. The results indicate that majority of area having poor to moderate groundwater potential zones. Remote sensing and GIS are advent tools used for groundwater potential zonation. The results provide significant information and maps to water policy maker as a base data to select the suitable sites for sustainable groundwater development and management.

KEYWORDS: Groundwater potential; Groundwater exploration; weightage analysis; Bori-Chikli watershed

INTRODUCTION

Groundwater is one of the major and valuable sources of fresh water. At present, most of the people in rural as well as urban region depend upon the groundwater & their groundwater dependency is increasing day by day. Exploration and exploitation of this valuable resource needs detailed geo-scientific investigations.

The emerging trends in applications of computers especially in mapping, development of information systems made quantitative and qualitative approach for surface characterization and mechanism for efficient interpretation and manipulation of geodata base. Moreover, advantages of digital earth concept over conventional methods are its ability to create, manipulate, store, and use spatial geographic data much faster and at a rapid rate (Magesh et al., 2011). Remote sensing and GIS techniques provide more reliable and accurate estimation and it is very helpful application for hydrological investigation (Vijith, H. and Satheesh, R., 2006; Wakode et al., 2011; Magesh et al., 2012). In Maharashtra, Deccan basalts, behaves diversely in different geological setups. Hydrogeological framework of aquifers and structural evaluation in the Deccan trapsstudied byAdyalkar et al. (1996); Agrwal (1995); Shet H.C. et al. (1997); Deshpande, G.G. (1998) ; Kulkarni and Deolanlkar (2000); Duraiswami (2005 and 2008); Bondre et al. (2004); Ranjini Ray et al. (2006) and Duraiswami R.A. and Subhjyoti Das (2012). Hydrogeological studies by Deolankar, S.B. (1980); Bhoyar et al. (2008) and Mule et al. (2010, 2012) expresses complex nature of lithological units and states about the art of geospatial tools and geophysical methods.

Various methods to delineate the groundwater potential zones with the contribution of Remote Sensing (RS) and Geographic Information System (GIS) were used by several researchers. Shahid et al. (2000) used ground water potential index method using GIS for groundwater potential modeling. Many researchers like Nag and Chakraborty (2003); Dinesh Kumar etal. (2007); Rokade et al. (2007); Nag and Ghosh (2012), Biswas et al. (2012) delineated groundwater potential zones using weightage overlay analysis in various study area. Pandey et al. (2013) applied GIS based ARC model to delineate potential areas for groundwater development. Rahmati et al. (2014), Pinto et al. (2015) applied Analytical Hierarchy Process (AHP) method to identify groundwater potential areas. Oikonomidis et al. (2015) applied weighted spatial probability modeling and mathematical method of Analytical Hierarchy Process (AHP) used to derive final groundwater potential map of their study area. Davoodi Moghaddam et al. (2015) applied bivariate statistical model to mapping the groundwater spring potential. Salwa Farouk Elbeih (2014) applied Remote Sensing (RS) and Geographic Information System (GIS) techniques for groundwater mapping in different regions of Egypt. Application of Geospatial tools for the Development and management of groundwater resources have studied by Singh et al (1993); Saraf and Choudhary (1998); Rokade et al. (2004); Ranade and Katpatal (2009). Main objective of the present study is to analyses and identify groundwater potential zones of the study area using remote sensing and GIS technique.

STUDY AREA

Study area is located in the western part of Jalgaon district of Maharashtra state. It lies between Longitude 75°19′10″ and 74°55′45″ E and Latitudes 20°40′05″ and 21°11′03″N, mapped by Survey of India toposheets (46 K/16, 46 L/13, 46 L/14, 46 O/4, 46 O/8, 46 P/1, 46 P/2 and 46 P/8) mapped on 1:50,000 scale and cover 1438.57 sq.km area (Fig.1). Climate of the area is dry and hot except during the monsoon period and the average annual rainfall of the area is 736.75 mm. About 99% of the annual rainfall is received during the southwest monsoon season during months of June to September. Average temperature in the area varies from 10°C to 46°C and the air is dry except during monsoon period. Agriculture is the main practice for survival of human beings, prominent crops harvesting in the area are Cotton, Jowar, Bajara, Maize and Grains.

