Short communication

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Delineation of Groundwater Recharge Sites Using Remote Sensing and GIS of Nagpur Region

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The geo-informatics technique is mainly applied through interpretation of satellite data alongwith use of collateral data. Geo-informatics is a tool which can be used for rapid and cost-effective assessment, planning, monitoring and management of precious natural resources like groundwater. Integration of multi-temporal and multi-sensor data covering large and inaccessible area within short span of time has been emerged as a essential tool for collection, storing, transformation, retrieval, display and analysis of spatial data with particular reference of real world, such as place, use, purpose, *etc*. Nowadays Geographic Information System (GIS) is being used extensively for variety of purposes such as evaluation of ground and surface water resources, feasibility of groundwater recharge sites, identification of contaminated sites, land use- land cover pattern, *etc.* In recent years several researchers have successfully applied remote sensing and GIS technique for mapping groundwater potential (Mishra *et al*. 2010; Hutti and Nijagunappa 2011; Kumar and Kumar 2011;Sharma *et al.* 2012; Patil *et al*. 2013). The present study focuses on the assessment of groundwater recharge. To estimate groundwater recharges, it is essential to delineate potential recharge zones of groundwater (Murugiah and Venkatraman 2013).

The groundwater is a precious natural resource, mainly used for the domestic and agriculture purposes. Hence, in order to ensure a sensible use of groundwater, its proper assessment and management is imperative. In past, the remote sensing and GIS have been used for estimation of groundwater. (Krishnamurthy *et al*. 2000; Shahid *et al*. 2000; Khan and Moharana 2002; Jaiswal *et al*. 2003; Rao and Jugran 2003; Sikdar *et al*. 2004; Sener *et al*. 2005; Ravi Shankar and Mohan 2006; Solomon and Quiel 2006).

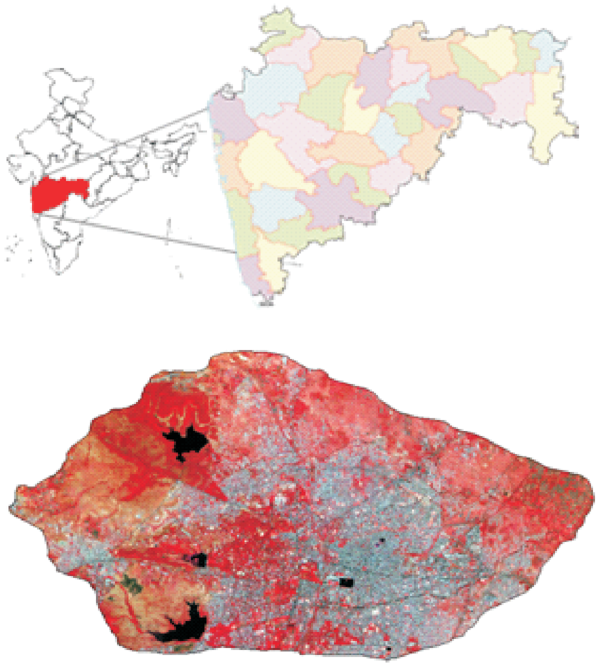

Fig 1. Study Area

The study area was the watershed of Nag Nadi in Nagpur district. The main occupation in this region is agriculture which highly depends on groundwater resources. The aim of the is to delineate the groundwater recharge zones of the watershed. Nagpur district (21° 41' N to 20° 35' N; 78° 15' E to 79° 45' E) is situated in the

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eastern parts of Maharashtra State, India. The study area is covered by the Survey of India (SOI) Toposheets of 55 K/16 and 55 O/04 (Fig. 1). Survey of India (SOI) Toposheets (1:1,00,000) 55 K/16 and 55 O/04 were collected from Survey of India, Nagpur. Soil information of the study area at 1:1,00,000 scale were collected from the Regional Remote Sensing Center-Central (RRSCC) Nagpur, Maharashtra. The pre- and post- monsoon groundwater data is collected from Central Ground Water Board Nagpur.

In the present study, to delineate the groundwater recharge zones of the study area, a multi parametric dataset comprising satellite data, Google Earth data and conventional maps including Survey of India (SOI) topographic sheets was used. Since, the satellite image or aerial photography may lack spatial reference information and hence the data does not align properly with other data set. Thus, it is needed to define them with standard map coordinate system. Geo-referencing involves assigning coordinates of ground control points to the reference points on the image. The Projection system used was WGS 1984 UTM 44N. The data from the geo-morphological and hydrological map overlays have been integrated and transferred on to the base map to prepare the ground water prospects map on 1: 2,50,000 scale. Further, ground water recharge sites are estimated using five categories zones *viz.* 'Very poor', 'Poor', 'Moderate', Good', 'Very Good' from groundwater recharge potential point of view.

