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Original Article

Impact Of Rapid Urban Expansion on Urban Climate, Land Surface and Environmental Sustainability in Bengaluru, India

Zade Rahul V.[1], Shnde Saheb L.[2]
[1]Asst. Professor, Department of Botany, S. C. M. Ardhapur, Dist. Nanded (MH)
[2]Professor, Department of Botany, Yeshwant Mahavidyalaya, Nanded (MH)

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Correspondence Address:
Zade Rahul V.
Asst. Professor, Department of Botany, S. C. M. Ardhapur, Dist. Nanded (MH)
Email: rhbotanist@gmail.com

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Abstract

Bengaluru, one of India's fastest-growing metropolitan cities, has undergone unprecedented urban expansion over the past three decades, resulting in substantial environmental transformation and climatic alteration. Rapid infrastructure development, deforestation, wetland encroachment, increasing vehicular emissions, population growth, and unplanned land-use changes have significantly altered the urban ecological balance of the city. The present study investigates the environmental impacts of rapid urbanization on climate variability, land surface temperature, rainfall patterns, air quality, and urban ecological sustainability in Bengaluru Metropolitan Region. The study integrates geospatial analysis, urban heat island assessment, land-use and land-cover (LULC) change detection, climate trend analysis, and environmental management approaches to evaluate the relationship between urban growth and microclimatic modification. Satellite-derived Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), and urban expansion mapping were used to identify ecological hotspots and regions vulnerable to climatic stress. The study further examines the decline in green cover, fragmentation of lake ecosystems, increased surface impermeability, and atmospheric pollution as major drivers of urban climatic instability. Elevated urban heat island intensity, increased ambient temperatures, altered hydrological processes, and declining ecological resilience were strongly associated with rapid land-use conversion. Sustainable urban management strategies including urban forestry, wetland restoration, climate-sensitive infrastructure planning, green corridor development, and sustainable transportation systems are proposed as critical interventions for enhancing urban climate resilience. The study contributes toward sustainable urban ecological planning, climate adaptation policy, and evidence-based environmental governance for rapidly urbanizing metropolitan regions in developing countries.

Keywords: *Urban Climate, Change Urban Heat Island, Climate Resilience, Urban Forestry, Geospatial Analysis*

Introduction

Urbanization is one of the dominant anthropogenic processes influencing environmental sustainability and climate dynamics in modern metropolitan regions. Rapid urban growth alters land-use patterns, increases built-up surfaces, reduces vegetation cover, and disrupts natural hydrological and atmospheric processes. Bengaluru, widely recognized as India's technology capital, has experienced extensive urban transformation characterized by population growth, infrastructure expansion, industrialization, transportation pressure, and ecological degradation. Historically known as the "Garden City of India," Bengaluru possessed extensive green spaces, interconnected lakes, and moderate climatic conditions. However, accelerated urbanization during recent decades has significantly reduced vegetation density, fragmented wetland systems, and intensified environmental stress. Expansion of impervious surfaces including roads, commercial infrastructure, residential complexes, and industrial corridors has contributed to increased urban heat island intensity and atmospheric pollution. The city has also witnessed increasing climatic irregularities including elevated temperatures, intense rainfall events, urban flooding, and declining groundwater recharge. Encroachment and degradation of urban lakes have further reduced hydrological resilience and ecological sustainability. Environmental

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degradation associated with urban expansion poses substantial risks to biodiversity conservation, public health, water security, and long-term urban climate stability. Despite increasing concern regarding urban climate change in Bengaluru, integrated studies combining urban ecology, land-use change, microclimatic assessment, and sustainable environmental management remain limited. The present study attempts to address this gap through a multidisciplinary geospatial and climate-resilience framework.

Discussion

Rapid urbanization in Bengaluru has substantially altered the ecological and climatic equilibrium of the metropolitan region. Conversion of vegetated landscapes into built-up infrastructure has intensified urban heat island effects and reduced natural cooling mechanisms. Decline in urban forests and wetland ecosystems has further reduced ecological resilience and hydrological regulation. The increase in surface impermeability has contributed to urban flooding and groundwater depletion. Elevated vehicular emissions and industrial activity have also increased atmospheric pollution and environmental stress. Similar patterns have been observed in rapidly urbanizing cities globally, where ecological degradation and land-use conversion significantly influence urban climate systems. Sustainable urban management strategies emphasizing ecological restoration, green infrastructure, urban forestry, lake rejuvenation, and climate-sensitive urban planning are essential for long-term environmental sustainability.

