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Research paper

Urbanization-induced geo-environmental changes in Naogaon municipality, Bangladesh: a comprehensive assessment

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Abstract

This study examines how urban growth impacts the environment in Naogaon Municipality, Bangladesh. We analyzed changes in land use, soil quality, water resources, air quality, and more. Our findings show that urbanization leads to loss of green spaces and agricultural lands, affecting biodiversity and soil fertility. Industrial activities and traffic contribute to air and water pollution. Drainage systems are extensive but unevenly distributed, and waste management needs improvement. We recommend comprehensive strategies to address these environmental challenges for sustainable urban development.

Keywords: *Environment; Naogaon Municipality; Pollution; Sustainability; Urbanization.*

1. Introduction

Urbanization is a hallmark of modern development, with profound implications for the environment, economy, and society. In regions undergoing rapid urban growth, such as Naogaon Municipality in Bangladesh, understanding the intricate interactions between urban development and geo-environmental conditions is imperative for sustainable management and planning. This research aims to investigate the multifaceted impacts of urbanization on the geo-environmental landscape of Naogaon Municipality, shedding light on key aspects such as land use changes, soil quality, water resources, air quality, geomorphology, ecological dynamics, and socio-economic factors.

The geo-environmental changes induced by urbanization in Naogaon are multifaceted and demand comprehensive assessment to grasp their full implications. These changes encompass alterations in land use patterns, depletion of natural resources, degradation of ecosystems, and heightened vulnerability to natural hazards [1], [9]. The burgeoning urban population, coupled with insufficient infrastructure and inadequate urban planning, exacerbates these challenges [10]. One of the fundamental implications of geo-environments lies in their profound influence on cultural and social dynamics [15].

The transformation of natural landscapes into urbanized areas brings about significant alterations in land use patterns, often resulting in the loss of green spaces, agricultural lands, and natural habitats. These changes not only affect the aesthetic appeal of the region but also have far-reaching implications for ecosystem services, biodiversity conservation, and overall environmental quality. Moreover, the rapid expansion of urban infrastructure and human settlements exerts pressures on soil resources, leading to changes in soil composition, fertility, and contamination levels. Understanding the dynamics of soil quality within the context of urbanization is crucial for sustainable land management practices and agricultural productivity enhancement.

In addition to soil, water resources play a vital role in sustaining urban populations, yet they are often subject to degradation and depletion due to urban development activities. Surface water bodies are vulnerable to pollution from industrial effluents, sewage discharge, and solid waste disposal, while groundwater reserves face the risk of over-extraction and contamination, exacerbating water scarcity issues in the municipality. Furthermore, the process of urbanization influences air quality through emissions from vehicular traffic, industrial activities, and residential sources. Elevated levels of air pollutants not only pose health risks to the population but also contribute to environmental degradation and climate change.

In the realm of geomorphology, urban development alters natural landforms and geological processes, leading to changes in erosion patterns, sedimentation rates, and the stability of slopes. These geomorphic changes have implications for infrastructure resilience, disaster risk management, and the long-term sustainability of urban settlements. Moreover, urbanization impacts ecological dynamics by fragmenting habitats, disrupting wildlife corridors, and altering ecosystem structure and function. Understanding these ecological changes is essential for biodiversity conservation efforts and the promotion of urban green spaces to enhance the resilience of urban ecosystems.

Finally, socio-economic factors intersect with geo-environmental dynamics, shaping the vulnerability, resilience, and adaptive capacity of communities to environmental changes induced by urbanization. Issues such as public health disparities, infrastructure provision, and resource access are intricately linked to urban development trajectories and governance structures. In light of these interconnected challenges and opportunities, this research seeks to provide a comprehensive understanding of the complex interactions between urban development and geo-environmental conditions in Naogaon Municipality. By elucidating the drivers, impacts, and implications of urbanization on the local environment and society, this study aims to inform evidence-based decision-making processes and policy interventions for promoting sustainable urban development pathways in the region.

