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Analytical account of Groundwater Situation in different Districts of Delhi and its Comparison with Bordering Districts of Haryana, India

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ABSTRACT: Groundwater is one of the valuable natural resource used in agriculture, industries, and for domestic purposes. It is present in the aquifers located below the surface of the earth in the pores and crevices of the rocks. The depleting groundwater levels is a matter of concern as it is associated with risks like drying up of wells, decreasing water in streams and lakes, increasing salinity of water, depleting quality of water and land subsidence. A comparison of groundwater levels from 2000 to 2022 brings a picture of decline and fluctuations in districts of the capital city, Delhi and its neighbouring state, Haryana. It also suggests that the situation of Delhi is better and improved in the last five years than that of Haryana as the percentage of overexploited assessment zones is reduced. Out of the eleven districts of Delhi, the South district has undergone extensive decline in groundwater levels and in Central Delhi water level has remained unchanged. The changing trend of groundwater levels in various districts calls for the differential extraction of groundwater depending upon its local availability. The study helps to identify reasons for depleting groundwater resources in different districts of Delhi, a metropolitan city, and neighbouring agricultural state, Haryana. It highlights the need for urgent steps to be taken for its conservation and better management. Suggestions are put forward to alleviate the problem of its scarcity and to attain sustainable use of groundwater.

Keywords: Groundwater level, assessment zones, overexploited, groundwater extraction, urbanization, sustainable.

INTRODUCTION

Groundwater is the important preferred replenishable resource of water for human use as it contributes to nearly thirty percent of available freshwater in the world (Guppy *et al.,* 2018; Scanlon *et al.,* 2023). It is located in the aquifers present in the under surface of the earth mainly in the pores and fractures of rocks as well as soil which hold water. It is often extracted for different uses like domestic, agriculture, industries etc. which is mainly replenished by monsoon rain and by other sources like seepage from canals, tanks, ponds etc. and return flow from irrigation. Sixty-seven percent of the ground water recharge annually is through rainfall and the rest thirty-three percent is from other sources (http://cgwb.gov.in/GW-Assessment/GWRA-2017-National-Compilation.pdf). Groundwater extraction is increasing worldwide in the recent past due to the increasing demand of the rising population, more urban development, and increasing industries (Kulkarni *et al.,* 2015; Achu *et al.,* 2020).

The quality of groundwater is also reduced due to excessive extraction and climate variation (Dreshaj *et al.,* 2012; Ghazavi and Aleboali 2017). The different parameters which affect the recharge of groundwater have recently been reported using geospatial techniques (Dileshwari *et al.,* 2021). The average water consumption of a person in Delhi is the highest compared to other states in the country which is 240 liters per capita per day (lpcd) (http://www.rainwaterharvesting.org/index_files/about_delhi.html).The water requirement of Delhi, a capital city of India, is met through different sources like water from the river Yamuna, Ganga canal(UP) and Munak canal (Haryana), Bhakra storage (HP), ground water, rainwater, and treated wastewater (http://delhiplanning.nic.in). Thus, Delhi relies on other states for supply of water as Yamuna is the only perennial river that flows in the eastern part of Delhi (http://www.rainwaterharvesting.org/index_files/about_delhi.html).

Delhi which is located in Indo-Gangetic plains of North India has varied geography. It has Yamuna flood plains in the North and East which is mainly sandy and alluvial and rocky terrain of Aravalli Hills in the South with a boundary of Thar desert in the West. The three sides of Delhi are bordered by Haryana and fourth by Uttar Pradesh (Fig. 1). The main

part of the city is located on the west of the river Yamuna, whereas some village areas and small region of Shahdara is on its east. Delhi, a metropolitan mega city of the country, is second to Mumbai with respect to population. The population of Delhi has almost doubled from 15,692,000 in 2000 to an expected 32,066,000 in 2022 (https://www.census2011.co.in/census/state/delhi.html). The consequent increase in water requirement in the city is met by surface water received from the bordering states and also by extracting from ground. The availability of water from ground is dependent on the population density, anthropogenic activities, water recharge and change in climate (Kumar *et al.,* 2022) When observed in terms of development of groundwater, Delhi is categorised as overexploited (Chatterjee *et al.,* 2009).

