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SPATIAL DISTRIBUTION OF GROUNDWATER QUALITY, DEPTH AND PLANT SPECIES DIVERSITY IN NATIONAL CAPITAL TERRITORY (NCT) OF DELHI, INDIA

Parul GUPTA, Kiranmay SARMA*

University School of Environment Management, GGSIP University, Sector-16C, Dwarka- 110078, New Delhi, India

Abstract

Groundwater and green cover being two important resources indicating extent of unplanned urbanization in National Capital Territory (NCT) of Delhi, India were considered in the study to understand the relationship between the two. Three vegetated land covers and one settlement area were selected with two sites under each land cover for the study. Canadian Council of Ministers of Environment Water Quality Index (CCME WQI) was used to quantify and classify groundwater quality based on water quality index values. Groundwater depth was also measured at selected study sites. Total plant species diversity was calculated at each site and spatial distribution maps were prepared using the Kriging tool of ArcGIS environment. According to CCME WQI, sites under protected forest have water quality in the classification range of 90-100 which is excellent and good groundwater quality with depth going more than 50 meters below ground level. Also, protected forest area recorded maximum plant species diversity, decreasing from south to northern parts of the city.

Keywords*: Groundwater; NCT of Delhi; Green cover; Kriging; Species diversity*

Introduction

Various processes decide the fate of water reaching the earth surface in different forms of precipitations, with majority of this water seeping down the earth surface as groundwater. Further, quality and quantity of this groundwater under different regions depends on multiple factors like evapotranspiration, types of aquifers, chemical and biochemical interactions, like weathering and dissolution, climate, topography and pumping rate. Along with these, anthropogenic factors like land use/land cover also plays a crucial role in deciding groundwater properties [1]. According to various studies throughout the world land use has strong effect on water quality with positive correlations existing between water quality and land use types [2-7]. Extensive extraction of groundwater and increase in impervious area due to urbanization leaves very little scope for recharge of groundwater through rainfall. While deteriorating surface water quality is increasing dependence on groundwater resources affecting its quality and quantity.

Like other nations, India is also growing dependence on groundwater resources, which are shrinking at an unprecedented rate throughout the country. In India, diversity in geological formations, lithological and chronological variations, complex tectonic framework, climatological dissimilarities and different hydrochemical conditions make groundwater occurrence complicated [8]. National Capital Territory (NCT) of Delhi, being an alluvium

* Corresponding author: kiranmay@ipu.ac.in

region is a potential groundwater reservoir, with its topology and geology controlling the groundwater movement [9]. But, with unplanned and uncontrolled urbanization activities in Delhi, not only reliance on groundwater resources have increased, this has led to the deterioration in groundwater quality and depth. Also, with increasing urbanization, Delhi's green cover is also dwindling. Thus, present work has been undertaken to relate groundwater and green cover in NCT of Delhi. Groundwater quality, depth and plant species diversity were considered for studying the relationship. Geographical Information System (GIS) being an important tool in hydrological studies was also used as kriging application to study the spatial distribution of groundwater and vegetation properties.

Methodology

The National Capital Territory of Delhi lies between 28°24′15" and 28°53′00" N latitudes and 76°50′24" and 77°20′30" E longitudes with total geographical area of 1,483km^2. Delhi region is a part of the Indo- Gangetic alluvial plains, at an elevation ranging from 198 to 220m above mean sea level [10]. Physiographically, the region shows four major variations, viz., a) The Delhi ridge, which is prolongation of Aravalli hills; b) The Chattarpur alluvial basin, which is occupied by alluvium derived from the adjacent quartzite ridge; c) Alluvial plains on the eastern and western sides of the ridge; and d) Yamuna flood plains deposits [11]. The primary source of groundwater in Delhi is from southwest monsoon rainfall which occurs during July to September [12, 1].