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2. Location and previous study

In Naogaon Municipality, situated in the Naogaon district of Bangladesh, the nexus between rapid urbanization and its impact on the surrounding geo-environmental conditions presents a compelling area for research. Naogaon, located in the northern part of Bangladesh (Fig. 1), is characterized by its agricultural significance, cultural heritage, and growing urban population.
Previous studies in this area have predominantly focused on aspects such as agricultural productivity, land use dynamics, and socio-economic development. However, there's a noticeable gap in research addressing the evolving geo-environmental landscape resulting from urbanization processes within Naogaon Municipality specifically. While broader studies on urbanization in Bangladesh exist, they often lack the localized context necessary to understand the nuanced interactions between urban development and environmental change at the municipal level.

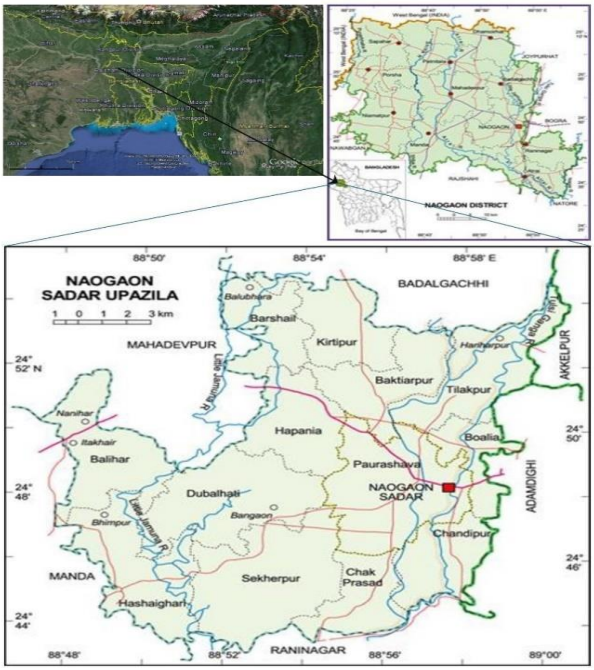

Fig. 1: Location Map of the Study Area.

Therefore, this research seeks to build upon and complement existing literature by delving into the specific geo-environmental dynamics of Naogaon Municipality. By doing so, it aims to provide a more detailed understanding of how urbanization is shaping the local environment, as well as its implications for sustainability, resilience, and community well-being. Through empirical research and data-driven analysis, this study endeavors to contribute valuable insights that can inform policy formulation, urban planning practices, and community engagement efforts aimed at fostering a more sustainable and resilient urban future for Naogaon Municipality and similar regions facing similar challenges.

3. Geological setting

Naogaon Municipality rests within the vast expanse of the Ganges-Brahmaputra-Meghna (GBM) Delta, an immense geological feature shaped by the relentless forces of three mighty rivers. Over millennia, the ceaseless flow of water from the Himalayas and the Indian subcontinent has deposited layers of sediment across the deltaic landscape, creating a mosaic of fertile plains that sustain life and livelihoods. The geological formations that underpin Naogaon Municipality primarily consist of Holocene deposits, relatively youthful in the grand narrative of geological time. Composed of clay, silt, sand, and gravel, these deposits form the foundation of the region's rich agricultural soils, nurturing crops that feed both local communities and distant markets. In Naogaon Municipality, understanding the geological setting is paramount. It informs decisions on land use planning, infrastructure development, and disaster preparedness. By embracing the geological tapestry that underlies the municipality, stakeholders can navigate the delicate balance between harnessing the earth's bounty and safeguarding against its unforgiving forces, paving the way for sustainable development and resilience in the face of environmental uncertainty. The study area is located in the northeastern part of the Indian subcontinent, covering the Bengal Basin, Bangladesh, and a part of eastern India (Fig. 2). This basin forms a remnant ocean basin [6], [8] at the juncture of three interacting plates, viz., Indian, Burma, and Eurasian plates. The intensity, dynamic nature, and pattern of plate-to-plate interaction varied with time, affecting the basin architecture and sedimentation style throughout the basin history. Basin development began in the early Cretaceous epoch (ca. 127 Ma) when the Indian plate rifted away from the combined Antarctica-Australia part of Gondwanaland and began its spectacular journey, initially northwestward and then northward. After plate reorganization, the Indian plate migrated rapidly northward and collided with Asia in 100 Ma [12]. The collision of these plates visualized in two different forms: (i) the north to northeasterly continent-continent collision of the Indian Plate into the Tibetan Plate, which is mainly expressed by thrusting, lateral displacements, and uplift associated with the development of eastern Himalayas; and (ii) the oblique subduction of the oceanic crust beneath the Burma Plate resulting in the development of accretionary wedges, which together with thrusting and folding, has subsequently uplifted the Indo-Burman Ranges and associated fold belt of the Chittagong Tripura Folded Belt [7[13],[2].
The Hinge Zone, a zone of deep-seat normal faults in the basement complex which divides the Bengal Basin into two broad divisions: (1) the 'Indian platform' (also known as the Stable shelf region) to the northwest and west, underlain by Precambrian continental crust, and (2) the deeper part of the basin, such as Chandpur Faridpur and Sylhet Troughs, in the south and east. The investigated area occupies a portion of the Indian platform of the northwestern stable shelf of the Bengal geosynclinals. The pile of thick Late Permian-Recent

