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Rural to Urban Land Transformation Effects on Ground Water Levels – A Case Study of Greater Noida, Gautham Budh Nagar District, Uttar Pradesh

Ashwani Kumar*[a] and S.M. Veerabhadrappa*[b]

Department of Remote senning, Amity University, Noida Campus, UP, India

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ABSTRACT

Greater Noida evolved from 1991 with 101 villages to 2020 with 293 villages. This is an ideal case of rural to urban transformation in immediate past. This transformation led to decrease in recharging natural surfaces and increase in impermeable surfaces. Along with reduction in recharge areas, increase in population has necessitated more and more extraction of ground water resulting in an imbalance of water extraction and recharge. The result is depletion of ground water levels in this area. The area is part of the wide Indo Gangetic alluvium with sand, silt and clay layers resting of quartzites of Delhi Super Group. Geomorphology created using digital elevation models of the area shows older and younger alluvial plains and active flood plains of the river Hindon. Time series analysis of key land use land cover classes shows that recharge areas were reduced from 77% to 30% from 2005 to 2019 and impervious surfaces has increased from 19% to 65% for the same period of time. Aquifers of the area are of both phreatic and semi confined in nature. The aquifer parameters estimated through step drawdown test and long duration aquifer performance test indicates that average coefficient of transmissivity of the area is 1752 m^2/day and average coefficient of storage is 4.84 x 10^{-4}. Discharge of the wells shows a yield of 8 to 16 lps for a drawdown of 3 to 6m. An attempt has been made to know the behavior of ground water levels during same time period as that of land use land cover. The results indicate that 74% depletion in ground water levels with an average annual depletion of 21%. Interrelationship between urban growth and ground water levels has been established in this study. This analysis indicates that as agriculture declined water levels also depleted and have a positive correlation of 0.852. On the contrary, as built-up increased water level has depleted hence have a negative relationship with a correlation coefficient of -0.851. In order to make it a sustainable resource, this over exploited aquifers need careful participatory management by Community, Scientists, and policymakers.

Key words : *Ground water, Aquifer recharge, Key land use classes, Transmissivity, Over exploited*

Introduction

Water is elixir for life. Mankind has evolved around this precious resource. As this life sustaining resource was so abundant in the immediate vicinity of humans, earlier he did not pay any special attention to this resource. Ground water is the most reliable fresh water source which can be readily used for all purposes without much processing (Morris *et al.*, 1994). More over ground water is replenishing annually through rainfall. As time passes, population has increased in an alarming rate, quest for living space and infrastructure, turned villages into big cities and towns. Extraction of fresh water for domes-

(*a Research Scholar, *b Director)
Corresponding author's email: *aashgup1111@gmail.com *b, emailsmveerabhadrappa@amity.edu

tic, commercial, industrial, and agriculture purposes expanded exponentially. Recharge areas of the earth becomes impermeable to water due to constructions. This all leads to an imbalance between ground water recharge and extraction rate resulted in depletion of the ground water resource (Shah *et al.,* 2000).

Urbanization process has altered the quality and quantity of ground water (Hemant *et al.,* 2018). Almost 100% of the drinking water requirements in urban areas are met with imported water supplies or Government controlled insitu water supplies. 50% of the industrial water requirements are fulfilled by ground water resources. As per the World Bank Statistics 37% of agricultural land in India are under irrigation and out of this 65% of irrigation is done by using ground water. 51% of the food crops are produced using ground water as irrigation means. Urbanization has resulted in contamination of ground water resource by industrial effluents, sewage water and by over usage of fertilizers and pesticides in the urban peripherals.

Generally, ground water is viewed through the lens of a supply sided source. In factual terms, it is a resource. Here lies the importance of its management. Ground water need to be managed scientifically. Ground water is not all about water extraction structures say wells, it is about aquifers were ground water lies, moves and stored. If storage is depleting, it needs to be re filled with participatory ground water management. Community, scientists, and policymakers are its components.

Greater Noida area is classed as over exploited in a ground water point of view. Well planned strategies are required to conserve and augment ground water resources. This will lead to have equal pace of water conservation and infrastructure development. Major institutional policy and technological initiatives are enquired to ensure an efficient socially equitable and environmentally sustainable management of our water resources. Development of water resources must be to an extent such that it ensures the sustainability of the resources, both for the present and future generations.

It is anticipated that global urbanization will bring 83% of developed countries and 53% of developing countries population to its cities by 2030 (Cohen, 2004). As a consequence of this coupled with irrigation through ground water, world ground water recharge - discharge balance is shrinking every day. Three major issued faced by world's ground water regimes are over exploitation, water logging and salinity and ground water pollution (Tushar *et al.,* 2000).

Ground water is a critical issue for cities around the world. The core of the issue is abnormal increase in population. The need of the hour is integrated development of water resources and conservation of available water resources. Community initiatives to manage the water resources in a sustainable manner at local levels are most required. In the present scenario, when surface water resources are fully contaminated and there is immense pressure on ground water reservoirs throughout India.

The land use land cover changes are the major indicator for environmental changes in an urban area. As urban area expands, there will be a toll on natural resources. Water resources are especially sensitive to urban sprawl due to corresponding increase in population, reduction in recharge areas. Surface water sources are getting polluted, and ground water will be over extracted without any consideration to its safe yield results in depletion of water resources in terms of quality and quantity.

