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RESEARCH ARTICLE

GROUNDWATER VULNERABILITY ASSESSMENT USING DRASTIC METHOD APPROACH IN AND AROUND KEOLADEV GHANA NATIONAL PARK, RAJASTHAN, INDIA

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ABSTRACT

An area of about 510 sq km around Keoladev Ghana National Park - A World Heritage Site - and Bharatpur city has been investigated for assessment of groundwater vulnerability. Groundwater is the major source of water for various uses in the study area. Hence, the DRASTIC method approach has been used as a valuable tool for identifying groundwater zones that are vulnerable to contamination. Adopting DRASTIC model approach, the Vulnerability Index has been determined for the entire area that ranges from 174 to 203. On the basis of Vulnerability Index, the area has been classified into three categories i.e. area with Vulnerability Index 174-185, 185-195 and 195-205 corresponding to low, moderate and high vulnerability zones, respectively. Using this classification, a groundwater vulnerability map has been generated which shows that 37% of the study area falls under low vulnerable zone, 51% under moderate vulnerable zone and only 12% falls under high vulnerability zone.

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INTRODUCTION

Groundwater is one of the most valuable natural resources which need to be protected from pollution and it should be used judiciously. The Sewar Block which encompasses Keoladev Ghana National Park - a World Heritage Site - and Bharatpur city falls in Bharatpur district, eastern Rajasthan (Fig. 1). In the area, demand for water has significantly increased due to a very high rate of urbanization and industrialization in past two decades. The annual recharge of groundwater in the area is far less than its consumption (Shekhawat and Chundawat, 2010). The groundwater is the major source of water for agriculture, domestic and industrial needs in the study area. Keoladev Ghana National Park is already facing perturbing water scarcity problem over the decade (Shekhawat and Chundawat, 2011). The first group of aquifer which is mostly unconfined throughout the study area is very potential for various contaminants through anthropogenic activities like agriculture, industrial and domestic activities. Thus, DRASTIC method approach has been applied for assessment of groundwater vulnerability in the area. DRASTIC is a groundwater quality model for evaluating pollution potential of large areas using hydrogeological setting of the region (Aller *et al.*, 1985, 1987).

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Study area

The study area - Sewar Block (27°05'04"- 27°19'44"N:77° 19'42"-77°40'44"E) encompassing Keoladev Ghana National Park - a World Heritage Site – and Bharatpur city falls in eastern Rajasthan with total geographical area of about 510 km^2 (Fig. 1). The population density of the area is 636 persons per sq km and decadal population growth rate is 23.20% for the period 2001 to 2011. Altitude of the area ranges from 171 - 200 m above mean sea level (msl) with a regional slope towards south-east; it is maximum in the north-western part and minimum in eastern part. The area falls under Banganga River Basin hence, its present topography is a result of fluvial activity of the river. Geologically, the area comprises mainly of alluvium and windblown sand of the Quaternary period and rocks of the Delhi Supergroup of middle to upper Proterozoic age (Gupta *et al.*, 1997). Rainfall plays an important role in groundwater availability because it is the major source for groundwater recharge in the area. The normal rainfall in the area is 662.50 mm per annum.

MATERIALS AND METHODS

In the present study, the most widely used Point Count System Model (PCSM) i.e. the DRASTIC method is used for evaluating the intrinsic vulnerability (Aller *et al.*, 1987) of the Sewar Block.

