Geospatial Data Integration For Groundwater Recharge Estimation In Hard Rock Terrain

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Abstract

The declining trend in groundwater table all over the world has posed the community to adopt suitable techniques for groundwater recharge estimation and induce runoff to subsurface. The recharge estimation in the present study has utilized all the impact parameters, which have been extracted from the remotely sensed data and derived as collateral information. The recharge calculation has been done on the basis of the coefficients derived through spatial analysis. The 'Weight Average Method' has been adopted for recharge estimation. To achieve the objective, different layers pertaining to various parameters have been generated and integrated. In Weight Average Method, weights have been assigned to various classes of different parameters like geology, geomorphology, slope, lineament density, soil type and runoff, according to the importance of these classes supporting groundwater recharge. After assigning weights to different parameters mentioned above, all the parameters have been integrated through overlay analysis and final map of estimated recharge has been generated. The results obtained shows that the methods of assigning weights to different parameters according to their importance in groundwater recharge and integration of various parameters proves to be more accurate for groundwater recharge estimation in the present study.

1. Introduction

Groundwater recharge is the process of movement of surface water to subsurface. In hard rock areas, the hydrogeological and hydrological units normally coincide, which may not be the case in alluvial areas where the aquifers traverse the basin boundaries. In hard rock areas, which occupy about 2/3-rd area of the India, assessing the ground water on watershed as a unit is more desirable. In the present study the groundwater recharge has been calculated in hard rock terrain of Bhandara District of Maharashtra State, India.

Ranking of the impact parameters within the integrated approach is an important factor, which also decides the accuracy of the results. This ranking can be achieved by several methods and may be based on individual's assumption and experience. The overlay analysis may be performed by directly adopting the qualitative characteristics (Sarkar et al. 2001) while quantitative values may be adopted to decide the contribution of the interacting parameters (Murthy et al. 2003). Several other workers have attempted the derivation of the regional parameters using the simple overlay techniques of more than one theme to generate the groundwater recharge characteristics in different areas (Srivastava et al. 2000). Also, groundwater estimations have been attempted using the rank as well as score method (Kamleshwar et al. 2000). But, the results obtained have been seldom validated by the suitable data. The weighted average method has been used in the present study by assigning contribution wise simple weights to the impact parameters in simple increasing order according to the importance. This method has been adopted for estimation of the groundwater recharge of Bhandara district.

2. About Study Area

Bhandara district is situated in the northeastern part of the state of Maharashtra and central part of India. It lies between North latitude $20^0 35'$ to $21^0 05'$ and East longitude $79^0 30'$ to $80^0 10'$. The district falls in the survey if India Toposheets 55 O/12, 55 P/9, 55 O/11, 55 O/15, 55 O/16, 55 P/13, 65 C/4. Geographical coverage of the area is about 4090 Sq. Km. Farming is the main occupation of the people in the district. A major part of working population is engaged in agriculture practices, whereas rest of the population is engaged in cottage industries. Hot summer, well-distributed rainfall and pleasant winter characterize the climate of the district. The southwest monsoon season is from June to September. The normal annual rainfall ranges from about 1250 mm to about 1500 mm. Figure 1, shows location of study area.