Expansion of urban areas are at the cost of cultivated land (Bhagavat *et al.,* 2018). Losing of cultivable land will leads to reduction in recharge areas of water resources. More and more rural recharge areas of ground water were turned into impervious urban surfaces. The Fig. 1 shows the number of villages brought under the urban agglomeration during the expansion of Greater Noida. This clearly indicates that more and more rural hubs joined in the making of present-day Greater Noida City.

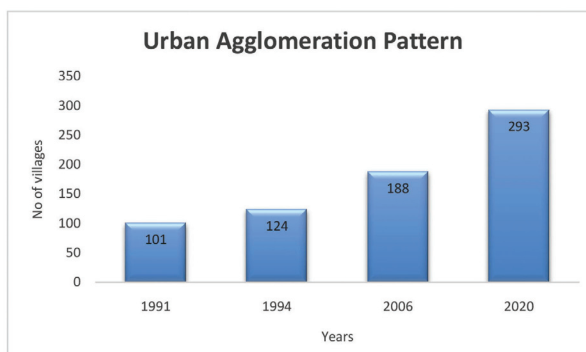

Fig. 1. Expansion pattern of Greater Noida

Objectives

The broad objectives of the study

- Temporal analysis of urban growth in Greater Noida area.

- Analyze the behavior of ground water levels due to infrastructure development

Scope

- Time series analysis of land use land cover of Greater Noida from 2005 to 2019
- Time series analysis of ground water levels
- Establish relationship between specific land use classes pertaining to urban growth

Study area

Greater Noida is an integrated township set up in 1991 under the Uttar Pradesh Industrial Area Development Act 1976. This industrial area is the inter section point of Western and Eastern Dedicated Freight Corridors and is a gate way to Delhi Mumbai Industrial Corridor (DMIC). It is part of the National Capital Region (NRC). It is the largest industrial town ship of Asia. The aim of developing this city is to provide basic enabling framework for developing an efficient and integrated modern city with high service and delivery standards. It is one of the India's smartest city and a modern urban development center of attraction. This metro center is developed for providing quality urban amenities to decongest Delhi. Administratively Greater Noida is part of Gautham Budh Nagar district of the State of Uttar Pradesh. The area is formed by agglomeration of about 124 of the east while villages of the region having an area of about 38,000ha. It is bordered in the North by Ghaziabad city, West by Noida city, East by GT Road and Northern Railway main line to Kolkata. Greater Noida lies on the Eastern bank of the River Hindon. River Hindon is separating Greater Noida from Noida city. Geographically it is bounded by North latitudes of 280 19′ 43″ and 280 39′ 43″ and East longitudes of 770 23′ 36″ and 770 41′ 12″. A location map is shown in Fig. 2 Physiography of the terrain is gently sloping undulating plains. Slope ranges between 0.1 and 0.2 percentage. Generally, slope is towards South West. The highest elevation is 214m a msl and lowest is 193m above msl.

Greater Noida is built by amalgamating may villages situated in the area. The transformation of a rural village to a world class city has its toll on exploitation of natural resources. Over exploitation of ground water is on such problems faced by the authorities responsible to cater drinking water to the communities. Over exploitation leads to lowering of water table which is forcing authorities to go deeper and deeper in quest for more water. This has exacerbated by illegal extraction of ground water by construction companies of the area. As per Central Ground Water Authority (CGWA), Greater Noida has surpassed the level of critical and reaching the level of over exploited