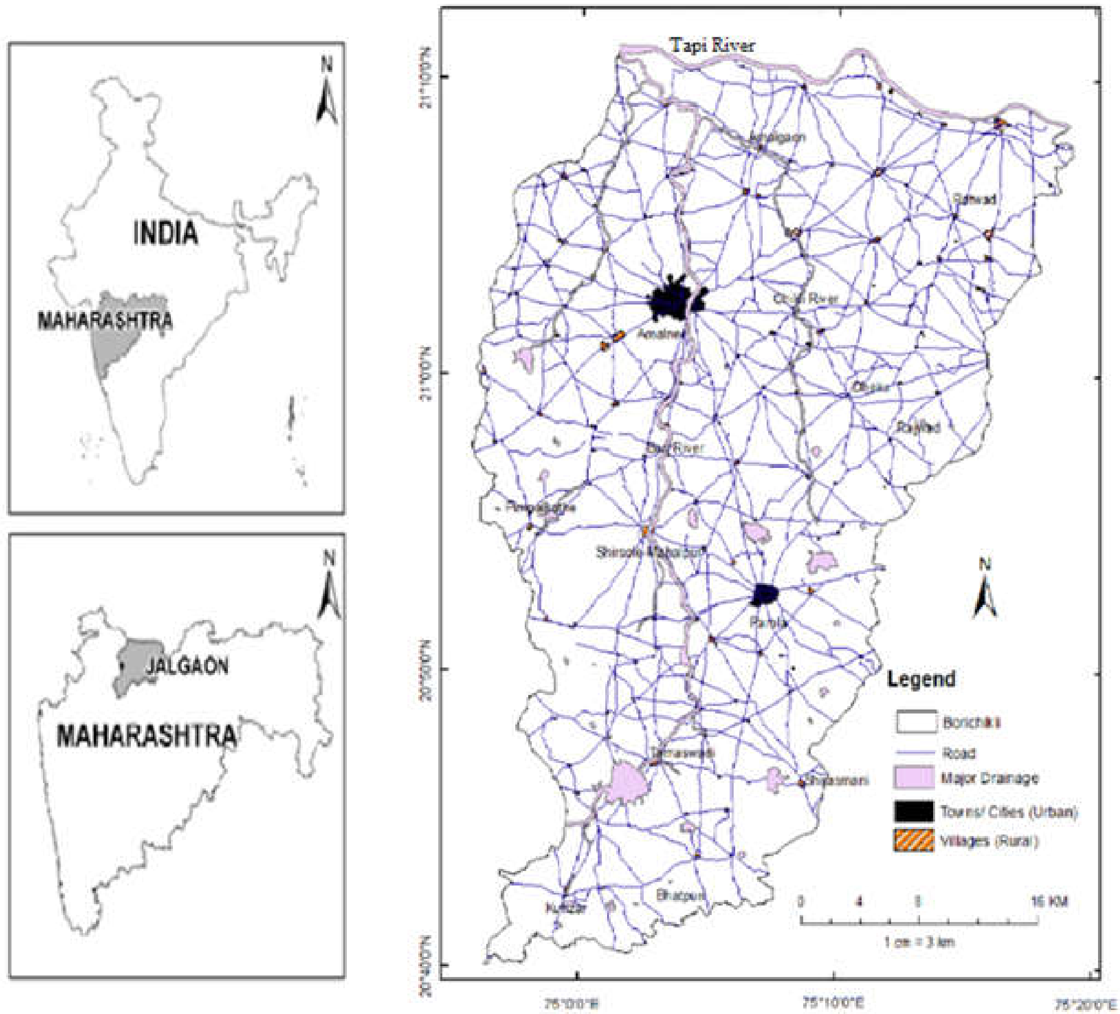

Figure 1: Location map of the study area.

MATERIALS AND METHODOLOGY

For present investigation all spatial and non-spatial information of the study area are collected from source organizations and generated using resources like LISS IV satellite data (2011), Survey of India's (SOI) toposheets, District Resource Map published by Geological Survey of India, Historic data of the wells and subsurface lithological details available with the Ground Water Survey and Development Agency (GSDA), Jalgaon and Field work notes (About the Geology, Geomorphology, Landuse/ Landcover etc.). ERDAS Imagine 9.1 software is used for Image processing and Image analysis and Arc GIS 10.2 software is used for generation and updation of thematic information, GIS integration, GIS analysis and modeling.

GIS modelling is the best practice to demarcate Groundwater Potential Zones. Weighted overlay analysis method is used to delineate groundwater potential zones. Groundwater potential zones are verified in the field.