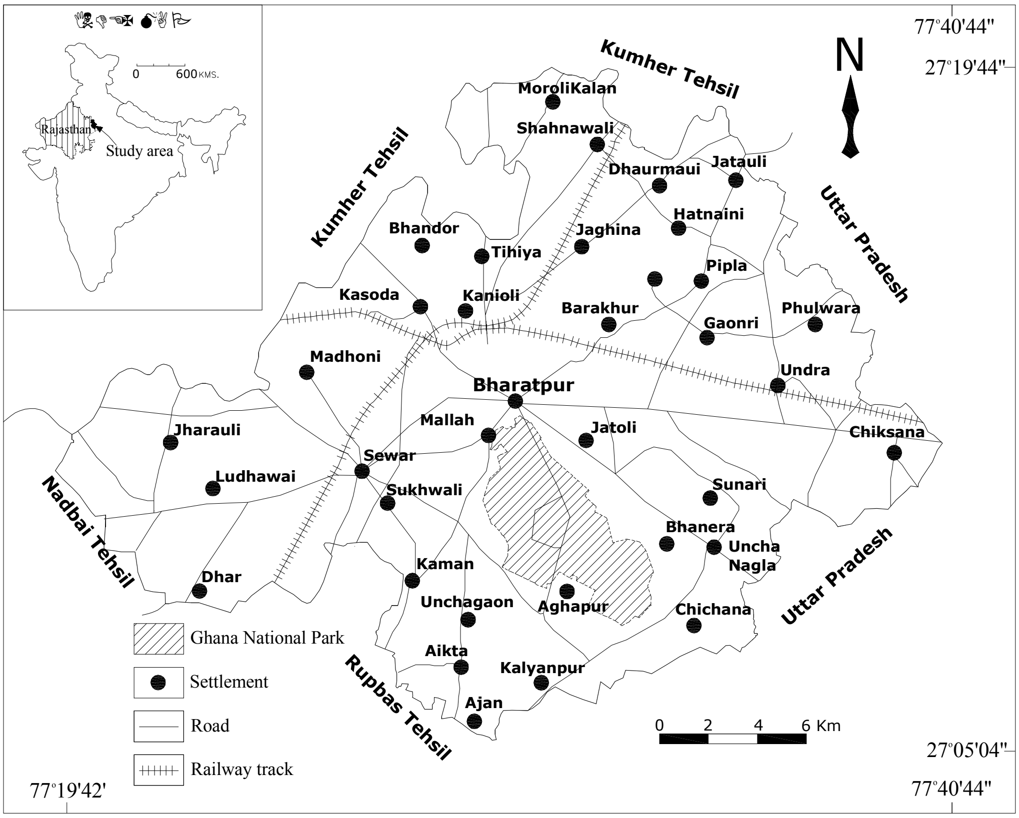

Fig. 1. Location map of the study area

DRASTIC includes various hydrogeological setting which influences pollution potential of a region. This model employs a numerical ranking system that assigns relative weights to various parameters that help in the evaluation of relative groundwater vulnerability to contamination (Table 1).

Table 1. Assigned weight for DRASTIC parameters (*after* Aller *et al.*, 1987)

Parameters	Rating (R)	Weight scale (W)
Depth to water table (D)	2, 3 and 5	5
Net Recharge (R)	9	4
Aquifer media (A)	8	3
Soil media (S)	5 and 6	2
Topography (T)	10	1
Impact of vadose zone (I)	1 and 2	5
Hydraulic Conductivity (C)	7, 8 and 10	3
Land Use/land Cover pattern*	8, 9 and 10	5

* in addition to DRASTIC approach as area is case sensitive

The parameters like depth to water table, net recharge, aquifer media, soil media, topography, impact of vadose zone and hydraulic conductivity of the aquifer have been considered for 13 evenly spaced monitoring stations in the area. These parameters have been arranged to form the acronym, DRASTIC for ease of reference.

The land use pattern is also an important factor which greatly influences the groundwater vulnerability. Thus, including land use pattern, all these factors have been re-arranged to form the acronym DRASTIC- LU which has been applied to determine vulnerable zones in the study area.

The following methodology has been used to determine hydrogeological settings which make up the acronym DRASTIC-LU and their relative values in the study area.

Depth to water table (D): Depth to water table below ground level has been measured at 13 uniformly distributed wells in the study area during pre- and post-monsoon period 2008 (Table 2). Using the well inventory data, a water level depth map has been prepared for post-monsoon period 2008 (Fig. 2). The depth to water table is important, primarily because it determines the depth of material through which a contaminant travels before reaching the aquifer and it also helps to determine the period of time during which it maintains contact with the surrounding media (Aller *et al.*, 1987). Therefore, the depth to groundwater is assigned the maximum weight (5) in determining vulnerability using DRASTIC method (Table 1). Depth to water table in the study area ranges from 6.30 to 15.10 mbgl during the post-monsoon 2008 (Table 2) and it has been assigned ratings of 7 and 5 (Table 3).

Net Recharge (R): The net recharge to water table has been determined from water level fluctuation map of the area for the period 2008 (Fig. 3). The water level fluctuation map has been prepared on the basis of water level fluctuation data of 13 uniformly distributed wells in the study area (Table 2). Net recharge is the principal media that transports the contaminants to the groundwater.

Table 2. Depth to water level data for uniformly distributed 13 hydro-stations in the study area for the year 2008

Location	Potential zone	Depth to water level (mbgl)		Seasonal water level fluctuation (m)
		Pre-monsoon	Post-monsoon	
Bharatpur	Alluvium	8.40	7.90	0.5
Chiksana	Alluvium	15.20	15.10	0.1
Kuma	Alluvium	10.30	10.10	0.2
Kalayanpur	Alluvium	10.20	9.90	0.3
Keoladeo Park	Alluvium	7.10	6.30	0.8
Ludhawai	Alluvium	12.22	11.50	0.72
Sewar	Alluvium	11.90	11.50	0.4
Uncha Nagla	Alluvium	10.12	9.50	0.62
Mallah	Alluvium	7.30	7.02	0.28
Jatauli	Alluvium	6.12	5.28	0.84
Pipla	Alluvium	7.20	6.40	0.80
Shahnawali	Alluvium	10.30	9.40	0.90
Kasoda	Alluvium	9.50	9.10	0.40