Almost 100% of the water demands of the

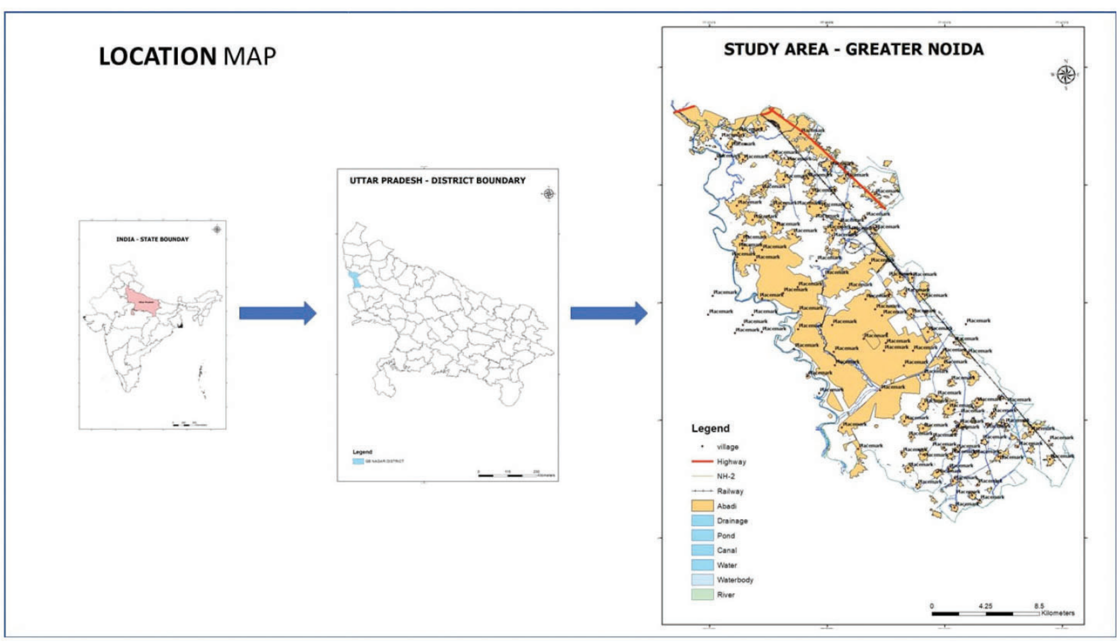

Fig. 2. Location map of the area

Greater Noida is fulfilled from ground water resources. So, this resource need to managed democratically. So good governance and good management is necessary for the authorities responsible for water distribution to its communities. It is much easier to go for more and more bore wells and go deeper and deeper for water and build more tanks for distribution. But as a nation to ensure access to water in adequate, equitable and sustainable way, we need to manage our precious resource carefully.

Hindon River is an ecological resource of the area along with few forest patches and some of the wetlands are the major ecologically sensitive area within the developmental area of Greater Noida. Some of the forest patches are also sensitive. The objective of developing this industrial city is to stop speculative land selling in this area, to provide job opportunities to the mass to decongest Delhi, and develop as a recreational and knowledge center of the country.

The study area falls under tropical climatic conditions with high temperature and humidity. Scorching summers and shivering winters are common in this kind of climate. The onset of winters starts from middle of October to February and summer starts from March to middle of June followed by rainy season up to middle of October. Overall climate of the area is given in Fig. 3. The details of the climatic parameters are given in Table 1.

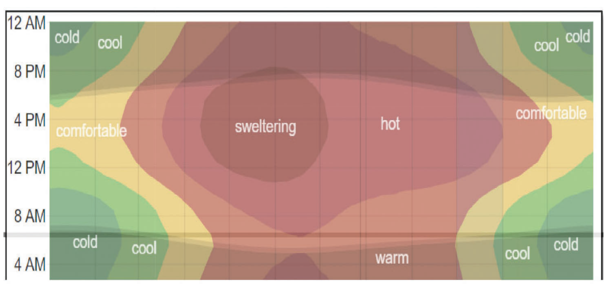

Fig. 3. Over all monthly climate of the area

The measured precipitation is majorly rainfall in mm. The average monthly rainfall is shown in Fig. 4.

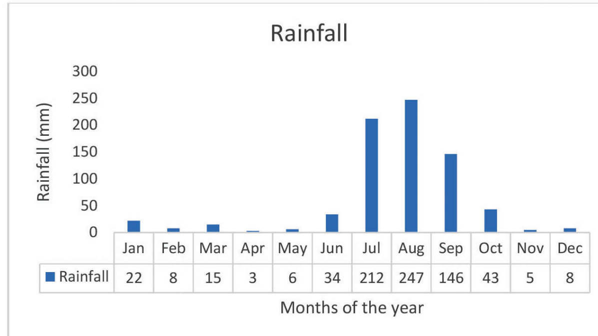

Fig. 4. Average monthly rainfall of Greater Noida

The Fig 3 shows that Greater Noida area receives an annual rainfall of 749mm with minimum rainfall months are April, May, November and December. Fig.5 shows the seasonal variations in rainfall. About 86 percent of the rainfall is happening during the monsoon season with scanty rainfalls in summer with 8 percent and winter with 6 percent. This shows that there is a possibility of inundation along the low-lying areas during monsoon season and high scarcity of water during other periods of the year.

An analysis of number of rainy days are shown in Fig 6. The total hours of rainfall in a month are con-

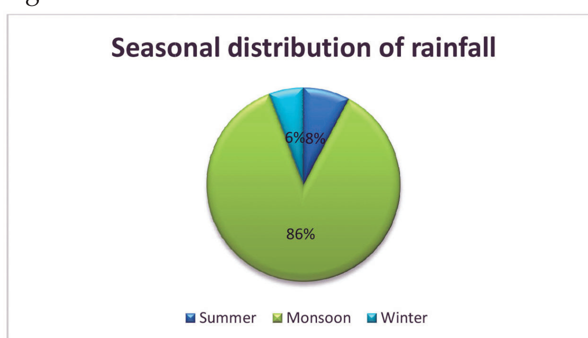

Fig. 5. Seasonal distribution of rainfall

Table 1. Climatic parameters of Greater Noida city

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature (°C)	14	17	22.8	29	33.3	34	31	30	29	26	20	16
Min. Temperature (°C)	7.6	10	15.2	21	26.1	28	27	26	25	19	12	8.1
Max. Temperature (°C)	21	24	30.4	37	40.6	40	35	33	34	33	29	23
Precipitation (mm)	22	8	15	3	6	34	212	247	146	43	5	8
Total sunshine (hours)	240	250	260	280	300	220	200	195	225	280	275	260
Relative humidity (%)	58	52	38	28	29	45	68	70	62	43	40	58
No of rainy days	2.4	4	3.9	4.3	6.5	12	23	24	12	2.3	0.8	1.3
Wind velocity (m/s)	1.6	1.6	2.4	2.4	2.4	3.2	1.6	1.6	1.6	0.8	0.8	1.6

verted to number of days so that actual number of wet days in a month can be ascertained. From this it is clear that July-August months are mostly rainy months and followed by June and September with more than 10 days of rainfall and rest of the months in the year is with scanty rainy days. This forms a pivotal information when planning for various rain water harvesting structures.