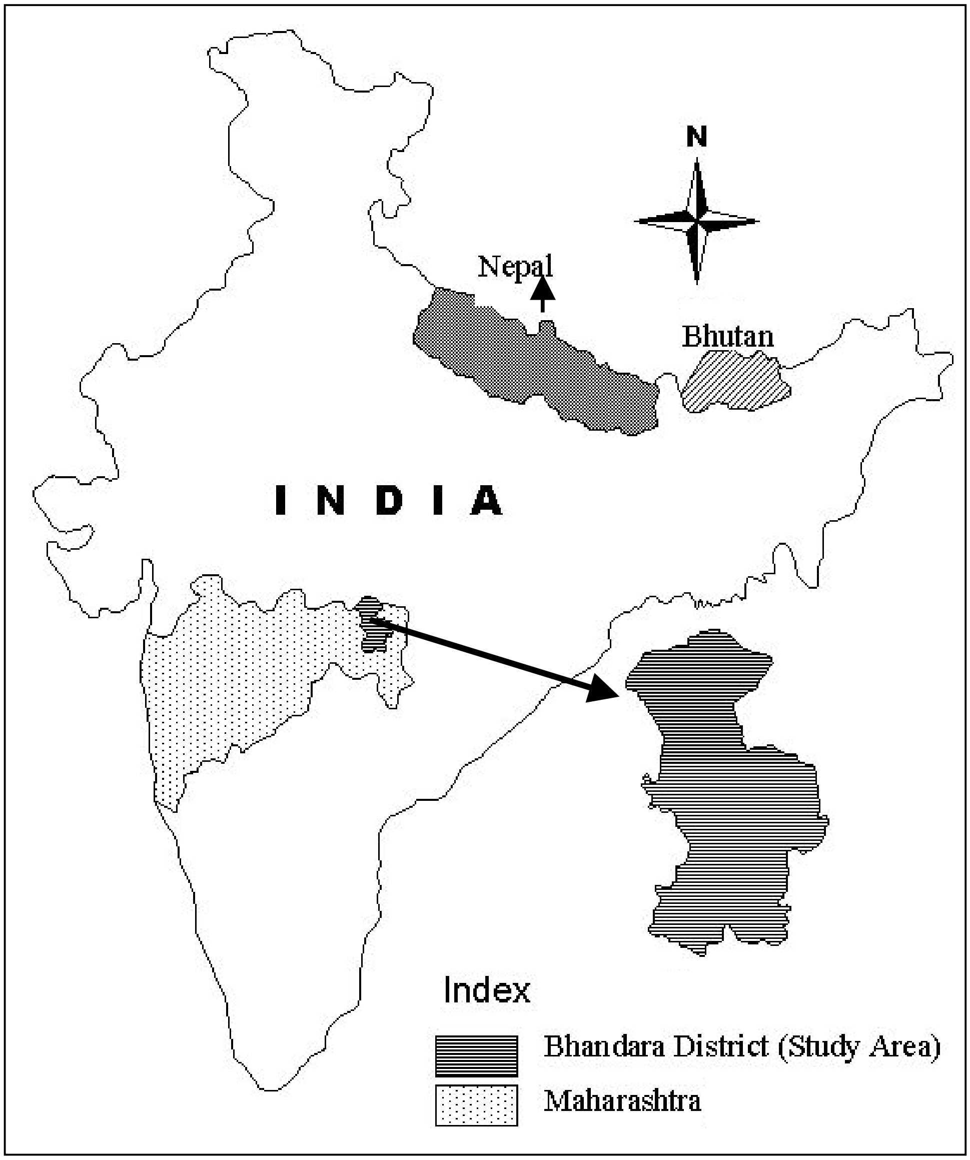

Figure 1: Location map of Study Area

3. Data Used

3.1 Satellite Data

- IRS 1C PAN

- IRS 1C LISS III

3.2 Collateral Data
- Survey of India Toposheets
- Field Data

4. Methodology

The estimated recharge has been calculated through Weight Average Method in which weights has been assigned to different parameters depending upon their contribution in groundwater recharge.

4.1 Scale for assigning weights:

An arbitrary scale to designate the importance of a parameter has been chosen on the basis of the field observations and the importance of the parameters. This range is kept uniform in the weight average method for all the parameters.

- The range of values selected was kept minimum, to keep the number of polygons minimum in the final template.
- Fractional values are not selected.
- Qualitative approach has been adopted while assigning weightages, as the selection is subjective.

The logical selection of weights is shown in the table below:

Sr. No.	Value	Logic
1	1	Least contribution to central theme.
2	2	Least to moderate contribution to central theme
3	3	Moderate contribution to central theme.
4	4	Moderate to high contribution to central theme.
5	5	High contribution to central theme.
6	6	Very high contribution to central theme.