sedimentary sequence began to deposit in the study area. The Barind Tract occupies the western part of the study area, which is a tectonically stable shelf zone of the Bengal Basin named as “Bogra Slope” [3]. The surface geology consists entirely of sedimentary formation, mainly revering in origin.

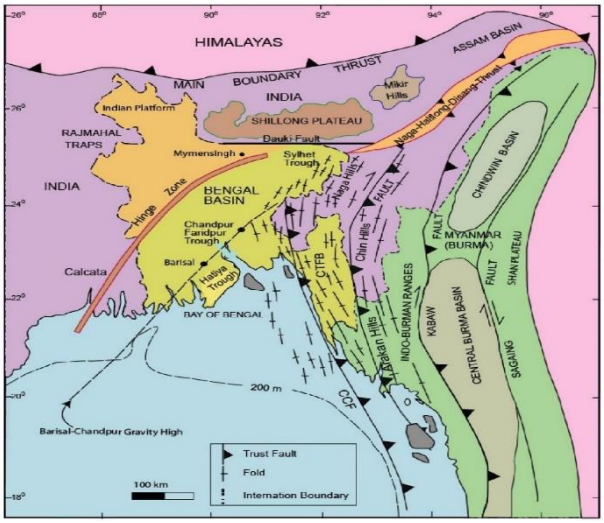

Fig. 2: Tectonic Map of the Bengal Basin and Surrounding Areas (After Alam Et Al.,2003). CTFB=Chittagong Tripura Folded Belt, CCR= Chittagong Cox’s Bazar Fault.

4. Methods of study

The methodology employed in this study involved a comprehensive approach to understanding the impact of urban development on geo-environmental conditions in Naogaon Municipality, Bangladesh. Data collection was conducted through both secondary and primary sources. Secondary data included the gathering of various maps, research publications, and relevant documents to establish a baseline understanding of the municipality's existing environmental landscape. Primary data collection involved field surveys to obtain firsthand information on key environmental parameters and photographic documentation to visually document changes over time.

The parameters examined in the data collection process encompassed a range of factors such as population density, waste disposal practices, industrial activities, and general geological data, alongside more specific environmental indicators including land use patterns, soil characteristics, water quality, and air pollution levels. These data were then subjected to rigorous analysis, involving tabulation, charting, and graphing to interpret different aspects of environmental changes within the study area. Statistical methods were employed to analyze trends and correlations among the various parameters, providing quantitative insights into the evolving environmental landscape.

In addition to quantitative analysis, qualitative insights were gained through photographic documentation and field surveys. High-resolution photographs served as a vital tool for visually capturing urban expansion, changes in land use, vegetation cover, and environmental degradation. Field surveys complemented these efforts by providing qualitative assessments and validation of the quantitative data. On-site assessments allowed researchers to document environmental features, sample soils and water bodies, and measure air quality, facilitating engagement with local communities and stakeholders.

Although geospatial analysis techniques such as GIS mapping and remote sensing were not mandatory for this study, they were identified as potential tools to enhance data interpretation if available. Spatial patterns and trends were analyzed using simple mapping techniques and visual interpretation of data, allowing for a deeper understanding of the spatial dynamics of urbanization-induced geo-environmental changes within Naogaon Municipality. The integration of findings from systematic data collection, photographic documentation, field surveys, and potential geospatial analysis provided a comprehensive understanding of how urban development influences geo-environmental conditions in Naogaon Municipality. These insights have significant implications for decision-making, policy interventions, and the promotion of sustainable development practices within the region.