The groundwater fluctuation is calculated by taking the difference between pre- and post- monsoon water level of the wells using the following equation:

$$\Delta L = \text{Pre- monsoonof the groundwater level} - \text{Post- monsoon of the groundwater level} \quad \ldots(1)$$

The Central Ground Water Board (CGWB), Government of India, New Delhi has suggested the concept of exploitable dynamic groundwater reserve, to estimate the aquifer yield (specific yield) with proper accuracy. The dynamic groundwater reserve actually represents the long-term average annual recharge under conditions of maximum groundwater use. Using this concept, the aquifer yields of delineated groundwater potential zones were estimated by using the following equation (CGWB 1984)

$$GWR = A_i \times \Delta L \times S_y \quad \ldots\ldots..(2)$$

Where, GWR is groundwater recharge (MCM), S_y is specific yield, A_i is area of geological formation if $i^{th}(m^2)$, and i^{th} is geological formation present in the watershed of Nag Nadi.

Average annual groundwater fluctuation was calculated using pre and post- monsoon groundwater level data of 5 years (2011-2015) collected from 28 sites of the watershed. Afterword, these fluctuations will be multiplied by area of geological formation present in the watershed area.

$$\Delta S = A \times \text{Avg wt } S_y \times \text{Avg wt. } \Delta L \quad \ldots.. (3)$$

Where, ΔS = Net recharge,
ΔL = difference in pre and post- monsoon groundwater level data, (m bgl)
S_y = Specific yield, A = Total area of watershed, (Km^2),

$$\text{Avg wt } S_y = \frac{Ai \times Sy}{A} \quad (4)$$

$$\text{Avg wt } \Delta L = \frac{Ai \times \Delta L}{A} \quad (5)$$

The entire watershed was delineated into the potential zones of groundwater recharge and depending on the values determined by the equation (3), these zones are classified as "very good" to "very poor". A map of average groundwater level decline is prepared using ArcGIS software. The potential zone map of the groundwater recharge zone was then superimposed on map of the average groundwater level decline in ArcGIS environment to determine the minimum and maximum values of average groundwater decline in each zone.

The watershed boundary, water bodies and streams were delineated by using Spatial Analyst of Arc GIS 10.3.1 (Fig. 2), Deccan trap covers most of the Nag Nadi watershed (84.77 km^2 which is 44.21 per cent of total area) comprising basaltic lava flows with inter-trapping beds and Lameta formations containing sandstones, siltstones and various clays (Table 1 and Fig. 3). The watershed forms part of the Deccan Plateau, having flat-topped and terraced features. The Granite Gneiss covers 57.27 km^2 (29.86 per cent of total area) followed by Lameta group (limestone, Sandstone) of about 35.56 km^2 (13.33 per cent of total area) and Alluvium (recent geology) of 23.74 km^2 (12.83 per cent of total area).

Table 1. Geological formation present in the Nag Nadi watershed

Sr. No.	Classes	Area (km^2)	Percentage
1	Alluvium (Recent Geology)	23.75	12.38
2	Deccan Trap (Massive Basalt)	84.77	44.21
3	Granite gneiss with migmatite	57.27	29.87
4	Lameta Group (Limestone, Sandstone)	25.57	13.33
5	Valley	0.38	0.20

The entire watershed is delineated into five classes from 'very poor' to 'very good' potential zones of groundwater recharge (Table 2 and Fig. 4). About 104.93 km^2 area (54.72 per cent of total area) of the watershed comes under the "Moderate" class of potential zone for groundwater recharge followed by "Very good" (24.78%), Good (18.26%) and "Poor" (1.22%) (Table 2). However, "very poor" class of potential has an area of 1.91 km^2 (0.99%). Thus, the watershed has very good potential (more than 70% of the total area) for groundwater recharge. These potential zones are surrounded by the river system and rainfed agricultural land in the north eastern portion of the watershed

Table 2. The classification of groundwater potential zones in Nag Nadi watershed

Sr. No	Potential Zones	Area (Km^2)	Percentage
1	Very Good	47.53	24.78
2	Good	35.03	18.26
3	Moderate	104.93	54.72
4	Poor	2.34	1.22
5	Very Poor	1.91	0.99

