Impact of Land-use and Land-cover Change on Groundwater Quality and Quantity in the Raipur, Chhattisgarh, India: A Remote Sensing and GIS approach

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Abstract: An attempt has been made to correlate groundwater quantity and quality concerning land use and land cover in the city, Raipur, Chhattisgarh, India. The land-use land-cover (LULC) is one of the dynamic processes of the urbanization method in a city or cities in a developing country. To assess the land use and land cover classes, we have used the multi-temporal remote sensing LANDSAT data of the year 2000 and 2018. There are ten LULC classes are identified, such as settlement, road, cultivation, industry, drainage, river, open land, vegetation, canal, and water bodies. The result shows that the LULC changes are mainly associated within the settlement and the cultivated area in the highest degree from 2000 to till date (2018). A comparison of LULC between the years 2000 and 2018 indicates that anthropogenic activities like settlement, road, and industrial areas have been expanded. The spatiotemporal variation of the water table and water quality parameters such as electrical conductivity (EC), Total Dissolved Solids (TDS), and Nitrate (NO3) between the year 2000 and 2018 have also been studied. The result shows that significant changes in the groundwater quantity and quality in the study area are due to anthropogenic activity.

Keyword: land use and land cover, groundwater, groundwater quality, remote sensing, and GIS
1. Introduction
Groundwater resources are an essential and crucial component for the sustainable development of the earth ecosystem [1, 2]. However, rapid urbanization is the process of demanding more water and land resources in the universe [3]. The changes in land-use and land-cover (LULC) are a dynamic pattern across global, regional, and local levels over the past few decades with future implications that may lead to an increase in hummade structures [4]. That, in turn, affect surface and subsurface water qualitatively and quantitatively [5, 6, 7, 8]. Land-use changes directly impact water dynamics of the entire watershed and catchment [9, 10, 11]. Singh et al. (2010) reported the impact of land-use and land-cover (LULC) changes on groundwater quality in the hilly area and emphasized the need for proper analysis of landscape and change in their use pattern and the associated impact of groundwater changes for sustainable developments. Even geogenic contamination of groundwater is also linked with intensive land-use and intensive groundwater development [12]. Several studies emphasized the key role of land use planning for regional socio-economic progress. Groundwater is a significant source of livelihood and fulfills potable water need across the globe, which is critical in monitoring the ecological services associated with it [8, 13, 14]. However, using groundwater patterns and related anthropogenic activities, both qualitatively and quantitatively [15]. Therefore, the assessment of groundwater potential and its use pattern are significant scientific challenges across regions [11].

The land-use and land-cover (LULC) changes influence water balance and water quality and is an essential topic on research in the national and international arena, leading to changes in regional climate and its hydrological cycle [16, 17]. Several international initiatives, including International Human Dimensions Program on Global Environment Change (IHDP), World Climate Research Program (WCRP), International Program on Biodiversity Sciences (DIVERSITAS), and International Geosphere-Biosphere Program (IGBP) etc. are critically examining the interrelationship between changes in LULS with BAHC (Biosphere Aspects of the Hydrological Cycle) along with climate frangibility associated with it [18, 19]. IGBP and IHDP further established the impact of changes in LULS on water resources and their availability [20]. Assessing groundwater's impact is that uses of water include agricultural, industrial, domestic, recreational, and environmental activities. Easy availability of groundwater and subsidized electricity and diesel enhanced groundwater development, and now it became the backbone of India's agriculture and drinking water security in urban and rural areas. At present, 90% of rural water sourced to groundwater while pumping from aquifers provides 70% of the water required in agriculture water used in agriculture [21].