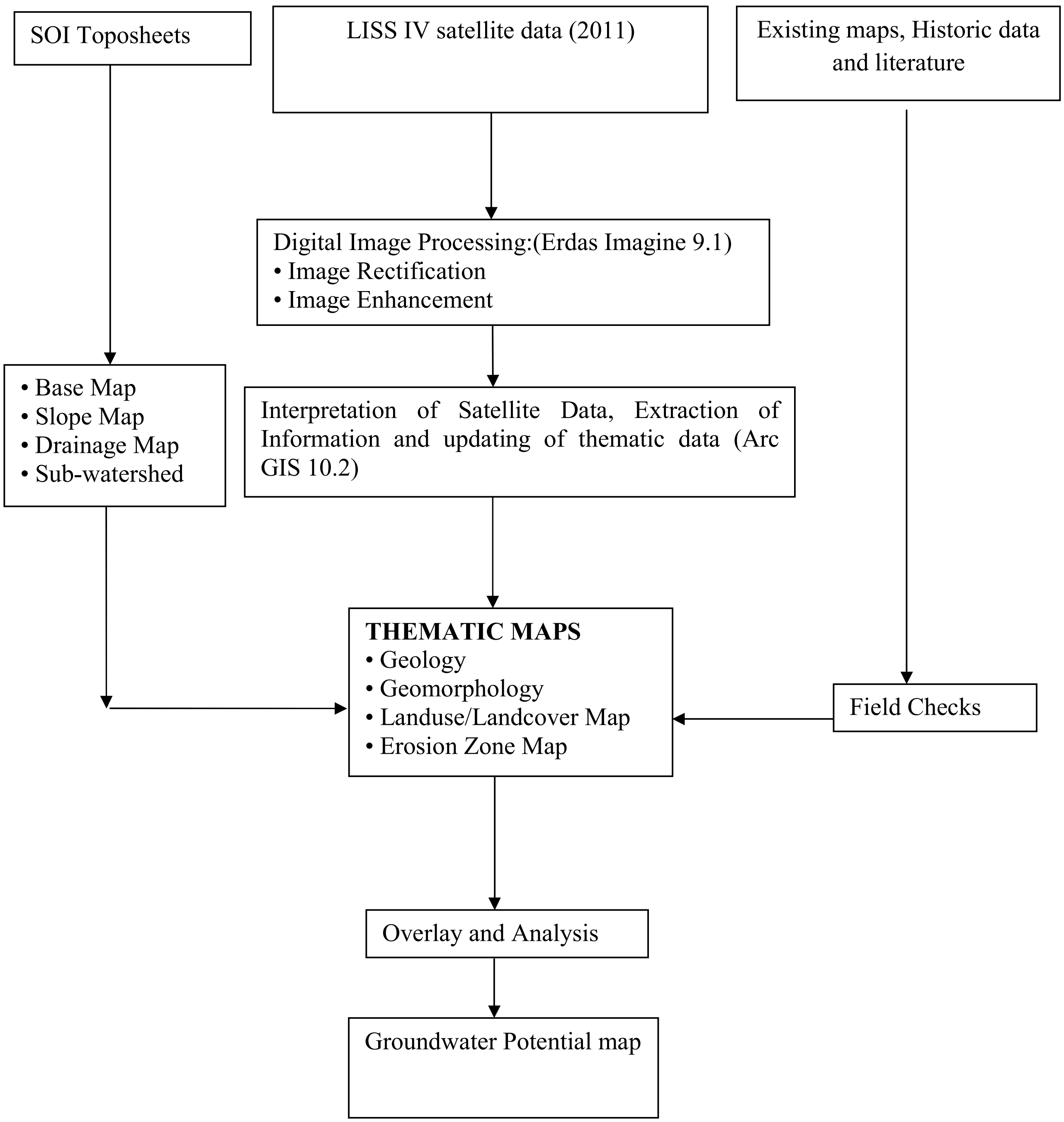

Figure 2: Flowchart of the methodology adopted in the study area.

RESULTS AND DISCUSSION

Geological Setup of The Area

On the basis of interpretation of satellite data, field work and existing District Resource Map of Jalgaon district (1: 2,50000 scale) published by Geological Survey of India, the area have been mapped basaltic flows of Sahyadri group of Deccan Trap and Alluvium constitute geology of the study area.Major part of study area is covered by Deccan Trap basalt flows of Upper Cretaceous to Palaeogene age. The lava sequence in study area is grouped under Sahyadri group (South of Tapi River). The group is further subdivided in to Upper Ratangarh Formation and Ajanta Formation. Lithologic sequence (Figure 3.) of study area consist Megacryst Lava flow (M2) at base then it overlain by 5 compound pahoehoe flows having sparsely to moderately porphyritic, non-porphyritic to sparsely porphyritic. Then it overlain by Megacryst Lava flow (M3) of Ratangarh formation. Above the Megacryst Lava flow (M3), 11 Aa flows and 5 compound flows of Ajanta formation with the intrusion of dykes. Lastly, at a top of lithologic sequence of study area, a thick sequence of Quaternary deposit, i.e. Tapti's Alluvium. The alluvium comprises of beds of clay and silt with lenses of coarse sand, gravels and pebbles**.** The lava assemblage of Sahyadri group consists of alternating sequence of pahoehoe and Aa flows with cumulative exposed thickness varying between 90 and 200 m (GSI Report, 2009).

Study area is having prominent intrusion of E-W, NE-SW and EEN-WWS trending basic dykes (Figure 3). Dykes in study area are mostly of basaltic composition and occasionally of doleritic composition. The E-W trending dyke in Parola is traced up to Sakri-Pimpalner and its more than 100 km in a length and 4-8 m in a width, probably it is a longest dyke in a region.

