Assessing the impact of urbanization on the declining groundwater level of Gazipur District, Bangladesh

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Keywords

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Abstract

The Gazipur District belongs to the 'Madhupur Tract,' situated in the northern part of Dhaka, the central upland area of Bangladesh. Gazipur district is located between 2353' to 2420' North latitudes and between 9009' to 9042' east longitude. Geographically, Gazipur is almost the center of Bangladesh, next to the fast-growing and developing Capital City, Dhaka. It is a growing industrial center causing fast urbanization. Due to rapid population growth, municipal services are stressed with the increasing demand for natural resources. Consequently, forest and water bodies are diminishing, resulting in significant environmental impacts. Gazipur City zone covers almost 48.50 km². This City region is subdivided into a center range, which encompasses 16 km2 surrounding the city's core, and a periphery region, which includes the remaining 32.5 km2. The highest population densities are situated in the center of the central zone, while rural or semi-rural enclaves are located on the periphery.

The population density of the Gazipur City Corporation is 1,884 inhabitants per square kilometer. Being part of the greater Dhaka area, this district also faces insurmountable obstacles due to its uncontrolled growth, high levels of poverty and social vulnerability, inadequate infrastructure, lack of social services, poor physical and social environment quality, and incompetent urban management. Domestic and industrial sectors consume the most water in the Gazipur District, with 85 percent of the urban water demand being met by groundwater and 15 percent by surface water. Groundwater reserves are in peril due to uncontrolled groundwater abstraction and chronically reduced recharge, resulting in a constant decline of >2 meters per year of groundwater level. It is necessary to link the impact of industrialization and urbanization on groundwater quality.

Study Area

The study area, the Gazipur District, belongs to the 'Madhupur Tract,' which is situated in the northern part of Dhaka, the central upland area of Bangladesh. (Figure 1)

Previously, Gazipur was a sub-division of Dhaka District; in 1984, it became an in-

Gazipur district is situated between 2353' to 2420' North latitudes and between 9009' to 9042' east longitude. (Parvin, 2018)

Gazipur District was selected as the study area because of its geographic location and fast urbanization. Due to population expansion, municipal services and natural resources are increasingly demanding. Consequently, forest and water bodies are diminishing, resulting in significant environmental impacts. (Yesmin et al., 2014)

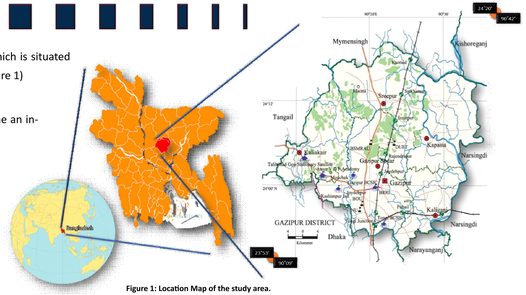


Figure 1: Location Map of the study area.

Spatial and Temporal Changes in Urbanization and Water Level at Gazipur

The district's total area is 1,806.36 km2, of which 17.53 km2 is riverine and 273.42 km2 is forest area. The Zila is bounded on the north by Mymensingh Zila and Kishoreganj Zila, on the east by Narsingdi Zila, on the south by Narayanganj and Dhaka zilas, and on the west by Tangail Zila. The district consists of 5 Upazilas, 43 unios, and 725 mauzas. The Upazilas are Gazipur Sadar, Kaliakair, Kaliganj, Kapasia and Sreepur. (BBS, 2013)

The terrain of the study area resembles terraces, with surface elevations ranging from 16 to 19 meters. Gazipur's principal rivers include the Old Brahmaputra, Shitalakshya, Turag, Bangshi, Balu, and Banar.