Urbanization is being taken up throughout India under the development of smart cities. Due to this government's movement, groundwater has undergone twofold stress, one from overuse of water to meet the requirement of an ever-growing population and others due to pavement of the ground surface and reducing groundwater recharge the groundwater system. The majority of human (70-80%) meet their water need from groundwater. Massive and poorly managed dumping of urban waste into water bodies, poorly designed and managed landfills posing serious threat to groundwater contamination [22, 23], which in turn become one of the most toxicological and environmental challenges with wider implications in India. The quantity of groundwater is also decreasing due to over exploration of groundwater and intensive irrigation. Extensive chemical-based filtration for drinking water also affects water quality and quantity adversely, so several attempts have also been made to develop a filtration matrix from natural material [24]. There are ample studies on lowering the groundwater table at an alarming rate, which may be associated with rapid LULC change [7]. Apart from ground observation, remote sensing and GIS technologies gave an edge to special and temporal monitoring of LULC and modeling and prediction based on high-resolution satellite imagery and processing of those images. Remote Sensing and GIS techniques are extensively utilized to map land cover, including forest cover [25]. The present study has been taken up to understand the changes in groundwater quality and quantity due to the rapid growth of urbanization, industrialization, and agriculture activity over a period of the last 18 Years are the major objective in the study area.
1.1 Study area
The study area is part of Raipur district, Chhattisgarh, India (Fig. 1), which lies between latitude 21°04'35" and 21°19'00" N and longitude 81°32'05" and 81°59'05" E and it is falling under the parts of the Survey of India (SOI) toposheets No. 64G/11, 64G/12 and 64G/16 of covering an area of 484 km². Annexed part of the Raipur city known as Naya Raipur, the combination of both is our study area. The city population is about 1,010,871 (Census, 2011), which is increased about 1.5 times of India's Government's last Census (2001). The city's present population density is about 20870 per km², which is the fourth-highest in India after the cities of Mumbai, Delhi, and Kolkata. The temperature varies minimum 14°C in winter and a maximum 42°C in summer with average relative humidity 85%. The annual rainfall (average) in the district is 1149.7 mm.

Figure 1. Map of Raipur city (study area), Chhattisgarh, India.

1.2 Hydrological setting
The study area is underlain by Chhattisgarh Super Group of Proterozoic rock, which occupy major parts of the Raipur district. Major rock types are argillaceous, arenaceous, and calcareous in nature. Major geological classes such as alluvium, stromatolitic dolomitic limestone, laterite with sandstone and shale found in the study area. The Flood plains are alluvium deposits ranging from gravels, coarse to medium sand, and silts in the area. They are extending substantially on either side (approx 2 Km), which may attain a thickness of 10 to 20 m. in the Kharun and Seonath River basin, which forms a good repository of groundwater. Limestone, dolomite, shale, sandstone, and dolomite of Chhattisgarh Supergroup of Proterozoic age and major hard rocks of the area. The weathered mantle of these rocks holds groundwater in phreatic conditions, which extends up to a depth of 25 mbgl, while the caverns of limestone and dolomite hold a good amount of groundwater mostly at a bit deeper level around 80 meters, which are the main aquifer system in the study area. Gunderdehi shale and Charmuria limestone are not much efficient aquifers for groundwater, while Cavernous limestone of Chandi formation forms the good aquifer in the district [26, 27, 28].

2. Material and Methodology

2.1 Data used

2.1.1 The LANDSAT satellite imagery. The LANDSAT satellite images with Datum WGS1984 and UTM zone 44N are used in the study downloaded from the www.earthexplore website. These data
(Table 1) are used to generate the two thematic maps of the survey for the years 2000 and 2018 using ArcGIS (10.5) software, as shown in Fig.3a and Fig.3b, respectively. Fig.2a & Fig.2b represent the LULC classes change during the year 2000 and year 2018 for the settlements, roads, cultivation area, industry area, drainage pattern, rivers, open lands, vegetation and canals, water bodies, respectively. Image pattern, texture, tone, and size of the image are vital for image interpretation, and all these elements have been used to verify the ground condition. Ten numbers of LULC classes have been identified in this study, such as the settlements, roads, cultivations, industries, drainages, water bodies, canals, rivers, open lands, and vegetation. The above two maps have been used to detect land-use and land-cover changes for the last 18 years using remote sensing data of the year 2000 and 2018 of the Raipur. Data are taken from the multi-sources viz., LANDSAT, and SENTIAL.2 from the United States Geological Survey (USGS), National Institute of Technology (NIT) Raipur, Survey of India (SOI), and Google Earth. The spatial and temporal variation of the water table and the water quality parameters having excess value (electrical conductivity, Total dissolved solids, and Nitrate; NO₃) are collected and analyzed as per standard methods prescribed by [29].