Delhi is divided into eleven revenue districts which are named as Central, North, South, South East, North East, South West, North West, West and Shahdara. Initially Delhi had only four districts (Central, South, North and East) in 1970, which increased to nine in the year 1997. In 2011, the South district was divided into South and South East whereas North East and East were recarved into East, Shahdara and North East. Thus, they were increased from nine districts to eleven in 2011 for better administrative work as the city has attracted people from different regions of the country due to its excellent opportunities in education sector, commerce, trade and employment (Fig. 1). The districts vary from each other in different aspects. North West is the largest district of Delhi with respect to both area and population. Central district is the smallest with respect to area while New Delhi is the smallest district by population.

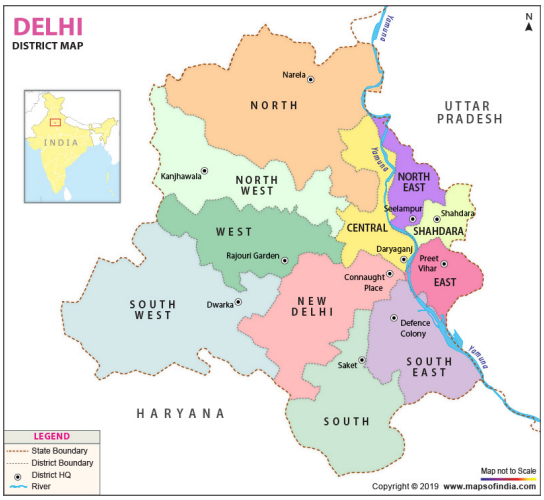

Fig. 1. Map of districts of Delhi (Source: https://www.mapsofindia.com/delhi/districts/7).

The present paper is focused on study and analysis of the groundwater situation in different districts of Delhi and its comparison with the neighboring districts of Haryana which is an important agricultural state of North India and is also facing groundwater crisis in recent years. Besides, major part of Delhi is bordered by Haryana and is also dependent on it for augmenting its water supply. Delhi shares its North, West and South borders with Haryana and only Eastern border with Uttar Pradesh. The analytical and comparative study will help in articulating and communicating the groundwater situation of Delhi and neighbouring districts of Haryana to emphasize on the need to take steps for its conservation and better management. The decreasing groundwater levels need immediate attention as it is associated with risks like drying up of wells, decreasing water in streams and lakes, increasing salinity of water and depleting quality of water resulting in increasing concentration of contaminants (Sharma *et al.,* 2022), land subsidence (Gezgin, 2022), consequently leading to more expenditure to extract water from ground (https://www.usgs.gov/special-topic/water-science-school/science/groundwater-decline-and-depletion qt science_center_objects=0#qtscience_center_objects).

MATERIALS AND METHODS

The data for groundwater levels was observed and noted from the Central Ground Water site (CGWB) for different regions of Delhi and of three adjoining districts of Haryana. The water levels in the various districts are depicted at different depths (less than 5m, 5-10m, 11-15m, 16-20 m) in 2000 and (8-10m, 11-15m, 16-20m and more than 30m) in 2020. The data for the number of assessment units categorized as overexploited, semi critical, critical and safe were taken from the same site and were expressed as percentage to study the comparative status of groundwater development of Delhi and Haryana. The information collected was analysed by comparing through graphs and tables. It is also correlated with the population, availability of piped water, geographical status, urbanization and land use.

RESULT AND DISCUSSION

A comparison of groundwater levels from 2000 to 2020 brings a picture of the decline and fluctuations in many areas of Delhi (Fig. 2). The results suggest that out of the eleven districts, South and South West districts' water levels dropped more compared to others. The