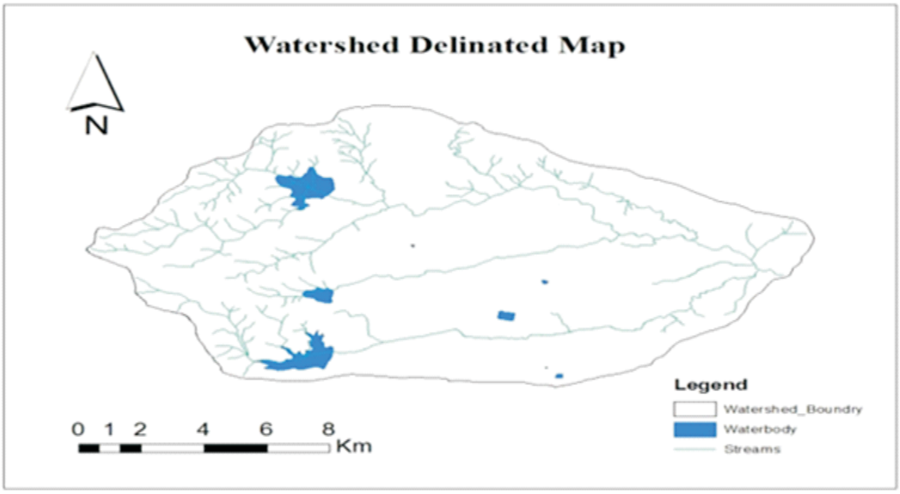

Fig. 2. Delineation of watershed boundary, water bodies and stream network

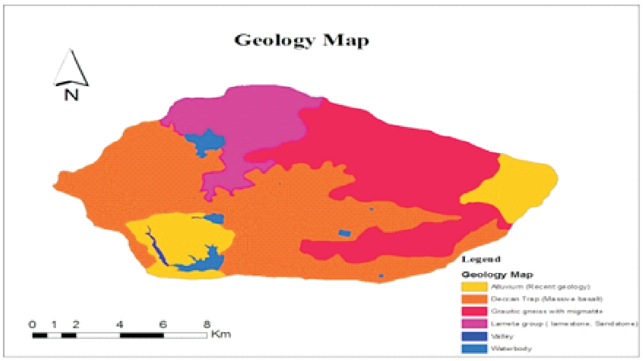

Fig.3. Geology Map for Nag Nadi watershed and stream network

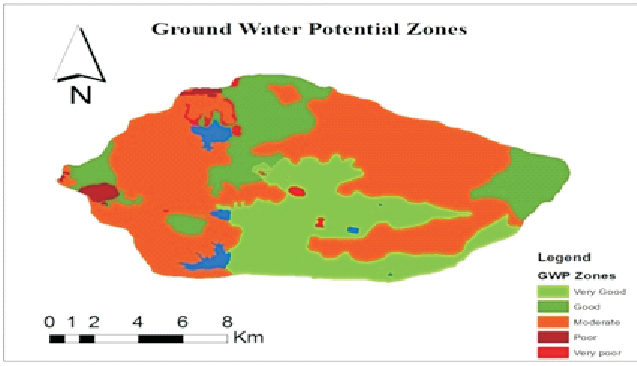

Fig. 4. Groundwater potential zone map of Nag Nadi watershed

The average groundwater level fluctuations were found to be 2.14, 1.86, 1.99, 1.54 and 1.32 during 2011, 2012, 2013, 2014 and 2015, respectively.

The estimation of the groundwater recharge was estimated using the groundwater fluctuation levels and specific yield of the aquifer. It was observed that for the Deccan trap, the highest groundwater recharge was found to be 4.475MCM in the year of 2011 and the lowest was 2.441 MCM in 2015 (Table 3). In the watershed, the Deccan trap covers maximum area. 0.419, 0.504, 0.899, 0.383 and 0.498 MCM for the geology of Lameta group, the highest groundwater was 0.899 MCM in the year of 2013 and the lowest was 0.383 MCM in 2013 and 2014. For the entire watershed, the total groundwater recharge (all geological formations together) were 8.300, 7.766, 8.657, 5.677 and 5.521 MCM in the year 2011, 2012, 2013, 2014 and 2015, respectively (Table 3 and Fig. 5).