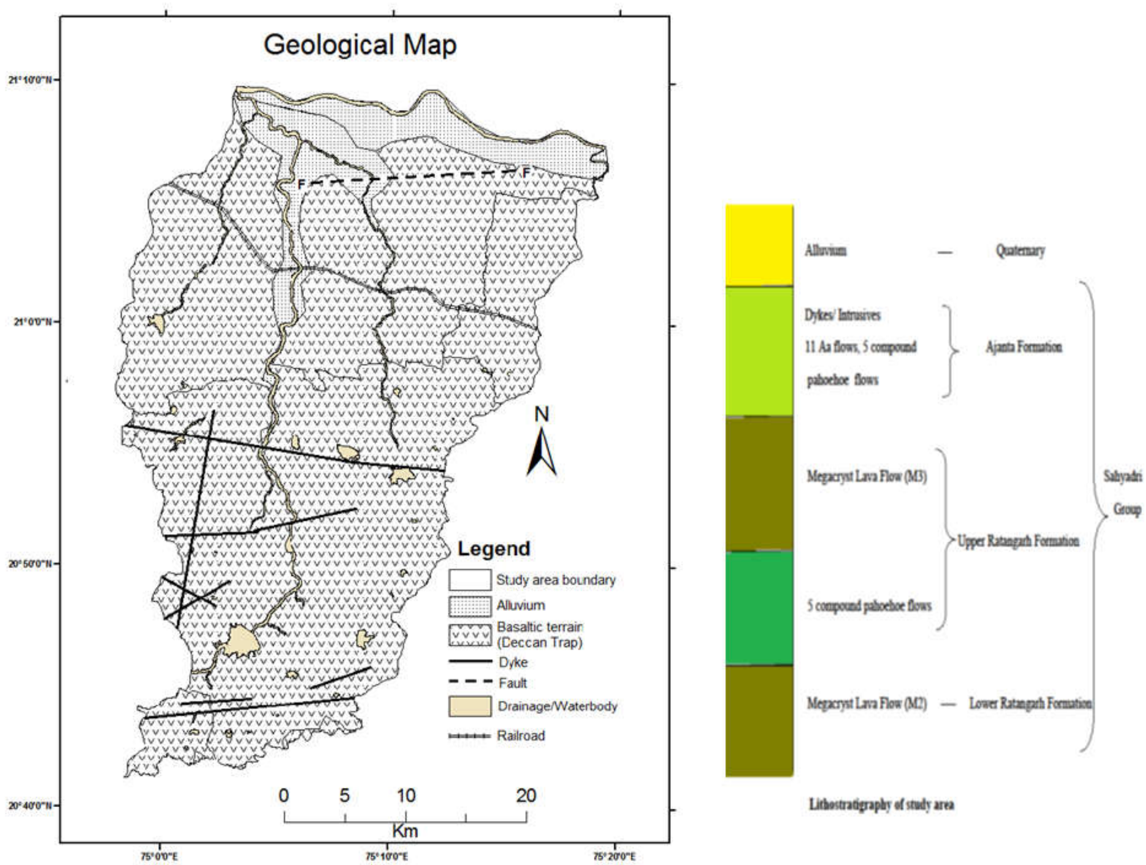

Figure 3: Geological setup of the study area.

Many small dykes of E-W trend in a study area are having sub-surface exposure, seen in dug wells near village Shevage. The lineament density ranges from 0 to0.9 km/km² and it categorized in to poor dense, moderate dense and high dense. Highest density (0.7–0.9 km/km²) is observed in the central and Northwestern parts of the study area. Areas with high lineament density are indicating good for groundwater potential.

Hydrogeology of the Area

Rock formation and structural set up of the area plays an important role in groundwater occurrence and movement. Most of the part of study area is composed from Aa flows and compound flows sequences with dykes intrusion.

The Deccan basalts form multilayered aquifer system as each flow has a top layer of vesicular basalt underlain by hard and compact massive basalt. Due to its hard nature, the occurrence and storage of ground water are very limited; as a result, the Deccan trap aquifers are moderately to poorly yielding aquifers (Varade et al., 2017).Apart from that, in a study area lineaments and intrusion of dykes also affect on groundwater occurrence and movement. Northern part of study area having thick alluvium deposition along Tapi River. Tapti's alluvium comprises of beds of clay and silt with lenses of coarse sand, gravels and pebbles, which provides good aquifer condition in study area. In the study area, there are several dykes were intruded as well as fault and lineaments are also present, these structural aspects affecting in the local region groundwater potential (Duraiswami et al., 2012).

In hydrogeological perspective, ground water in Deccan Trap Basalt occurs mostly in the upper weathered and fractured parts. At places potential zones are encountered at deeper levels in the form of fractures and inter-flow zones. The discharge from these wells varied from 0.14 to 29.16 litres per second (lps) and Static water levels are in the range of 5.20 to 140.00 m bgl(CGWB, 2009). The entire thickness of Alluvium is up to 5 m bgl(GSDA, 2012). Major NE-SW, N-S, NNW-SSE and NW-SE trending lineaments, fractures, vertical and columnar joints.