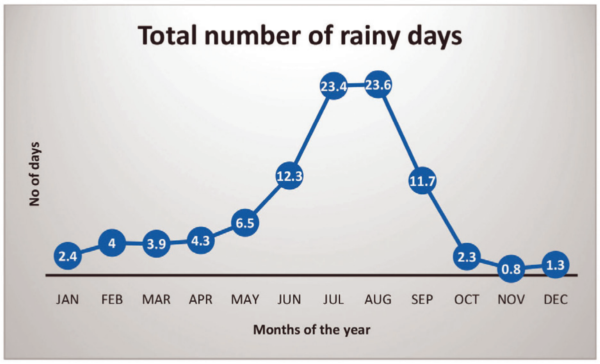

Fig. 6. Month wise number of rainy days

Geological Setup

Geologically the area is part of the vast Indo Gangetic alluvial plains with unconsolidated deposits of Sand, silt, Clay, gravel and kankar lying over Quartzites of Delhi Super group. Table 2 shows the geological succession of the area. The alluvium and Delhi super groups and the Quaternary sediments are separated by a marked unconformity. Lithologs of the wells made in these alluvial tracts shows deposits of sand, silt and clay along with gravels and kankar. The collected lithology shows that in Greater Noida part of the area basement rocks of Delhi supergroups are not encountered in the drilling. This may be due to low drilling depths.

Geomorphology

The geomorphology controls movement of water in an area. Geomorphologically the study area is part of Ganga-Yamuna flood plain with Hindon River as the Western boundary. It is a vast flood plain of the River Hindon dissected by its tributaries. Geomorphologically the area can be divided into three main categories

i. Older alluvial plains
ii. Older flood plains
iii. Active flood plains

As the area is part of an interfluves of the River Hindan and River Ganga, older alluvium occupies vast tract of the area. Ravines are common along active drainages as rivers flowing through older soft alluvial plains. These ravines are formed due to erosion of the older alluvial plains and gives an undulating topography to the area. These are visible along Hindan, Lohiya Nadi, Bhuriya Nala area. Within the planes at places meandering scars can be interpreted from Satellite Images and SOI toposheets. These palaeo channels are with coarse sand and ideal for ground water recharge. The elevation details and analysis of Digital Elevation Model (DEM) shows that area is prone to un precedented floods in Hindan River as well as River Yamuna. General low topography is a big constraint in managing storm water in the city.

Soil

As the study area is part of Indo-Gangetic alluvial

Table 2. Stratigraphy of Greater Noida area

Period	Age	Super Group	Group	Lithology
Pleistocene to recent	2.58 million years to 0.012 million years	Quaternary alluvium	Recent etc.	Sand, silt, Clay, kankar, gravel
		Older alluvium		Piedmont gravels, pebbles, cobbles, sand, gravel, clay and calcareous concretions
		Unconformity		
Late Pre Cambrian	735 million years	Post Delhi	Intrusive	Quartz vein, pegmatites, granites, amphibolite
Archaean to Pre Cambrians	4.6 billion years	Delhi	Ajabgarh, Alwar	Quartzites, phyllites, mica schists, calc schists, gneisses, marble, basic flows, conglomerate and other schists.

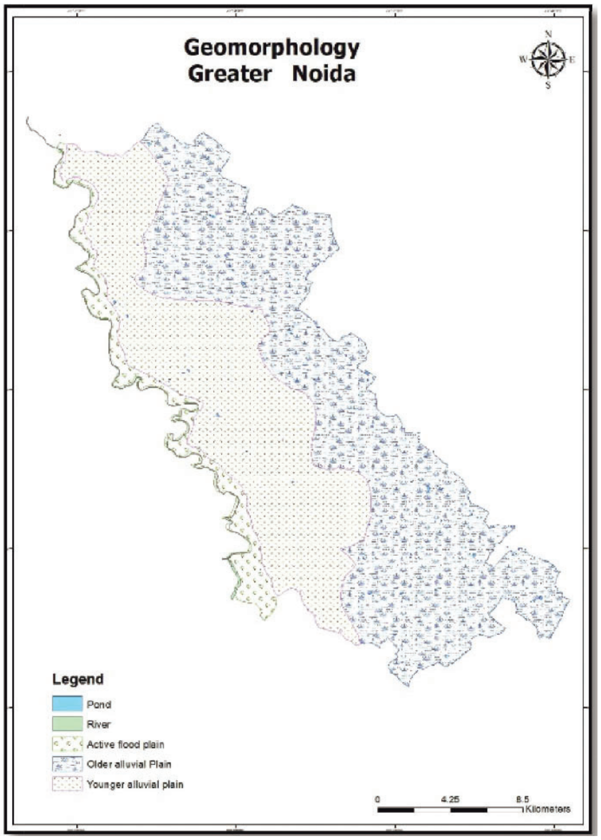

Fig. 7. Geomorphology of Greater Noida

plains, soils are composed of combinations of sand, silt and clay. It ranges from pure sand to stiff clay (Joshi, 2009). Pure Sand is called

Bhur and clay is called Matiar. The fertility of soil is depending upon the proportion of sand and clay. Pure clay exposures exhibit bad land topography and with sparce vegetation. Fresh alluvial soils and found along the Hindan River. At places Kankars are also associated with clay. Kankar wherever it found forming small mounds. In general, top soils are of high infiltration type. As the study area is part of vast alluvial plane, its thickness is considerable.

