Chapter 6
Impact of Urbanization on Ganga River Basin: An Overview in the Context of Natural Surface Water Resources

Ankit Modi, Chandrashekhar Bhagat, and Pranab Kumar Mohapatra

Abstract The Ganga river, a symbol of faith for hundreds of millions of Indians, provides all essentials for the development of human beings such as ample amount of freshwater for domestic-agriculture-industrial purposes, productive agricultural land for food production, and diversified flora-fauna for a sustainable ecosystem in its one million km^2 basin. Over the years, various alternatives have been introduced in the basin to feed the growing population, and in the last hundred years manifold changes have been made. Various multipurpose dam/barrages were constructed on the river's main stem and on its tributaries for hydropower production, irrigation, and drinking water supply. Similarly, forest cover changed into agricultural land, and barren land was developed for buildings to support housing and industries for an increasingly urban population of the basin. The effects of anthropogenic activities and anthropogenic activity-induced climate change have started to degrade surface water bodies in terms of their quality and quantity, and in some cases, surface water bodies have been lost completely. For example, the major tributaries of the Ganga river in upper part of the basin, Alaknanda and Bhagirathi, had been altered by ~8% and ~35%, respectively, due to dam/barrages. In the Ramganga basin (a major sub-basin of the Ganga river basin), the surface-subsurface water storage was reduced by ~0.2 MCM/km^2 during 1982–2013. The increment of lead concentration (Pb, a heavy metal) from 3 μg/L to 26.9 mg/L indicates the influence of anthropogenic activities and human encroachment. The increasing pH (>9) and metal concentration near Kanpur stretches indicate industrialization's impact on water quality. Out of 629 lakes and wetlands, 338 were entirely extinct in the Delhi district. Thus,

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this chapter enlightens the urbanization impact on the surface water bodies in the Ganga river basin. The chapter also discusses the future research scope from the sustainable development perspective.

Keywords Ganga river basin · Urbanization · Surface water · Climate change · Anthropogenic activity

1 Introduction

India is the second largest country in population after China. Its population is increasing at an average rate of ~1% annually (Gu et al. 2021). As per the Census of India 2011, rural areas contributed ~69%, and the urban regions contributed ~31% of the total population. The population percentage was higher in the rural areas but lower than the ~89% in 1901. So, the urban population is increasing continuously. In the last 10 years, India's urban population growth rate has been reported to be between 2.3% and 2.4% annually (Gu et al., 2021). The number of towns and cities in India is also increasing rapidly, which signifies increased urbanization. It is noted that urbanization is a response to the opportunity created by better technological, economic, social, political, and geographical factors of an area (Cohen, 2006; Fox, 2012). Or in other words, urbanization means more population in cities due to better opportunities for jobs, education, and entertainment (refer – https://www.nationalgeographic.org/encyclopedia/urbanization/). As per the Census of India 2011, 7935 towns were reported in India in 2011, which were 5161 in the year 2001. In India, an area is called a town with at least 5000 persons, a population density of 400 persons per km^2, and more than 75% persons with nonagricultural occupation (Rijesh et al. 2022). The number of towns and cities with a million-plus population is also rapidly increasing in the last few decades. According to the Census of India 2001 and 1991, the number of urban cities with a million-plus population was 25 and 35, respectively. This number was 53 in 2011, as per the Census of India 2011.

Most of the cities in India were developed at the banks of the river as rivers, and surface water bodies have always been a driving force for the evolution of human civilization. Throughout history, it is evident that all great civilizations were developed at the banks of major rivers or in river valleys because water is an essential commodity for survival, routine work, and growth. For example, Varanasi (old name Kashi) and Prayagraj (old name Allahabad) at the bank of the Ganga river, Agra, Delhi, and Mathura at the bank of the Yamuna River, etc. have their cultural heritage and rich history in development and facility. With increasing industrialization and population, these cities have proliferated and expanded their spatial areas (Bhagat et al., 2021a). Many cities, including heritage cities, are growing in terms of urbanization. These cities have created more opportunities to attract more population by developing industrial clusters resulting from urban agglomeration.

Figure 6.1 demonstrates the spatial and temporal variation of the cities in India from 1991 to 2011. It may be seen from the figure that many new million-plus cities have been aroused, especially in the Ganga river basin. The exact reason behind urbanization in these cities is the livelihood opportunity created by the service sectors and industrial clusters for a growing population (Joshi, 2021). Studies on urbanization, urban agglomeration, and urban sprawl reported that these cities are continuously spreading even though they are in a stagnant situation for basic