5. Urbanization and its impacts in the study area

Urbanization, originating from the Latin term "Urbs," denotes the systematic transition of rural landscapes into urban environments characterized by infrastructural advancements and socio-economic complexity [4]. It encapsulates a multifaceted process influenced by the socio-economic dynamics and infrastructural advancements inherent in urban centers [5]. In the developmental context of Bangladesh, urbanization plays a crucial role in shaping national economic trajectories, fostering regional development, and generating employment opportunities [14].

In regions like Naogaon, Bangladesh, the demographic landscape is witnessing a profound shift due to rural-to-urban migrafution patterns, resulting in a notable increase in urban population density. As of the latest data, the population of Naogaon district stands at 124,048, with an annual growth rate of 0.79%. Within Naogaon Pourashava, the urban population has surged to 150,025, indicating a substantial influx of migrants seeking better amenities and economic prospects [11].

Industrial zones, notably in areas like Katal Tole and the bypass area, are characterized by a prevalence of small and medium-scale enterprises engaged in various industrial activities, including milling operations. However, these industrial activities contribute to atmospheric pollution through the emission of particulate matter and other pollutants. Despite current compliance with regulatory standards, the potential for environmental degradation looms large with anticipated industrial expansion. Effective waste management practices are imperative to mitigate environmental concerns associated with urbanization. However, inadequate solid and liquid waste disposal mechanisms exacerbate environmental degradation, posing significant challenges to environmental sustainability (Fig. 3). Data from Naogaon Pourashava Authority [11] indicates that approximately 4 tons of solid waste are generated daily, necessitating robust waste management strategies to ensure environmental integrity.

Land use dynamics within Naogaon reflect shifting demographic trends, with urbanization accelerating since the early 2000s. However, inadequate transportation infrastructure necessitates reliance on non-motorized modes of transport for intra-city commuting. Additionally, drainage systems, both natural and anthropogenic, play a crucial role in managing surface water runoff (Fig. 4). However, man-made drainage structures often exacerbate environmental impacts through alterations in hydrological patterns and contamination. To address these challenges, sustainable urban planning strategies must be implemented to mitigate the adverse effects of urbanization on environmental quality and human well-being.

Fig. 3: Photographs Showing the Solid Waste Disposal in Various Place of the Study Area (A) Waste Disposal Site at Kumaigari, (B) Dustbin at Hat Naogaon Locality, (C) Drug Bottle Piles at Per-Naogaon, (D) Various Solid Waste Kathaltole Area, (E) College Road Area and (F) Beside Choto Jamuna River Bridge.

Fig. 4: Photograph Showing (A) the Drainage System at Kazirmore (the Arrow in the Photographs Indicate Sanitary Leaching Mixed in the Drainage System, (B,C) Household Wastes Fill the Drain That Is A Signature of Unconsciousness (D) Outlets of the Drain in the Choto Jamuna River Water (Arrow Sign Indicates Waste Water Mixing in the River).

6. Results and discussions

The Naogaon Pourashava area boasts an extensive man-made drainage network spanning 55.18 km, comprised of various structures like pipes, Reinforced Cement Concrete (RCC), and brickwork. These serve as secondary and tertiary drains, intricately connected to nearby rivers. The primary drainage artery, the Choto Jamuna River, meanders through the central zone covering roughly 8.15 km. On the other hand, the Tulshi Ganga River courses through the eastern sector, stretching over 4.24 km. While the Choto Jamuna maintains a steady flow year-round, certain sections experience dry spells in winter, contrasting sharply with the Tulshi Ganga, which dries up entirely during the same season (Fig. 7). Both rivers play crucial roles as primary drainage channels for the Pourashava.

Naogaon Pourashava is equipped with five identified secondary drains, distributed across its wards. Interestingly, these drains have been constructed without a cohesive plan, showcasing disparities in distribution across different wards (Fig. 5). For instance, Ward Nos. 1 and 8 exhibit a skewed ratio of secondary to tertiary drains, with only one secondary drain each, compared to multiple tertiary drains. Shockingly, Wards Nos. 7 and 9 lack secondary drainage systems altogether. Out of the five identified secondary drains, only three are constructed using the robust RCC method, while the rest employ less durable materials like Katcha or brickwork. To enhance safety and efficiency, it's recommended to transition to RCC construction due to its structural integrity and the necessity for coverage with slabs to prevent accidents and open discharge.