Table 1: Logical selection of weights

The vector file has been generated in desired layers from the rasterized maps. These files carry only spatial information and not the attribute information. The attribute tables were created and then updated with the necessary parameters required for the analysis through domain updation. Unique Ids were assigned to imported polygon maps. These polygons were then compared with the polygons in the attribute table. The appropriate classes were assigned to the unidentified polygons in the attribute table. The attribute data were then linked to spatial data. Using finally updated thematic maps and their attribute tables, weightages were assigned to each parameter that was conceived in the weight model.

Since the objective demands a polygon map having only weights, a weight attribute map was developed using vector operation of attribute map using final updated polygon maps linked with the attribute tables. This operation is applied to all the themes of the study area. Such weight attribute vector maps developed on the basis of the theme attributes was created for each theme. The scale of each theme was finalized on the basis of the ranges of the maximum and minimum values within each theme. To achieve the ultimate objective, all weight maps were superimposed one by one by union. In union operation process, first two themes were crossed followed by a crossing of above crossed map with another weight map and so on until the final operation. Area numbering was carried on the final crossed map to identify total different patches with variation of weightages. The final crossed weightages so obtained in the attribute table were added field wise. All these total weightages were divided into different recharge classes as poor, very low, low, average, moderate, moderately good and good depending on the final weight values assigned to polygons in the final layer.

The overall methodology adopted has bee presented in the form of a flow chart, which is given as bellow:

