Identification of Groundwater Prospecting Zones in Basaltic Landscape Using Geoinformatics Techniques: A Case Study of Pora River Sub Basin, Central India

B.S. Manjare[1]*, Vineesha Singh[2], Snehal P. Motghare[1]
[1]Department of Geology RTM Nagpur University, Nagpur (MS) India,
[2]Department of Earth Sciences, Barkatullah University Bhopal M.P
*Email: yogesh_manjare1@rediffmail.com

(Received on 1 February 2023; in final form6November 2023)

***DOI**: https://doi.org/10.58825/jog.2024.18.1.57*

Abstract: Remote sensing and GIS plays a crucial role in identificationGroundwater Prospecting Zones (GWPZ) in Basaltic Landscape. In the present study GWPZ have been carried out sing hydrogeological parameter and to delineate the GPZ of Pora River sub basin in basaltic landscape Nagpur districts, India using satellite data geoinformatics. For the preparation of groundwater potential map different thematic layers viz. geology, lineaments/fracture, geomorphology, slope and land use/land cover were prepared and assigned with spatial analysis techniques in ARC GIS and assignedvalues as per their groundwater properties. From the total 122.34 km^2 area the ground water prospect zones the 30.40 km^2 area shows the good category, good to moderate is 25.86 km^2 moderate 17.59 km^2, moderate to poor 5.93 km^2, Poor 6.19 km^2, Habitation gives 35.70 km^2 and very good to good 0.43 km^2 respectively.
Keywords: Geoinformatics, GWPZ, Pora river sub basin

1. Introduction

The water below earth surface is seeps into the ground through a process of infiltration and in hard rock it is great concern because of use of ground water (Gupta and Srivastava 2010). Geoinformatics techniques are useful for gathering, storing, transforming, retrieving, displaying and analyzinggeospatial and non-spatial data (Sharma et. al., 2012. Manjare, 2020).Now a day'sground wateris very important entities in industries, social and agricultural consumptions on the earth (CGWB, 1985, Zeinolabedini, M., &Esmaeily, A, 2015). In hard rock terrains the Occurrence of groundwater is of limited extent and mainly confined to fractured/ cracks and weathered to non-weathered horizons (Uday and Kumar 2010, Manjare, 2014). Geoinformatics has proved to be anefficient techniques for urban and rural planning and ground water studies for soil and water conservation (Manjare, 2014, Manjare, 2020). The integration of Remote Sensing (RS) and GIS provides accuratedata for mapping and monitoring of natural resources and their management. The lithology, structures, geomorphology, slope, land use/ land pattern and drainage system of any landscape play very important role in movement and occurrence of ground water. (Gurugnanam et al., 2008).

The integration of hydro-geomorphological studies with other hydrogeological parameters such as structural/lineament, morphometric parameters, LULC, geology, geomorphology etchave proved to be very effective tool tofindingGWPZ in the watershed and hence integration of RS and GIS techniques is used for urban and rural planning for ground water studies for soil and water conservation.

2. Study area

The study area bounded by the 2102'15'' N to 21^{0}7'30''N latitude and 79^{0}7'20'' E to 79^{0}11'40" E longitude respectively and falls in Nagpur district of Maharashtra, Central India. The area is located in the southern part of Nagpur district with total area 647.516km^2. It is covered in the Survey of India (SOI) toposheet numbers 55O/6 on 1:50,000 scale (Figure 1). Pora river is tributary of Nag river which is originated from Ambazari lake of Nagpur district.

3. Climate and Rainfall

The climate of study area is tropical and the area receives most of the rainfall during southwest monsoon period (June to September) with mean annual rainfall of 1129.6mm. May is the warmest month with an average temperature of 35.8°C and December is the coldest month with a mean temperature of 22.3°C.The average annual rainfall for the last 10 years has been given in table 1.

Geology

Geology plays a very crucial role in the distribution and occurrence of groundwater (Krishnamurthy and Srinivas, 1995). Geologically the area is covered by Granitic gneiss with migmatites and undifferentiated basalt covered by Gondwana sandstone shale and Alluvium formation. The bottom succession of Archean age of streaky granitic gneisses with migmatites. Proterozoic meta-sediment of Sausar and Sakoli series consist of Tirodi gneissic complex (seen near Hudkeshwar). The area overlained by Undifferentiated Basalt found in Nagpur district. Basaltic rocks in the study area shows dark with fine grained texture showing compact and massive surface. The Gondwana rock unconformably over the older formation such as Archean and are overlained by Undifferentiated basalt. The chief rock types are Conglomerate, Sandstone, Shale and Limestone. Sandstone with medium to coarse grained with gritty conglomeratic band and interrelated ferrugenous Shale.