Table 1. Change detection in land-use in the study area between the years 2000 and 2018.

| Class       | Observed area (km²) in the year 2000 | Observed area (km²) in the year 2018 | Area (%) in the year 2000 | Area (%) in the year 2018 | Change in area (%) between 2000 & 2018 |
|-------------|--------------------------------------|--------------------------------------|--------------------------|--------------------------|---------------------------------------|
| Cultivation | 210.82                               | 161.22                               | 43.56                    | 33.29                    | 10.27                                 |
| Industry    | 0.41                                 | 2.11                                 | 0.08                     | 0.43                     | 0.35                                  |
| River       | 1.29                                 | 1.19                                 | 0.08                     | 0.43                     | 0.35                                  |
| Vegetation  | 13.13                                | 21.27                                | 2.71                     | 4.39                     | 1.68                                  |
| Water Bodies| 18.41                                | 13.12                                | 3.80                     | 2.71                     | 1.09                                  |
| Settlement  | 68.88                                | 121.87                               | 14.23                    | 25.17                    | 10.94                                 |
| Road        | 6.48                                 | 18.67                                | 1.33                     | 3.85                     | 2.52                                  |
| Open land   | 164.59                               | 144.79                               | 34                       | 29.9                     | 4.11                                  |
| Total       | 484                                  | 484                                  | 100                      | 100                      |                                       |

Figure 2a. Spatial Distribution Map of LULC Classification for 2000
2.2 Methodology

Ground Control Point (GCP) of georeferenced toposheets- 64G/16, 64 G/12, and 64G/11 into a spheroid, World Geodetic System 1984 and datum, 44N in the UTM projections using ArcGIS software used for georectification of satellite imageries [30]. The study area's image was clipped by overlaying the study area boundary on the georeferenced image with the help of the “clip” function of Spatial Analyst Tools and the module of ArcGIS Software. Google Earth Image is used as a reference image. In order to study land-use changes (Table 1), data have been used in the study area, and ArcGIS software has been used for the classification of the data. To understand the various activities required for preparation of various maps and correlation between the data, we use the primary data as the satellite and remote sensing maps and the secondary data as the groundwater information. The groundwater data like EC, TDS, and NO3 are integrated, and respective thematic maps were prepared. Image classification may be carried out with the help of pre/post-classification change detection approaches and performed via supervised or unsupervised techniques. The preparation of the LULC map was the on-screen visual interpretation of satellite images [30]. Google earth and SOI toposheets are used for verification of interpretation keys like pattern, texture, tone, and size of imageries. The study area satellite image of the year 2000 and 2018 were digitized (ArcGIS software), and a spatial database was created. Different image interpretation elements were verified with field checks. Further, other LULC classes have been identified viz. human habitation, transport rout, agriculture land, industry, drainage, water bodies, canal, river, open land, vegetation. Finally, different thematic maps are generated for LULC, groundwater level pre/post-monsoon, water quality (EC, TDS, and NO3) using the interpolation (IDW) technique.

Calibration data must be appropriately sampled over the study area in supervised classification, while an algorithm is needed in an unsupervised classification that might find a pre-specified number in the measurement space from a remotely sensed image dataset. These clusters must be assigned to classify LULC without having information of ground cover in the study site [7]. The acquired pixels that is procured from different time periods were classified in the ArcGIS (10.5) software. In the present investigation, supervised and unsupervised classification has been done separately on two different remote sensing datasets. Training sites were made by demarcating a polygon or area of interest for the known land-cover or land-use type using the signature editor tool in ArcGIS software. On the basis of these signatures, the whole image was classified. Ground-level information was incorporated in the refinement of training site selection during the final classification. This supervised classification approach was based on the maximum likelihood classification decision rule. The accuracy of classified
images should exceed 84% for the best results [31]. Fig.3a and Fig.3b show land-cover and land-use types in the classified images for the years 2000 and 2018, respectively. The thematic layers prepared with GIS tools’ help include settlement, road, cultivation, industry, drainage, river, open land, vegetation, and canal and water bodies: drainage networks, geomorphology, geology, slope, land-use, and land-cover of the area.