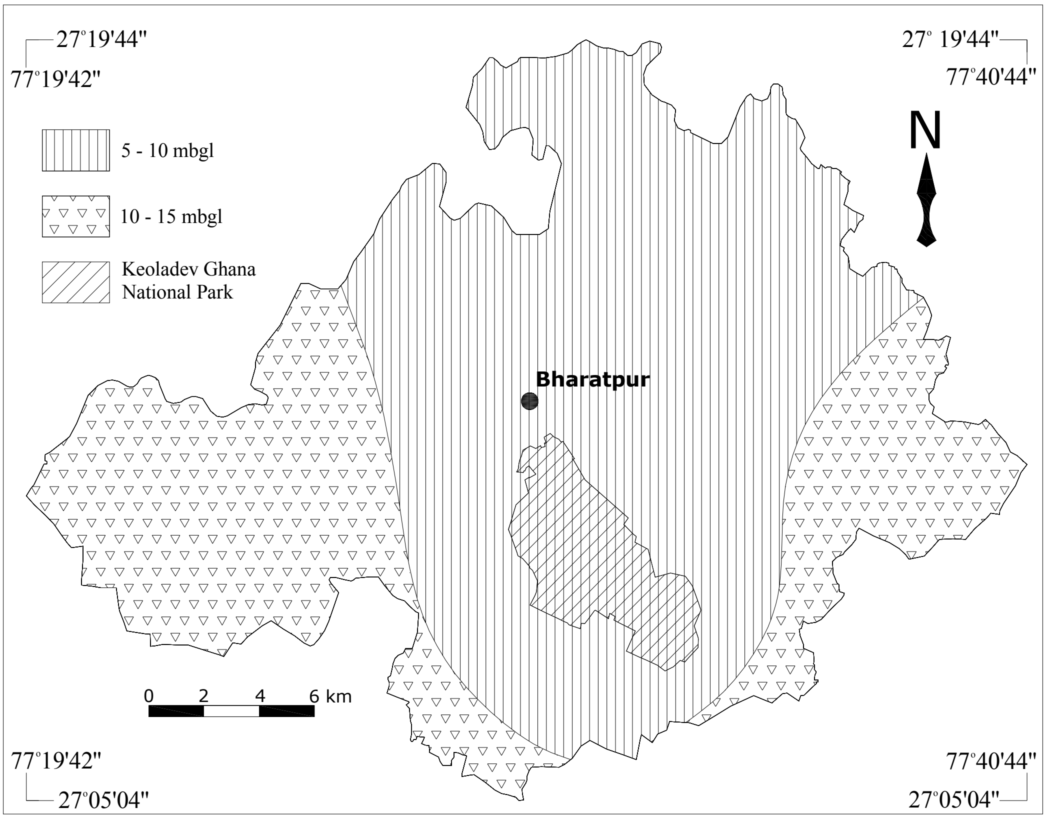

Fig. 2. Depth to water level in the study area for post-monsoon 2008

If net recharge is more, then there are greater chances of transporting contaminants to the groundwater table. In the area where the aquifer is unconfined, the recharge to aquifer occurs more readily and the pollution potential will be higher than in the areas with confined aquifers. This recharge water is thus available to transport a contaminant vertically to the water table and horizontally within the aquifer (Aller *et al.*, 1987). The average net recharge in the study area is >254 mm (0.25 m) and it has been assigned common rating of 9 (Table 3). The net recharge has been assigned a weight "4" in the DRASTIC method (Table 1).

Aquifer media (A): The study area represents a flood plain having alluvium as the first and a major aquifer. The composition (media) of this aquifer has been determined from lithologs of exploratory borewells of CGWB (2005). If an aquifer has larger grain size and more fractures or openings then its permeability will be higher and the attenuation capacity will be lower, consequently the pollution potential will be higher (Umar *et al.*, 2009). In the study area, aquifer material/media is nearly homogeneous which is represented by sand mixed with gravel and hence, assigned a uniform rating of 8 (Table 3). The recommended weight for this type of aquifer media is 3 (Table 1).

Soil media (S): The principle types of soil in the area are sandy-loam and clayey-loam (DST, 1999). It has a significant impact on the amount of recharging water which infiltrates into the ground and hence, influences the ability of a contaminant to move vertically into the vadose zone. The pollution potential of a soil is largely affected by type of clay present and grain size of the soil (Umar *et al.*, 2009).

Table 3. Determination of Vulnerability Index in study area using DRASTIC model approach