Fig. 1. Study sites in Delhi

For the present study, four land use/ covers i.e., protected forest, trees outside forest, maintained park and settlement area were considered with two sites under each land cover (Fig. 1 and Table 1). Total 48 groundwater samples were collected from the 8 selected study sites for

physicochemical analysis during October 2012–June 2014. Groundwater samples were collected in polyethylene bottles from tube wells and hand pumps after pumping the water for 10 min. Groundwater depth was measured using Piezometers installed by Central Groundwater Board (CGWB). Groundwater temperature and pH were measured on-site using digital meters. Groundwater samples were analyzed for TDS, hardness (total, calcium, and magnesium), total alkalinity, chloride, nitrate, sulfate and fluoride according to the standard procedures given in APHA Standard Methods [13]. Canadian Council of Ministers of the Environment (CCME) [14] water quality index, developed by Water Quality Index technical subcommittee of the CCME water quality guidelines was used in the study to summarize the water quality data. The classes of water quality with index values (Table 2) and Bureau of Indian Standards (BIS) (2012) drinking water standards were used as test objectives for the water quality index (Table 3).

Table 1. Study sites and land covers in Delhi

Site code	Site name
Land cover 1: Protected/Undisturbed Forest	
Site 1	Asola Wildlife Sanctuary
Site 2	Mahavir Vanasthali Park
Land cover 2: Trees Outside Forest	
Site 3	Bhalswa Lake
Site 4	Mayur Vihar
Land cover 3: Maintained Park	
Site 5	Vikas Puri
Site 6	Rohini
Land cover 4: Settlement Area	
Site 7	Kingsway Camp
Site 8	Mangol Puri

Table 2. Water quality classification according to CCME WQI

Category	WQI Value	Water Quality
Excellent	95-100	Water quality is protected; Conditions very close to natural or pristine level
Good	80-94	Water quality is protected with minor threat; conditions rarely depart from natural level
Fair	65-79	Water quality is usually protected but occasionally threatened; conditions sometimes depart from natural levels
Marginal	45-64	Water quality is frequently threatened; conditions often depart from natural level
Poor	0-44	Water quality is almost always threatened; conditions usually depart from natural levels

Table 3. Drinking water quality standards by Bureau of Indian Standards (BIS) (2012)

Parameters (mg/L)	Indian Standards BIS (10500)	
	Desirable	Permissible
pH	6.5	8.5
TDS	500	2000
Hardness	200	600
Calcium	75	200
Magnesium	30	100
Nitrate	45	-
Sulphate	200	400
Chloride	250	1000
Fluoride	1	1.5
Total Alkalinity	200	600

CCME WQI is calculated as:

$$WQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right) \quad (1)$$

Where, F_1 represents the percentage of variables that do not meet their objectives at least once during the time period under consideration.

$$F_1 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right) X100 \quad (2)$$

F_2 represents the percentage of individual tests that do not meet objectives.

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right) X100 \quad (3)$$

F_3 represents amount by which failed tests values do not meet their objectives.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right) \quad (4)$$

Normalized sum of excursions (*nse*) can be calculated as:

$$nse = \left(\frac{\sum_{i=1}^{n} excursions_i}{\text{total number of tests}}\right) \quad (5)$$

$$excursions_i = \left(\frac{Failed\ test\ value_i}{Objective_i}\right) - 1 \quad (6)$$

After CCME, calculated index values were ranked by relating to the five categories defined by guidelines given in Table 2.

Data acquired was used for generation of spatial variability maps by kriging tool for groundwater depth and water quality index values by using ArcGIS 10.2 software.

Results and Discussion

Groundwater Quality

Groundwater quality was calculated for all the eight study sites with respect to various parameters and CCME WQI (Table 4) was further calculated based on BIS drinking water standards.

Table 4. CCME WQI values and respective water quality for study sites

S. No.	Sites	WQI value	Water quality
1	Asola WLS	100	Excellent
2	Mahavir Park	92.15	Good
3	Bhalswa	50.62	Marginal
4	Mayur Vihar	91.72	Good
5	Vikas Puri	91.48	Good
6	Rohini	64.9	Marginal
7	Kingsway Camp	59.98	Marginal
8	Mangol Puri	91.05	Good

According to CCME WQI values, Asola Wildlife Sanctuary (WLS) under protected forest area has excellent groundwater quality. And one site under each land cover was found to have either good or marginal quality of groundwater. This implies that, groundwater quality at Mahavir Park, Mayur Vihar, Vikas Puri and Mangol Puri is protected with conditions rarely departing from natural conditions. While groundwater quality at Bhalswa, Rohini and Kingsway Camp often depart from natural or desirable conditions and are prone to pollutants exposure. None of the areas were reported to have index value in range 0 to 44. Thus, groundwater in Delhi did not report poor quality (Fig. 2).