In 2000, a considerable change in water level was observed, which is exceedingly unusual considering the absence of evidence of violent or rapid weather changes. At 65 meters above sea level, the GWL revealed a larger and deeper depression cone in 2013. Between 12 and 19 m above sea level, the eastern side extracts less groundwater. The average water level variation of two decades comparatively exhibits a decline in the urban areas. (Figure 3)

Unsustainable groundwater usage is a possible risk factor that gradually affects diverse water uses, including urban water resource management and socioeconomic impact. For this reason, it is essential to comprehend the cause. While it is evident that increasing population pressure and unrestricted groundwater extraction are responsible for diminishing groundwater levels, it is also true that climate change is a contributing factor. (Mitchell et al., 2007)

The study completed by Parvin (2019) indicated a very alarming condition of Groundwater level in Gazipur. She compared population growth to groundwater level fluctuation. Her comparative study indicated a drastic water level drop as the population multiplied over the years, reaching a peak by 2019. (Figure 2)

Urban environments alter precipitation patterns over hundreds of square kilometers (Kaufman et al., 2007). Urban growth will also impact the world climate. It is projected that roughly 5 percent of total emissions from tropical deforestation and land-use change are attributable to the direct loss of vegetation biomass in areas with a high potential for urban growth.

Urbanization also affects the regional ecology in its entirety. In regions downwind of large industrial complexes, precipitation, air pollution, and the frequency of days with thunderstorms all rise. Not only can urban areas influence weather patterns, but also water runoff patterns. Generally, urban areas create more precipitation but reduce water penetration and lower water tables. This indicates that runoff happens faster when peak flows are bigger. As flood levels increase, so do downstream flooding and water pollution. Populations in urban areas interact with their environment. The consumption of food, energy, water, and land by urban residents alters the ecosystem.

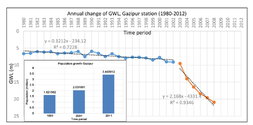
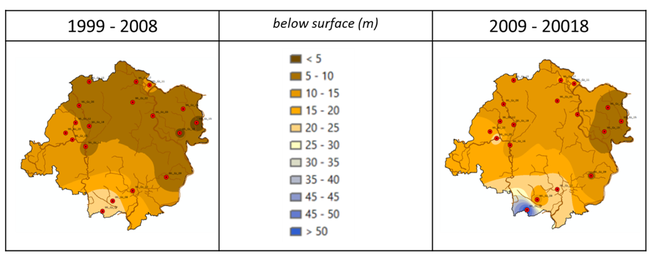


Figure 2: Comparative change between Groundwater Level (GWL) and Population Change (growth). (source: Parvin, 2019)

Figure 3: Average water level difference over two decades indicate a steep water level drop over the Gazipur District.



The spatial and temporal developments of the Gazipur District over nearly two decades have been evaluated. Figure 4 depicts 2000, 2005, 2010, 2015, 2019, and 2021. (Figure 4)

Methodology

To understand the status of the groundwater condition, 17 well data were collected from BWDB. Daily Water level data for years from 2008 to 2018 were used. Unfortunately, few blank values were identified. Each station's water level data were taken as a mean monthly and yearly to represent groundwater conditions. Mean monthly datasets for the selected reference period (2008-2018) were processed for assessment. The changes indicated the depletion rate. It is necessary to determine the maximum depletion period for the Dupi Tila aquifer. Annual mean groundwater levels (below ground) within the Gazipur districts were plotted against time to understand GWL fluctuation.

GIS Mapping was applied for mapping, classification, and concentration distribution assessment.

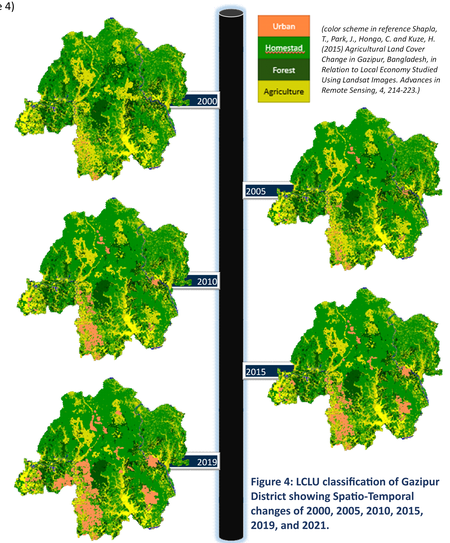
The spatial and temporal developments of the Gazipur District over nearly two decades have been evaluated. Using field data and the geographical features on land use maps, high-resolution images, and SOB topographic maps, LULC maps were reviewed. The classification accuracy was also assessed using a non-parametric Kappa test that considers all elements of the confusion matrix, not just the diagonal ones.