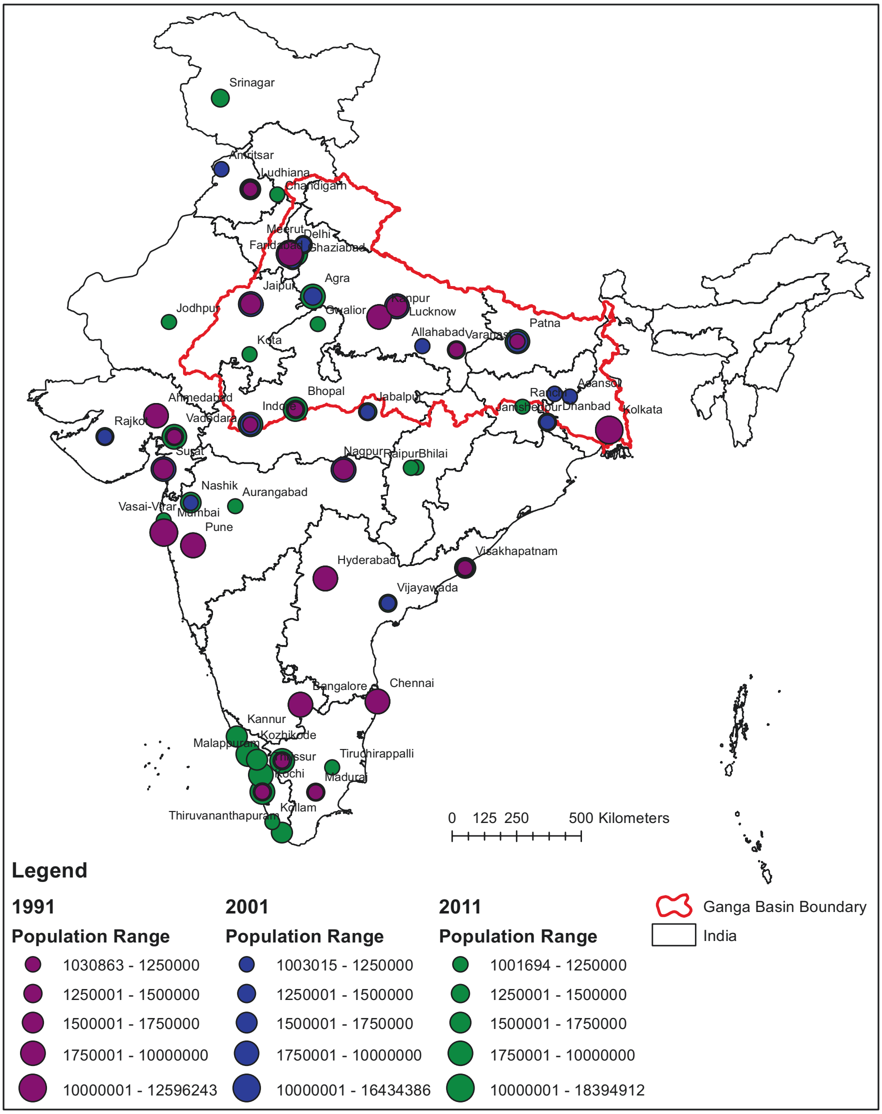

Fig. 6.1 Temporal variation of the population of the cities in India from 1991 to 2011

amenities. With better facilities for living, transportation, medical, water supply, and sanitation, these cities are capturing adjacent agricultural lands, surface water bodies, barren lands, forest areas, floodplains, etc., to develop an urban infrastructure and lead to the disturbed entire ecosystem (Modi et al. 2022a). Domestic and industrial water supply is ensured through nearby rivers, dams/barrages, and canal systems or water supply pipelines. Various water projects, river linking projects, and canal systems have been developed to fulfill the water demand, keeping in mind the nearby river systems and surface water bodies by city planners and managers (Bhagat et al., 2021b; Kumar et al., 2020; Singh et al., 2022).

Surface water storage in the Ganga river basin in northern India is a valuable source of freshwater supply for domestic, agricultural, and industrial demand (Routray, 2022). The process of urbanization and industrialization along the river stretch has put this freshwater source on high risk to vanish. The surface water bodies like ponds, lakes, and small rivers, including some parts of the floodplain Ganga river, are converted into built-up areas (Tyagi & Sahoo, 2022), leading to disturbing the entire ecosystem and biodiversity (Modi et al., 2022a). These urban areas have been spreading rapidly and creating urban sprawls to support more populations. This expansion converted forest cover and small surface water bodies into impervious zones by creating buildings for domestic and industrial purposes leading to increase the flood event and soil erosion in the watershed of River Ganga (Anand et al., 2018a). Also, lots of open lands or barren land areas are utilized only in this way. The urbanization encroached on many natural entities like natural forest cover, small surface water bodies like ponds, lakes, small river beds, floodplains, etc., in the Ganga river watershed, which supported groundwater recharge, local climate, and regional biodiversity (Mani et al., 2021; Modi and Tare, 2022). Few researchers reported that urbanization along with industrialization has disturbed many natural processes of hydrological water balance components like rainfall, surface runoff, groundwater recharge, and base flow of the Ganga river basin (Anand et al., 2018a; Modi et al., 2021; Shukla et al., 2020). It also degraded the water quality significantly of surface water bodies and groundwater aquifers. Therefore, in light of the abovementioned issue, the present chapter provides a comprehensive overview and discusses the impact of urbanization on surface water bodies in the Ganga river basin in detail.