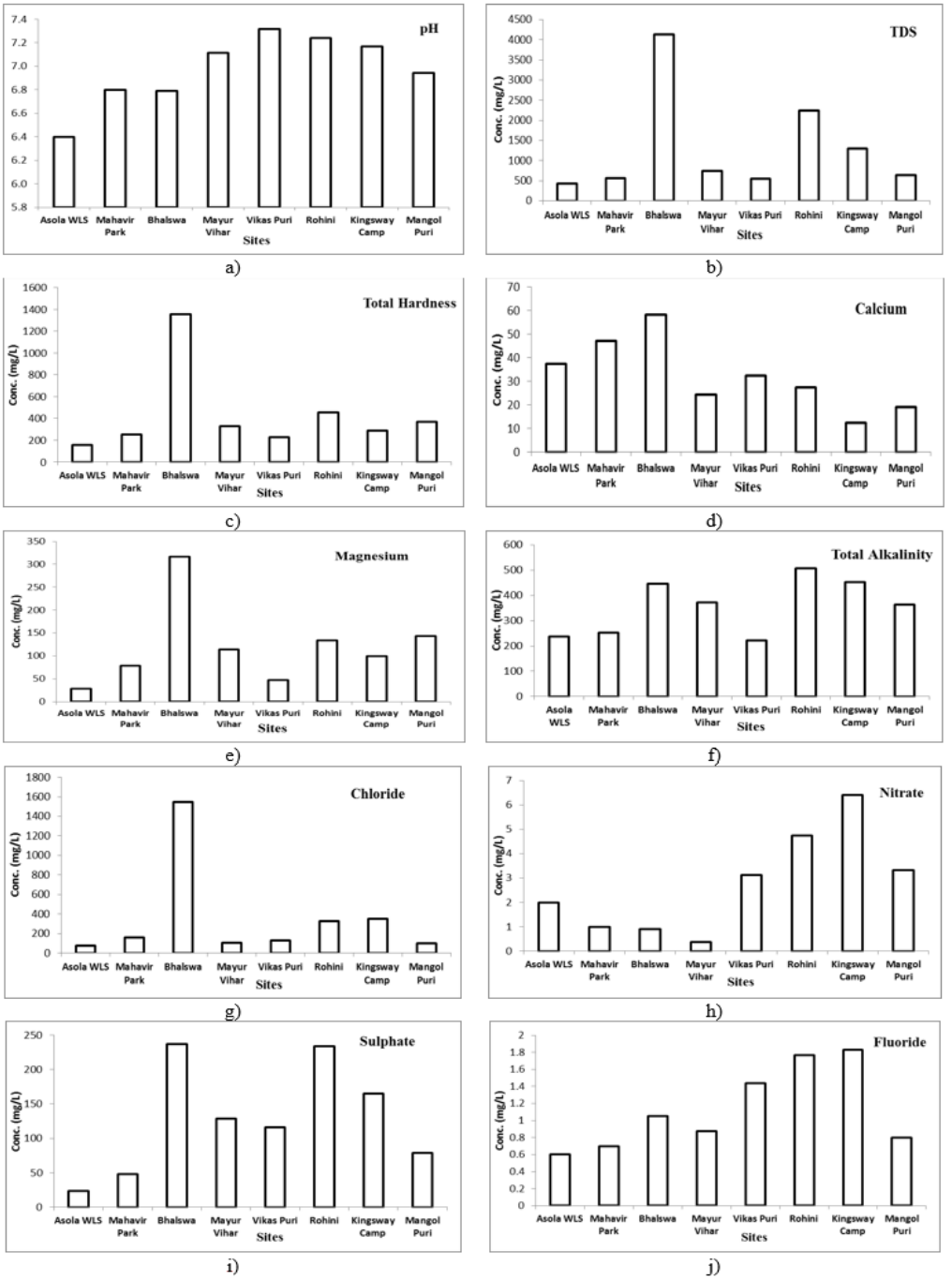

Fig. 2. The results of physical-chemical analysis of groundwater parameters at study sites