level decreased from 16-20m from the surface to more than 30m and from 11-15m to 16-20m in the South and South West respectively in a period of twenty years (Table 1). The South district already had a low water table compared to other districts with a more than 10m decline in just 5 years (2000-2005) and since 2005 its groundwater level is below 30m. North, North East, and North West levels dropped from less than 5m to 5-10 m, whereas Central and East Delhi had levels at 5-10m in the year 2000 which declined to 8-10m and 11-15m in 2020 respectively. New Delhi is the only district where groundwater level has remained almost the same from 2000 to 2020 which may be attributed to the fact that it is the least populated district with a population density of 3,820 persons per sq. km (CGWB) and land usage shows mainly government offices, embassies, residences of ministers and Govt. employees which already have a good piped water supply. Localities in the proximity of surface water bodies in East Delhi (close to Yamuna River), some regions of North Delhi (near Yamuna Canal), and West Delhi (close to Najafgarh drain) show less decrease in water level. The water level declining each year in different districts varies.

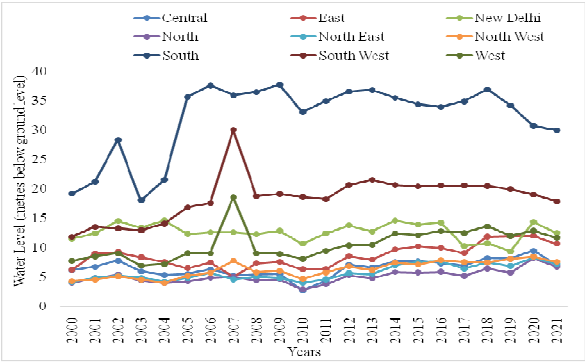

Fig. 2. Groundwater levels of eleven districts of Delhi from year 2000 to 2021.

Table 1: Comparative change in groundwater level in various districts of Delhi and in neighbouring districts of Haryana in year 2000 and 2020.

Districts of Delhi (D) and Haryana (H)	Groundwater level							
	Year 2000				Year 2020			
	<5m	5-10m	11-15m	16-20m	8-10m	11-15m	16-20m	>30m
Central (D)		√			√			
East (D)		√				√		
New Delhi (D)			√			√		
North (D)	√				√			
North East (D)	√				√			
North West (D)	√				√			
South* (D)				√				√
South West (D)			√				√	
West (D)		√				√		
Gurugram (H)			√					√
Faridabad (H)		√						√
Sonipat (H)	√					√		
Jhajjar (H)		√			√			

As Delhi has undergone extensive demographic expansion, there is an increasing load on water sources from other states and also on its internal groundwater resources. The city's current water supply capacity is only 935 million gallons per day (MGD) as against a demand of 1,260MGD (http://timesofindia.indiatimes.com/articleshow/81487927.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst). The availability of raw water is also affected by its declining water table due to unrestricted and unregulated extraction (Nagpal *et al.,* 2019). The substantial amount of water requirement of Delhi is met through groundwater. The newly developed colonies which do not have regular piped water supply use groundwater for domestic purposes also. The sustainability of groundwater requires a strict balance in the withdrawal and replenishment rates (Chatterjee *et al.,* 2009). Depletion of water level is a consequence of the fast rate at which it is withdrawn causing the water table to go deeper. The sharp decline in water level is observed in the year 2007 in South West and West districts though rainfall received was high thus indicating the result of anthropogenic activities leading to overextraction of water from the ground.

The availability of water in aquifers in any area is determined by the hydrogeological characteristics, alluvial formation, quartzitic hard rocks, and its physiography. The Northern part of Aravalli is the Delhi ridge region, which is made of quartzite rocks in the southern and western bank of Yamuna. There is fluctuation in levels of groundwater in all eleven districts of Delhi where the South and South West are affected more. There is a difference in the supply of tap

water in various districts by MCD. Districts of Central and New Delhi have good piped supply of water compared to South, South West and North Delhi which face the problem of water shortage (Biswas and Gangwar 2020). A report also shows that people in Mehrauli and Narela get only 29 and 31 liters of treated water per person per day respectively, whereas 509 and 462 liters is distributed to the cantonment area and Lutyens's Delhi and 337 liters per person per day is supplied to Karol Bagh Zone (http://www.rainwaterharvesting.org/index_files/about_delhi.htm).