2 Urbanization and Surface Water Bodies in the Ganga River Basin

Since immemorial, the Ganga river basin has been a cradle of human civilization. The oldest civilization reported in the Ganga river basin is the Indus Valley Civilization (Sameer et al., 2018; Singh, 2019). The basin has variations in climate (rainfall pattern, temperature range), cropping pattern, and ecology (flora and fauna). The human settlement with different social and cultural life had progressed over time through this diversity. Many cities with more than one million population had been developed at the river banks and their tributaries. The Ganga river basin is the largest river basin of India among 22 river basins in India, with an 861,452 km^2 drainage area (Duttagupta et al., 2021). This 26.3% of the geographical area of India supports 42% of the total population of India. The basin's average annual surface water storage potential is assessed as ~230 km^3 (Shamsudduha & Panda, 2019). The average annual rainfall is not uniform in the basin, and it varies from east to west as 2000 to 350 mm, respectively (Anand et al., 2018b). The basin is spread in eleven states of the country, viz., Uttar Pradesh, Madhya Pradesh, Rajasthan, Bihar, West Bengal, Uttarakhand, Jharkhand, Haryana, Chhattisgarh, Himachal Pradesh, and Delhi. The river basin covers Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and Delhi. Table 6.1 shows state-wise drainage area and population variation in the last three decades as per the census of India. From Table 6.1, it is evident that Delhi's contribution is lowest in the drainage of the basin, but its contribution in the

Table 6.1 State-wise drainage area and population variation in the Ganga river basin in the last three decades

State	Drainage area (km^2)	Million-plus cities	Population (2011) millions	Population (2001) millions	Population (1991) millions
Uttar Pradesh	241392 (~28%)	Meerut	1.42	1.16	–
		Agra	1.76	1.33	–
		Kanpur	2.92	2.71	2.03
		Lucknow	2.90	2.24	1.67
		Allahabad	1.21	1.04	–
		Varanasi	1.43	1.20	1.03
Madhya Pradesh	181070 (~21%)	Bhopal	1.88	1.46	1.06
		Gwalior	1.10	–	–
		Indore	2.17	1.50	1.11
Rajasthan	112496 (~13%)	Jaipur	3.04	2.32	1.52
		Kota	1.00	–	–
Bihar	93580 (~11%)	Patna	2.05	1.69	1.10
West Bengal	71489 (~8%)	Asansol	1.24	1.06	–
		Kolkata	14.05	13.20	11.02
Uttarakhand	52989 (~6%)	–	–	–	–
Jharkhand	50390 (~6%)	Dhanbad	1.20	1.06	–
Haryana	34343 (~4%)	Faridabad	1.41	1.06	–
Chhattisgarh	17908 (~6%)	–	–	–	–
Himachal Pradesh	4317 (~1%)	–	–	–	–
Delhi	1484 (~0.2%)	Delhi	16.35	12.87	8.41

population is highest. It is located on the banks of the Yamuna River. The stretch of the Yamuna River in Delhi is highly degraded and polluted, which shows the impact of urbanization on the river (Arora and Keshari 2021). The geographical extent of the Ganga basin, covered states, and million-plus cities are shown in Fig. 6.2.

Urbanization in the Ganga river basin has increased manifold in the last five decades. Over time, many new million-plus population cities have emerged along the river and its tributaries. The existing million-plus population cities have been significantly expanded. In Fig. 6.3, different land use-land cover (LULC) maps are prepared for the Ganga river basin for different periods using various public domain resources. The LULC maps for 1985, 1995, and 2005 are prepared using the data provided by ORNL DAAC (Roy et al., 2016). The LULC map for 2021 is prepared using the data provided by ESRI (Karra et al., 2021). From Fig. 6.3, it can be seen that the urban area (shown in black color) is expanded over the period. The yellow dotted circle over the Delhi region shows a spatial expansion clearly during the last four decades. Many other black areas show the increment of the urban areas of the Ganga river basin. The LULC maps clearly show that urbanization had increased in the basin.

The basin's surface water bodies mainly comprise the Ganga river and its tributaries, lakes, ponds, and man-made reservoirs. The Ganga river, whose main stem length is 2525 km, is joined by many different order tributaries. The rivers, Yamuna, Ramganga, Kali, Gomti, Ghaghra, Gandak, Kosi, Son, and Tons are the major tributaries of the Ganga river. A line diagram in Fig. 6.4 shows the major tributaries of the Ganga river along with dam/barrages and canal systems. For other surface water bodies, the basin has 1750 ponds and lakes with a minimum of 0.030 km^2 size (Raju et al., 2015). The reduction in the level of the Ganga river water was observed as -6.03 ± 0.76 cm.year^{-1} using in situ water level data during the pre-monsoon season from 1999 to 2013 (Mukherjee et al., 2018). Also, the reduction in base flow was observed at around 50% during the summer season in the last three decades and 75% compared to 1970 (Mukherjee et al., 2018).