On studying physicochemical parameters separately, only total alkalinity for both the sites under protected forest and magnesium for site 2 (Mahavir Vanasthali Park), exceed the drinking water standard (Table 3). Least ionic concentrations in forest area were also reported by *Choi et al.* [15]. For sites under trees outside forest, site 3 (Bhalswa) exceeds values for all

parameters except calcium, nitrate and fluoride. While site 4 (Mayur Vihar), have fifty percent of parameter values within desirable standard range. TDS, hardness and chloride values for sites 3 and 4 show high variation among themselves. High dissolved constituents near Bhalswa lake samples can be attributed to leachates from Bhalswa landfill [16, 17]. According to *Todd* [18] rock materials can be primary source of soluble salts in the groundwater. Among sites under maintained parks, site 6 (Rohini) show more concentration of parameters than site 5 (Vikas Puri). Sites 7 (Kingsway Camp) and 8 (Mangol Puri) under settlement area had TDS, hardness, magnesium and total alkalinity exceeding desirable limit. Sulphate and fluoride for site 7 exceed permissible limits.

Delhi's groundwater quality was found to be alkaline during the study, which was also reported by *Kumar et al.* [19]. Among all the study sites, both sites under protected forest area had best quality of groundwater. While site 3, under trees outside forest, had worst groundwater quality. *Kumar et al.* [19] indicated the outcome was due to weathering process, evaporation and water-rock interactions in Delhi region.

Groundwater Depth

Maximum groundwater depth of 57mbgl (meter below ground level) was recorded from site 1 (Asola WLS) and minimum of 1.5 mbgl from site 3 (Bhalswa). Thus, average water depth from protected forest area was found out to be 41.7mbgl and that of trees outside forest is minimum with 4.1mbgl. Maintained parks reported groundwater depth near to 10mbgl and settlement area reported depth within 5mbgl (Figure 3). Deeper water level in ridge area was also reported by *Chatterjee et al.* [20].

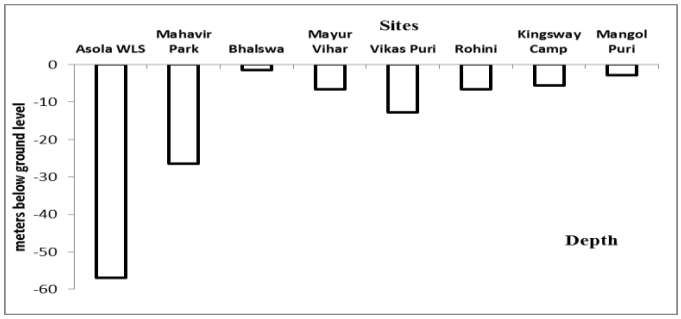

Fig. 3. Graphical representation of groundwater depth at study sites

Vegetation Characteristics

Floristic composition and total species diversity at the study sites during sampling period was also recorded. Total number of trees recorded from all the sites is 31, while the numbers of shrub and herb species are 15 and 30, respectively. Maximum number of trees, shrubs and herbs were recorded from protected forest area and least from trees outside forest and settlement area. *Prosopis juliflora* (Sw) DC was the most abundant at protected forest and trees outside forest area. Prosopis juliflora being one of the most abundant species and found at almost all the land covers is also one of the most invasive tree species in the world [21-23]. Total species diversity of all the study sites and land covers were calculated. Maximum plant species diversity of 2.75 was recorded from Mahavir Vanasthali park (site 2) under protected forest area, while minimum diversity of 0.64 was recorded from Bhalswa (site 3) under trees outside forest area (Table 5).

Table 5. Total plant species diversity at study sites

Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
2.24	2.75	0.64	2.31	2.31	2.55	1.95	1.7

For land covers, settlement area recorded least plant species diversity of 1.97 (Table 6). According to *Krishnamurthy et al*. [24] vegetation in Delhi is dominated by few species, with most of the species displaying random and clumped distributions.