Sustainable Urban Management Recommendations

Proposed Intervention	Expected Environmental Benefit
Urban forestry	Reduction in urban heat island
Wetland restoration	Improved hydrological balance
Green corridors	Enhanced biodiversity
Sustainable transportation	Reduced emissions
Rainwater harvesting	Groundwater recharge
Climate-sensitive zoning	Reduced environmental vulnerability
Rooftop gardens	Urban cooling effect
Permeable pavements	Reduced runoff and flooding

Table-1.: Proposed Intervention and Expected Environmental Benefit

Comparative Scientific Importance of Satellite Datasets

Satellite Source	Major Application	Resolution	Importance in Climate Research
Landsat 8	Land Surface Temperature (LST), Urban Heat Island	30 m	Urban thermal analysis
Sentinel-2	NDVI, vegetation and land-use mapping	10 m	Urban ecological assessment
MODIS	Thermal climate monitoring	250 m–1 km	Long-term climatic trends
Google Earth	High-resolution visual interpretation	High spatial resolution	Urban growth visualization

Table-2.: Comparative Scientific Importance of Satellite Datasets

Major Causes of Urban Flooding in Bengaluru

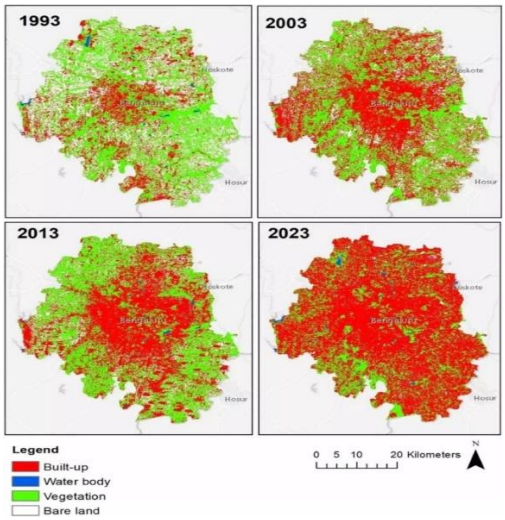

Fig.1: 1993-2023, showing Built-up area, Water body, Vegetation and Bare land (Source: Bangalore Mirror, 2025)

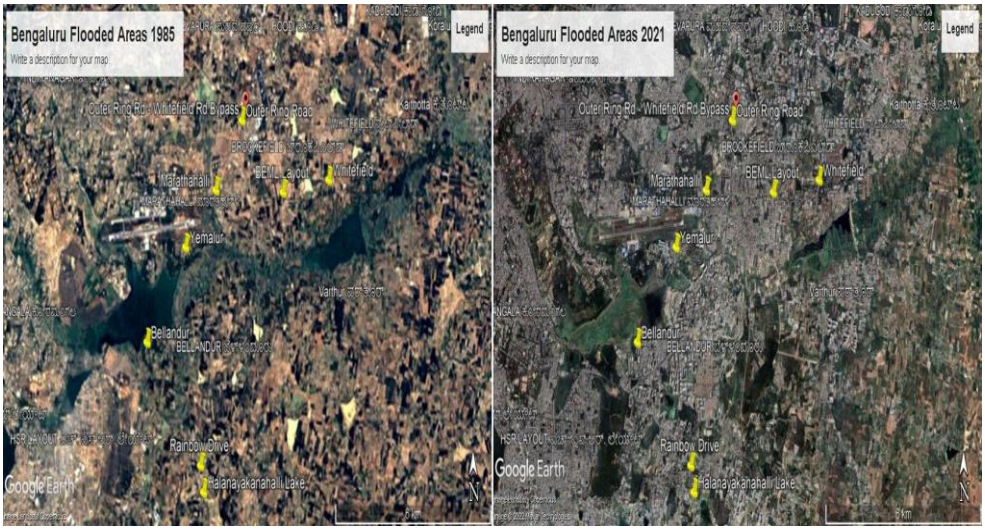

Fig.2: showing Bengaluru Flooded Areas from 1985-2021 (Source: IISc Bengaluru urban flood analysis, 2022)

Environmental Factor	Scientific Impact
Wetland encroachment	Reduced natural water storage
Loss of lakes	Increased runoff
Rapid urbanization	Increased impervious surfaces
Poor drainage infrastructure	Waterlogging
Climate change	Intense rainfall events
Deforestation	Reduced infiltration
Concrete surfaces	Increased surface runoff
Unplanned construction	Floodplain obstruction

Table-3.: Comparative Scientific Importance of Satellite Datasets

Conclusion

The present study demonstrates that rapid urbanization and ecological degradation significantly influence climate variability and environmental sustainability in Bengaluru Metropolitan Region. Reduction in green cover, wetland loss, increasing built-up intensity, and atmospheric pollution collectively contribute to urban climatic instability and ecological stress. Recent urban flood studies reported: more than 94 km² high-risk flood zones across Bengaluru, severe flood exposure in eastern and central Bengaluru, and increasing climate-related urban vulnerability. Koramangala-Challaghatta Valley, Hebbal Valley, and Bellandur Basin as major flood-susceptible regions. 730 out of 837 lakes in Bengaluru Urban have experienced encroachment, significantly reducing natural flood-buffer capacity. Integrated sustainable urban management, ecological restoration, climate-sensitive infrastructure planning, and geospatial environmental monitoring are critical for improving urban climate resilience and long-term sustainability.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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