Urbanization and surface water bodies have a close correlation as water bodies provide many goods and services to fulfill the requirements of urbanization. In goods, water, sand, boulders, food, and energy are supplied by surface water bodies. In services, recreational activities, conveyance, nutrient recycling, sediment transport, water quality alteration, and spiritual and aesthetic values are received by water bodies.

3 Impact of Urbanization on Surface Water Bodies in the Ganga River Basin

The rapid growth of population and industrialization has caused severe problems in the Ganga river basin that are discussed in the forthcoming sections.

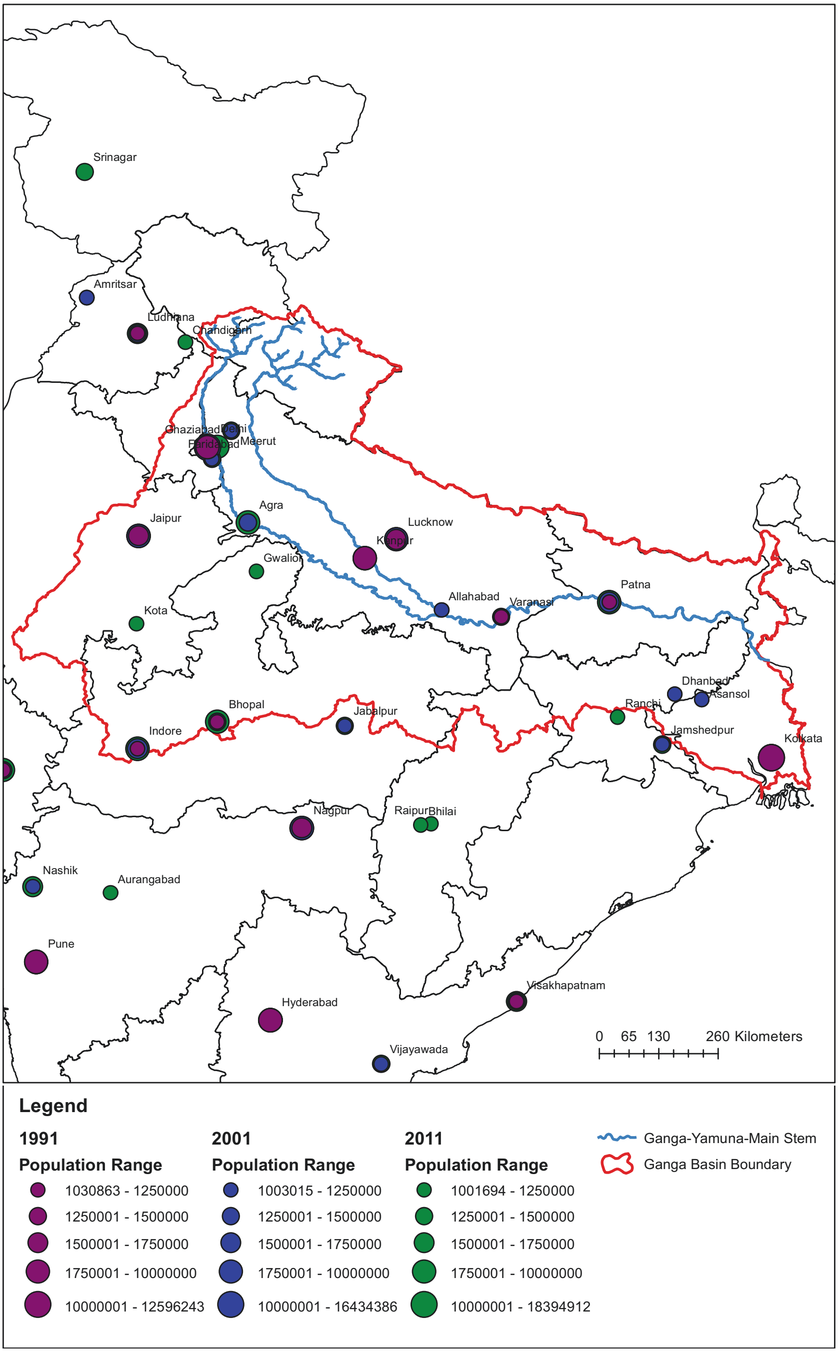

Fig. 6.2 Geographical extent of the Ganga basin, covered states, and million-plus cities

