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Research Article

Evaluating the interaction between built-up and blue infrastructure in Berhampore town: A case study of a Class-I city of West Bengal, India

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Abstract: *Berhampore town which falls in the Murshidabad district is a fast-growing urban center in Bengal. Rapid increase of population and haphazard infrastructure growth of the town has triggered considerable transformation of the adjoining blue infrastructure. The current paper is a case study directed towards estimating the impact on urban wetlands around Berhampore town from the years 1967 to 2016 using Corona aerial photo and high-resolution Google Earth image. Urban changes were assessed using visual image classifying techniques as well as some spatial analyses that used to enable a meaningful stress assessment of the urban wetlands over time. The outcomes indicated that; the built-up features of this area have nearly doubled (21.69% to 42.16% of the total land area) during this study period. The growth of urbanized zone leads to decrease of blue space buffer zone as a result, blue infrastructure, a critical natural resource, decreased from 4.72% to 3.31%, losing 57.78 hectares (29.89%). This study offers imperative understandings for policymakers and urban planners on the role of blue infrastructure in improving urban environmental conditions and mitigating heat in cities and their adjoining areas.*

Keywords: *Class-I town; Blue infrastructure; Gangetic floodplain; Corona image*

1. Introduction

The expansion of urban and peri-urban areas has been a significant global concern since the twentieth century, during which the urban population increased nearly tenfold, contributing to approximately 58% of total wetland loss [1]. Urbanization, a demographic process associated with cultural advancement and rapid landscape modification, has drastically altered human settlement patterns. Before 1900, only a small percentage of the global population lived in urban environments; however, by 1950, this figure had risen to 30% [2] and is projected to reach 60% by 2030 [3]. Consequently, studying blue space has become increasingly important in the context of urban ecology, as highlighted by numerous studies [1, 4-6]. Blue space in agricultural landscapes differ from those in urban settings in terms of ecological status and economic benefits. Blue spaces provide valuable services in both urban and non-urban environments, but in urban areas, they are particularly integral and crucial components of the landscape due to their unique contributions. Urban growth and blue space loss are dual threats to eco-environments, manifesting through habitat destruction caused by direct encroachment and water quality degradation resulting from increased urban effluent [5]. Urbanization has exacerbated the Urban Heat Island (UHI) effect, leading to major public health issues [7]. Blue spaces—like rivers and lakes—play a significant role in lowering UHI by providing cooling effects. The abundance of blue areas in the Lower Gangetic Flood Plain provides essential ecological services [8-9] and contributes to in local temperature regulation. But human activity and fast urbanization are endangering these bodies of water, reducing their capacity to cool the surrounding regions. Land surface temperature (LST) is significantly influenced by the interaction between artificial surfaces and blue space [10] artificial surfaces tend to heat the environment, whilst blue spaces cool it. In order to solve these problems, sustainable urban development is essential, but because social, constructed, and natural systems are tightly connected, it can be difficult to generate useful planning indicators.

India has been one of the pathways of fast urbanization in the recent decades; however, it is very dynamic in nature [11]. From 1951 to 2011, the urban population in India grew significantly from 62 million to 377 million [12]. According to the Census of India, the urban settlements are classified as “cities” and “towns” and further classes based on the size of the population. Here, the majority of the urban population live in the Indian Census Class I cities (a city with a population of 1, 00,000 or more) where near about 70% of the total urban population exist [11-12]. Thus, the tremendous population pressure in such growing cities has led to accelerated peripheral physical expansion with progressively increased land consumption [11] Here, many of such urban areas are located in the low laying areas of the major river system; Berhampore town is the example of such growing urban center in Murshidabad district of West Bengal where rapid urban growth exemplifies the challenges posed by increasing population pressure and peripheral expansion. This unplanned growth often comes at the expense of critical natural resources like wetlands, which play a vital role in maintaining ecological balance. The current study focuses on quantifying the extent of wetland loss in this rapid urbanizing landscape and accentuates the significance of blue infrastructure in mitigating urban heat and improving environmental sustainability.