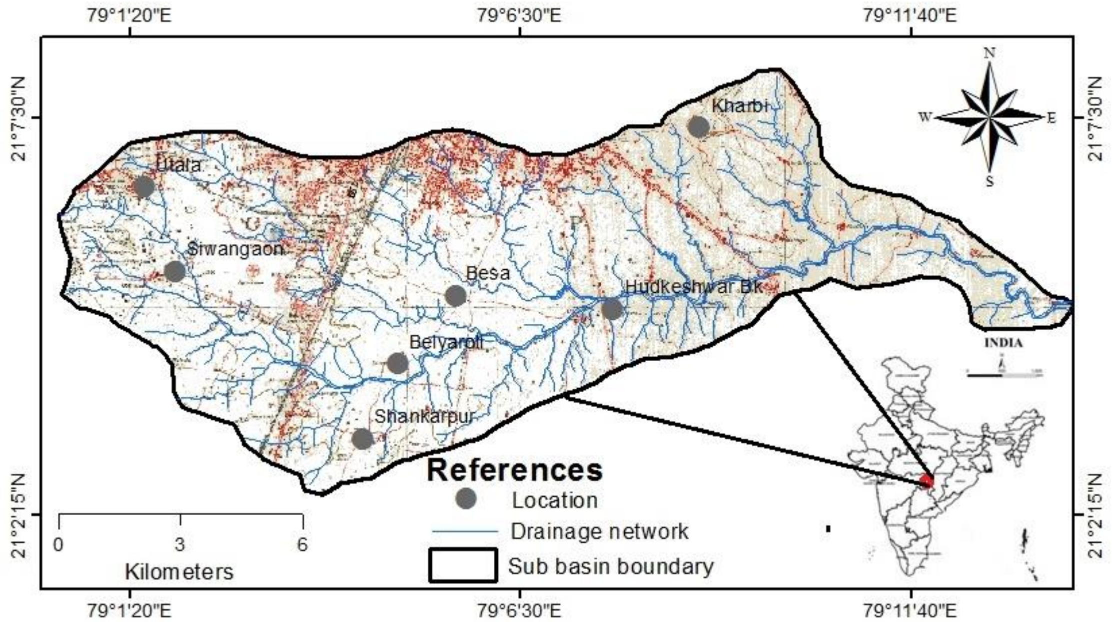

Figure1. Location and topomosaicmap of study area

Table 1. Average annual Rainfall data study area (2002-2011)

Tahasils	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average Rainfall
Nagpur Gramin	1229	689	1274.7	1205.5	966.3	953.2	947.4	1494.7	913.8	1064.0
Umrer	1296.8	747.1	1856.3	1014.2	1464	1060.36	926.2	1551.2	887.1	1164.9
Bhiwapur	1146.3	740.4	1431.2	1045.6	1341.8	853.2	993.7	1690.1	1088.4	1125.4

(Source:www.agri.mah.nic.in)

The top Gondwana formation of sandstone and shale covered by Alluvium formation which is black cotton soil with silt and clay seen by near kharbi area (Figure 2a).

