

LAND USE LAND COVER TRANSFORMATION AND ENVIRONMENTAL DEGRADATION AROUND THE KANO ANCIENT CITY WALL, NIGERIA (1994-2024)

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ABSTRACT

This study examines Land Use/Land Cover (LULC) transformation and associated environmental degradation around the Kano Ancient City Wall (KACW) over a thirty-year period (1994-2024). Using multi-temporal Landsat satellite imagery, field observations, and semi-structured interviews. Results revealed dramatic landscape transformation: built-up areas increased by 44.86% (from 11.75 km² to 17.47 km²), vegetation declined by 72.75% (from 4.33 km² to 1.36 km²), and water bodies decreased by 76.47% (from 0.74 km² to 0.04 km²). Accuracy assessment achieved an overall accuracy of 85.0% for 1994, 83.0% for 2004, 84.3% for 2014, and 86.0% for 2024, with corresponding Kappa coefficients of 0.796, 0.769, 0.786, and 0.809, respectively. The average Kappa coefficient across all four periods was 0.790 (79.0%), indicating substantial classification agreement. These changes have increased flooding risks, groundwater depletion, urban heat island intensification, biodiversity loss, and reduced tourism potential. The near-total loss of water bodies has eliminated critical groundwater recharge zones, with static water levels declining 4-27.6 meters in certain areas. The study concludes that unchecked urbanization around heritage structures creates cascading environmental consequences that extend beyond the immediate site boundaries. Recommendations include integrated environmental-heritage planning, restoring green infrastructure, and adopting climate-resilient conservation strategies.

Keywords: Land use/land cover, environmental degradation, urbanization, Kano Ancient City Wall, heritage conservation

INTRODUCTION

The relationship between urbanization and environmental degradation has become a critical concern in rapidly growing African cities (Barau et al., 2015). Kano, one of West Africa's largest cities, exemplifies these challenges, with population growth averaging 3.2% annually (NPC, 2023) and the metropolitan population exceeding 2,828,861 by 2006. Within this, the combined population of the Dala, Gwale, and Kano Municipal local government areas, which formed the KACW, was 1,146,361 and projected to reach 1,718,468 by 2023 (NPC, 2023). This rapid urbanization has placed unprecedented pressure on natural resources and cultural heritage sites, including the Kano Ancient City Wall (KACW).



Previous studies have documented various aspects of Kano's environmental challenges. Barau et al. (2015) identified progressive biodiversity decline and temperature disparities between the walled city and rural areas. Mohammed, Hassan, & Badamasi (2019) documented significant declines in groundwater levels in Kano Metropolis. Umar et al. (2023) estimated that approximately 138 ponds historically existed within the Kano Metropolis, covering 40.7 km² and storing 33,084.3 million liters. However, comprehensive analysis linking LULC transformation to environmental consequences around heritage sites remains limited.

Historic city walls worldwide have been recognized not only as cultural assets but also as environmental infrastructure, providing ecosystem services such as erosion control, microclimate regulation, and biodiversity support (Li et al., 2021; Araoka et al., 2017). The KACW, constructed approximately 900 years ago (Osiboye, 2018), historically provided these services through associated vegetation cover, water bodies (ponds), and green spaces. However, accelerated urbanization has transformed the landscape surrounding the wall, with significant environmental implications.

This study addresses this gap by conducting a systematic LULC analysis around the KACW from 1994-2024 and linking observed transformations to environmental impacts. Specific objectives include: (1) quantifying LULC changes over the study period, (2) assessing environmental consequences including flood risk, groundwater depletion, thermal changes, and biodiversity loss, and (3) providing recommendations for integrated environmental-heritage conservation.

MATERIALS AND METHODS

Study Area

The study area, KACW, comprises Kano Municipal, Dala, and Gwale LGAs within Kano Metropolis, Nigeria. It lies between latitudes 11°59'15" to 12°01'20" N and longitudes 8°29'10" to 8°31'50"E, covering approximately 23.04 km² and bordered by the remaining local government areas of Kano Metropolis, such as Tarauni and Kumbotso, to the south and southeast; Nasarawa and Fagge to the east and northeast; and Ungoggo to the north and northwest, respectively. The climate is tropical dry-and-wet (Köppen Aw), with mean annual rainfall of 884 mm and a temperature of 26°C. The area is underlain by Precambrian basement complex rocks, with ferruginous tropical soils developed over these formations.