Monitoring stations	Depth to water		Net recharge		Aquifer media		Soil media		Topography		Vadose zone		Hydraulic Conductivity		Land use/land cover	Vulnerability Index
	mbgl	Rating	mm	Rating	Type	Rating	Type	Rating	Type	Rating	Type	Rating	m/day	Rating	Rating	
Bharatpur	7.9	7	>254	9		8	Clay loam	3		10		6	12.22-28.52	4	10	203
Chiksana	15.1	5	>254	9		8	Clay loam	3		10		6	4-12.22	2	9	182
Kuma	10.1	5	>254	9		8	Sandy loam	6		10		6	12.22-28.52	4	8	189
Kalayanpur	9.9	5	>254	9		8	Clay loam	3		10		6	12.22-28.52	4	8	183
Keoladeo Park	6.3	7	>254	9		8	Clay loam	3		10		6	12.22-28.52	4	8	193
Ludhawai	11.5	5	>254	9	Sand & Gravel	8	Clay loam	3	0-1.5 degree slope	10	Sand & Gravel with significant silt & clay	6	4-12.22	2	9	182
Sewar	11.5	5	>254	9		8	Clay loam	3		10		6	12.22-28.52	4	9	188
Uncha Nagla	9.5	5	>254	9		8	Clay loam	3		10		6	12.22-28.52	4	8	183
Mallah	7.02	7	>254	9		8	Sandy loam	6		10		6	12.22-28.52	4	8	199
Jatauli	5.28	7	>254	9		8	Clay loam	3		10		6	4-12.22	2	9	192
Pipla	6.4	7	>254	9		8	Clay loam	3		10		6	4-12.22	2	8	187
Shahnawali	9.4	5	>254	9		8	Clay loam	3		10		6	1-4	1	8	174
Kasoda	9.1	5	>254	9		8	Clay loam	3		10		6	12.22-28.52	4	9	188

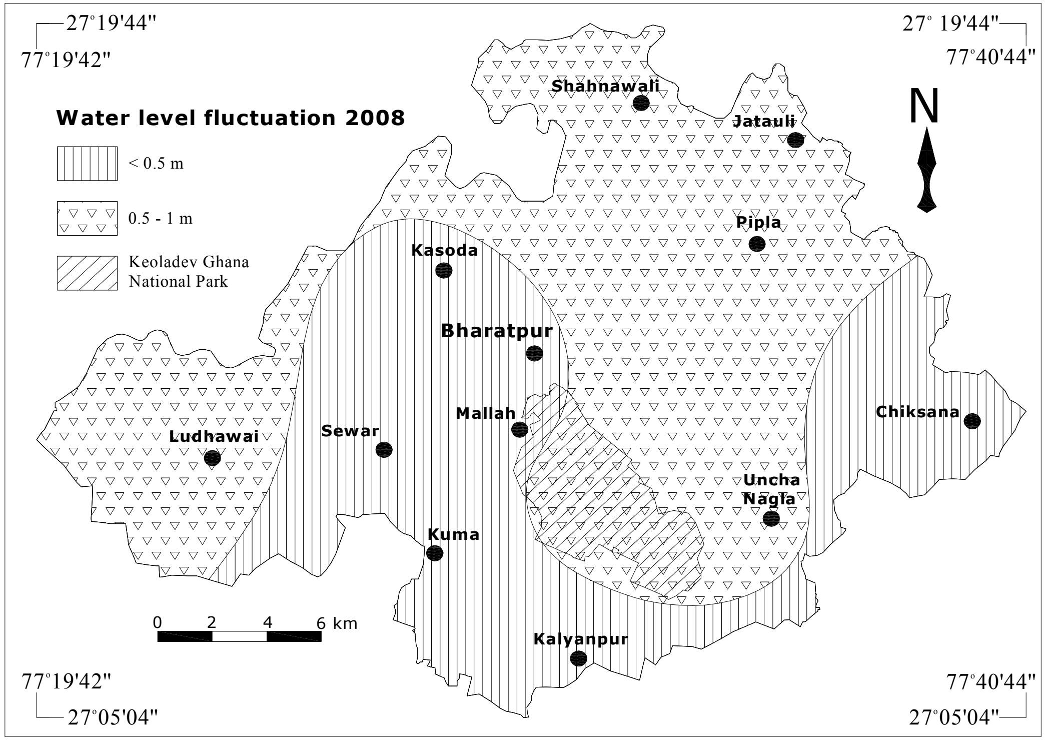

Fig. 3. Water level fluctuation map (2008) of the study area

The two types of soil *viz.* sandy loam (≈ inceptisols) and clayey loam (≈ alfisols) occurring in the area corresponds to a rating of 6 and 3 respectively (Table 3). This parameter has been assigned a weight '2' in the DRASTIC method (Table 1).

Topography (T): The slope map (Fig. 4) has been prepared with the help of Survey of India toposheet No. 54 E/7, 54 E/8, 54 E/11 and 54 E/12 on 1:50,000 scale following the method of NRSA (2000). It shows that the study area is almost flat having slope less than 2° towards the east which corresponds to a rating of 10 (Table 3). The parameter has been assigned a weight '1' in the DRASTIC method (Table 1).

Impact of vadose zone (I): In the study area it has been determined from lithologs of exploratory borewells of CGWB (2005). The texture and media of the vadose zone have significant impact on path length and routing of the contaminants. In the area, vadose zone media comprises sand and gravel with significant quantity of silt and clay which corresponds to a rating of 6 (Table 3). This parameter has been assigned a weight "5" in the DRASTIC method (Table 1).