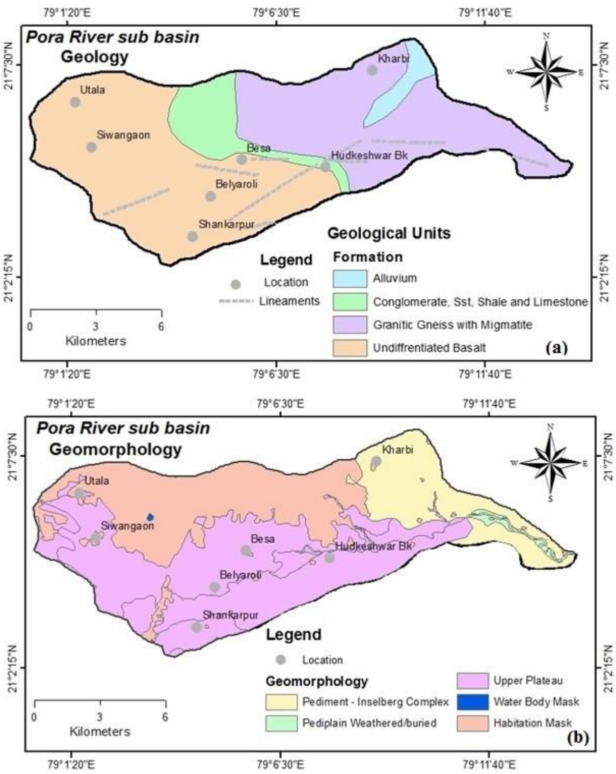

Figure 2. Geology (a) and geomorphology (b) map of the study area

Geomorphology

Geomorphologicalthe northeast side of the study area are forms the slightly weathered and moderately buried Pedi plains.Most of the part of the north-east Nagpur forms Pediment -Inselberg Complex. Part of the area comes in Nagpur covers most of the Habitation mask geomorphological feature, surrounded by pediment zone from east and then by upper plateau from southern direction. The Pora River along with the Dora river are the right bank tributaries of the Nag River. The pattern of drainage is dendritic to sub-dendritic (Figure 3a).

4. Methodology and data used

The Indian Remote Sensing Satellite LISS-III of 23.5 m of spatial resolution has down loaded from Bhuvan Website and rectified and registered with SOI topographical maps on 1:50000 scale using ARC GIS 10.6 software with digital image processing techniques. The false colour composite generated from green, red and near infrared (NIR) spectral bands (2, 3, and 4) (Figure 3b). SRTM DEM of 30 m. spatial resolution has been downloaded from USGGS website with single pass, synthetic aperture radar interferometry (InSAR) of February 2000. Satellite imagery has been used for better interpretation of the geological, geomorphological, land, slope, lineaments and ground water information of the study area. All the data then analysed in the ARC GIS

10.6 software and produce the different thematic layers for preparation of the GWPZ map of the study area.

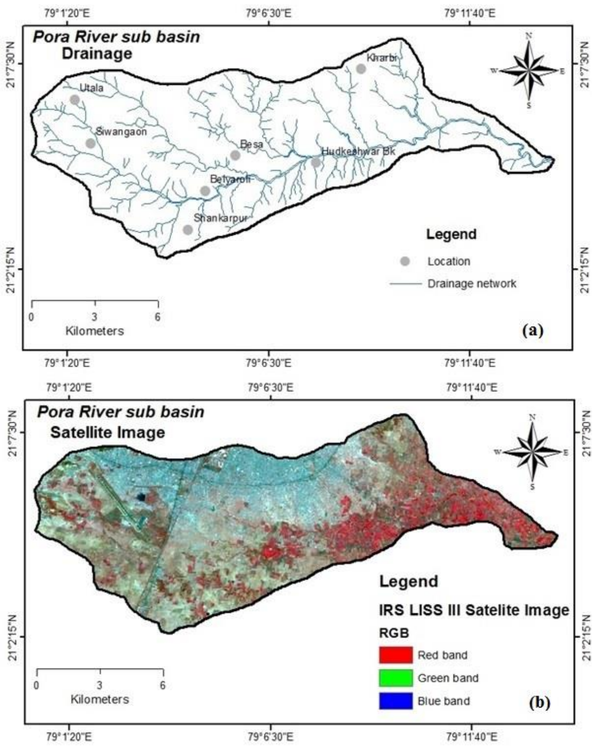

Figure 3. Drainage (a) and FCC image (b) map of the study area.

Data Integration and overlay analysis in GIS environment

With the help of generated thematic layers and combination of the thematic layers overlay in the vector and raster overlay analysis techniques and order the classes using Analytical Hierarchy Process (AHP) tool final GWPZ map of the study area.

By taking the weightage of different units of ground water condition seven groundwater prospect zones (i) poor to nil, (ii) poor, (iii) moderate to poor, (iv) moderate to good and (v) good, vi) good to moderate and vii) Very good have been prepared with statistics of different ground water prospect zones.

Slope mapping

The slope map has been prepared from SRTM DEM of 30 m spatial resolution and. categorized into seven classes as per the National Remote Sensing Centre Guidelines (NRSA, 1995). The elevation in the study area ranges from 256 mto 605 m (Figure4a). While slope shows the level to nearly level, gentle, moderate and steep slope class. In the given study area level to gentle slope and western part of the study area shows the small patch of the steep slope (Figure 4b).