2.3 Data and analysis
Land use and land covered (LULC) data are collected from the satellite images (LANDSAT and SENTIAL2) for the year 2000 and 2018 for the study area, respectively, which were used for generating the two thematic map of the study area for the year 2000 and 2018 using ArcGIS (10.5) software (Fig.3a and Fig.3b). These images represent the LULC classes change during the year 2000 and year 2018 over the study area in terms of settlements, roads, cultivation area, industry area, drainage pattern, rivers, open lands, vegetation, and canals water bodies. Different image interpretation elements like tone, texture, size, and pattern were used to verify the actual ground condition. Ten numbers of LULC classes have been identified in this study, such as the settlements, roads, cultivations, industries, drainages, water bodies, canals, rivers, open lands, and vegetation. The above two maps have been used to detect the changes in LULC for a period of last 18 years by using multi-temporal remote sensing data (LANDSAT of the year 2000) and (SENTIAL2 2 of the year 2018) and (Goggle image 2015) in the Raipur city, Chhattisgarh, India. Data are taken from the multi-sources viz., LANDSAT, and SENTIAL2 from the United States Geological Survey (USGS), National Institute of Technology (NIT) Raipur, Survey of India (SOI), and Google Earth. The spatial and temporal variation of the water table and the water qualities (such as the excess values of the electrical conductivity (EC), Total dissolved solids (TDS) and Nitrate (NO3) inclusion are collected from the Central Groundwater Board (CGWB) Ministry of water resources, Government of India, a nodal agency to the Government of India to monitoring and management of groundwater data.

3. Result and Discussions
Land-use and land-cover (LULC) areas of ten classified groups, including canal, cultivation, drainage, industry, open land, river, road, settlement, vegetation, and water bodies, are shown in Table 1. LULC of study (Figures 2a & 2b; Table 1) undergone a continuous decrease in the cultivation area from 210.82 km² to 161.22 km² and the industrial area increased from 0.406 km² to 2.10 km². Similarly, the vegetation area has increased from 13.13 km² to 21.26 km² and the area under water bodies has been reduced from 18.40 km² to 13.12 km². However, the settlement area approximately doubled from 68.88 km² to 121.86 km². On the other hand, the open land area is decreased from 164.5 km² to 144.79 km².

Figure 3 is showing the percentage of area changes in the year 2018 (red), 2000 (blue), and change between the years 2000-2018 (green) with respect to the land use classes (cultivation, industry, river, vegetation, water bodies, settlement, road, and open land). Results show that increase in cultivation area by 10.27%, the industry increased by 0.35%, river decreased by 0.02%, vegetation increased by 1.68%, water body area decreased by 1.09%, settlement area is increased by 10.94%, the road is increased by 2.52%, and open land decreased by 4.11%. Fig.3 indicates the overall changes over 18 years (2000-2018).

Groundwater (Pre-monsoon and post-monsoon) level maps were generated using ArcGIS (10.5), shown in Figure 4 and Figure 5, respectively. Pre-monsoon depth to water level data indicates the deepest water level in the phreatic aquifer. In order to understand the behavior of change depth to water level over a period of time, the area under various depth ranges (0-3m;3-5m;5-7m;7-10m;10-15m; 15-20m; and beyond 20m) have been calculated (Table 2) and noted that there is a decline of depth to water level for the entire study area. However, during the post-monsoon water level, depth again became stabilized in the phreatic aquifers only.
Figure 3. The plot shows the available percentage areas of cultivation area, industry, river, vegetation, waterbody, settlement, river, open land areas between 2000 and 2018, and the change percentages of the same classes between 2000 and 2018.