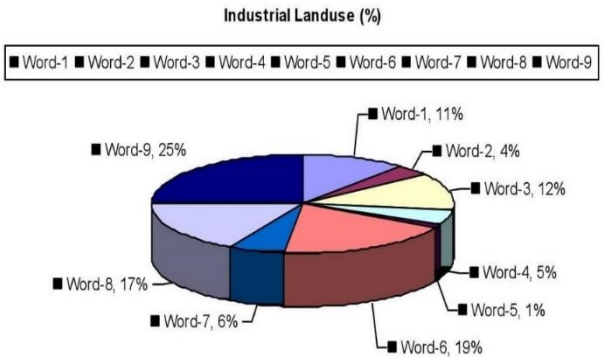

Fig. 5: Pie Diagram Showing the Percentage of Industrial, Residential and Homestead Land Use within Pourashava Area.

Turning to water resources, residents in the study area enjoy reliable access to safe drinking water, with a significant proportion utilizing supply water and tube well water. Notably, there are no reported instances of households relying on potentially contaminated sources like khal/river or pond water for drinking. However, the study area grapples with various hazards and environmental challenges, adversely affecting its geo-ecological conditions. These hazards, ranging from natural phenomena to human activities, pose significant risks to life and property. It's imperative for future development initiatives to prioritize comprehensive hazard assessments to mitigate potential disasters and safeguard human welfare and assets.

Land degradation is a pressing issue, driven by factors like overexploitation of agricultural biomass, unscientific cultivation practices, and irregular rainfall patterns. Moreover, soil quality degradation in floodplains is exacerbated by improper chemical fertilizer and pesticide usage, further compounded by siltation from flash floods and riverbank erosion (Fig. 6). Industrial expansion and untreated effluent discharge contribute significantly to land and soil quality deterioration.

Fig. 6: Photograph Showing (A, C) Land Degradation Due to Construction of Brick Field in the Irrigated Area, (B) Land Degradation by Cutting and Filling of Soil for the Construction of Industry and Housing.

Waterlogging presents a formidable challenge, arising from a combination of natural factors and human-induced activities such as unplanned urbanization and inadequate drainage infrastructure. Consequently, waterlogging intensifies progressively, posing a growing concern for local inhabitants (Fig. 7).

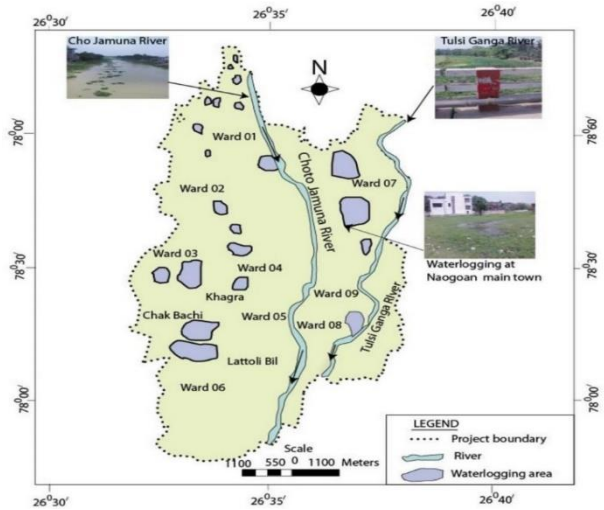

Fig. 7: Map Showing Waterlogging in the Study Area.

Despite its historical reputation as a flood-free zone, the Naogaon Pourashava has experienced multiple flood incidents in recent years, necessitating protective measures along the Choto Jamuna River banks by the Bangladesh Water Development Board (BWDB). Rapid urbanization exacerbates environmental pollution, notably air and water contamination. Urban areas, including Naogaon, witness escalating

vehicular emissions, open burning, and industrial discharges, contributing to air quality deterioration. Traditional gold processing techniques, such as "Chotka," employed in local jewelry shops, further exacerbate air pollution concerns (Fig. 8).

Fig. 8: Photograph Showing Air Pollution from (A) Auto Rice Mill, (B) Brick Field, (C) & (D) by Chotka in Jewelery Shope and (Circle and Arrow within the Picture Indicating Emission of Smoke Like SO_2, CO, CO_2 Etc).