2. Study Area

Berhampore, is the district headquarter, located in the fertile Gangetic floodplain of Murshidabad district, West Bengal, (Figure 1) shaped by its rich history. It is situated on the left banks of the Bhagirathi River, a distributary of the Ganges, the town prospers on agriculture, with its alluvial soil supporting crops like rice, jute, and mangoes. The surrounding landscape, marked by wetlands and river channels, sustains livelihoods while influencing the region’s urban-rural dynamic. According to Census of India, the Berhampore town has been identified as Class I city [13-14] situated at the middle part of the state that creating a nodal point of road network between North and South Bengal. The rapid urban growth of Berhampore has led to extensive degradation of the environment, encroachment of natural wetlands, open space, and agricultural land. Berhampore experiences a humid subtropical climate, with annual rainfall ranging from 1,300 to 1,600 mm, primarily during the monsoon season, while temperatures vary from 10°C in winter to 40°C in the summer months. Its strategic location as a communication nodal point connects North and South Bengal, making it a vital hub for trade, transportation, and cultural exchange. However, rapid urbanization has introduced challenges such as congestion, uneven development, urban heat, and loss of natural spaces, which exacerbate issues like seasonal flooding [14] and water pollution.

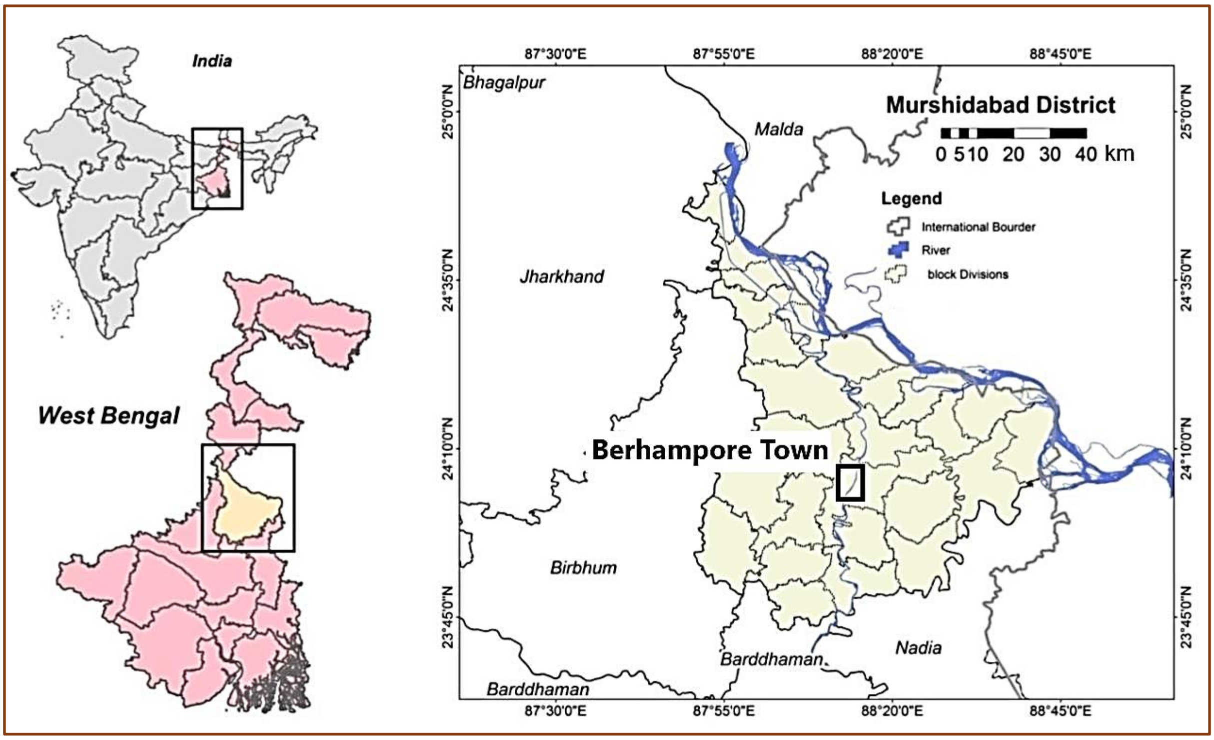

Figure 1: Location of Berhampore town within Murshidabad District

3. Methodology