|          | Cultivation | Industry | River | Vegetation | Water Bodies | Settlement | Road | Open land |
|----------|-------------|----------|-------|------------|--------------|------------|------|-----------|
| 2000(%)  | 43.56       | 0.08     | 0.27  | 2.71       | 3.8          | 14.23      | 1.33 | 34        |
| 2018(%)  | 33.29       | 0.43     | 0.25  | 4.39       | 2.71         | 25.17      | 3.85 | 29.9      |
| Change(%)| 10.27       | 0.35     | 0.02  | 1.68       | 1.09         | 10.94      | 2.52 | 4.11      |

Figure 4. Spatial Distribution Map of Pre-Monsoon for 2000(a) & 2018(b).

Figure 5. Spatial Distribution Map of Post-Monsoon for 2000(a) & 2018(b).
The suitability of groundwater for drinking purpose is mainly depending upon the optimum presence of soluble substances in the groundwater. Water quality depends on the range of chemical parameters such as EC, TDS, NO3, and many more present in the water. Electrical conductivity is an essential water parameter to define the status of dissolve ions (minerals/salt) in the water. There is a direct correlation between the TDS and EC. The composition of mineral salts through which water flows affect the electric conductivity of groundwater. From Table 2 it is noted that a sharp decline of water quality parameter EC for the entire study (Figure 6a and Figure 6b) after a period of 18yeras. Table 2 data shows that in the year 2000 EC affected region, the area increases 364km² at depth 10m and then decreases with depth. This implies that groundwater below 10m was good in quality before the year 2000 and was not affected by pollutants too much. However, the scenario of EC has changed in the year 2018 (Table 2) it shows that more EC (>3500) reported beyond the depth of 20m.

![Figure 6. Spatial Distribution Map of EC for 2000(a) & 2018(b).](image)

**Table 2.** Area covered with electric conductivity (EC); water table (WT); TDS and nitrate values.

| S. No. | Type of measurements | Year | 0-3m | 3-5m | 5-7m | 7-10m | 10-15m | 15-20m | >20m | Total area (Km²) |
|--------|----------------------|------|------|------|------|-------|--------|--------|-----|-----------------|
| 1      | EC(area)             | 2000 | -    | 12   | 77   | 364   | 30     | 0.50   | 0.50 | 484             |
|        |                      | 2018 | -    | 7    | 16   | 78    | 301    | 52     | 30  | 484             |
| 2      | WT(area)             | 2000 | 236.3| 246.42| 1.28 | -     | -      | -      | -   | 484             |
|        |                      | 2018 | 7.25 | 109.45| 254.70| 80.3  | 17.1   | 12.1   | -   | 484             |
| 3      | EC (area/ppm)        | 2000 | 111  | 175  | 93   | 29(3500) | 5(>3500) | 12.1 | -   | 484             |
|        |                      | 2018 | 89(250)| 194  | (750) | (3250) | 15(>3500) | 12.1 | -   | 484             |
| 4      | TDS (area/mg)        | 2000 | 375  | 109  | (530) | (1720) |        |        |     | 484             |
|        |                      | 2018 | 328  | 156  | (530) | (1720) |        |        |     | 484             |
| 5      | NO3 Area(ml)         | 2000 | 481  | 3(>45)|       |       |        |        |     | 484             |
|        |                      | 2018 | 421  | 62   | (<45) |       |        |        |     | 484             |
The total dissolved constituents in water are referred to as the total dissolved solids (TDS). Fig. 7 and Table 2 show that TDS variation with the area covered for the year 2000 and 2018. In the year 2000, the area of 375 km$^2$ covered with TDS in the range of 175-530 mg/l, and 109 km$^2$ area affected by TDS value of more than 1720 mg/l however, in the year 2018 the more areas are affected by the TDS such as 325 km$^2$ and 156 km$^2$ for the TDS of 530 mg/l and 1720 mg/l respectively. According to the Bureau of Indian Standards (BIS), the ideal TDS for drinking water should be below 300 mg/l, and the maximum permutable limit of TDS is 600 mg/l. To understand the change of water quality over the study area, TDS maps are generated are shown in Figure 7a and Figure 7b between the period 2000 and 2018.