Hydrogeology

The thick unconsolidated sediments of Indo Gangetic alluviums form the aquifers of the area. Thickness of the deposits are highly variable from few meters to 400 m bgl. These are very good repository for ground water. The granular zones composed of sand, silt and gravel interlayers with clay deposits creating multiple layers of aquifers. These clay layers are the confining layers making deeper aquifers as semi confined to confined. Otherwise ground water in shallow aquifers are in phreatic conditions.

Phreatic aquifers are shallow in nature and found to be a depth of 100 m bgl. Intermediate and deeper aquifers are going up to 400m bgl which are confined or semi confined in nature.

The aquifer parameters estimated through step drawdown test and long duration aquifer performance test indicates that average coefficient of transmissivity of the area is 1752 m^2/day and average coefficient of storage is 4.84×10^{-4}. Discharge of the wells shows a yield of 8 to 16 lps for a drawdown of 3 to 6m.

Land use land cover mapping

Land use land cover maps of Greater Noida area has been prepared for the years 2005, 2015, 2019. Satellite images of various resolutions were used in the study as per the availability. Historic data of 2005 and 2015 were prepared on 1:50,000 scale with low resolution images. The images of 2005 and 2015 were converted to its land use land cover features of the area by classification techniques and final maps are in the form of raster outputs. However, during 2019 very high-resolution images were available and land use land cover maps were prepared using on screen interpretations followed by detailed ground verification.

Land use land cover data has further analyzed for key land use land cover features classes. Agriculture, built up, forest, barren land and wet land were taken as the key land use land cover features of the area. Most of the sub classes were merged with these key land use land cover classes. For example, agricultural plantations and fallow land were merged with crop land to get total area for agriculture. Similarly, all urban built-up classes were merged to get the built-up class. So is the case with forest and wetlands.

During 2005 the study area compasses about 77% of agricultural land and 19% built up land. These were the major land use classes and remaining barren land, wet land and forest were with 1 to 2% of the total area.

During 2015 the agricultural area reduced to 62%. Built up land increases to 33% and forest, barren land and wet land shows 0.73%, 1.5% and 3% respectively.

Most recent satellite image interpreted land use

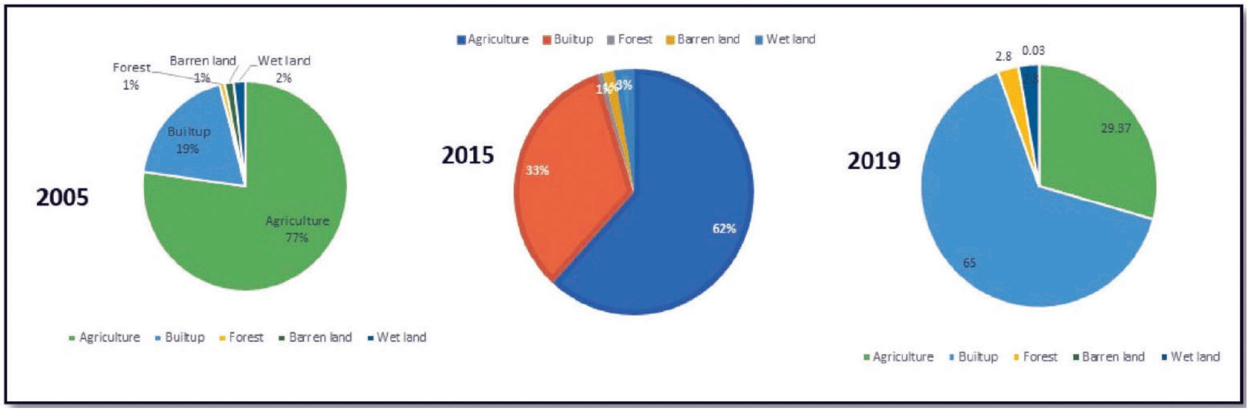

Fig. 8. Key land use land cover area statistics for the year 2005, 2015 and 2019

land cover details shows that agricultural land has shrink to 30% and built-up increase considerably to 65%. Forest and wet land have 2.8% of the total area while barren land remains with 0.03%.

Ground water data analysis

Ground water level data has been collected as a primary data directly from the field. Water levels of 51 wells were collected through field survey. The well locations are distributed across the study area. Average water level of the area is 18.53 m bgl. Distribution of water levels across the area has been depicted in Fig.9 and contour lines for the same is also shown in Fig. 9.The figure shows that in most of the areas of Greater Noida, static water level is between 15 and 20 m bgl. Southern part of the area shows shallow water levels and middle to northern portions shows deeper water levels.