LULC Mapping

The LULC map has been prepared by using satellite image with supervised classification for identification of vegetation cover using different band ration. Satellite image also used to identify different objects related to urban area based on visual interpretation techniques. Based on the supervised classification different LULC units have been extracted (Figure 5 and table 2). In the LU/LC mapping the area is divided in the barren rock, crop land, deciduous land, fallow land, land with scrub, without scrub plantation, settlement and water. They are crop land (57.45km$^{2)}$, fallow land(14.34km^2), land with scrub (1.50km^2) land without scrub(7.64km^2), plantation(0.38km^2), tanks (0.06km^2), Town/cities(36.76km^2) and villages(1.90km^2). Broadly the crop land is situated in the eastern part whereas towns are in western and central parts of the study area (Figure 5a).

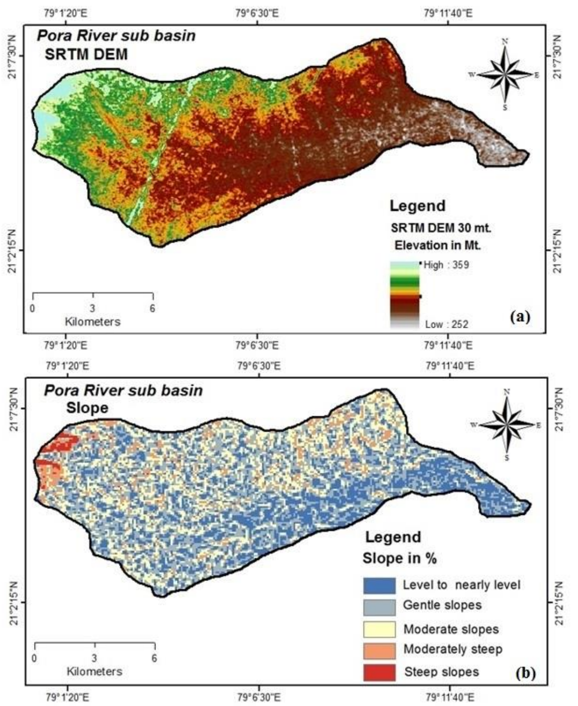

Figure 4. (a) SRTM DEM 30 m spatial resolution (b) and slope (c) map of the study area.

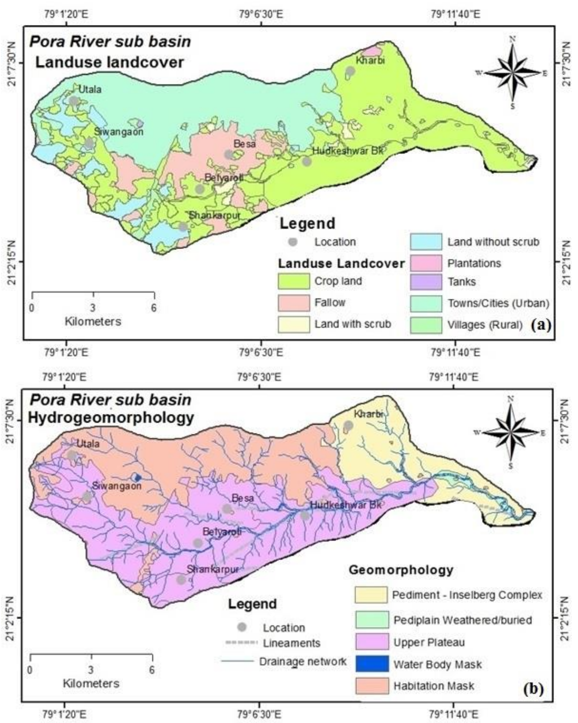

Figure 5.a) Landuse/landcover (b), hydro-geomorphological map of the stud area.

Table 2. LanduseLandcover units of the study area

Sr.No.		Area in sq.km
1.	Crop Land	57.48
2.	Fallow	14.34
3.	Land with scrub	1.508
4.	Land without scrub	7.64
5.	Plantations	0.388
6.	Water Tanks	0.065
7.	Towns/ Cities (Urban)	36.76
8.	Villages (Rural)	1.904

Hydro-geomorphological setup of the study area

When Hydro-geomorphological information linked with hydrogeological analysis and structural/lineament or fractures with integration of RS and GIS technology touse to delineate the GWPZ identification (Agrawal and Mishra 1992, Bhattacharya et. al., 1997, Manjare, 2017).