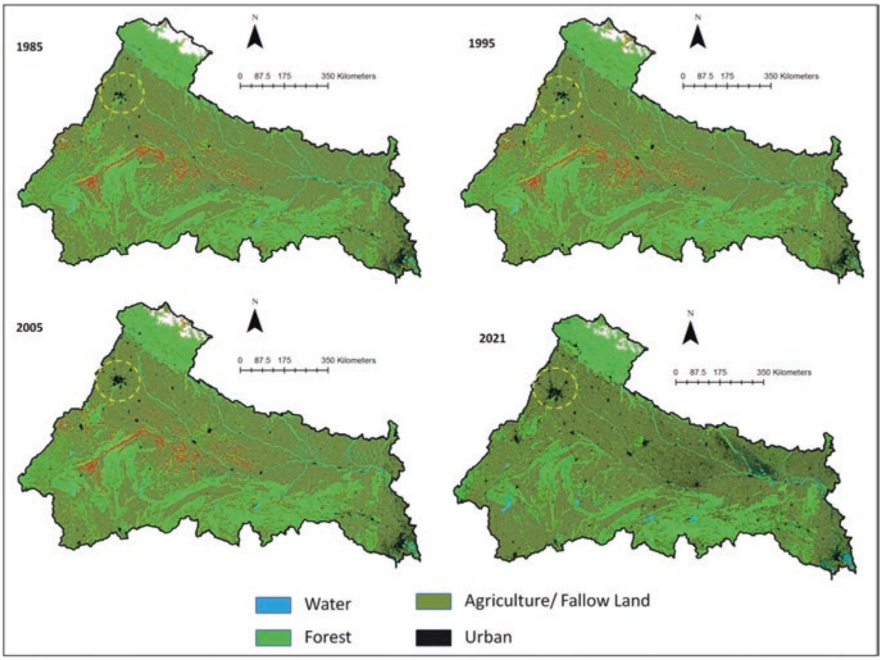

Fig. 6.3 Decadal LULC maps of the Ganga river basin

3.1 Extinction of Lakes, Ponds, and Wetlands

Urbanization has impacted the ecological, environmental, social, economic, and limnological aspects of the basin's lakes, ponds, and wetlands (Bassi et al., 2014). Many studies found the significant conversion of the lakes and ponds into built-up areas and its negative impact on the various functioning of the system. Delhi had faced the severe impact of urbanization on the extinction of these water bodies. Chaudhuri et al. (2022) pointed out that between 1970 and 2013, out of 629 lakes and wetlands, 338 were entirely extinct in the Delhi district due to urbanization, which ultimately resulted in the loss of the ecosystem. In another study on the extinction of the Delhi region's ponds and lakes, Singh et al. (2013) highlighted the impact of the extinction of lakes and ponds in the Delhi district on groundwater recharge and eco-hydrology of the study area. They found that the only reason for the extinction of these surface water bodies was rapid urbanization in the Delhi district. Similar studies have been done for water bodies of Uttar Pradesh and Bihar. The Upper Ganga stretch (Brijghat to Narora stretch of the Ganga river in Uttar Pradesh) is a type of floodplain-wetland. It has significant importance in the context of the eco-hydrology of the basin. It was declared a Ramsar site in 2005 to protect this water body from encroachment for agriculture and dumping of domestic-agriculture-industrial effluents/wastes. Sharma and Singh (2021) studied the status of wetlands and ponds in Bihar and found that many wetlands and ponds have