To analyse land-use changes between two time periods, this study employs a systematic methodology using visual image classification techniques in GIS software. The recent imagery from Google Earth and historical Corona satellite imagery has been acquired. The Corona images were georeferenced using ground control points derived from the Google Earth imagery to ensure alignment in the same coordinate system. A classification scheme is developed, categorizing land use into three major classes such as built-up area, blue infrastructure lime wetland, river, and pond, and non-built-up area. Using visual interpretation techniques, features has been manually identified and digitized based on shape, texture, tone, and pattern, with classification performed separately for the historical and recent imagery. For change detection, classified maps from both periods are overlaid in GIS software to create a change detection statistic. The areas of each land-use category for both time periods are calculated, and the changes are quantified by computing the differences in area coverage.

4. Results

The maps (Figure 2) highlight the spatial distribution and transformation of various land-cover types, including built-up areas, non-built-up areas, wetlands, rivers, sandbars, roads, and railways. In the left map (earlier period), the built-up areas are concentrated in certain clusters, indicating limited urban development. In the right map (later period), built-up areas expand significantly, covering a much larger portion of the landscape.

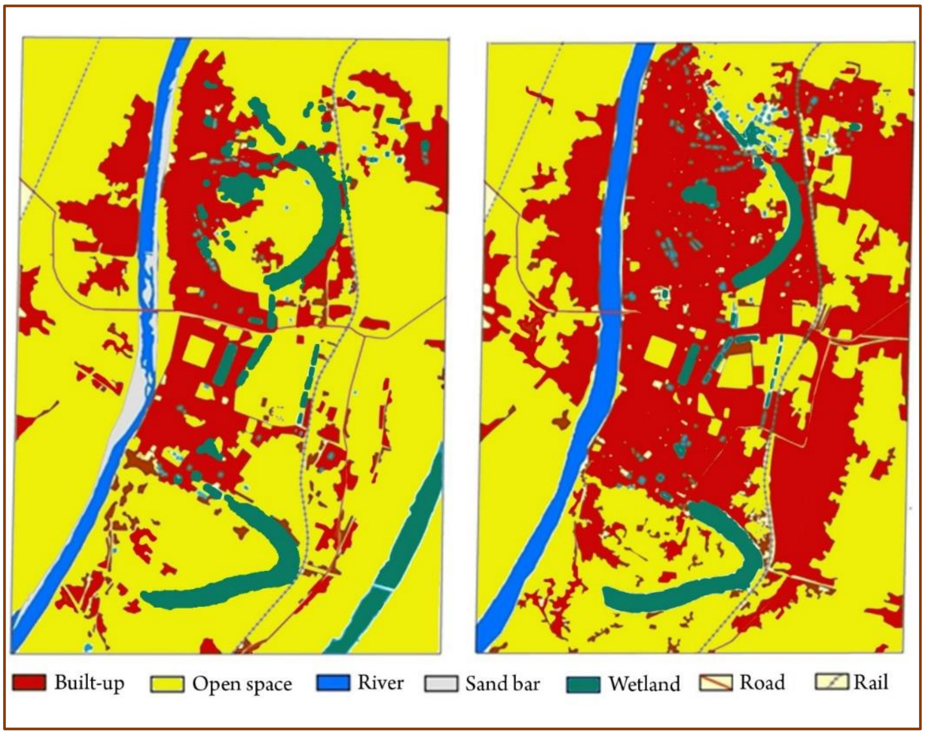

Figure 2: The change detection map compares land-use/land-cover patterns between two different time periods, likely 1967 (left) and 2016 (right).

