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Variations in Groundwater Quality under Different Vegetation Types in Delhi, India

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Abstract

Present work was undertaken to study the groundwater quality and depth under different vegetated land covers in Delhi viz. protected forest area, trees outside forest and maintained park. Phytosociology, groundwater quality and depth for each land cover were studied. Protected forest area has the best groundwater quality as per BIS drinking water standards. Trees outside forest area reported the worst water quality among all the land covers with Water Quality Index (WQI) value of 297. Groundwater under maintained parks was also found in the category of 'very poor' quality according to WQI value. Water was available at minimum depth of 4.36 m below ground level under trees outside forest area. While maximum depth is reported from protected forest sites. Maximum number of tree species is recorded from protected forest area with only seven species common to all the three land covers. Land cover with maximum groundwater depth i.e., protected forest area has maximum tree species while trees outside forest area with groundwater available at least depth has reported minimum number of species.

1. Introduction

From the time water is condensed into the atmosphere, to the time it is discharged through a tube well, groundwater properties change with various processes like infiltration, precipitation, geology, land use etc. In an urban ecosystem, with deteriorating surface water quality, reliance on groundwater resources is increasing. But with increase in urbanization, there is increase in impervious area, effecting groundwater recharge. Delhi is not an exception. With increasing urban population, Delhi is also facing problem to meet its water demand. It is forced to meet fifty percent of its water demand by groundwater (Central Ground Water Board, 2006; Dash *et al.*, 2010).

Authorities are preserving and developing forest area, constructing check dams and planting trees to improve the groundwater resources (Economic Survey of Delhi, 2008) in Delhi. But, the effects of vegetation on groundwater can be both positive and negative. According to Forest Survey of India report (India State of Forest Report, 2011) 19.97 percent of Delhi's area is under tree and forest cover. Therefore, for the present study, vegetation of three land cover types viz. protected forest area, trees outside forest and maintained park, with two sites under each land cover were studied and related with groundwater resources in Delhi.

2. Materials and Methods

Total 18 groundwater samples were collected from the selected study sites (Table 1) for physico-chemical analysis. Samples were collected from tube wells and hand pump during October 2012 to June 2013. Groundwater depth was measured using Piezometers installed by Central Groundwater Board (CGWB). Samples were analyzed according to standard procedures given in APHA (1998).

Table 1: Study sites

Site code	Site name	District
Land cover 1: Protected forest		
Site 1	Asola Wildlife Sanctuary (Southern Ridge)	South
Site 2	Mahavir Vanstahli Park (Central Ridge)	New Delhi
Land cover 2: Trees outside forest		
Site 3	Bhalswa Lake	North West
Site 4	Mayur Vihar	East
Land cover 3: Maintained park		
Site 5	Vikas Puri	West
Site 6	Rohini	North West

Water Quality Index (WQI) was calculated using Bureau of Indian Standards (BIS, 2012) standards for drinking purpose (Table 2). For computing WQI, three steps are followed: (Vasanthavigar *et al*., 2010).

Table 2: Drinking water quality standards by BIS (2012)

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

In the first step, each of the 8 parameters (TDS, Cl^-, SO_4^{2-}, NO_3^-, F^-, Ca, Mg, hardness) have been assigned a weight (*wi*) according to its relative importance in the overall quality of water for drinking purposes. In the second step, the relative weight (*Wi*) is computed using following equation:

$$Wi=wi/\sum_{i=1}^{n} wi$$

Where : *Wi* is the relative weight; *wi* is the weight of each parameter and *n* is the number of parameters.

In the third step, a quality rating scale *(qi)* for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS (2012) and the result is multiplied by 100:

$$qi = (Ci/Si) \times 100$$

Where: *qi* is the quality rating; *Ci* is the concentration of each chemical parameter in each water sample in milligrams per liter and *Si* is the Indian drinking water standard for each chemical parameter in milligrams per liter according to the guidelines of the BIS (2012).