Water pollution, attributable to diverse sources including agricultural runoff and urban activities, poses significant ecological and public health risks. Chemical fertilizers, pesticides, and herbicides used in agriculture leach into water bodies, compromising water quality (Fig. 9). Similarly, waste disposal practices contribute to surface and groundwater contamination, necessitating comprehensive management strategies. Noise pollution emerges as a growing concern in Naogaon town, stemming from industrial operations, traffic congestion, and cultural practices.

Fig. 9: Photograph Showing the Evidence of Water Pollution from (A) Fish Market and (B) Agricultural Field.

The proliferation of small-scale industries, coupled with vehicular noise and public gatherings, exacerbates noise pollution levels, impacting residents' physical and psychological well-being. Inadequate waste management practices also contribute to odor pollution (Fig. 10) in the study area, further underscoring the urgency of holistic environmental management strategies.

Fig. 10: Photograph Showing (A) Odor Pollution at Kumaigari Area (B) Bad Smell Spreading from Overfilled Dust Bin at Kalitola Locality.

7. Discussions

Geological and environmental studies in Naogaon municipality reveal a landscape mainly characterized by the Stable Shelf of the Bengal Basin, with extensive alluvial plains and the Barind Tract rising about 16 meters above sea level. Urban growth in the area is driven by a moderately high influx of people from rural to urban areas. However, this rapid urbanization has led to various environmental problems such as water supply issues, sanitation and drainage problems, air pollution, solid waste disposal challenges, and the management of industrial and hospital waste.

Accumulation of municipal and industrial waste in low-lying areas like Kumaigari, Souremari dara, and along the Tulsi Ganga River has become a major source of pollution for both groundwater and surface water . Additionally, the continuous use of chemical fertilizers and

insecticides in agriculture contributes to water pollution and disrupts the chemical balance of the area. Natural hazards like flooding, waterlogging, soil erosion, land degradation, and riverbank instability further compound the environmental challenges. The degradation of the natural environment in Naogaon has been ongoing, highlighting deficiencies in current management practices. To address these issues, strict adherence to regulations and raising public awareness through training programs and campaigns is crucial. Immediate action through community-based initiatives led by both government and non-governmental organizations is necessary. Population growth is a significant driver of environmental degradation, leading to increased pressure on resources and exacerbating issues like air and water pollution, deforestation, and soil degradation. Urbanization intensifies these problems by concentrating populations and activities, resulting in increased pollution from vehicles, industries, and solid waste.

Air pollution in Naogaon arises from various sources, including vehicular emissions, industrial activities, and particulate matter from anthropogenic sources, leading to respiratory problems and health risks.Mitigating environmental challenges requires a multi-faceted approach, including flood control measures, water purification efforts, strict air pollution regulations, and effective waste management practices. An integrated developmental approach, informed by geological and climatological data, is essential for sustainable development in Naogaon. Collaboration between government and non-governmental organizations is key to implementing effective environmental conservation initiatives and protecting the area's natural resources.

8. Conclusions

The study on urban development and its impact on geo-environmental conditions in Naogaon Municipality, Bangladesh, provides valuable insights into the complex interactions between urbanization and environmental dynamics. The findings underscore the significant alterations in land use patterns, soil quality, water resources, air quality, landforms, and ecological dynamics resulting from urban expansion.

Urbanization leads to the loss of green spaces, agricultural lands, and natural habitats, adversely affecting biodiversity and ecosystem services. Soil composition, fertility, and contamination levels are influenced by urban development, posing challenges for sustainable land management and agricultural productivity. Water bodies face pollution from industrial effluents and sewage discharge, while air quality is compromised by vehicular emissions and industrial activities. Changes in landforms and erosion patterns impact infrastructure resilience and disaster risk management. Urbanization also disrupts habitats and wildlife corridors, necessitating conservation efforts to mitigate ecological fragmentation. Socio-economic factors intersect with environmental changes, shaping community vulnerability and resilience to urbanization-induced impacts. To address these challenges, comprehensive strategies are required, including regulatory measures, public awareness campaigns, and stakeholder collaboration. Sustainable urban planning practices, improved waste management systems, and conservation initiatives are essential for promoting sustainable development and enhancing resilience in Naogaon Municipality and similar regions facing urbanization pressures.

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