Hydraulic Conductivity (C): The hydraulic conductivity at selected locations in the study area has been obtained from pumping test data of CGWB (2005) (Table 4). An aquifer with high conductivity is vulnerable to substantial contamination (Rehman, 2008). Hydraulic conductivity is different from an aquifer media because an aquifer with an impermeable media can still conduct water in the presence of fractures (Fritch *et al.*, 2000). It is controlled by the amount and interconnection of void spaces within the aquifer. In the area, it ranges from 0.95 to 28.52 which correspond to a rating of 1, 2 and 4 respectively (Table 3, Fig. 5). This parameter has been assigned a weight '3' in the DRASTIC method (Table 1).

Land Use system and groundwater vulnerability: Groundwater quality in the area is being deteriorated due to ongoing industrial and sewage pollution (in the urban area). The land use pattern has strong bearing on groundwater quality. Therefore, land use pattern has been included in vulnerability mapping. The land use/land cover map of the area has been prepared from geo-coded Landsat imagery of October, 1999 acquired from the Enhanced Thematic Mapper (ETM+) instrument onboard the Landsat 7 satellite (Fig. 6). Hussain *et al.* (2006) also utilized land use pattern in DRASTIC approach for vulnerability mapping.

Table 4. Important hydraulic parameters at different locations in the study area

S.No	Location	Depth drilled (mbgl)	Potential zone thickness (m)	Formation tapped	Transmissivity (m^2/day)	Hydraulic Conductivity (m/day)
1	Ludhawai	121.53	19.20		201	10.46
2	Chiksana	186.82	22		171	7.77
3	Mallah	140.82	28		787	28.10
4	Kamalpur	30.12	4	Alluvium	67	16.75
5	Barah	158.83	27		57.25	2.12
6	Bhanera	106.00	14		326	23.28
7	Kumher	207.28	56		53.73	0.95

Source: CGWB, 2005

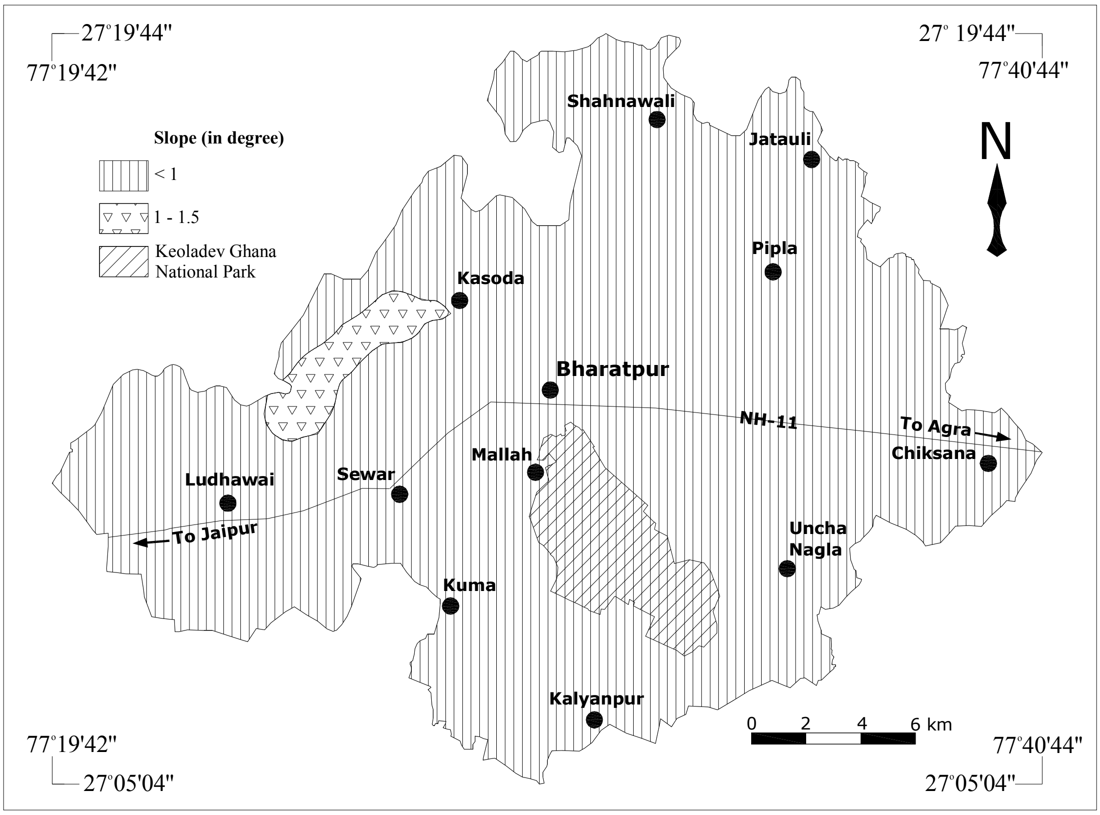

Fig. 4. Slope map of the study area

On the basis of land use pattern (Fig. 6), qualitative ratings have been given for the different types of land use categories in the area (Table 5). The assigned weight for this parameter is 5 (Table 1) and its corresponding ratings are 8, 9, and 10 (Table 3).