The water storage capacity of the rock formationsmainly depends on the available porosity and permeability of the rock strata. The movement of ground water basically takes place from areas of recharge to areas of discharge under the influence of hydraulic gradients and hydraulic conductivity and permeability of the rock strata.For the preparation of the GWPZ map different thematic layers such as linements, geomorphology, geology, slope, topography or landscape has been used. In the study area the hydro-geomorphological map shows the overall representation of the different thematic layers to identify the GWPZ the study area (Figure 5b).

Structure/Lineament Setup

Lineaments are defined as linear geological surface features that differ distinctly from the patterns of adjacent features and topographic reflection with the dynamics of the sub surface phenomenon (O'Leary et al. 1976). Lineaments may be formed by the caused by the linear alignment of regional morphological features such as streams, escarpments, and mountain ranges and tonal features that in many areas are the surface expressions of fractures or fault zones.Satellite images now days extremely used to extract lineaments by using different digital image processing techniques such as edge enhancement techniques with different wavelength intervals of the electromagnetic spectrum (Lillesand and Kiefer, 1994). Now days the lineament is important for studies related to tectonics, engineering, geomorphology and in the exploration of natural resources such as groundwater, petroleum and minerals (Koopmans, 1986, Kar 1994, and Philip, 1996). The lineament of the study area isbeing extracted by using satellite image andsuperimposed on the geological map which shows the north east south west trends (Figure 5b).

Ground water prospect

In the given study areaGWPZ map is prepared using different thematic layers such as hydro-geomorphic, lineament, geological, slope and drainage etc. By overlying all these maps, a with actual ground check on ground water table level, well yield, geomorphic units, as result hydro-geomorphological map. Different geological formations resulted in to various land formswhich have different water holding capacity, porosity, permeabilityand aquifer qualities. With generated all thematic maps and giving proper weightage topographic and geologic units GWPZ in to seven categories such as good, good to moderate, moderate, moderate to poor, poor, poor to nil and Very good to good. The area statistics of different ground water prospect zones are given in table 3. From the total 122.34 km^2 area the GWPZ the 30.40 km^2 area shows the good category, Good to moderate is 25.86 km^2, Habitation is 35.70 km^{2}Moderate 17.59 km^2, Moderate to poor 5.93 km^2, Poor 6.19 km^2, Poor and Very good to good 0.43 km^2 respectively. The majority of the Pora river sub basin area shows the good, good to moderate and moderate GWPZ (Table 3 and Figure 6).

Table 3. Area wise statistics of different ground water prospect zones identified in the study area.

Sr.No	GWPZ	Area in sq,km	%
1	Good	30.401979	24.849957
2	Good to moderate	25.861872	21.138966
3	Moderate	35.708624	29.187500
4	Moderate to poor	17.591834	14.379206
5	Poor	5.931586	04.848357
6	Very good to good	6.195077	05.063792
7	Habitation	0.435331	0.355830
8	Water body mask	0.215874	0.176451
9	Total Area	122.342177	

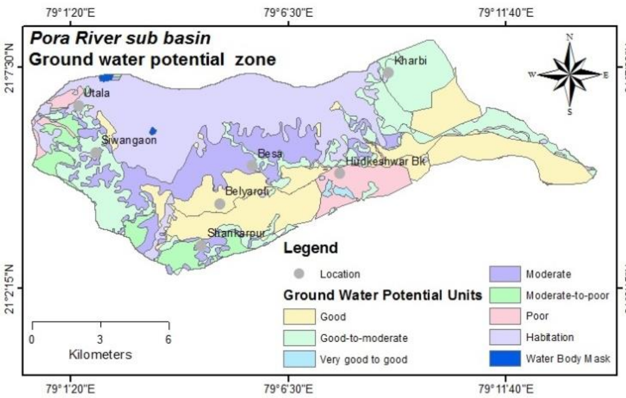

Figure 6. GWPZ map of the stud area.

Conclusion

For the preparation of groundwater potential map different thematic maps viz. geology, primary structures, geomorphology, and relief were used and assigned with differential weightage values as per their groundwater properties.In the study area groundwater is primarily controlled by rock type, primary structures, geomorphology, relief and drainage density. The integration of all the thematic maps e.g. lithology, primary structure, geomorphology and hydrology, with filed studies ground water potential zones were generated and classified.The integrated GWPZ map in the study area has been categorized into seven classes on the basis of the cumulative weightage of the thematic maps. From the total 122.34 km^2 area the ground water prospect zones the 30.40^2 km area shows the good category, good to moderate is 25.86^2 km^2moderate 17.59 km^2, moderate to poor 5.93 km^2, Poor 6.19 km^2, Habitation gives 35.70 km^2 and very good to good 0.43 km^2 respectively. The majority of the Pora river sub basin area shows the good to moderate ground water potential zone. The final ground water prospect map could be used for different purposes like location of drinking water wells, irrigation tube wells, bore wells and other management of groundwater etc.