Contour map shown in Fig 9 indicates that hydro static pressure is high in the northern portion of the study area. Whereas rest of the area shows very gentle pattern of contours which indicate low hy-

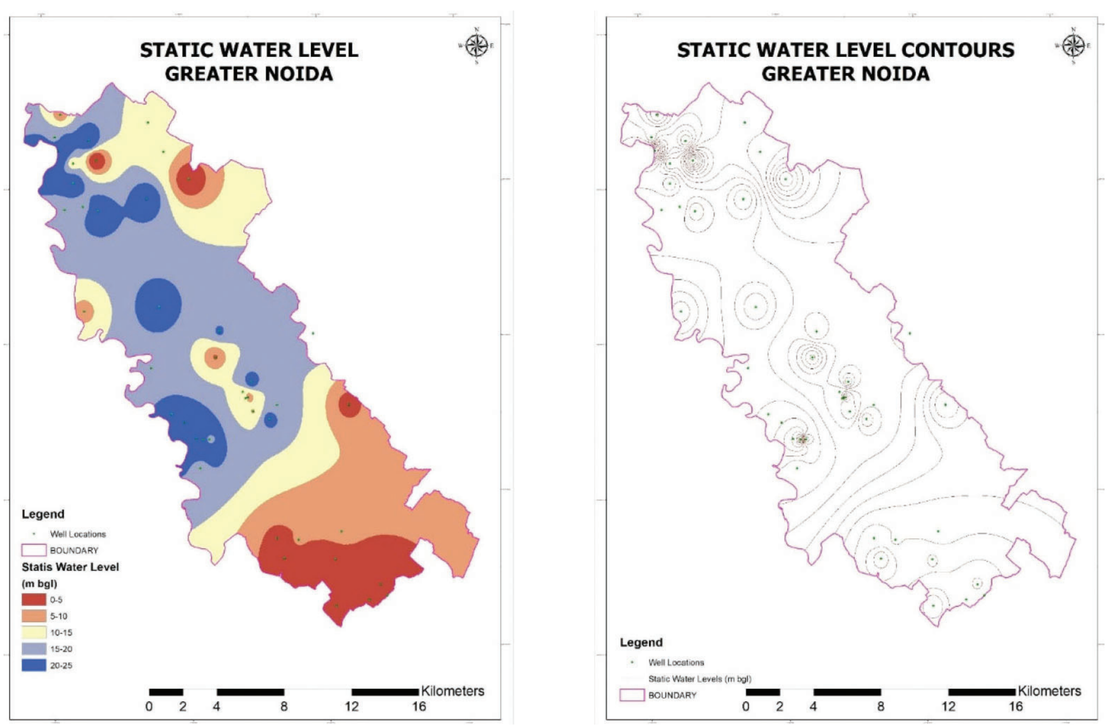

Fig. 9. Static water levels across Greater Noida

dro static pressure on ground waters of the area.

Historic water level data has been collected from Central Ground Water Board (CGWB). Fig. 10 shows the temporal changes in the static water levels of the area.

The above figure shows that during 2005 the average water level of the area was 10.63 m bgl and subsequently the water levels gone deeper and deeper and now the average water level is 18.53 m bgl. This clearly indicates that within a span of 15 years water levels has gone down to about 8m. This contributes to the urban expansion and its consequent population increase and more quest for ground water.

Considering 2005 as base year water levels have gone down in a significant way. Towards 2020 water level has gone down to 74% with respect to the base year. Average decline in water level is 21% during this period. This clearly shows that with developing of urban infrastructure, stress on water level was there in Greater Noida and the rate at which water level lowering is alarming pointing to the need of water sensitive urban development.

Impact of urbanization on ground water levels

Above section clearly shows that by passing years ground water levels have been lowered considerably. In this research an attempt has been made to evaluate the relations ship between the land use changes and lowering of water levels. Land use sta-