For computing the WQI, the SI (Sub-Index) is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation:

$$SIi = Wi \times qi$$

$$WQI = \sum SIi$$

Where: SI*i* is the sub-index of *i*th parameter; *qi* is the rating based on concentration of *i*th parameter and *n* is the number of parameters.

According to Ramakrishnaiah *et al*. (2009), Vasanthavigar *et al*. (2010) and Yidana and Yidana (2010); computed WQI values are classified into five categories as given in Table 3.

Table 3: Classification of water based on WQI values

WQI Value	Water quality
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
>300	Unsuitable for drinking

3. Results and Discussion

3.1. Protected forest area

Delhi ridge area is considered as green lungs for the city and appropriate place to look for its native vegetation. Parts of central ridge and southern ridge were selected for the study. 24 tree species were reported from the protected forests sites, with only six species common to both sites of the land cover. Species with maximum abundance in protected forest area is *Prosopis juliflora* (Sw.) DC., while species with maximum dominance is *Anogeissus pendula* Edgew.. Groundwater was found at maximum depth of 41m below ground level (mbgl), with water quality, according to WQI values was calculated to be good and suitable for drinking purpose (Table 4).

Table 4: WQI values for groundwater quality

Land cover	WQI value	Water quality
Protected Forest	78.5	Good
Trees Outside Forest	240	Very poor
Maintained Park	164	Poor

3.2. Trees outside forest area

Forest Survey of India in 2011 estimated 120 km^2 of tree cover in Delhi other than forest cover, making it 8.09 percent of total geographical area. Total twelve tree species were identified from trees outside forest sites, with only *Prosopis juliflora* (Sw.) DC. common at both the study sites. *Prosopis juliflora* is the most abundant and dominant species of the land cover. Groundwater was available at the depth of 4.05 mbgl, with very poor water quality of WQI value 240.

3.3. Maintained park area

Delhi Development Authority and Municipal Corporation of Delhi are maintaining neighborhood parks in the city as ornamental playgrounds, surrounded by residential colonies. Nineteen tree species were identified from the parks under study. Four species were common at both the study sites. *Pithecellobium dulce* (Roxb.) Benth. has maximum abundance and dominance among all the tree species. Groundwater was available within 10 mbgl with poor water quality.

Table 5: Tree species found in different land covers in Delhi

S. No.	Species	Protected forest area	Trees outside forest area	Maintained park area
1	*Acacia leucophlea*	+	-	-
2	*Acacia senegal*	+	-	-
3	*Alstonia scholaris*	-	-	+
4	*Anogeissus pendula*	+	-	-
5	*Azadirachta indica*	+	-	+
6	*Cassia fistula*	+	-	-
7	*Cassia javanica*	+	-	-
8	*Dalbergia sisso*	+	-	+
9	*Diospyros cordifolia*	+	-	-
10	*Eucalyptus spp.*	+	-	+
11	*Fernandoa adenophyllum*	+	+	+
12	*Ficus benghalensis*	+	+	-
13	*Ficus elastica*	-	+	+
14	*Ficus palmata*	-	-	+
15	*Ficus religiosa*	+	+	+
16	*Ficus virens*	-	+	+
17	*Grevillea robusta*	+	-	-
18	*Morus alba*	+	+	+
19	*Pithcellobium dulce*	+	+	+
20	*Plumeria obtusa*	+	-	-
21	*Plumeria rubra*	-	-	+
22	*Polyalthia longifolia*	+	+	-
23	*Pongamia pinnata*	+	-	+
24	*Prosopis juliflora*	+	+	+
25	*Psidium guajava*	+	-	+
26	*Pterospermum acerifolium*	+	+	+
27	*Saraca asoca*	-	-	+
28	*Senna siamea*	+	+	+
29	*Tectona grandis*	-	+	-
30	*Thevetia peruviana*	+	-	+
31	*Wrightia tinctoria*	+	-	-

Table 5 shows presence and absence of tree species in all the three land covers. Protected forest with best quality of groundwater has water available at maximum depth, while trees outside forest with least depth have hard water. Both the land covers have *Prosopis juliflora* as most abundant species. Zhao *et al.* (2005) reported that same type of vegetation can affect water recharge differently under different conditions of groundwater depth. Groundwater depth and salinity are reported to be important factors controlling vegetation distribution in an area (Antonellini and Mollema, 2010).