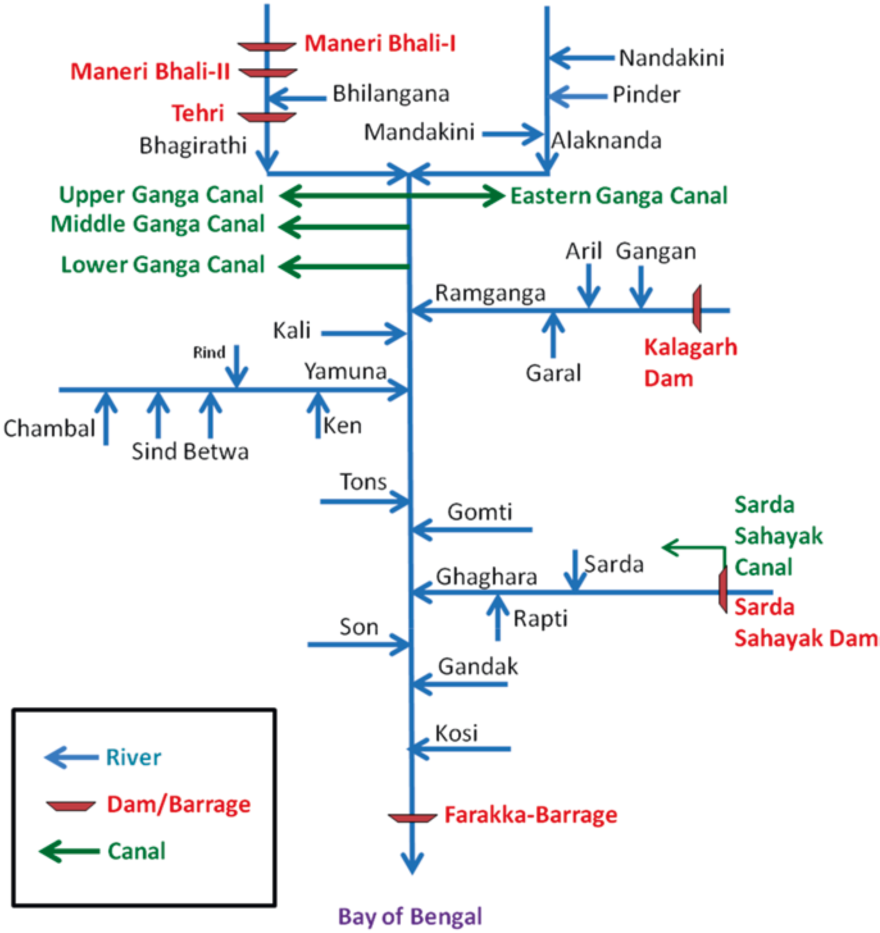

Fig. 6.4 A diagram of major tributaries, dam/barrages, and canal systems in Ganga river basin. (Jain et al., 2007)

become extinct due to urbanization. Kabartal wetland in Bihar, which was declared a Ramsar site in 2020, had faced severe encroachments by agricultural and urban activities.

3.2 *Fragmentation of Rivers*

The continuity of the river flow is an essential aspect of the river's biotic components. Due to urbanization, water demand for drinking and industrial purposes became high. For that, various multipurpose projects were developed on the main stem of the Ganga river and its tributaries. Tehri multipurpose project in Tehri

(Uttarakhand), commissioned in 2017, is used for supplying drinking water to Delhi and generates electricity to cater to the demand for energy for household and industrial needs. Other projects include Kalagarh multipurpose project on the Ramganga River for drinking water supply, irrigation, and electricity generation, the Upper Ganga canal project on Bhimgoda barrage (Haridwar, Uttar Pradesh) for irrigation and domestic water supply, and and the Lower Ganga canal project on Narora barrage (Narora, Uttar Pradesh) for irrigation. However, these projects have fragmented the rivers significantly (Modi et al. 2022b). This fragmentation had caused a severe impact on the biodiversity of the system. The Ganga river dolphins that are considered an indicator of the excellent health of the Ganga river are found only in a few reaches of the river, while these were found in the entire stretch of the Ganga river pre-dam era (Behera et al., 2014; Sinha & Kannan, 2014). The river's sediment transportation, self-cleaning properties, and influent-effluent mechanism have been affected severely due to the fragmentation of the river imposed by urbanization (Bawa et al., 2014; Khan et al., 2018, 2022; Simon & Joshi, 2022). S. Khan et al. (2018) modeled sediment load for the middle stretch of the Ganga river and found that present-day sediment peaks are lower than half of the simulated peaks due to dam/barrage abstraction. Khan et al. (2022) assessed the hydro-geo-chemical parameters of the Saman wetland (Uttar Pradesh) in the Ganga basin. They found that degradation in the wetland water quality and quantity was due to the loss of the influent-effluent relationship of the wetland with the Ganga river.