Table 6. Total plant species diversity at land covers

Protected Forest	Trees outside Forest	Maintained Park	Settlement Area
3.03	2.49	2.92	1.97

Application of GIS

Kriging tool of ArcGIS was used as spatial interpolation technique to generate spatial distribution maps of Delhi groundwater quality, depth and total plant species diversity (Figure 2, Figure 3 and Figure 4). According to spatial distribution maps water quality of Delhi is improving from north to south of Delhi, while groundwater depth is found to be lowering in opposite direction, i.e., from south to north Delhi. Maximum WQI of 95 to 100 of excellent category was recorded for 159.2km^2 area, including parts of south and south west Delhi. Maximum Delhi area (900.2km^2) has good quality of groundwater. Marginal quality of groundwater with WQI ranging from 45 to 54 was reported from 128.4km^2 area (Table 7 and Table 8). Increase in hydraulic gradient towards northeast as reported by *Dash et al*. [10] may be attributed to lower depth in the northern parts of Delhi**.** Maximum area under moderately low groundwater levels from 12.9 to 23.04mbgl were reported from parts of Northwest, West, Southwest, and Central districts [25]. While plant species diversity was observed to have pattern similar to spatial distribution of groundwater quality in Delhi i.e., species diversity improving from north to south of Delhi.

To relate groundwater depth, quality and plant species diversity in Delhi, spatial distribution maps were overlaid (Figure 7). The results indicate that the areas with high species diversity coincide with parts of areas with excellent and good groundwater qualities but groundwater depth of more than 33mbgl. And with plant diversity, decreasing from south to north of Delhi, areas under moderately low to low species diversity in north and northwest parts of Delhi, are areas with fair to marginal groundwater quality, with groundwater available within 13mbgl. Therefore, on relating groundwater quality, depth and plant species diversity, it can be concluded that in Delhi, high plant species diversity is supported by deeper water levels and good quality of groundwater in NCT of Delhi.

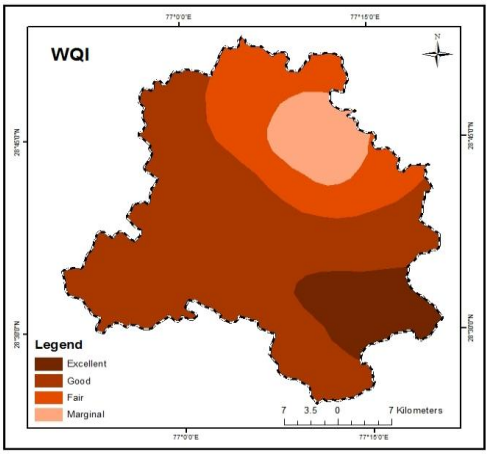

Fig. 4. Spatial distribution of CCME WQI values

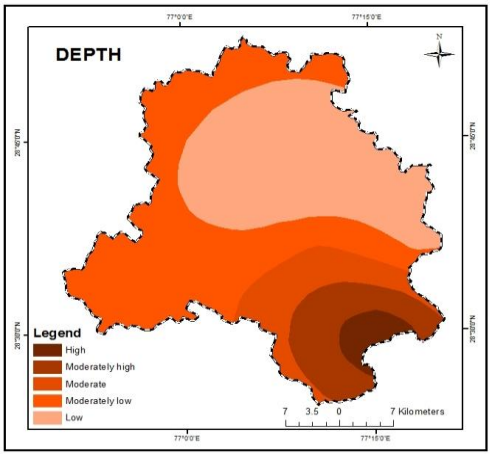

Fig. 5. Spatial distribution of groundwater depth

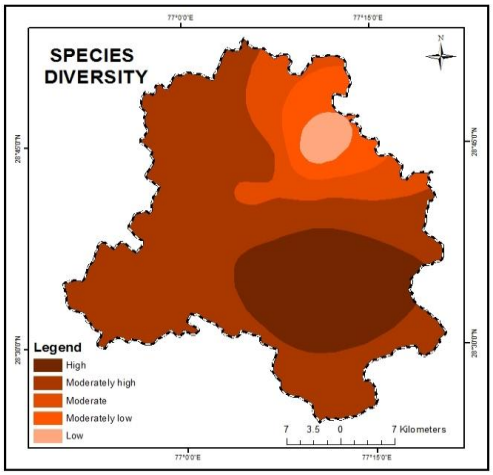

Fig. 6. Spatial distribution of total plant species diversity

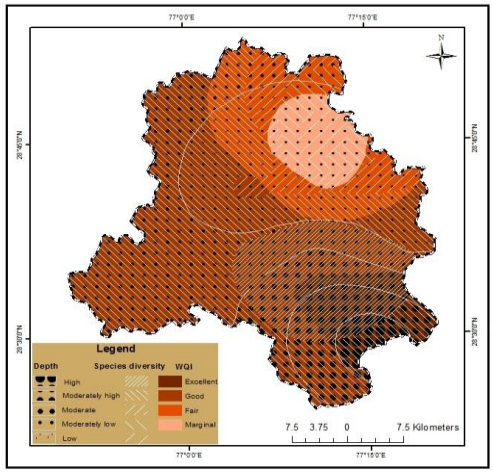

Fig. 7. Spatial distribution of total plant species diversity, WQI and groundwater depth