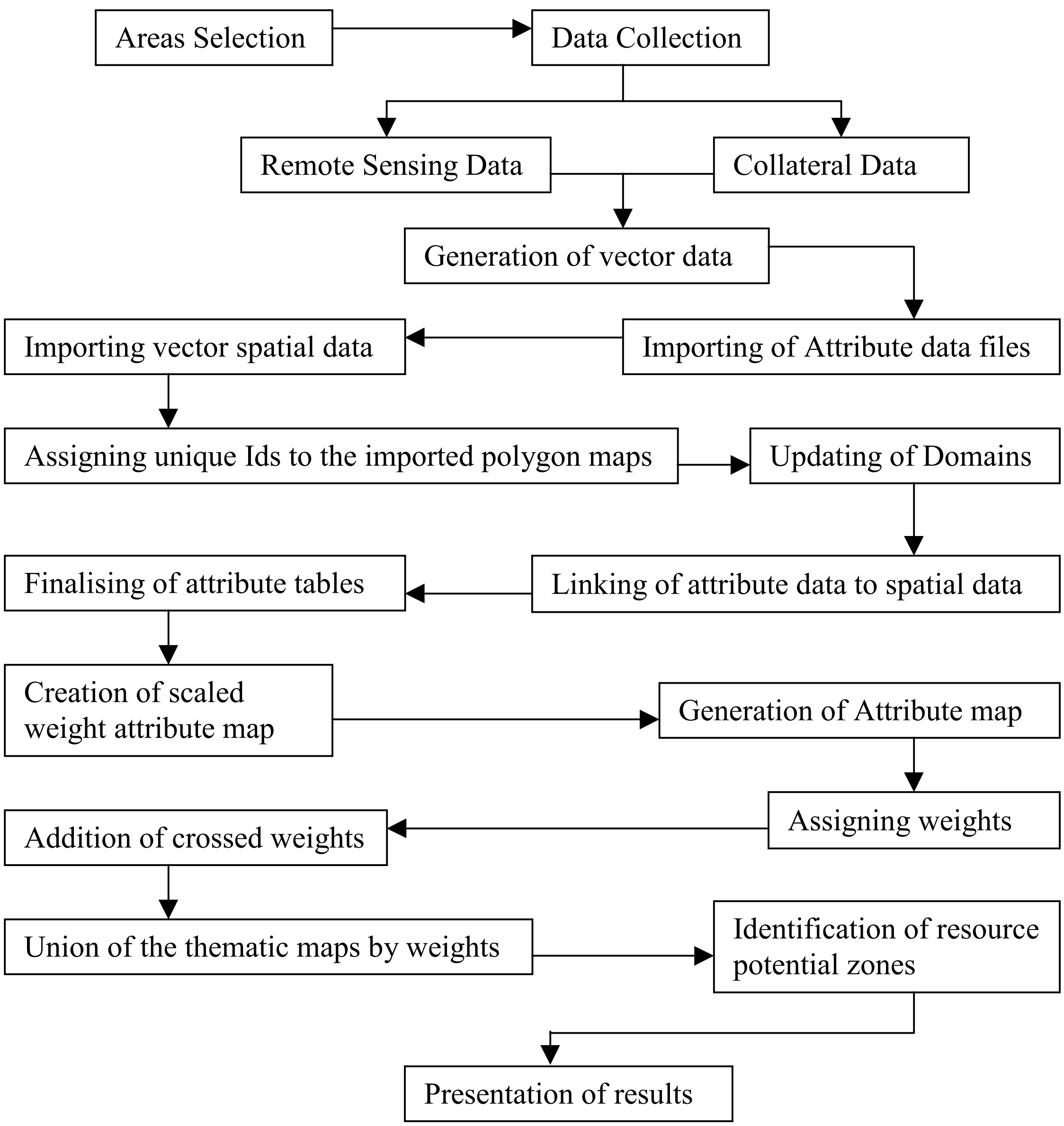

Figure2: Flow chart showing overall methodology

5. Result and Discussion

Watershed with well-defined hydrogeological boundaries is an appropriate hydrological unit for ground-water resource estimation (Sharma, S. K., 1997). In hard rock areas, which occupy about 2/3-rd area of the country, assessing the ground water on watershed as a unit is more desirable. Groundwater recharge calculation as suggested by the GEC (1997) is done by the taking the water level data and the water table fluctuation supported by the estimation of aquifer transmissibility and storage coefficients. The estimation of these parameters in the field takes lot of efforts and time. Hence, the parameters which are generally available and which can be generated easily on GIS from the primary parameters have been used here to calculate the groundwater recharge.

In the present study "Weight Average Method" has been adopted for groundwater recharge estimation. The various parameters used in this approach are as below:

a) Geology b) Geomorphology c) Slope d) Lineament Density e) Soil type f) Run off

The different classes of above mentioned parameters selected for recharge estimation were assigned suitable weights keeping in view the importance of these classes supporting groundwater recharge. The weights allotted to various classes are shown in following tables:

a) Lithology:

Sr. No.	Geological classes	Weights
1	Alluvium	13
2	Laterite	7
3	Sandstone and ferruginous	6
4	Sandstone	6
5	Shale	4
6	Dolomite marble	6
7	Quartzite & quartz. muscovite schist	8
8	Muscovite biotite schist, phyllite	8
9	Calc.gneiss & pink marble	8
10	Quartz-feldspar muscovite schist & quartzite	8
11	Silicified zone and quartz reef	6
12	Granite	1
13	Meta gabbro	7
14	Cherty quartzite	6
15	Meta rhyolite/tuff	1
16	Mica schist	8
17	Phyllite, tuffaceous phyllite & Carbo. phyllite	4
18	Meta basalt	7
19	Banded iron formation	1
20	Gritty quartzite, meta arkose and conglomerates	12
21	Banded hematite quartzite	1

22	Quartzite, gritty quartzite	6
23	Granite gneiss	8
24	Granite gneiss with migmatite granite	8
25	Granulite	5

Table 2: Weights allotted to lithounits for recharge estimation by 'Weight Average Method'.

As shown in Table 2, the alluviums followed gritty quartzite, meta arkose and conglomerates was assigned highest weight as the support high recharge a compare to other lithounits where as the granites, rhyolites etc., were assigned lowest weights as they supports very less recharge.

b) Slope

Sr. No.	Slope classes (m/km)	Weight
1	Less than 10	12
2	10-20	10
3	20-80	8
4	80-150	5
5	150-300	3
6	300-600	1

Table 3: Weights allotted to slope classes for recharge estimation by 'Weight Average Method'.