Two types of satellite images were used: Landsat 4-5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+). In both cases, cloud cover was kept at 0% or almost 0%. Landsat satellite images for 2000, 2005, 2010, 2015, 2019, and 2021 were downloaded from the United States Geological Survey (USGS) website. Gazipur is included within the Landsat path 137, row 44. Map projection of the images is UTM within Zone 46N WGS 84. The topographic feature was taken from DEM data based on SRTM.

In 2000, lowlands, agricultural land, and aquatic bodies were the predominant land use types, and urban expansion was moderate. By 2005, the transformation had begun to accelerate at a regulated and moderate rate, with declining water bodies and accelerated settlement or urbanization. In 2010, the replacement of aquatic bodies gained prominence. Urbanization became dominant and began to border agricultural fields. In 2019, a radical shift in land usage became apparent, and the replacement of water bodies grew so aggressive as to be irreversible. Urban and industrial constructions started to predominate, while agricultural lands became, at times, seasonal features - alternating as seasonal sources of water.

Urban area changes varied from 1 percent in 2000 to nearly 30 percent in 2021 (Figure 5). This transformation was most pronounced in Gazipur Sadar, followed by Kaliakair. Considerable urbanization has happened in the Gazipur-Sadar subdistrict in the Dhaka metropolitan region. Importantly, a portion of the fertile agricultural land has to be shifted to other uses as a result of rising urbanization. In Sreepur, the forest cover decreased by about 30 percent, Kaliakair by 14 percent, Kapasia by 20 percent, and Gazipur Sadar by more than 40 percent.

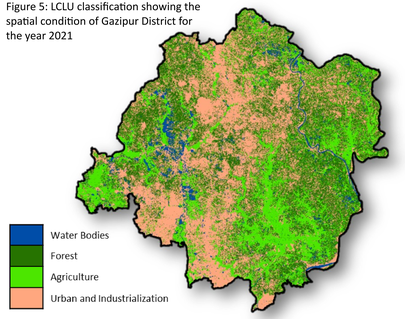
Such dramatic shifts generate severe environmental repercussions. Generally, deforestation is irreversible, causing permanent harm to habitats and biodiversity. The urban environment's pollution impacts the urban population's health and quality of life.



(color scheme in reference Shapla, T., Park, J., Hongo, C. and Kuze, H. (2015) Agricultural Land Cover Change in Gazipur, Bangladesh, in Relation to Local Economy Studied Using Landsat Images. Advances in Remote Sensing, 4, 214-223.)

Figure 4: LCLU classification of Gazipur District showing Spatio-Temporal changes of 2000, 2005, 2010, 2015, 2019, and 2021.

Figure 5: LCLU classification showing the spatial condition of Gazipur District for the year 2021



Conclusion

Domestic and industrial sectors consume the most water in the Gazipur District, with 85 percent of the urban water demand being met by groundwater and 15 percent by surface water. Groundwater reserves are in peril due to uncontrolled groundwater abstraction and chronically reduced recharge, resulting in a constant decline of >2 meters per year in the average groundwater level. Changes in hydrogeological factors have a negligible effect on the projected flow pattern, whereas recharge and uneven abstraction has a substantial impact.

The spatial maps of groundwater levels during wet and dry periods for the averaged condition reveal that the groundwater level can rise by 5 meters from dry to wet under the current environmental conditions. Urbanization and industrialization in Gazipur are direct results of rural and urban migration, as seen by the increasing population density of the district.

In Bangladesh more than 40 million reside in urban centers. By 2060, when the country's total population is expected to stabilize at 230 million, more than 70 percent of the population will be urban-

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