Table 7. Area and range for groundwater depth and total plant species diversity under different classes

Classes	Depth		Species Diversity	
	Area (sq. km)	Range (mbgl)	Area (km sq.)	Range
High	45.5	>43.24	314.4	>2.679
Moderately High	157.8	33.14-43.24	881.5	1.972-2.326
Moderate	150.5	23.04-33.14	157.3	1.619-1.972
Moderately Low	600.7	12.9-23.04	92.3	1.265-1.169
Low	528.5	<12.9	37.5	<0.91

Table 8. Area and range for CCME WQI under different classes

Class	Area (sq. km)	Range
Excellent	158.8	95-100
Good	900.2	80-94
Fair	297	65-79
Marginal	127	45-64

Conclusion

Different studies have been conducted worldwide, to relate type of vegetation with the groundwater properties of the area. Present study was taken up for National Capital Territory (NCT) of Delhi to find out the relationship between land covers viz., protected forest area, trees outside forest, maintained park and settlement area with groundwater quality and depth. Suitability of groundwater quality for the eight sites under consideration was assessed by CCME water quality index and sites under protected forest area reported best quality of groundwater. Protected forest area sites also recorded maximum groundwater depth. Floristic composition and total plant species diversity for all the eight sites was also calculated. Asola WLS under protected forest area recorded maximum diversity while Bhalswa under trees outside forest area recorded least plant diversity. All the data for CCME water quality index, groundwater depth and plant species diversity was interpolated using the kriging tool of GIS for the whole Delhi. According to the spatial distribution observed, groundwater quality of Delhi, improves from north to south of Delhi while groundwater depth goes deep in the same

direction. Total plant species diversity of Delhi was recorded highest in southern parts, decreasing gradually towards north of the city. On studying all the three parameters i.e., groundwater quality, depth and species diversity together by overlaying the spatial distribution maps, it was observed that areas with good groundwater quality are those with deeper water levels and high plant species diversity in Delhi. Thus, for Delhi, it can be concluded that higher plant species diversity favors good groundwater quality but may be responsible for depleting groundwater resources.

References

[1] P. Gupta, K. Sarma, *Variations in groundwater quality under different land covers in Delhi, India*, **Journal of Global Ecology and Environment**, **1**(1), 2014, pp. 1-10.

[2] L. Sliva, D.D. Williams, *Buffer zone versus whole catchment approaches to studying land use impact on river water quality*, **Water Research, 35**(14)**,** 2001, pp. 3462-3472.

[3] K.P. Woli, T. Nagumo, K. Kuramochi, R. Hatano, *Evaluating river water quality through land use analysis and N budget approaches in liverstock farming areas*, **Science of the Total Environment, 329**(1-3)**,** 2004, pp. 61-74.

[4] M.H. Mehaffey, M.S. Nash, T.G. Wade, D.W. Ebert, K.B. Jones, A. Rager, *Linking land cover and water quality in New York City's water supply watersheds*, **Environmental Monitoring and Assessment, 107**(1-3)**,** 2005, pp. 29-44.

[5] J.E. Schoonover, B.G. Lockaby, S. Pan, *Changes in chemical and physical properties of stream water across an urban-rural gradient in western Georgia*, **Urban Ecosystems, 8**(1)**,** 2005, pp. 107-124.

[6] M.I. Stutter, S.J. Langan, B.O.L. Demars, *River sediments provide a link between catchment pressures and ecological status in a mixed land use Scottish River system*, **Water Research, 41**(12)**,** 2007, pp. 2803-2815.

[7] J. Tu, *Spatially varying relationships between land use and water quality across an urbanization gradient explored by geographically weighted regression*, **Applied Geography, 31**(1), 2011, pp. 376-392.