3.3 Degraded Water Quality

The untreated wastewater from households, industries, and other commercial activities of the cities near the river and its tributaries goes directly into the river and causes degradation in water quality. Many reaches and tributaries have now been converted into wastewater drains to carry out sewage and industrial effluents. On average, around 900 MLD of sewage reaches the main stem of the Ganga river directly or through its tributaries, responsible for 75% of the total pollution load of the river (Jain et al., 2007; Kumar & Tortajada, 2020). The river is exposed to partly treated effluents from pharmaceutical industries in the upper reaches of the Ganga river, between Rishikesh and Haridwar (Mariya et al., 2019). Also, municipal wastewater load is high in this reach due to the local population and religious visits by pilgrims. The water quality at Haridwar stretch was highly contaminated due to heavy metals, as the concentration of Cr was observed to be 43–196 $\mu g.L^{-1}$ (permissible limit is 100 $\mu g.L^{-1}$ by WHO), and Pb concentration was reported to be 108–690 $\mu g.L^{-1}$ (permissible limit is 50 $\mu g.L^{-1}$ by WHO) (Siddiqui & Pandey, 2022). These high concentrations indicate that river water quality at this stretch is no longer suitable for potable use. Further downstream, cities like Bijnor, Garhmukteshwar, Narora, and Kannauj do not add much pollution load to the river due to the absence of industrial clusters. This reach contributes base flow of the river during the non-monsoon season (Jain et al., 2007). Downstream of Kannauj city, the river water quality is inferior due to the industrial clusters and domestic wastewater in Kanpur city. The main stem of the Ganga river between Kanpur city and Buxar city is found to be significantly degraded due to industrial and domestic waste from the urban population and industries (Shukla et al., 2018). The leather industries in Kanpur are the main contributor of chromium and other chemicals to the river (Khwaja et al., 2001). In this stretch, the concentration of trace metals found in river water was very high, ranging from a few $\mu g.L^{-1}$ to 27.596 $mg.L^{-1}$ (Nazir et al., 2022). The wide range of heavy metals exceeding their permissible limits in the river water and the sediment deposits indicates water quality degradation (Bhattacharjee et al., 2022). A high level of pH range was reported near the Kanpur city stretch, indicating the alkaline river water due to the discharge of untreated wastewater (Nazir et al., 2022). In Allahabad city, the pollution load is mainly contributed by domestic wastewater due to its dense population (Chakarvorty et al., 2015). The range of heavy metals found at this stretch varies from a few $\mu g.L^{-1}$ to 11.9 mg of $Fe.L^{-1}$ which exceeded the permissible limit, indicating that river water is not suitable for domestic use and therefore needs a good treatment before supply to the communities. After that, in Varanasi city, a similar kind of situation is being faced by the river. Varuna and Assi are two tributaries, mainly wastewater drains that carry sewage from the city and dump it into the Ganga river. Another factor that causes river pollution is having the cremation ghats at the river banks in the stretch of Varanasi city. It is reported that around 40 thousand dead bodies are cremated at these ghats every day, and their ashes or remains (partially burnt or unburnt corpses) are dumped into the river (Arnold, 2016). The river water quality at the different ghats in Varanasi stretch was heavily polluted due to the heavy metals. The heavy metal concentration varies with very high concentrations of Zn (15.32 $mg.L^{-1}$), Cr (1090 $\mu g.L^{-1}$) Pb (240 $\mu g.L^{-1}$), and Cu (1700–2000 $\mu g.L^{-1}$) that indicates degraded situation of the river water due to the anthropogenic activities (Kumari et al., 2021). After that, in Bihar, cities like Patna contributes pollution load to the river through fertilizer industries, oil refineries, and domestic sewage. In West Bengal, Kolkata city also contributes to pollution through domestic sewage and numerous industrial effluents.

Apart from the main stem of the Ganga river, a major tributary, the Yamuna River is also facing severe challenges in terms of water quality and quantity due to urbanization (Misra, 2011; Sarker et al., 2021). The main cause of pollution load is untreated domestic sewage and industrial effluents from households and industries of the cities situated at the river banks. Major towns in Uttar Pradesh (Saharanpur, Muzaffarnagar, Ghaziabad, Noida, Vrindavan, Mathura, Agra, and Etawah) and Haryana (Yamuna Nagar, Karnal, Panipat, Sonipat, Gurgaon, Faridabad, Chhachhrauli, Indri, Radaur, Gharaunda, Gohana, and Palwal) are responsible for the pollution load in the Yamuna River (Singh et al., 2021b). Alone, Delhi state contributes a considerable amount of pollution load in the river due to the densely populated situation. The area nearby Delhi has expanded so much that all agricultural lands have been converted into colonies, shops, and industries. It affects the river in two ways – one is the domestic pollution load increment, and the second is the wastewater used earlier in agricultural irrigation, which is now dumped into the river without any treatment. Also, the river's floodplains are encroached by illegal human settlements, which have affected the local hydrology of the river system. Other than rivers, the surface water bodies like lakes, ponds, and wetlands are highly polluted due to changes or alterations in the natural landscapes due to urbanization. The recreational activities and waste discharge have increased manifolds that have caused eutrophication, sediment deposition, and degraded water quality. Also, these water bodies are being used as waste dumping sites which have degraded water quality mainly due to eutrophication, other physiochemical processes, and water temperature rise. Various studies have also reported the rise in the temperature of surface water bodies like rivers, lakes, and ponds due to the mixing of industrial effluent and thermal power projects (R. Sharma et al., 2021).

3.4 Decreased Water Quantity

Urbanization has increased the demand for water for domestic and industrial usage. Water purifiers, washing machines, dishwashers, and flushing systems in toilets require more water than actual necessity. So, in comparison to rural living, the urban lifestyle demands more water. Also, industries like tanneries, pulp-paper, distilleries, diaries, etc. are water-based industries that consume ample amounts of water to get the ultimate products and release large amounts of effluent (Singh et al., 2021a; Sonawane & Murthy, 2022). The water supply is made by groundwater pumping and canal systems from dams/barrages. These dams/barrages are responsible for lowering water volume in the river downstream of the abstraction. Sometimes no water is released through these abstractions due to the heavy demand for water for domestic-agricultural-industrial usage. In the Ramganga basin (a major sub-basin of the Ganga river basin), surface-subsurface water storage was reduced by ~0.2 MCM/km^2 from 1982–2013 (Modi et al., 2021). The reduced flow in the river was found due to upstream storage in the river. So urbanization is responsible for decreasing water volume downstream in rivers, lakes, ponds, and wetlands.