Table 5. Rating of land use categories

Land use Category	Ratings
Urban and Industrial	10
Rural and Industrial	9
Rural and Agriculture	8

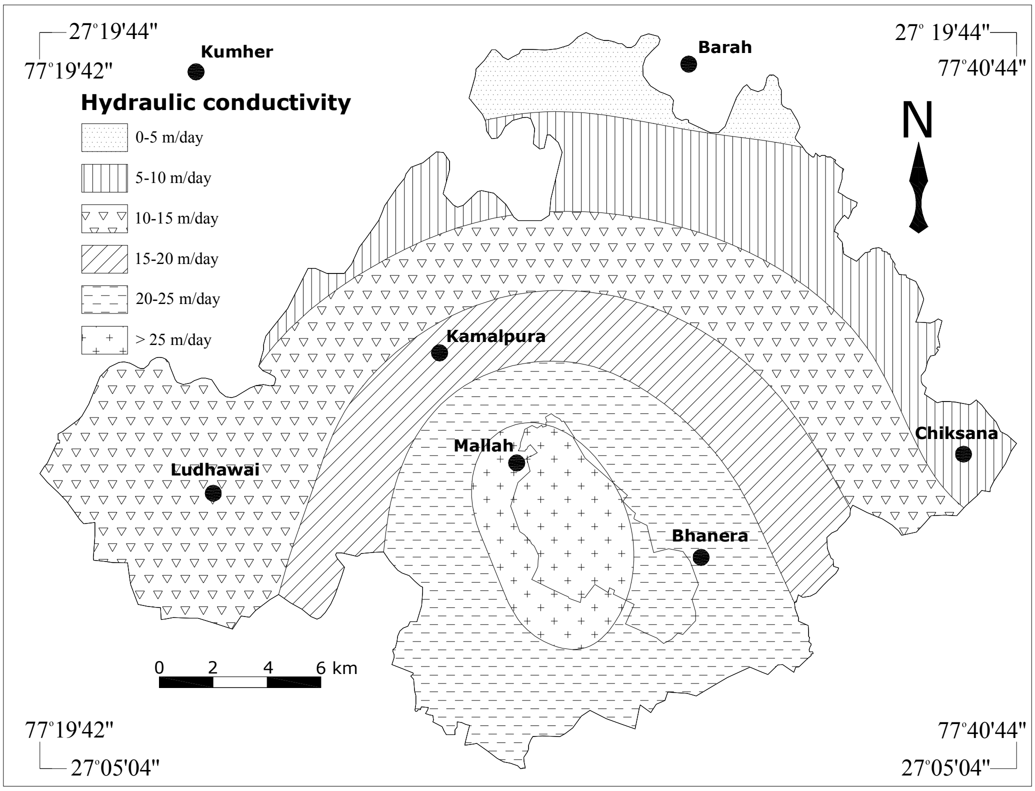

Fig. 5. Hydraulic Conductivity map of the study area

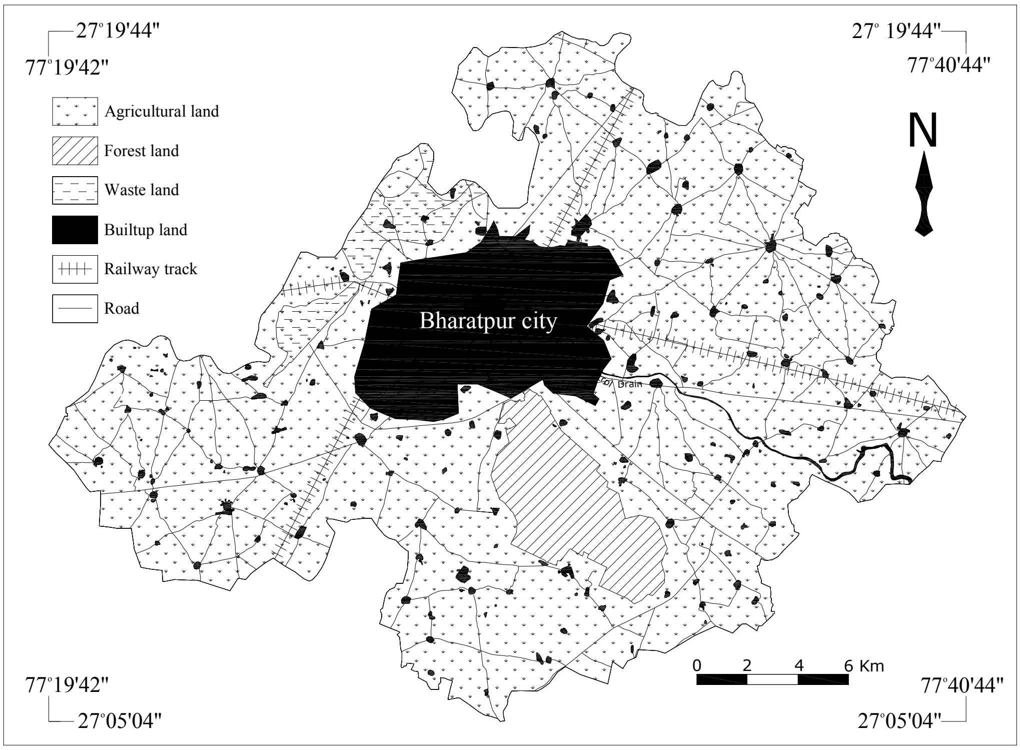

Fig. 6. Land use and land cover map of the study area derived from the Lands at multispectral imagery acquired on 22nd October, 1999