As shown in Table 3, the areas having gentle slopes were given higher weights where as the areas under high slope categories were given less weight as per their contribution in groundwater recharge.

b) Geomorphology

Sr. No.	Geomorphological units	Weight
1	Hill ridges with or without narrow valley	1
2	Linear, sharp crested hill ridges, curvilinear	1
3	Parallel high hill ridges	4
4	Residual hills subdued hill ridge remnants hillocks	1
5	Pediments/ pediplain	5
6	Degraded land , bad land within and outside colluvial foot slope	4
7	Highly eroded plateau remnants with subdued short parallel ridges & Hills	4
8	Isolated valley flats	3
9	Infilled valley	5
10	Colluvial foot slope	2

Table 4: Weights allotted to different geomorphological units for groundwater recharge estimation by 'Weight Average Method'.

The infilled valleys, pediments and Pediplains in the study area were given higher weights were as the hill ridges were assigned less weights as shown in Table 4.

d) Lineament density:

Sr. No.	Lineament density	Weight
1	Very low	2
2	Low	4
3	Medium	6
4	High	8
5	Very high	10

Table 5: Weights allotted to different categories of lineament density classes for recharge estimation by 'Weight Average Method'.

The areas under high lineament density were given higher weights as the supports high recharge whereas the areas under low lineament density were giver less weight as given in Table 5.

e) Soil:

Sr. No.	Soil types	Weight
1	**Laterite**	4
2	Medium black	1
3	Older alluvium	2
4	Red loamy	5
5	Red sandy	4

Table 6: Weights allotted to different soil classes for recharge estimation by 'Weight Average Method'.

As shown in Table 6, lateritic and red sandy soils were given higher weights where as the medium black and older alluviums were given less weight.

f) Run-off:

Sr. No.	Run-off (mcm)	Weight
1	0 – 25	10
2	26 – 50	9
3	51 – 75	8
4	76 – 100	7
5	101 – 125	6
6	126 – 150	5
7	151 – 175	4
8	176 – 200	3
9	201 – 225	2
10	226 – 250	1

Table 7: Weights allotted to different run-off zones for recharge estimation by 'Weight Average Method'.

The areas which suffer high runoff were given less weight as compare to areas under less runoff which were given high weights as areas under less runoff supports more ground water recharge as compare to areas under high runoff.

The overlay analysis has been performed through the union of above layers and final map showing estimated recharge has been generated which is shown as figure 3. It is clear from the figure that maximum part of the district supports average to moderate recharge.