Geomorphology of the Area

Geomorphic landform plays an important role in geo-scientific groundwater exploration and exploitation. Study area shows that a hilly region towards the southern part with thin forest covered and gently undulating plains. In study area, the highest peak is having elevation of 321 m and lowest of 29 m elevation. The The low-lying flood plains of the Tapi River present towards northern part of study area. The geomorphic units of the area are broadly classified on the basis of interpretation of satellite image, SOI Toposheets, field visits and well data and by considering the relief, slope, depth and type of weathered material. Geomorphologically area is classified as alluvial plain, flood plain, habitation mask, denudational hill, structural hill, plateau and water body mask (Figure 4). Northern part of study area having Tapti's thick alluvium and flood plains. Eroded alluvial plain areas covering western part of Parola and Amalner tehsil whereas, Structural hills and plateau area present in aparts of Parola, Amalner, northern part of Chalisgaon and western part of Dharangaon Tehsil.

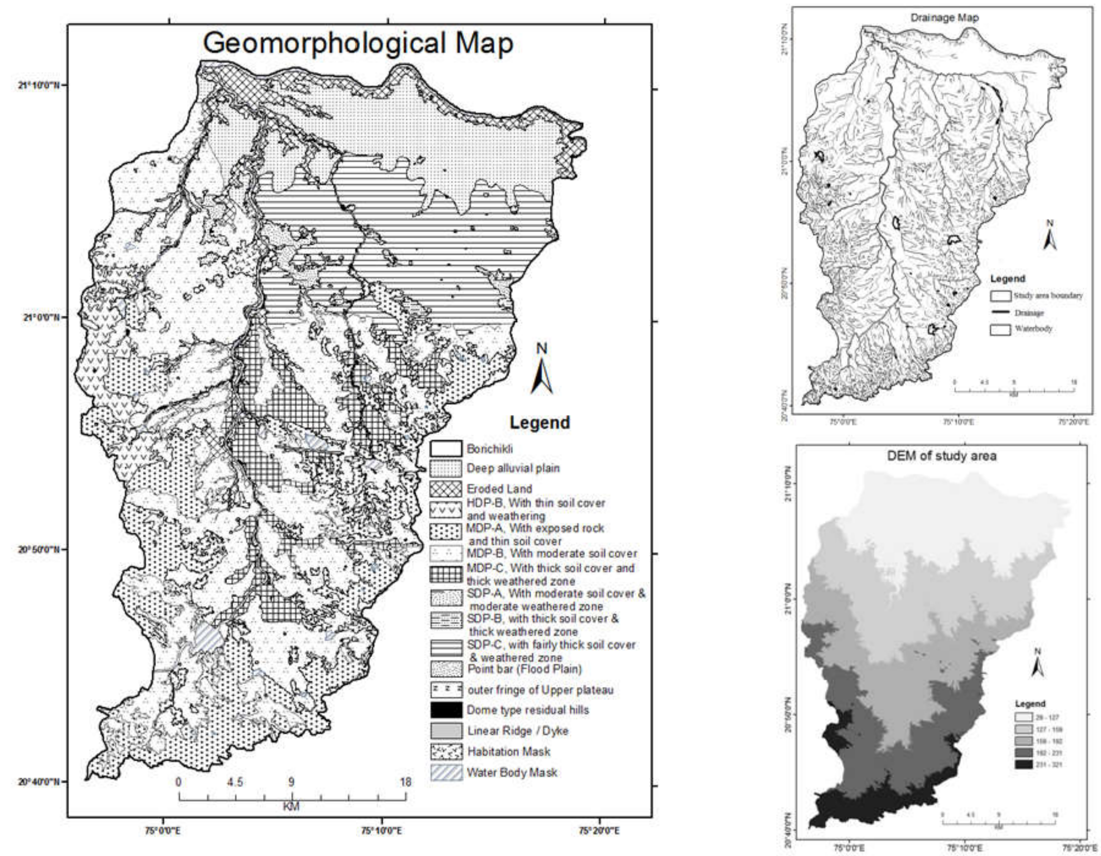

Figure 4: Geomorphic landforms in the study area.

Land Use / Land Cover

For present investigation Land use/land cover map (Figure 5) of the study area has been prepared using Digital Image Processing techniques and verified and updated by field visits and LU/LC map published by NBSS and LUP, Nagpur. In the present study area agriculture is the major activity of people. More than 70% area of the watershed comes under agricultural region. The crops are generally cotton, grams, wheat, Jowar, Bajara and Chana. About 25% area comes under deciduous forest and remaining 5% area comes under water bodies, built-up land and wastelands. Part of Hiwarkhede, Dalwel, Shewage, Shirsode, Jirali, Pimpal Bhairao, Batpuri, Kunzar, Mhasave, Mehu, Kholsar, Rajur and Hedave villages and northern fringe of study area having waste land and rest of all land is under agriculture, built-up and water bodies.