This suggests substantial urban growth over time. Urban sprawl is evident, with built-up areas spreading into previously non-built-up regions, likely replacing agricultural land, open spaces, and wetlands. Non-built-up areas dominate the landscape in the left map, providing open space for natural vegetation, agriculture, or undeveloped land. In the right map, these areas shrink noticeably as they are converted into urban areas, indicating the pressure of urbanization on natural and rural landscapes. Wetlands are scattered across the left map in small patches near rivers and low-lying areas. These patches are less prominent in the right map. This indicates the degradation or conversion of wetlands, likely due to encroachment by urban areas or land reclamation for development purposes. The ecological impacts of this loss include reduced biodiversity, altered water flow, and potential flooding issues. The road (red lines) and rail (dotted lines) networks remain relatively consistent between the two maps, but their connectivity with built-up areas increases in the later period. This reflects the development of transportation infrastructure to support urban growth and improve accessibility. The river systems remain stable across the two periods, with no significant changes in their courses. Sandbars are present along the rivers in both maps, though they may have shifted or reduced slightly due to human activities or natural processes like sedimentation and erosion.

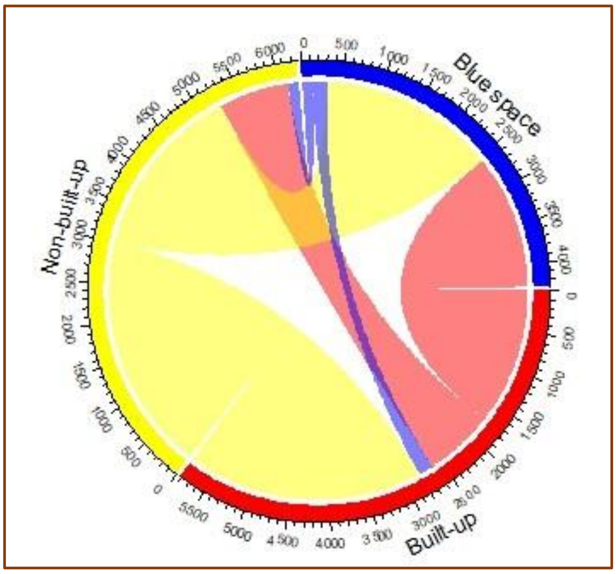

Figure 3: LULC class transformation from 1967-2016

The LULC data (Figure 3) for 1967 and 2016 demonstrates significant environmental and urban transformation over 49 years, with urban expansion being the dominant trend. The built-up area increased from 21.69% to 42.16% of the total land area, nearly doubling in size. This reflects urban sprawl and development, likely driven by population growth, economic activities, and the need for housing and infrastructure. The increase of 838.57 hectares (93.96%) suggests that urbanization was a major driver of land-use changes during this period. Non-built-up areas, which may include agricultural lands, open spaces, and vegetation, decreased significantly from 73.59% to 54.53%. This highlights the substantial conversion of natural or undeveloped land into urban areas to accommodate expanding cities, which may affect ecological balance and reduce space for agriculture or biodiversity. Wetlands, a critical natural resource, decreased from 4.72% to 3.31%, losing 57.78 hectares (29.89%). The loss of wetlands is particularly concerning due to their importance in flood control, water purification, biodiversity, and climate regulation. This reduction may indicate insufficient conservation efforts or the prioritization of urban development over ecological preservation. The dramatic increase in urban areas suggests growing developmental pressures, but it also highlights the environmental trade-offs, including habitat loss and reduced ecosystem services. The reduction in wetlands and non-built-up areas raises concerns about long-term sustainability, such as increased vulnerability to flooding, decreased biodiversity, and reduced agricultural capacity. This trend calls for better urban planning and land management strategies to balance development with environmental conservation and resource preservation.