Vulnerability Index

The DRASTIC or Vulnerability Index, a measure of the pollution potential, is computed by summation of the products of rating and weight for each DRASTIC parameter. DRASTIC Index = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw + LrLw

where, Dr = Ratings to the depth to water table, Dw = Weights assigned to the depth to water table, Rr = Ratings for ranges of aquifer recharge, Rw = Weights for the aquifer recharge, Ar = Ratings assigned to aquifer media, Aw = Weights assigned to aquifer media, Sr = Ratings for the soil media, Sw = Weights for soil media, Tr = Ratings for the topography, Tw = Weights for topography, Ir = Ratings assigned to vadose zone, Iw = Weights assigned to vadose zone, Cr = Ratings assigned of hydraulic conductivity, Cw = Weights given to hydraulic conductivity, Lr = Weights assigned of land use, Lw = Ratings assigned of land use.

The Vulnerability Index determined for the study area ranges from 174 to 203 (Table 3). It has been classified into three categories *i.e.* 174-185, 185-195 and 195-205 corresponding to low, moderate and high vulnerability zones, respectively. Using this classification, a groundwater vulnerability map has been generated which shows low, moderate and high vulnerable zones in the study area (Fig. 7).

RESULTS AND CONCLUSION

The vulnerability map shows that about 37% of the study area falls under low vulnerable zone, 51% under moderate vulnerable zone and only 12 % falls under high vulnerability zone (Table 6, Fig. 7). Major part of the area comes under the moderate category. Central part of the area that covers Bharatpur city and northern half of the Keoladeo Ghana National Park is falling under high vulnerability zone. While, the middle part of the area covering rest of the area of Keoladeo Ghana National Park falls under moderate vulnerability zone (Fig. 7). Moderate to high vulnerability zones are characterized by high values of Vulnerability Index, and are attributed to high values of hydraulic conductivity and water levels. The sites with high Vulnerability Index are more vulnerable to contamination and hence, need to be managed more closely.

Table 6. Distribution of study area under different classes of vulnerability

Classes of vulnerability	Area (%)
Low vulnerable	37%
Moderate vulnerable	51%
High vulnerable	12%