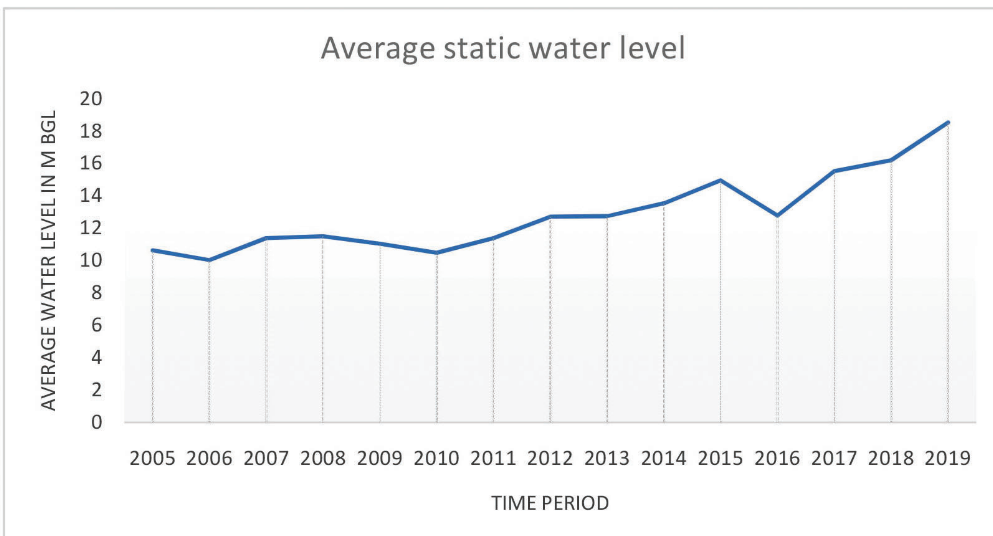

Fig. 10. Historic water levels of Greater Noida

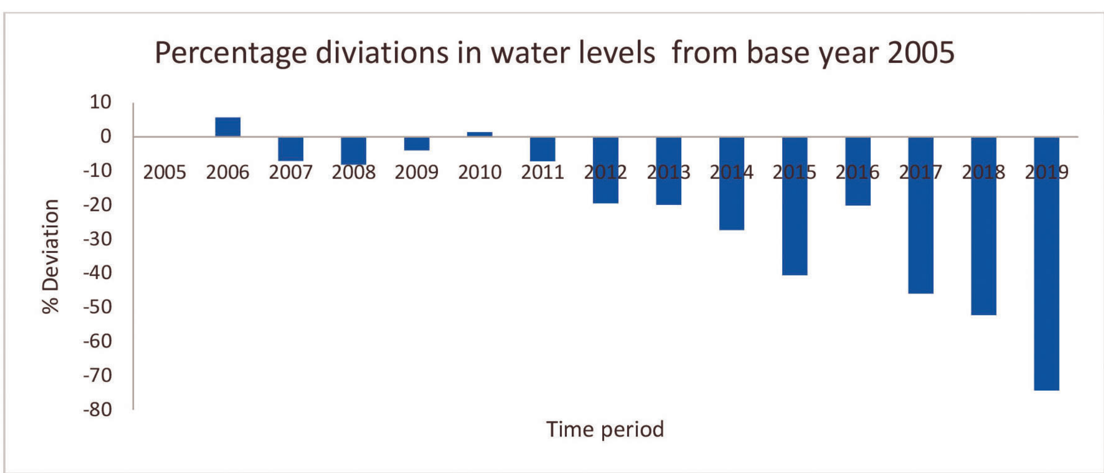

Fig. 11. Percentage lowering of ground water levels with respect to base year 2005

tistics were worked out for the years 2005, 2015 and 2019. These data set has been worked in terms of percentage of total area. Out of the key land use classes for which area statistics were worked out, agriculture and built-up classes were selected for this analysis.

Ground water levels were available continuously from 2005 to 2019. But land use information is available only for specific years of 2005, 2015 and 2019. So intervening years land use situation is estimated taken the assumptions that land use changes were linearly happened in between 2005 and 2015 and also in between 2015 and 2019. The data thus generated is given in table no.3 along with various statistics worked out of it. Now continuous data is available for the variable ground water level and land use classes.

The relationship between ground water levels and extent of agriculture and ground water levels and built-up land is depicted in Fig.12 and Fig.13 respectively. The land uses classes always represented by percentage of total area.

The above Figure shows the relationship between changes in agriculture and ground water levels. Ground water levels were shown as meters below ground levels and hence the values are depicted as negative numbers were ground level is zero. That means as years goes ground water levels go deeper and deeper. Figure shows that agriculture is declining year after year and change is in more rate from 2016 onwards, that is in recent years. This shows the pace of urban development is more in recent years. Ground water levels also show corresponding changes in tune with the changes in agriculture.

It is also observed that with the decline of agricultural areas ground water levels show more and more lowering. Thus, these two parameters show clearly positive relationship that means, as agricul-