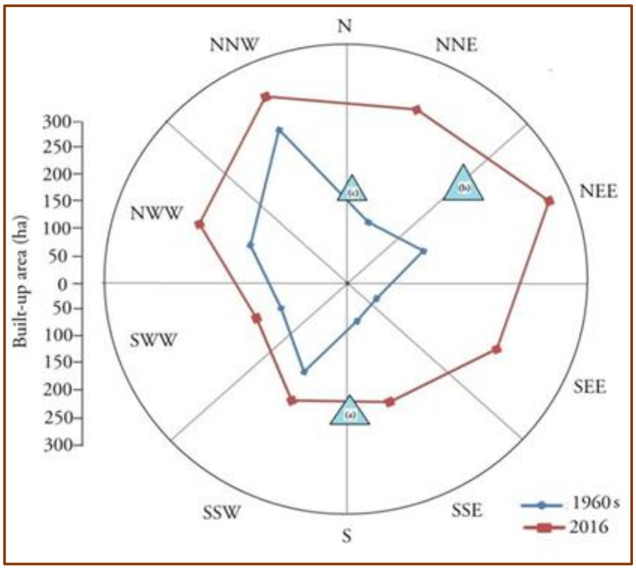

Figure 4: The radar plot, compares built-up areas (in hectares) for two time periods: the 1960s and 2016.

The plot is divided into directional segments (Figure 4) representing different compass directions (e.g., N, NNE, NE, etc.) and shows how the extent of urban development has changed over time in each direction. Urban development was more concentrated (smaller areas) in the 1960s, as indicated by the smaller area enclosed by the blue line. In 2016, the red line shows significant expansion of built-up areas in all directions, with notable growth in the southeast (SEE) and northeast (NEE) directions. The diagram visually emphasizes urban sprawl and growth over time, highlighting how development has expanded significantly in 2016 compared to the 1960s. Specific directions (e.g., SEE and NEE) experienced greater expansion, suggesting patterns or trends in urbanization during this period.

The change detection map underscores the dynamic transformation of the landscape over time (Figure 5). While the development of urban infrastructure reflects economic progress, the loss of natural land-cover types, particularly wetlands, emphasizes the need for sustainable land-use planning and environmental conservation to mitigate the adverse impacts of urbanization.