Table 3. Total groundwater Recharge during 2011 to 2015 for Nag Nadi watershed

Formations / Year	**Groundwater Recharge (MCM)**				
	2011	**2012**	**2013**	**2014**	**2015**
Deccan	4.468	3.240	3.130	2.546	2.441
Gneiss	2.321	2.906	2.995	2.084	1.727
Lameta	0.418	0.504	0.899	0.383	0.498
Alluvium	1.093	1.116	1.634	0.665	0.855
Total	8.300	7.766	8.657	5.677	5.521

The net groundwater recharge was calculated from 5 years (2011-2015) pre- and post- monsoon groundwater level data of 28 wells and using equation 3. The net groundwater recharge were found to 8.240, 7.720, 8.667, 5.647 and 5.511 MCM during the year 2011, 2012, 2013, 2014 and 2015, respectively (Table 4 and Fig. 6).

Table 4. Net Recharge during 2011 to 2015 for Nag Nadi watershed

Sr. No	**Year**	**Net recharge (MCM)**
1	2011	8.240
2	2012	7.720
3	2013	8.667
4	2014	5.647
5	2015	5.511

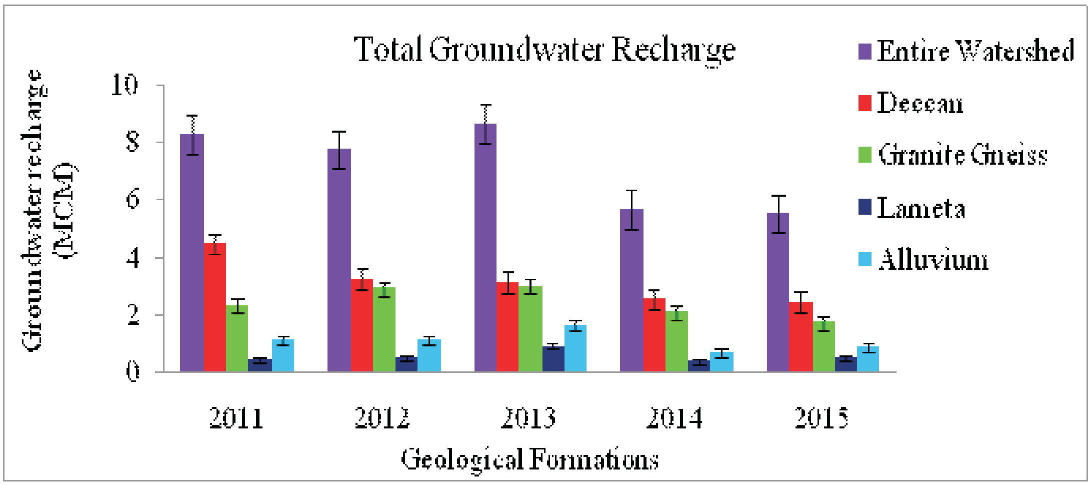

Fig. 5. Total groundwater Recharge during 2011 to 2015 for Nag Nadi watershed

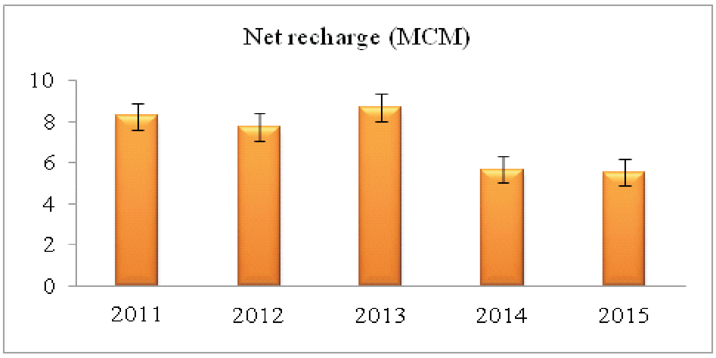

Fig. 6. Net groundwater recharge during 2011 to 2015 for Nag Nadi Watershed

The Nag Nadi watershed has five types of geological formations dominated by the geology of Deccan trap which covers 84.77 km^2 (44.21%) followed by lameta group (29.86%), granite gneiss (13.33%) and Alluvium (12.38%). The entire watershed has been delineated into five classes of potential zones, *viz.,* "Very good, "Good", "Moderate", "Poor" and "Very poor" and the "Moderate" potential zone covers maximum area of 104.93 km^2 (54.72%) and "Very poor" potential zone has an area of 1.91 km^2 (0.99%). The watershed has very good potential for groundwater recharge. The highest and lowest groundwater recharge were observed as 15.27 MCM in the Deccan trap and 1.29 MCM in Lameta Group. The highest total groundwater recharge calculated to be 8.657 MCM in the year 2013 and the lowest was 5.521 MCM andin 2015. The net recharge was estimated maximum as 8.667 MCM and minimum as 5.511 MCM in the year 2013 and 2015, respectively.

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