Slope

Slope has a dominant influence on the surface and subsurface water flows and control the water infiltration or percolation rate, surface runoff and erosion intensity. In study area, the maximum elevation is 321 m and the lowest point of elevation is of 29 m. In study area, southern, southern-west region of area is having steep to moderate slope gradient (5-15%) and Northern and eastern region shows gentle to very gentle slope gradient (0-3 %). The steep slope area cannot able to penetrate water up to enough depth below the upper horizon. Most of the watershed area having very gentle slope gradient (Figure 5).

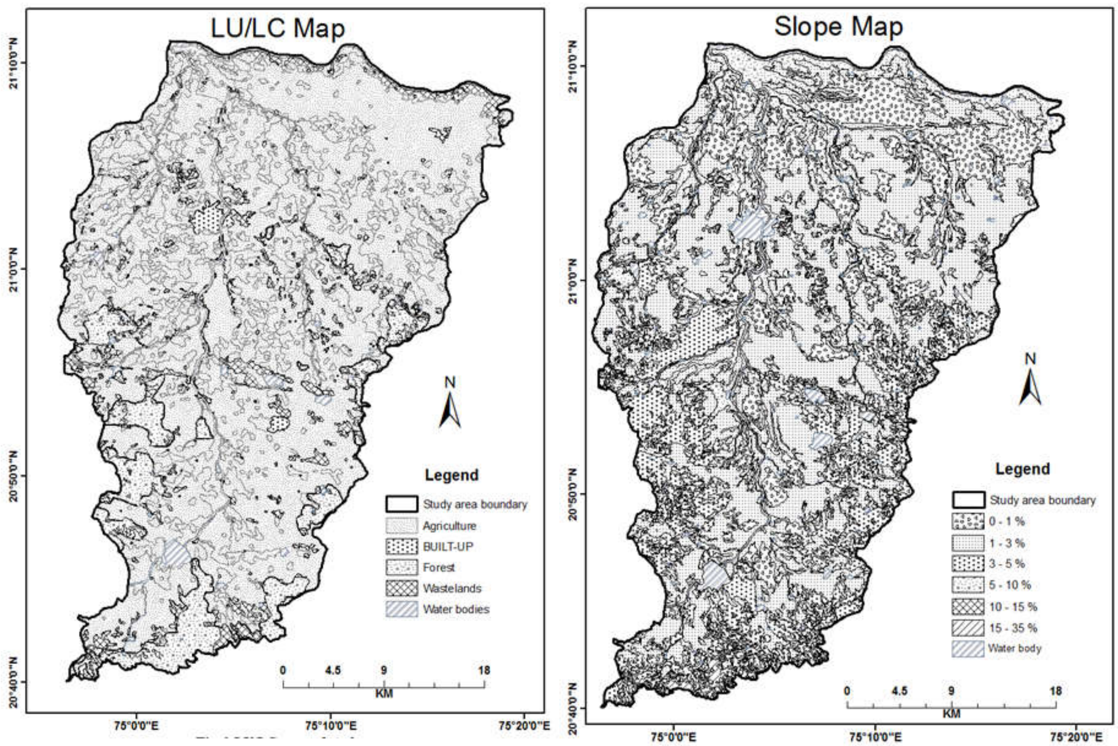

Figure 5: Land use/landcover and Slope map of the study area.

Soil Depth

Soil depth is an important factor for groundwater potential. On the basis of interpretation of satellite image, field visits and well data soil erosion of the area is classified under seven categories as Very Shallow (<10 cm), Shallow (10-25 cm), Moderatly Deep (25-50cm) , Deep (50-100cm), Very Deep (>100cm) and Water body Mask. Areas covering southern and western part of Parola and Amalner tehsil having moderately deep to shallow soil depth and northern part of study area having deep to very deep soil thickness (Figure 6).

Drainage and Drainage Density

Drainage pattern in the study area is mainly observed as dendritic drainage pattern and small patches of annular drainage pattern at few places (Figure 6). Dendritic drainage pattern is associated with areas having homogeneous lithology and very gentle and/or flat, rolling topographic surface with extremely low relief and annular drainage pattern is shown by small hillocks/mounds present in the area. According to Strahler (1964), low drainage density values occur where basin relief is low while high Dd is favored where basin relief is high. The drainage density of the study area is classified into five classes: Poorly dense (0-1.5), moderately dense (1.5–3), Moderate to Highly dense (3–4.5), highly dense (4.5–6) and Very Highly dense (6 –7. 5). High to very highly drainage density observed in southern and south-western part of the study area and low drainage density observed in northern part of the study area. Low drainage density (Figure 6) is indicative of the presence of highly permeable rocks with good groundwater potential zones and high drainage density is characterized by mounds and/or impermeable areas.