[8] Central Ground Water Board, **Groundwater Year Book of National Capital of Territory, Delhi**, Ministry of Water Resources, Government of India, New Delhi, 2014.

[9] S. Das, **Groundwater Resources of India**, National Book Trust, New Delhi, 2011.

[10] J.P. Dash, A. Sarangi, D.K. Singh, *Spatial Variability of Groundwater depth and quality Parameters in the National Capital Territory of Delhi*, **Environmental Management, 45**(3)**,** 2010, pp. 640-650.

[11] M. Kumar, A.L. Ramanathan, M.S. Rao, B. Kumar, *Identification and evaluation of hydrogeochemical processes in the groundwater environment of Delhi, India*, **Environmental Geology, 50**(7), 2006, pp. 1025-1039.

[12] P.S. Datta, S.K. Tyagi, *Major ion chemistry of groundwater in Delhi area, India*, **Journal of Geological Society of India, 47**, 1996, pp. 179-188.

[13] Standard Methods, **Standard Methods for the Examination of Water and Wastewater**, American Public Health Association, Washington DC, 1998.

[14] Canadian Council of Ministers of the Environment, *Canadian water quality guidelines for the protection of aquatic life: CCME Water Quality Index 1.0, User's Manual*, **Canadian Environmental Quality Guidelines, 1999**, Canadian Council of Ministers of the Environment, Winnipeg, 2001.

[15] B.Y. Choi, S.T. Yun, S.Y. Yu, P.K. Lee, S.S. Park, G.T. Chae, B. Mayer, *Hydrochemistry of urban groundwater in Seoul, South Korea: Effects of land-use and pollutant recharge*, **Environmental Geology, 48**(8), 2005, pp. 979-990.

[16] S.K. Srivastava, A.L. Ramanathan, *Geochemical assessment of groundwater quality in vicinity of Bhalswa landfill, Delhi, India, using graphical and multivariate statistical methods*, **Environmental Geology, 53**(7), 2008, pp. 1509-1528.
[17] M. Kumar, R. Jr. Herbert, A.L. Ramanathan, M.S. Rao, K. Kim, J.P. Deka, B. Kumar, *Hydrogeochemical zonation for groundwater management in the area with diversified geological and land-use setup*, **Chemie Erde – Geochemistry, 73(3)**, 2013, pp. 267-274.
[18] D.K. Todd, **Groundwater Hydrology**, 2nd edition, John Wiley and Sons, Inc., 2014.
[19] M. Kumar, B. Sharma, A.L. Ramanathan, Al., M.S. Rao, B. Kumar, *Nutrient chemistry and salinity mapping of the Delhi aquifer, India: source identification perspective*, **Environmental Geology, 56**(6), 2009, pp.1171-1181.
[20] R. Chatterjee, B.K. Gupta, S.K. Mohiddin, P.N. Singh, S. Shekhar, R. Purohit, *Dynamic groundwater resources of National Capital Territory, Delhi: assessment, development and management options*, **Environment Earth Science, 59**(3), 2009, pp.669-686.
[21] E. Mwangi, B. Swallow, *Invasion of Prosopis juliflora and Local Livelihoods: Case Study from the Lake Baringo Area of Kenya*, **ICRAF Working Paper No. 3, World Agroforestry Centre, Nairobi**, 2005.
[22] C. Bromilow, **Problem Plants and Alien Weeds of South Africa**, Briza Publications, Pretoria, 2010.
[23] S. Dzikiti, K. Schachtschneider, V. Naiken, M. Gush, G. Moses, D.C. Le Maitre, *Water relations and the effects of clearing invasive Prosopis trees on groundwater in an arid environment in the Northern Cape, South Africa*, **Journal of Arid Environments, 90**, 2013, pp. 103-113.
[24] Y.L. Krishnamurthy, H.M. Prakasha, A. Nanda, M, Krishnappa, H.S. Dattaraja, H.S. Suresh, *Vegetation structure and floristic composition of a tropical dry deciduous forest in Bhadra Wildlife Sanctuary, Karnataka, India*, **Tropical Ecology, 51**(2), 2010, pp. 235-246.
[25] P. Gupta, K. Sarma, *Spatial distribution of various parameters in groundwater of Delhi*, **Cogent Engineering, 3,** 2016, ID Article 1138596.

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