References

Agrawal A. K. and D. Mishra (1992). Evaluation of Groundwater Potential in the Jhansi city, Uttar Pradesh Using Hydro-geomorphological Assessment by Satellite Remote Sensing Technique. Journal of Indian Society of Remote Sensing, 20{2&3): 121-128.

Bhattacharya A. K., T. K. Kurien, K. krishnanunni and D. N. Sethi (1979). Geomorphic Mapping in Parts of Kerala State. Journal of Indian Society of Remote Sensing. 7(1): 1-9.

Central Ground Water Board (CGWB), (1985). Report on hydrogeology and groundwater potential of Mirzapur district U.P.

Gupta M. andP. K. Srivastava (2010). Integrating GIS and remote sensing for identification of groundwater potential zones in the hilly terrain of Pavagarh, Gujarat, India. Water International, 35(2), 233–245.

Gurugnanam B., N. Prabhakharan,M. Suvetha, S. Vasudevan andB. Gobu (2008). GeographicInformation technologies for hydro-geo-morphologicalmapping in parts of Vellar Basin, Central Tamilnadu.Jour. Geol. Soc. India, 72, 471-478.http://srtm.csi.cgiar.org)

Kar A. (1994). Lineament Control on Channel Behaviour During the 1990 Flood in the South-eastern Thar Desert. Int. Jour. of Remote Sensing, 15, pp.2521-2530.

Koopmans B.N. (1986). A comparative study of lineament analysis from different remote sensing imagery over areas in the Benue Valley and Jos Plateau Nigeria. Int. Jour. of Remote Sensing, 7, pp.1763-1771

Krishnamurthy J. and G. Srinivas (1995). Role of geological and geomorphological factors in groundwater exploration: a study using IRS LISS data. Int J Remote Sensing 16(14): pp 2595–2618

Lillesand T.M. and R. W. Kiefer(1994). Remote Sensing and Image Interpretation (New York: Wiley), 750pp.

Manjare, B. S., 2014. Identification of groundwater prospecting zones using Remote Sensing and GIS techniques in Upper Vena River Watersheds Nagpur District, Maharashtra, India. In 15th ESRI India User Conference. PP. 1-14.

Manjare B. S. (2017). Identification of groundwater prospecting zones in hard rock terrain using Remote Sensing and GIS techniques: a Case Study of Jam River Sub Basin Central, India Journal of Ind. Geol. Cong. June 2017, Vol.09. No.1, pp.37-43.

Manjare B.S. and Pophare A.M. (2020). Identification of Groundwater Prospecting Zones in Morna River Sub-Basin, Central India Vol. 5, No.2, July, 2020, pp. 139-145

NRSA (1995). Integrated Mission for Sustainable Development Technical Guidelines, National Remote Sensing Agency, Dept. of Space, Hyderabad.

O'Leary D.W., J. D. Freidman andH. A. Pohn (1976). Lineaments, linear, lineation-some proposed new standards for old terms. Geological Society of America Bulletin vol. 87, pp.1463-1469.

Philip G. (1996). Landsat Thematic Mapper data analysis for Quaternary tectonics in parts of the Doon Valley, NW Himalaya, India. Int. Jour. of Remote Sensing, 17, pp.143-153.

Sharma M. P., A. Kujur andU. Sharma (2012). Identification of groundwater prospecting zones using Remote Sensing and GIS techniques in and around Gola block, Ramgargh district, Jharkhand India. International Journal of Science and Engineering Research, 3(3), 1–6.

Uday K. and B. Kumar (2010). Ground Water Targeting in Hard RockTerrain using Remote Sensing Techniques in Sanjai River Watershed,Jharkhand, Abs. Regional Workshop on Exploration, Development andManagement of Ground Water in Hard Rocks with special reference toJharkhand State.

Zeinolabedini M. andA. Esmaeily (2015). Groundwater potential assessment using geographic information systems and AHP method (case study: Baft city, Kerman, Iran). International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 40(1W5), 769–774.