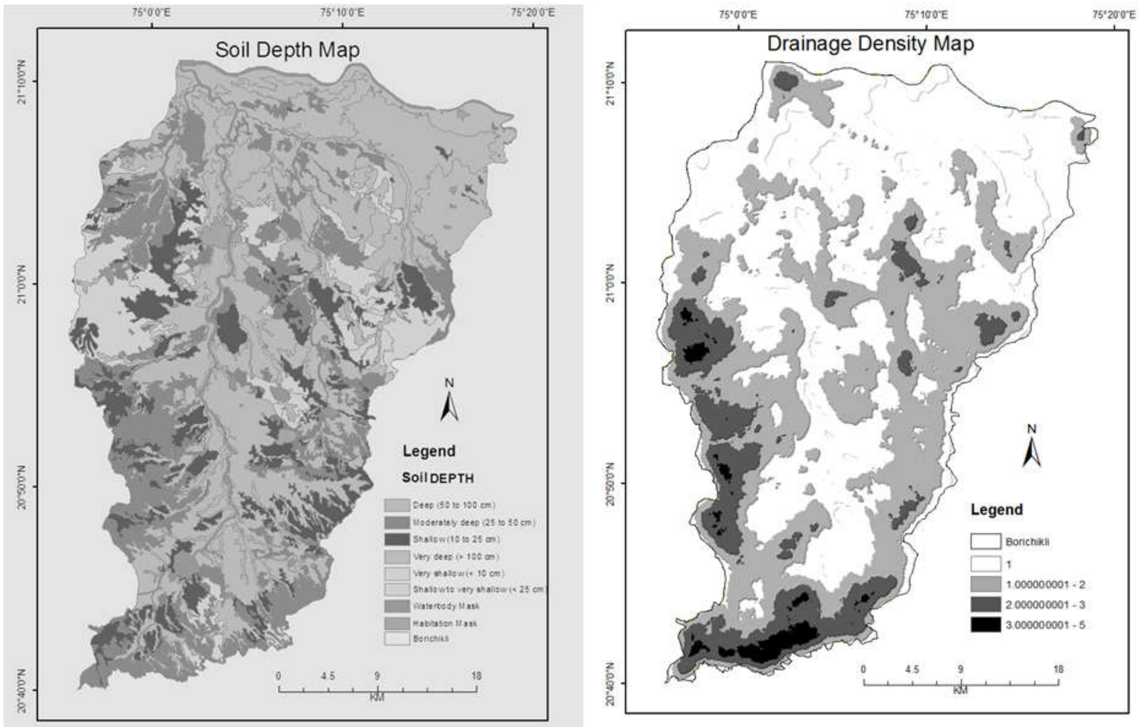

Figure 6: - Soil depth and Drainage density map of the study area.

Weighted Overlay Analysis

Based on the influence of groundwater movement and storage of groundwater each theme assigned a weightage and a knowledge base ranking. Area is mostly covered by basaltic rock and the groundwater occurrence and movement mostly depends upon the geology and structural set up of the area. In study area, geomorphology plays an important role for groundwater storage followed by slope, soil depth, land use land cover, drainage density and lineament density. The highest weightage 20 assigned to geomorphology and slope and lowest weightage of 15 assigned to the remaining other themes. Layer features with specific Ranking and weightage after considering characteristics are given in Table 1. On the basis of Weighted overlay analysis Groundwater potential zones are demarcated.

Groundwater Potential Zonation

Groundwater potential map of the area is plays an important role in detailed geo-scientific investigations for groundwater exploration and exploitation. In present research, groundwater potential map is generated by integrating thematic data and by Weighted Overlay Analysis using GIS platform.

Table 1: Weightage and ranks of different layers utilized for Overlay Analysis for Groundwater Potential Zonation

Sr. No.	Layer	Ranks*
1.	**Geology (Weightage 20 %)**	
	Alluvium	3
	Basalt	2
	Dyke	1
2.	**Geomorphology (Weightage 20 %)**	
	Alluvial Plain / Flood Plain	4
	Highly Dissected Plateau	3
	Moderately Dissected Plateau	2
	Slightly Dissected Plateau	1
3.	**Slope (Weightage 15 %)**	
	0 – 1 %	5
	1 – 3 %	4
	3 – 5 %	3
	5 – 10 %	2
	More than 10 – 15 %	1
4.	**Landuse/ Landcover (Weightage 15 %)**	
	Water bodies	4
	Agriculture Land	3
	Waste Land	2
	Built-up Land	1
5.	**Soil Depth (Weightage 15 %)**	
	Deep to Very Deep (> 100 cm)	4
	Moderately Deep (25 cm - 50 cm)	3
	Shallow (10 cm - 25 cm)	2
	Shallow to Very Shallow (< 10 cm)	1
6.	**Drainage Density (Weightage 15 %)**	
	Poorly Dense	4
	Moderately Dense	3
	Moderately to Highly Dense	2
	Highly Dense	1

(*Rank 1 indicates least important feature and higher rank is indicating most important feature for groundwater potential).