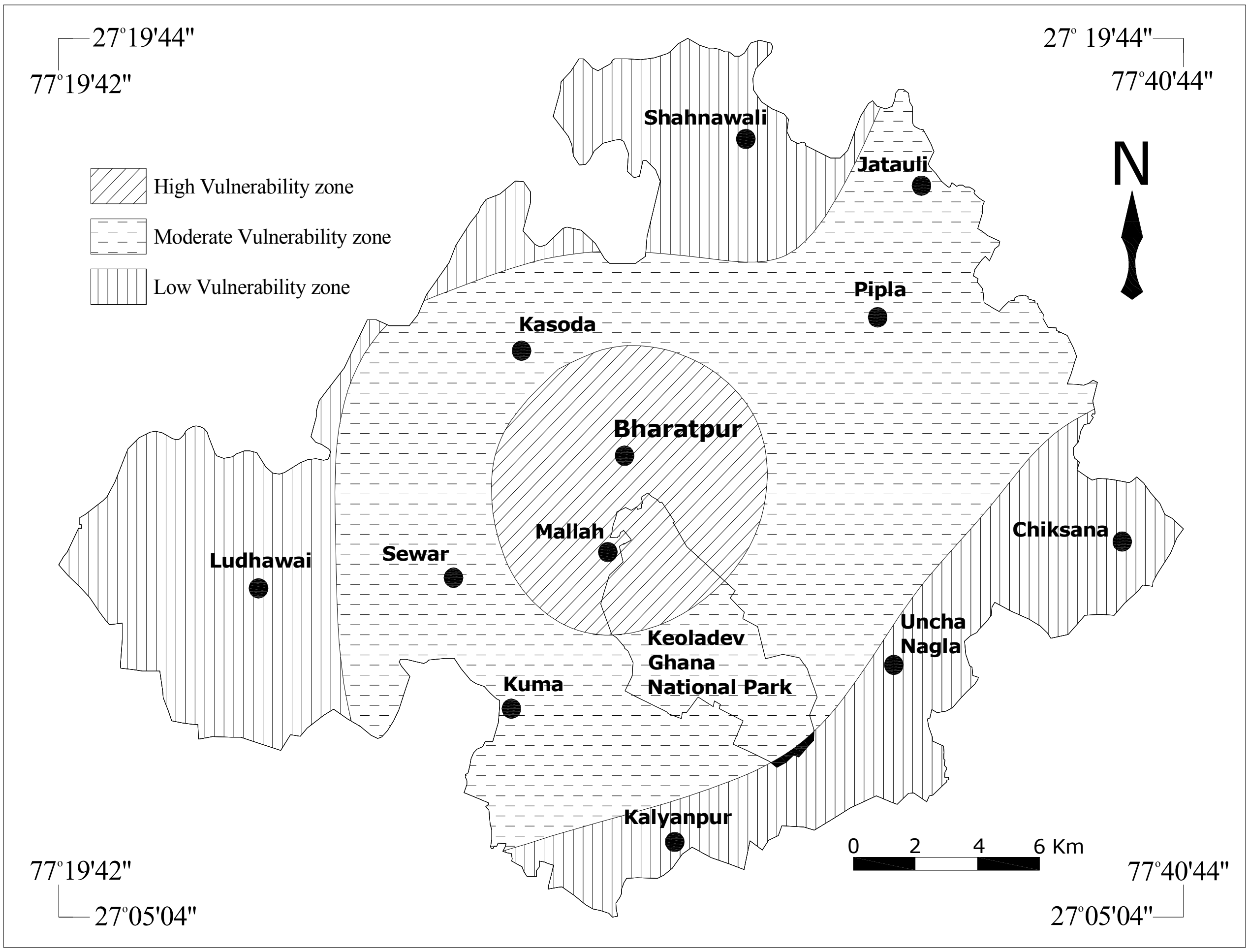

Fig. 7. Groundwater vulnerability map of the study area

The vulnerability map also indicates an adverse impact of urbanization and industrialization on the groundwater resource mainly in Bharatpur city which is an epicenter for vulnerability grading in the study area. Protection of groundwater from contaminants costs less than remediation. Thus, using the vulnerability map, land use and associated human activities could be planned and/or controlled as an integral part of an overall policy of groundwater protection at regional level. Therefore, agricultural and industrial activities in the region should be directed properly to prevent the aquifer from pollutants. The developed vulnerability map may be helpful to planners for selection and implementation of the best groundwater management practices in different areas on priority basis for long-term pollution free availability of groundwater in the region in general and Keoladeo Ghana National Park and Bharatpur city in particular.

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REFERENCES

Aller, L., Bennet, T., Lehr, J.H., Petty, R.J. and Hackett, G. 1987. DRASTIC: A standardized system for evaluating groundwater pollution potential using hydrogeologic settings. EPA/600/2-87-035.

Aller, L., Bennett, T., Lehr, J.H., and Petty, R.J. 1985. DRASTIC: A standardized system for evaluating groundwater pollution potential using hydrogeologic settings. U.S. Environmental Protection Agency, Robert S. Kerr, Environmental Research Laboratory, Ada, OK, EPA/600/2-85/0108, 163p.

CGWB, 2005. Yearbook. Central Ground Water Board, Western region, Jaipur, 143-144.

DST, 1999. District Planning Map Series (Soils), Bharatpur District, Rajasthan. National Atlas and Thematic Mapping Organisation, Department of Science & Technology, Government of India.

Fritch, T.G., McKnight C.L., Yelderman J.C. and Arnold, J.G. 2000. An aquifer vulnerability assessment of the Paluxy aquifer, central Texas, USA, using GIS and a modified DRASTIC approach. *Journal of Environmental Management*, 25: 337–345.

Gupta, S.N., Arora, Y.K., Mathur, R.K., Iqbaluddin, Balmiki Prasad, Sahai, T.N. and Sharma, S.B. 1997. The Precambrian Geology of the Aravalli Region, Southern Rajasthan and Northeastern Gujarat. *Mem. Geol. Surv. India*, 123: 262p.

Hussain, M.H., Singhal, D.C., Joshi, H. and Kumar, S. 2006. Assessment of Groundwater vulnerability in a tropical alluvial interfluves, India. *Bhu-Jal News Jour.*, 21(1-4): 31-43.

NRSA, 2000. Rajiv Gandhi National Drinking Water Mission: Technical guidelines for preparation of groundwater prospects maps. National Remote Sensing Agency (NRSA), Department of Space,, Hyderabad.

Rehman, A. 2008. A GIS based DRASTIC model for assessing groundwater vulnerability in shallow aquifers in Aligarh, India. *Jour. Appl. Geography*, 28(1): 32-53.

Shekhawat, M. S. and Chundawat, D. S. 2010. Estimation of Groundwater Resource in and around Keoladev Ghana National Park, Rajasthan, India. *International Journal of Earth Sciences and Engineering*, 3(6): 793-799.

Shekhawat, M. S. and Chundawat, D. S. 2011. Aquifer Characteristics in and around Keoladev Ghana National Park, Bharatpur, Rajasthan, India. *International Journal of Earth Sciences and Engineering*, 4(1): 45-56.

Umar, R., Ahmed, I. and Alam, F. 2009. Mapping Groundwater Vulnerable Zones Using Modified DRASTIC Approach of an Alluvial Aquifer in Parts of Central Ganga Plain. *Jour. Geol. Soc. India*, 73: 193-201.

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