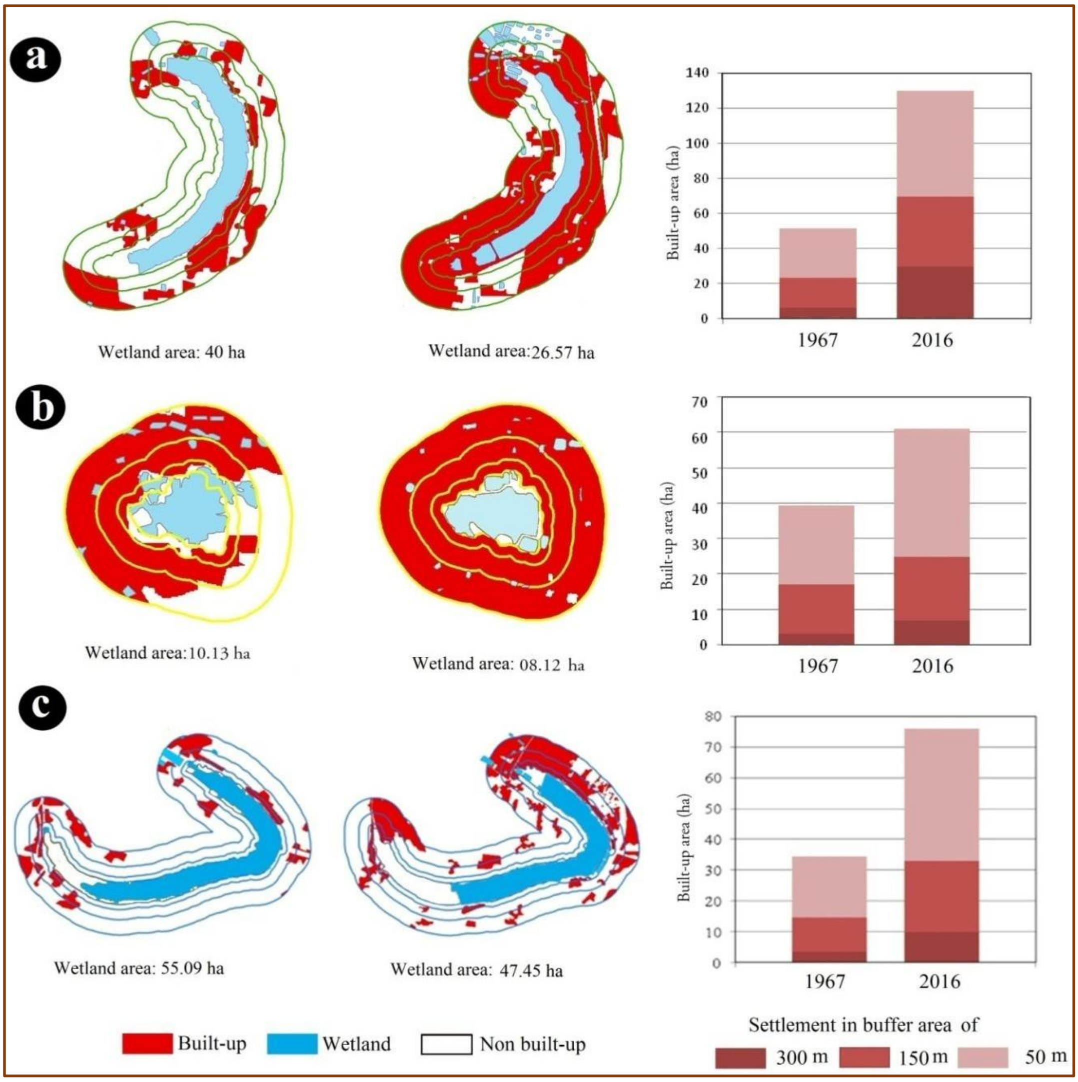

Figure 5: The diagram illustrates the changes in wetland area and built-up area over time (from 1967 to 2016) for three different locations (labeled as a, b, and c).

The bar chart highlights a steady increase in built-up areas across all buffer zones (50 m, 150 m, and 300 m), with the 300 m zone experiencing the most significant expansion, especially by 2016. Although the wetland areas have experienced significant decline over 49 years. Across all three wetlands, urban development has caused a consistent decrease in wetland areas, with the most notable growth in settlements occurring in the 300 m buffer zone. This pattern underscores the pressure of urbanization on wetlands, leading to their gradual loss.

5. Discussion

Blue spaces, like rivers, lakes, and wetlands, are essential parts of the environment. They provide numerous benefits, such as cooling the surroundings, improving air quality, and offering recreational spaces for people. These spaces also play a vital role in maintaining the ecological balance and contributing to our overall well-being. But many of these studies represent that it gradually decreased due to anthropogenic activity [15-17], but blue spaces are shrinking due to human activities, especially urbanization. As cities grow and populations increase, natural landscapes are replaced with buildings, roads, and other infrastructure. This puts tremendous pressure on water bodies, leading to pollution, encroachment, and degradation. Cities like Berhampur face these challenges. Rapid urbanization has impacted local blue spaces, leading to issues like rising temperatures, poor air and water quality, and reduced access to these vital resources for local communities. The result is not just environmental damage but also a growing risk to people's health and quality of life. Berhampore has brought significant land use changes, with the built-up area expanding from 21.69% to 42.16%. This growth has occurred primarily at the expense of non-built-up areas, which have declined from 73.59% to 54.53%, and wetlands, which have decreased from 4.72% to 3.31%. These changes are driven by population growth and economic development, leading to the encroachment on natural spaces and the loss of critical wetlands. Addressing this requires urgent action. Restoring and protecting blue spaces can help mitigate these problems. Solutions like cleaning up polluted water bodies, making sustainable urban drainage systems, and restoring wetlands can improve the situation. Cities need to include blue space conservation in their planning to ensure these resources are preserved for future generations while making urban areas healthier and more viable.

6. Conclusions

The case study of Berhampore is indicative of the loss of urban wetlands due to urbanization, which was prevalent over a stretch of fifty years. The study accentuates the critical role of blue infrastructure in promoting urban resilience by regulating climatic conditions, controlling the urban heat islands, and providing an aesthetic environment. This information should be useful for the urban policymakers in devising approaches to protect the existing wetlands by incorporating blue infrastructure into the holistic urban development plan. By addressing these challenges, cities like Berhampore can achieve a more balanced growth trajectory while preserving vital natural resources for future generations.