![Figure 7. Spatial Distribution Map of TDS for 2000(a) & 2018(b).](image)

Relatively, little Nitrate is found in natural water. The source of Nitrate in groundwater is mainly inorganic fertilizer, food preservatives, and sewage contamination. The nitrate concentration in groundwater elevates from leaching from sewage/landfills, agriculture runoff, and animal waste decay (Makhijani and Manoharan 1999). The excess level of Nitrate in water can create conditions that make it difficult for aquatic animals or fish to survive. Its excess is also responsible for Methemoglobinemia/blue baby syndrome [33, 34]. As per the Bureau of Indian standard, the acceptable limit for Nitrate is 45 mg/l [35].

![Figure 8. Spatial Distribution Map of Nitrate for 2000 (a) & 2018 (b).](image)

The nitrate concentration of water (unit mg/l) has been plotted on the map presented in Figure 8a and Figure 8b for the period 2000 to 2018. Table 2 shows that the nitrate values of more and less than 45 units affected the area covered. In 2000 and 2018, the NO$_3^-$ values affected areas are 481 km$^2$ and 421
km$^2$ of NO$_3$ concentration less than 45, which changes to 3 km$^2$ to 62 km$^2$ for nitrate concentration more than 45, respectively.

Fast urbanization led to the conversion of the ground surface with natural cover to humanmade structures, mainly impervious concrete, which further blocked every possibility of groundwater recharge. Without recharge, rainfall in cities turned into urban floods or a flash flood in one hand while the other hand stopped groundwater recharge so, induced rapid lowering of the water table. In the present investigation, urbanization has increased; there is a clear and visible impact on the groundwater levels. The groundwater levels declined from 10m to 15m. Which may be linkage due to the increased Urbanization requirements and decrease recharge due to concretization [36].

Several studies have been established the interconnections of land use with that of water quality; in many cases, it is found linearly correlated. Correlation of land use with water quality is indicative of the extent of water quality deterioration that has a linear correlation with the residential land use, which is further subdivided based upon population density across the city from dense to sparse categories [7]. It is found that the electrical conductivity of most of the borehole's water quality in the Chhattisgarh state has deteriorated with respect to EC and TDS. The present finding regarding the study area's water quality is substantiated with a previous study based on LULC remote sensing and GIS-based investigations [30, 37]. This area is found to have prone to weathering as indicated by a higher concentration of major anions (Ca and Mg) in groundwater [38]. The groundwater table shows spatial variation in the sub-soil water is more than 20 meters deep in the study area.

4. Conclusions
The present study demonstrates remote sensing and geographic information systems to understand the change in LULC utilizing satellite images of the year 2000 and 2018 (LANDSAT). The study shows rapid urbanizations as the settlement area has increased, and the cultivation area decreases in equal proportion resulting decrease in water table depth since 2000. The amount of Nitrate (NO$_3$), Total Dissolved Solids (TDS), and Electrical Conductivity (EC) of water has increased substantially, which further contaminating the limited freshwater available in the study area. Therefore, expanding city infrastructure-induced LULC is directly involved in the deterioration of groundwater quality and water budget in the study area. The use of satellite imagery for tracing LULC changes requires periodic analysis on special and temporal aspects and their further validation with the ground-based observation of quality and quantity of groundwater resources.

The present study attempts to establish a credible investigation strategy of special and temporal changes in groundwater quality with the help of a remote sensing database of a well-defined area like Raipur, where recent changes in LULC are prominently established. The finding of the present investigation provides essential information for water resource managers to support their efforts to conserve the natural resources in general and groundwater in particular. This may help create awareness among local population government agencies and policymakers about possible consequences of LULC change on groundwater resources and the overall water availability to all potential stakeholders.

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