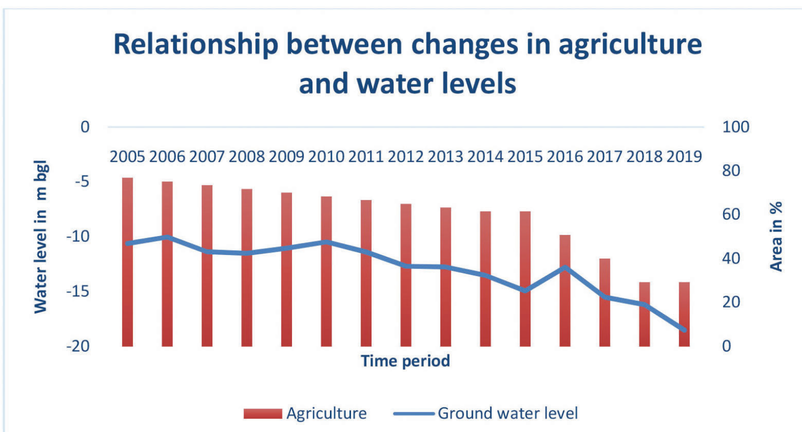

Fig. 12. Changes in agriculture and ground water levels from 2005 to 2019

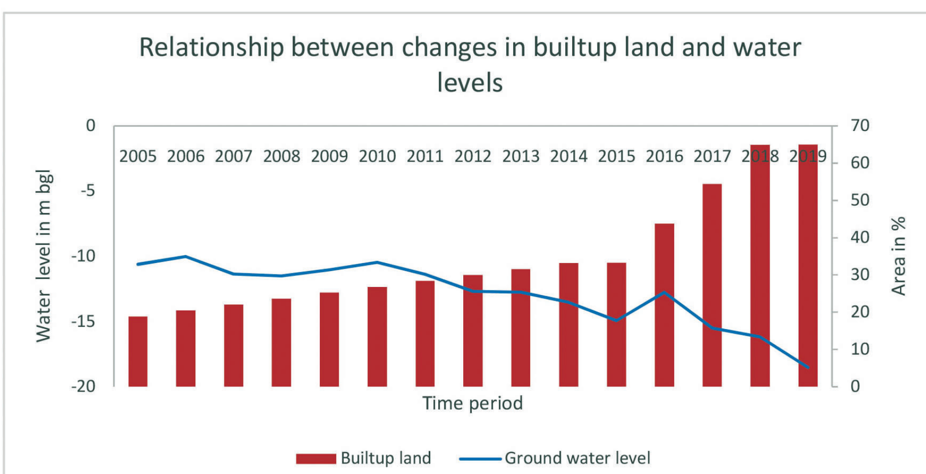

Fig. 13. Changes in built-up land and ground water levels from 2005 to 2019

ture decreases water levels will go deeper and deeper.

The Figure 13 shows the relationship between the built-up land use class and ground water levels. Built up land is showing uniform increase from 2005 and during 2015-16 it is showing sharp increase. This shows that urbanization is in an increase pace in recent past. Ground water levels are showing corresponding decline. This shows as built-up land increases ground water level gone deeper and deeper. Thus, a negative relationship is observed between built-up land and ground water levels.

Table 3. Statistical analysis of ground water levels and key land use classes

Year	Ground Water Level m bgl	Agriculture	Built-up
		% of total area	
2005	-10.63	76.95	18.87
2006	-10.03	75.25	20.46
2007	-11.38	73.55	22.05
2008	-11.5	71.85	23.64
2009	-11.05	70.15	25.23
2010	-10.48	68.45	26.82
2011	-11.39	66.75	28.41
2012	-12.7	65.05	30
2013	-12.75	63.35	31.59
2014	-13.54	61.65	33.18
2015	-14.95	61.64	33.22
2016	-12.78	50.89	43.81
2017	-15.52	40.14	54.4
2018	-16.19	29.39	64.99
2019	-18.53	29.37	65
Average	-12.89	60.30	34.78
STD Deviation	2.44	15.71	15.28
Covariance		32.67	-31.72
Correlation coefficient		0.852	-0.851

The above table shows the statistics worked out between ground water levels, agricultural land and built-up land. Covariance between ground water level and agriculture shows positive values and between ground water level and built-up area is negative. Correlation coefficient worked out shows very good correlations between urban development and ground water levels. Agriculture shows positive correlation of 0.852 and built-up land shows negative correlation of -0.851. The values near to 1 shows very good correlation and both agriculture land use and built-up land have equal impact on ground water. This indicates that built-up land has been increased with a compromise on agricultural land. Either reduction in agricultural land or increase in built-up land have equal impact on ground water levels.

Conclusion and Suggestions

This research study leads to the conclusion that ground water is the most reliable fresh water source which can be used for all purposes without much processing. The reasons for ground water level depletion are imbalance between the rate of extraction and rate of recharge. Greater Noida area is classed as over exploited in a ground water point of view. The reason behind this is urban expansion. As more and more villages converted to urban areas and impermeable built-up areas increases, shrinking of recharge areas took place and water levels gone deeper and deeper. Average annual rainfall of the area is 749mm.

Geologically the area is part of the vast Indo Gangetic alluvial plains with unconsolidated deposits of Sand, silt, Clay, gravel and kankar lying over Quartzites of Delhi Super group. Hydrogeologically the area is exhibiting both phreatic shallow aquifers as well as deep confined to semi confined aquifers. Thickness of the alluvium in this part is about a meter to 400 m. The aquifer parameters estimated through step drawdown test and long duration aquifer performance test indicates that average coefficient of transmissivity of the area is 1752 m^2/day and average coefficient of storage is 4.84×10^{-4}. Discharge of the wells shows a yield of 8 to 16 lps for a drawdown of 3 to 6m.

Land use land cover of the area is mapped for 2005, 2015 and 2019. Agriculture, built up, barren land, wet land and forest land are taken as the key land use classes for the analysis purpose. Agriculture has reduced from 77% to 62% to 30% from 2005, 2015 and 2019 respectively. Similarly built up has increased from 19% to 33% to 65%. Barren land has reduced and wet land and forest land has shown minor increases. Average ground water level of the area is 18.53 m bgl.

Ground water levels ranges from 15 to 20 m bgl. Southern part of the area shows shallow water levels and middle to northern portions shows deeper water levels. Hydro static pressure is high in the northern portion of the study area. Time series analysis of the ground water levels indicate that from 2005 to 2020 ground water level has depleted to 74% with an average decline of 21% per year. Interrelationship between urban growth and ground water levels has been established in this study. This analysis indicates that as agriculture declined water levels also depleted and have a positive correlation of 0.852. On the contrary, as built- up increased water level has depleted hence have a negative relationship with a correlation coefficient of -0.851.

As the aquifers of the area were impacted with rural to urban transformation and its storage is depleting, it needs to be re filled with participatory ground water management. Community, scientists, and policymakers are its components. Infrastructure development need to be water sensitive and extraction need to be compensated with water conservation measures such as rain water harvesting and aquifer recharge. Major institutional framework, policy decisions and technological initiatives are required for the same. are required for the same. Development of water resources must be to an extent such that it ensures the sustainability of the resources, both for the present and future generations.

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