References

1. Ehrenfeld, J. G. (2000). Evaluating wetlands within an urban context. Ecological Engineering, 15(3), 253-265.
2. Faulkner, S. (2004). Urbanization impacts on the structure and function of forested wetlands. *Urban ecosystems*, *7*(2), 89-106.

3. United Nations Population Division. (2002). World Urbanization Prospects: The 2001 Revision. New York: United Nations.
4. Guntenspergen, G. R., & Dunn, C. P. (1998). Introduction: Long-term ecological sustainability of wetlands in urbanizing landscapes. *Urban Ecosystems*, 2(4), 187-188.
5. Seilheimer, T. S., Wei, A., Chow-Fraser, P., & Eyles, N. (2007). Impact of urbanization on the water quality, fish habitat, and fish community of a Lake Ontario marsh, Frenchman's Bay. Urban Ecosystems, 10(3), 299-319.
6. Unnikrishnan, H., & Nagendra, H. (2015). Privatizing the commons: Impact on ecosystem services in Bangalore's lakes. *Urban Ecosystems*, *18*, 613-632.
7. Arifwidodo, S. D., & Chandrasiri, O. (2020). Urban heat stress and human health in Bangkok, Thailand. *Environmental Research*, *185*, 109398.
8. Tripathi, R. N., Ramachandran, A., Tripathi, V., Badola, R., & Hussain, S. A. (2022). Spatio-temporal habitat assessment of the Gangetic floodplain in the Hastinapur wildlife sanctuary. *Ecological Informatics*, *72*, 101851.
9. Talukdar, S., Singha, P., Mahato, S., Praveen, B., & Rahman, A. (2020). Dynamics of ecosystem services (ESs) in response to land use land cover (LU/LC) changes in the lower Gangetic plain of India. *Ecological Indicators*, *112*, 106121.
10. Bekele, N. K., Hailu, B. T., & Suryabhagavan, K. V. (2022). Spatial patterns of urban blue-green landscapes on land surface temperature: A case of Addis Ababa, Ethiopia. *Current Research in Environmental Sustainability*, *4*, 100146.
11. Mithun, S., Chattopadhyay, S., & Bhatta, B. (2016). Analyzing Urban Dynamics of Metropolitan Kolkata, India by Using Landscape Metrics. Papers in Applied Geography, 2(3), 284-297.
12. Census of India (2011) Office of the Registrar General of India and Census Commissioner, Government of India
13. Mondal, D. (2012). Urban land use change assessment using RS and GIS: a case study of Berhampore town and its surroundings, Murshidabad district, West Bengal. Geo-analyst, 2(1), 26-30.
14. Mondal, D., & Pal, S. (2016). Monitoring Dual-season Hydrological Dynamics of Seasonally flooded Wetlands in the Lower Reach of Mayurakshi River, Eastern India. *Geocarto International*, DOI: 10.1080/10106049.2016.1240720.
15. Zhou, J., Liu, J., Yan, D., Wang, H., Wang, Z., Shao, W., & Luan, Y. (2019). Dissipation of water in urban area, mechanism and modelling with the consideration of anthropogenic impacts: A case study in Xiamen. *Journal of Hydrology*, *570*, 356-365.
16. Takyi, S. A., Amponsah, O., Darko, G., Peprah, C., Apatewen Azerigyik, R., Mawuko, G. K., & Awolorinke Chiga, A. (2022). Urbanization against ecologically sensitive areas: effects of land use activities on surface water bodies in the Kumasi Metropolis. *International Journal of Urban Sustainable Development*, *14*(1), 460-479.
17. Chen, K., Wang, X., Li, D., & Li, Z. (2015). Driving force of the morphological change of the urban lake ecosystem: A case study of Wuhan, 1990–2013. *Ecological Modelling*, *318*, 204-209.