3.5 Increased Sediment Load

Vegetation cover helps protect against soil erosion through surface runoff. During the process of urbanization, vegetation cover gets converted into a wide variety of built-up areas with two implications, increased surface runoff, and the second decreased groundwater recharge. With increased surface runoff, soil erosion increases and causes more sediment deposition in lakes, ponds, wetlands, rivers, or water depressions. Ultimately, it reduces the storage capacity of lakes due to sediment deposits. Due to the lack of a proper waste management system in the city, dumping of waste also causes a reduction in the storage capacity of these water bodies. For example, Saha et al. (2010) studied the ponds of Brij (near Mathura district in Uttar Pradesh) for silting problems. They found that the rapid urbanization caused a loss of vegetation cover in the study area. Due to that, the erosion of sand was high and deposited in the ponds through surface runoff in the rainy season.

3.6 Disturbed Hydrology of the Region

Urbanization has impacted the basin's hydrology by changing the land use-land cover (LULC) of the basin. For any river basin, runoff volume, flood peak, and groundwater recharge (including base flow) depend on the amount of perviousness of the basin. Urbanization is responsible for increasing the basin's imperviousness as the forest-barren-shrub land cover is converted into built-up areas. Consequently, it negatively impacted the soil integrity, exchange of nutrients, infiltration rate, surface roughness, leaf area index, rooting depth of vegetation cover, and albedo. These changes ultimately affect groundwater recharge, evaporation, evapotranspiration, and other water balance components. Urbanization also affects the microclimate of a specific region if the evapotranspiration-rainfall relationship is highly correlated. LULC changes due to urbanization had also affected the variation in the flood frequency due to a shift in the curve number of the surface. Many researchers have also studied LULC changes and their impact on base flow. Many researchers have also studied LULC change and soil erosion. Small ponds were/are being converted into built-up areas, which have wholly vanished the local hydrology of the surface water bodies and negatively impacted the pond's local ecosystem. Also, these water bodies have been used as waste dumping sites, reducing water storage capacity. For example, Anand et al. (2018b) assessed the impact of anthropogenic activities impact on the hydrology of the Ganga river basin. Through simulated results, they found that in the present situation, annual water yield had lower down by ~35% in the Ganga basin in comparison to the virgin condition (the condition with no anthropogenic activities). Further they pointed out that in the upper reaches of the basin, stream flow had increased while it had been reduced in the lower reaches and tributaries. They also found the availability of water in water resources had decreased significantly in the basin. The change in LULC, e.g., conversion of small ponds into built-up areas, has changed the basin's hydrology and negatively impacted the basin's local ecosystem.

4 Discussion and Conclusion

Population growth is a natural process that can be managed up to a certain level if the legislation is implanted strictly by the government and with the support of communities. Based on that, urbanization can also be handled up to a certain level in the Ganga river basin. So, to handle the problematic situation, three approaches can be taken: stabilizing the population, strict implementation of environmental protection law, and raising and protecting the existing water resource. These things cannot be achieved totally, as every approach has restrictions. So, by maintaining an equilibrium approach, surface water bodies can be managed sustainably with urbanization development in the Ganga river watershed. It is the only solution for mitigating the problems aroused by urbanization to the river Ganga and different surface water bodies.

India's economy has changed from an agricultural-based economy to a service-based economy over the last few decades. So, water-related policies have shifted from surface water development to surface water management. In surface water management, the main focus has been on urban river management, as urbanization significantly impacted surface water bodies. It is now time to manage surface water bodies integrated with urban planning. So following provisions can be adopted for surface water management:

- Provision for sewerage systems and effluent treatment can help remain surface water bodies unpolluted. The mismanagement of domestic and industrial waste was frequently reported in the entire Ganga river stretch.
- Mapping surface water bodies and their geotagging is also imperative to conserve surface water bodies from exploitation.
- The provision of environmental flows from diversion structures is also a sustainable solution to managing water bodies and urban development.
- Hydro-geological studies for surface water management can also prepare urban river management plans to effectively, efficiently, and sustainably manage the surface water bodies.
- The implementation and monitoring of river water quality should be displayed the water quality parameter to the nearby localities so that the local people are aware of the impacts of wastewater discharge in the river. It will help to reduce water demand as treated water can be utilized for various purposes in domestic industries, the agricultural sector, the horticulture sector, and other commercial activities.
- Frequent water quality monitoring at the specific locations across the stretch must be implanted, and data should be displayed. It will increase their concerns about the water contamination-related issue, which may lead to the cooperation of local communities to protect the water bodies and maintain the water quality of surface water bodies.
- Increasing the awareness about rainwater management and motivating the local communities to implement the rainwater harvesting system in their house, which may lead to reducing urban flooding, degradation of water quality of surface water bodies, and reducing the stress on water resources.

Overall, the present study concludes that urbanization is critical for surface water bodies and should be managed sustainably.

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Declarations No Conflict of interest to declare.

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