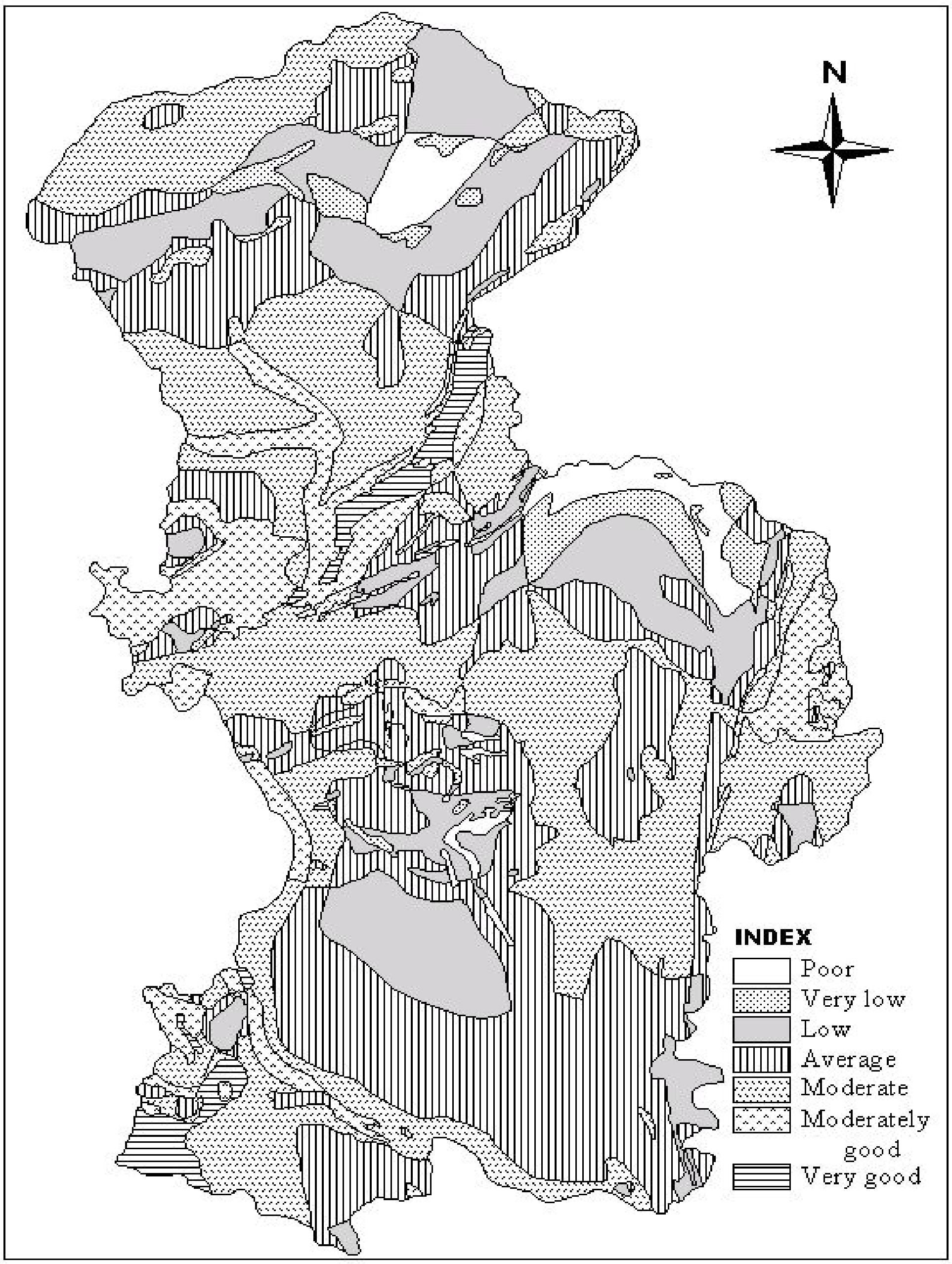

Figure 3: Estimated run-off in Bhandara District through Weight Average Method

The northern, north eastern and some central part of the Bhandara district shows poor, very low and low recharge which are mainly hilly regions in the study area. Small part of southwestern and northern part of the area shown very good recharge where as moderately good recharge areas can be seen in southwestern, eastern and western part of the district in patches.

6. Conclusions

The study finally leads to the following conclusions:

1. The 'Weight Average Method' used for groundwater recharge estimation in Bhandara District of India proves to be most appropriate in the present study, as the accurate estimation can be made, where various parameters can be assigned suitable weights according to their contribution in groundwater recharge. At the same time methodology proves to be less time consuming and cost effective.
2. The union of different layers through overlay analysis proves to analyse various parameters in single domain.
3. Finally it has been concluded that as maximum part of Bhandara district (study area) supports good recharge, particularly the precipitated water should be targeted for groundwater recharge. The areas, which favor moderately good to very good recharge, should be targeted as primary sites for artificial recharge to combat declining water levels. The areas which falls between moderate to average recharge zones should be taken as secondary sites for artificial recharge where as areas under low to poor recharge zones should be considered under tertiary artificial recharge sites.

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