South district which is the most affluent of all residential districts of Delhi shows a very poor picture with respect to groundwater level. It has large sized residential houses in many areas and urban villages like Shahpur Jat and Hauz Khas village which have transformed in the last few years to hubs for boutiques, restaurants and art galleries etc. There is an extensive conversion of large residential houses to apartments/ floors with an increase in the number of occupants. This puts more stress on the planned infrastructure and increases water requirements resulting in rise in illegal as well as unrestricted water extraction through borings to fill the gap of demand and supply of regular water. Its geological conditions are very diverse and the land has alluvium but predominantly quartzite rocks which retain less groundwater through the alluvium of the Chattarpur region is made of predominantly sand with silt, clay and khankar which is more porous. The increasing number of farmhouses in Mehrauli and Chattarpur areas of the South district is another cause of concern as they rely on extracted groundwater to meet their water requirements. The concretisation and encroachments is considered another reason which prevents groundwater recharge (Bajpai 2011; Gupta and Misra 2018).

South West district has Gurugram on the Southern side, and Jhajjar on its Western location which belong to the state of Haryana. Area-wise comparison puts Southwest in the second position with 420 sq. km of geographical area. It has three tehsils under it namely Delhi cantonment, Najafgarh and Vasant Vihar. As per the census 2011, the district's population is 22,92,958 and has an average density of population as 5458 persons per sq. km (https://censusindia.gov.in/census.website/data/population-finder). It also includes Dwarka which is one of the largest prosperous residential colony of Asia. Besides this, it has Indira Gandhi International airport and some very populus residential colonies like Uttam Nagar, Vasant Kunj, Vikas Puri, Janakpuri etc. The extensive urbanization, flourishing societies, poor land terrain, and anthropogenic activities put more stress on already poor water resources aggravating its problem. The quality of ground water is also deteriorating due to Industries located in the west, south, and east of Delhi as well as the three power generation thermal plants which are driven by coal, namely Badarpur, Indraprastha, and Rajghat.

Comparing the situation of Delhi with that of Haryana shows that in the last five years that is from 2017 to 2022, Delhi is better than Haryana as the overexploited percentage of the groundwater wells is reduced from 65 to 44 and the safe zone increased from 9 to 12 percent. (Table 2). The overexploited percentage in Haryana remains unchanged though the safe zone percentage increased from 19 to 25. Gurugram and Faridabad, two neighboring districts of Haryana show a sharp decline in water level that is from 11-15 m and 5-10 m to more than 30 m in a period of 20 years (Fig. 3). The major IT firms located in Gurugram have driven large-scale migration to this area due to more job prospects. The other two districts that is Jhajjar and Sonipat also show a declining trend but this is less compared to that of Gurugram. The quality of groundwater of Jhajjar district is also poor and is not suitable for drinking due to a number of geogenic factors (Gupta and Misra 2018). Out of the four districts of Haryana, Gurugram has the lowest water level. In Haryana, a large part has semi-arid climatic conditions and there are no perennial rivers running through the state. It is an important agricultural state where the farmers rely on groundwater for irrigation and extracting it in the most unsystematic and unplanned manner. Fast electrification in the rural areas of the state along with the available advanced pump technologies has led to a rise in the borewell numbers to fulfill water demand. However, the farmers still follow the previous traditional and well-established paddy-wheat cycle in the state, where paddy, being an additional water consumer, is largely responsible for the quick decrease in groundwater.

Table 2: **Ground water status of Delhi and Haryana in years 2017, 2020, and 2022.**

State	Year	Number (percent) of assessment units in category*			
		Overexploited	Critical	Semi critical	Safe
Delhi	2017	22(64.71%)	2(5.88%)	7(20.59%)	3(8.82%)
Delhi	2020	17(50%)	7(20.59%)	7(20.59%)	3(8.82%)
Delhi	2022	15(44.11%)	7(20.59%)	8(23.53%)	4(11.76%)
Haryana	2017	76(61.79%)	3(2.44%)	20(16.26%)	24(19.51%)
Haryana	2020	84(61.76%)	11(8.09%)	13(9.56%)	28(20.59%)
Haryana	2022	87(61.70%)	10(7.10%)	8((5.67%)	36(25.53%)