Vegetation effects water depth by processes like interception, evaporation and evapotranspiration. Study conducted by Allen and Chapman (2001) also reported that irrespective of the type of vegetation, it influences the rain water reaching the ground surface, thus, reduces infiltration and effects water depth. Also, water uptake by root system has significant effect on the water table of the area.

Water quality at all the three land covers was different from each other, with significant contribution of total hardness. On correlating hardness with number of trees and species diversity, negative correlation was observed, which suggest that increase in number of trees and species lowers hardness in groundwater, thus improves water quality.

On observing the trend for land covers (Fig. 1), number of tree species decreased as moving from protected forest to maintained park and trees outside forest area, while depth of groundwater was found to be deteriorating in opposite order. This suggests increasing diversity and number of tress have negative

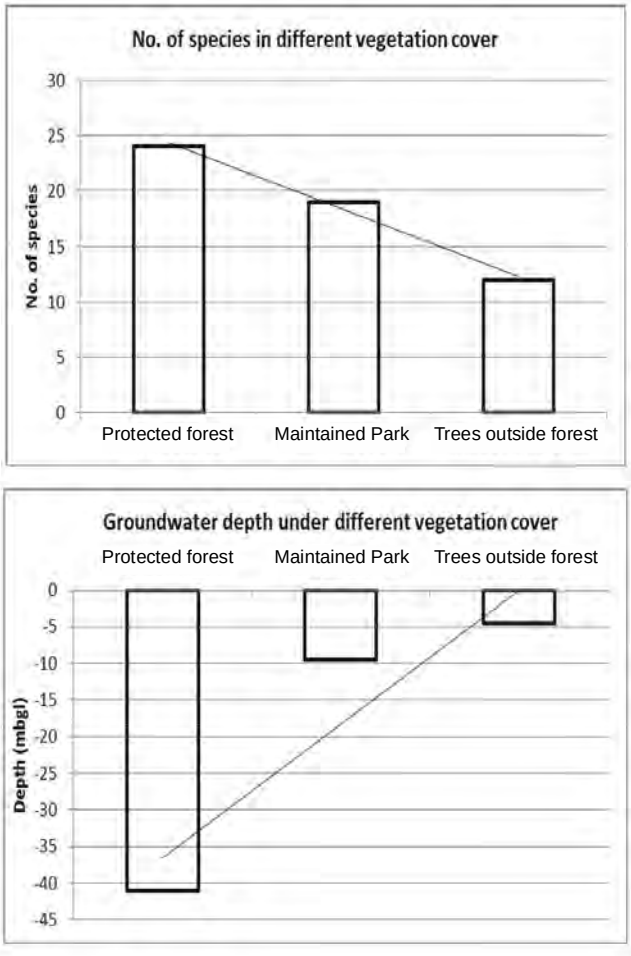

Fig. 1: Trend of number of species and depth of groundwater at different land covers

effects on groundwater depth. McCulloch and Robinson (1993) also observed that infiltration of water is more in grassland than in the forest area. Zheng *et al.* (2012) suggested to plant shrubs and grasses to improve the groundwater depth.

4. Conclusion

Phytosociology, groundwater quality and depth at all the three land covers under consideration were studied. Protected forest area with maximum tree diversity has maximum depth of groundwater and best water quality. With decrease in number of tree species and diversity, groundwater quality deteriorated from protected forest to maintained park and trees outside forest area. While, groundwater depth improved in the same order. Therefore, it can be concluded that, the groundwater quality is negatively related with groundwater depth and positively with tree species diversity for Delhi.

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