In categorized groundwater potential zones, each zone has relation to its lithology, geomorphology, drainage and hydrogeological characteristics of the study area. Excellent, Very good to good, good groundwater potential zone is characterized by low drainage density and poor, poor to moderate groundwater potential zone is by high drainage density. Maximum area of the Bori-Chikli watershed comes under moderate to good groundwater potential zones followed by good to excellent and moderate to poor and poor zones (Figure 7). The area of Tapti river alluvium is characterized by low drainage density, very gentle slope and none to slight soil erosion this condition helps it to be an excellent groundwater potential zone.

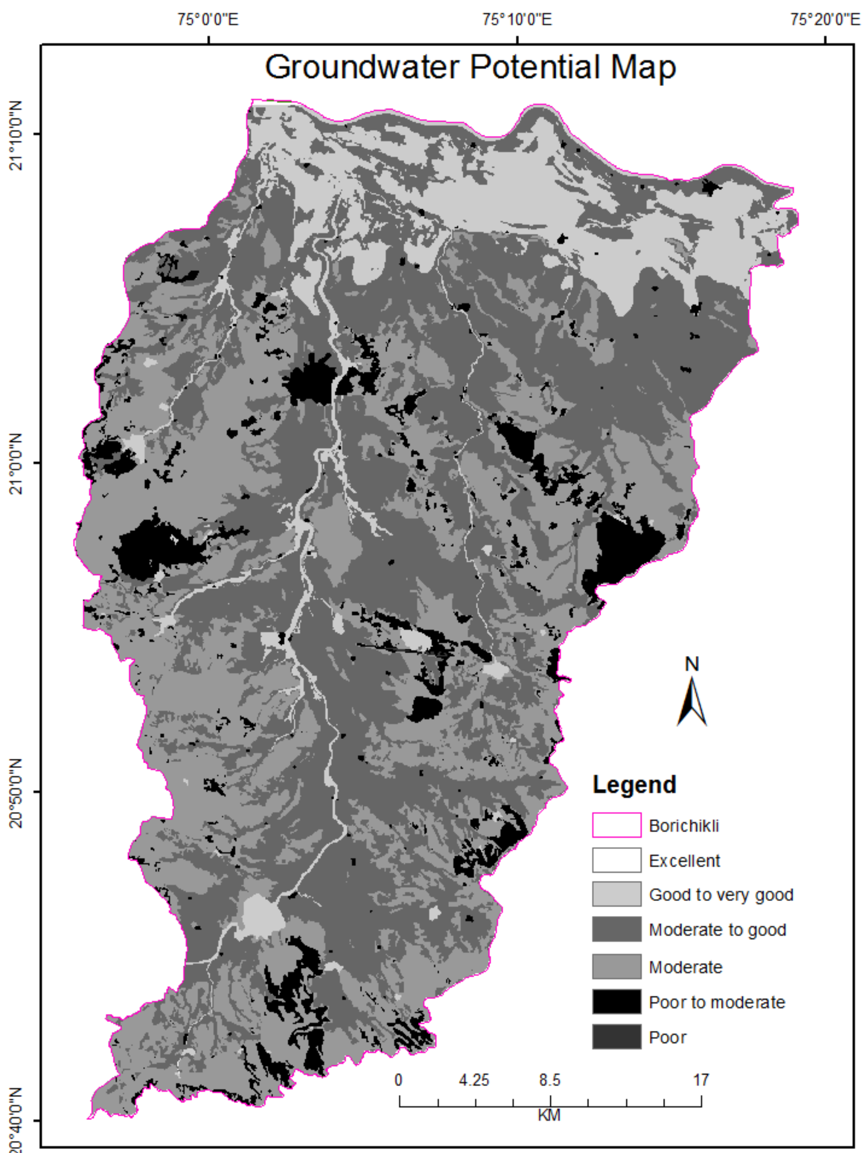

Figure 7: Groundwater Potential Zonation map of the study area.

CONCLUSION

Study area is located in the North Maharashtra region which is dominantly marked as a alluvium and basaltic flows of Sahyadri group of Deccan Trap. Present study shows that, the usefulness of remote sensing and GIS in identifying ground water potential zones in hard rock well as alluvium. Basically, this study has been established methodology for demarcation of groundwater potential zones by considering weightage overlay analysis in addition to geospatial techniques.

The upstream part of the study area is covered with hard basaltic rock which gives high slope percentage (15-35 %), high drainage density and less soil depth, whereas, the downstream part of the study area having poor to null slope percentage, low drainage density and high deposition. With poor slope, low drainage density and alluvium in downstream part of study area are found favorable for groundwater exploration and development, which also categorized into good to excellent groundwater potential zones. According to geomorphologic categorization, maximum area of the Bori-Chikli watershed is characterized by moderately dissected plateau (MDP) having moderate to good groundwater potential. In study area there are five groundwater potential zones have been identified i.e. Excellent, Very Good to Good, Good to Moderate, Moderate to Poor and Poor.

The obtained results can be used for sustainable groundwater resource development and management plan as well as it can be used for artificial recharge site suitability.

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