* Categorization of assessment units based on the stage of groundwater extraction (https://cgwb.gov.in/Documents/GEC2015_Report_Final%2030.10.2017.pdf)

Stage of groundwater extraction	Category
≤ 70%	Safe
> 70% to ≤ 90%	Semi critical
> 90% to ≤ 100%	Critical
> 100%	Overexploited

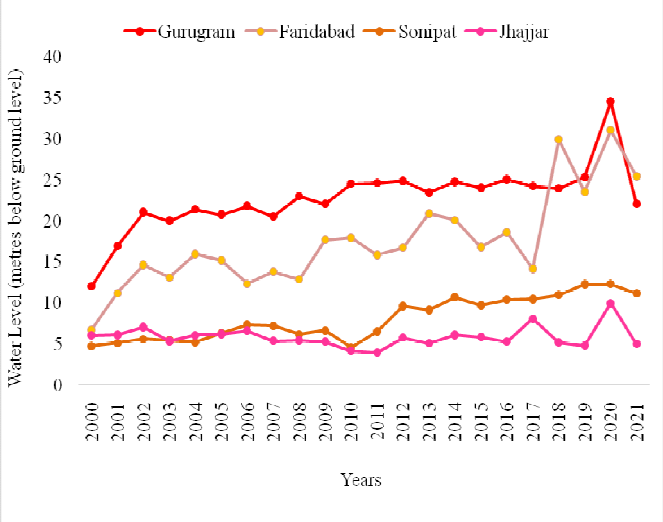

Fig. 3. Groundwater levels of four districts of Haryana from 2000-2021.

Thus, the groundwater augmentation in Delhi and Haryana needs urgent steps though Delhi's situation is better which may be a result of some regulations for its use imposed by Delhi Jal Board. Regular monitoring and mapping of potential groundwater zones of different districts will help to better manage groundwater situation as envisaged for other areas in India (Verma *et al.,* 2020; Sohail *et al.,* 2019) As the sources of water supply are very restricted with no scope of addition to the previous allocation in near future, it is essential to have judicious use of groundwater. Artificial recharge to replenish water located below the ground needs to be given top priority, especially in the districts of South and South West so as to make it a sustainable resource and also to improve its quality which is deteriorating because of overexploitation. Recycling wastewater and rainwater harvesting should be encouraged. Though it is made mandatory that rooftops of the Government buildings of Delhi and of all the buildings which are nongovernment with an area above 100 sq m should store and conserve water through the technique of Rainwater harvesting (RWH), but efforts have to be made for its effective implementation. An alternate approach to augment groundwater is to utilize the excess waters during urban floods. A pilot program of artificial groundwater recharge was initiated by state government in Palla region (flood plains of Yamuna) of Delhi in 2019. This had started showing promising results in 2021 with filling of artificial reservoir with flood waters of Yamuna and rise in groundwater table by 0.5 - 2m up to 2 km radius (August 1,2021 and June 24, 2022. https://indianexpress.com/article/cities/delhi). New methods and technologies need to be explored for recharging groundwater taking into consideration the geographical terrain of overexploited areas. Remote sensing and GIS techniques should be used to identify the areas of potential groundwater and for locating sites for artificial recharge. Strict rules should be enforced to regulate construction activities and apartmentisation. Since groundwater is a natural, common resource for all, there is no justification for private property rights over its extraction. Regulation of groundwater extraction as well as prevention of its contamination is essential to ensure not only sufficient but safe drinking water for everyone.

CONCLUSIONS

Our findings suggest that condition of groundwater levels in districts of Delhi is improving in the last five years except South district where urgent measures are needed to tackle the still deteriorated groundwater state. The condition of groundwater situation in Delhi (metropolitan city) is better than Haryana (agricultural state) though the reasons of decline in both the states are different. Increasing dependence of agriculture sector of Haryana on groundwater is a challenge to be tackled judiciously. Government initiatives along with sensitization and awareness in public is required for sustainable use of groundwater.

FUTURE SCOPE

Future scope of present study is that the joint efforts of local Government agencies and public is expected to augment groundwater resources of overexploited districts of Delhi and Haryana by focussing on suggested measures.

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Conflict of Interest. None.

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