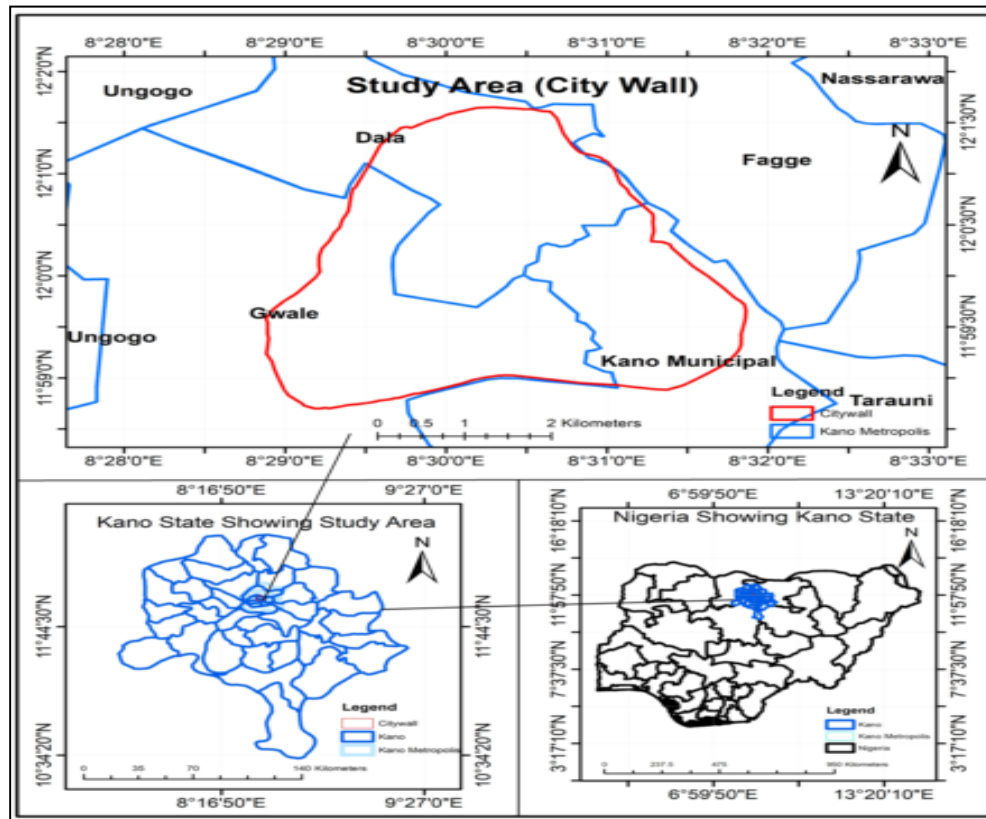


Figure 1: Kano ancient city wall

Data Collection and Analysis

We obtained Landsat satellite imagery for 1994 (Landsat 5 TM), 2004 (Landsat 7 ETM+), 2014 (Landsat 8 OLI-TIRS), and 2024 (Landsat 9 OLI-2TIRS-2) from the United State Geological Survey (USGS). We processed these images in ArcGIS 10.8 using radiometric correction, layer stacking, and subsetting. We applied supervised maximum likelihood classification with four LULC classes (built-up, bare land, vegetation, water bodies) using training samples validated through field surveys and high-resolution Google Earth imagery. To ensure the Reliability and Validity of the LULC classification results, we conducted an accuracy assessment using the Kappa Coefficient (K) statistic. The Kappa coefficient measures agreement between classified map data and reference data. We used stratified random sampling to select validation points for each LULC class across the four study periods (1994, 2004, 2014, and 2024). We collected at least 50 reference points per class using High-resolution Google Earth imagery as the primary reference source for all years. The overall average Kappa coefficient across all three decades (1994-2024) is $\hat{K} = 0.790$ (79.0%), indicating substantial agreement between the classified LULC maps and reference data.

We performed LULC change detection using the post-classification comparison technique. Independently classified LULC maps for 1994, 2004, 2014, and 2024 were compared using cross-tabulation matrices to identify and quantify class transitions (e.g., vegetation-to-built-up, water-to-bare land) over the study period. This method was selected as it provides detailed "from-to" change information, minimizes atmospheric effects between image acquisition dates, and does not require rigorous radiometric normalization. Semi-structured interviews were conducted with four museum custodians purposively selected from Gidan Makama Museum (n=2) and Gidan Danhausa Museum

(n=2) based on their direct involvement in KACW management and curation and at least 5 years of relevant experience. Interviews covered environmental effects, tourism impacts, cultural significance, flooding, and governance challenges. Interview data were audio-recorded, transcribed verbatim, and analyzed thematically following Braun and Clarke's (2006) six-phase framework. The analysis involved coding the interview responses and grouping related codes into major themes. The identified themes were compared with the LULC results and field observations to triangulate the qualitative and spatial findings.

RESULTS

LULC Transformation around Kano Ancient City Wall (1994-2024)

In 1994, built-up area constituted the dominant land-use class within the Kano Ancient City Wall, covering 11.75 km² of the study area. Bare land accounted for 6.22 km², while vegetation covered 4.33 km², reflecting cultivated areas and urban green spaces. Water bodies occupied only 0.74 km², indicating their relatively limited spatial extent within the study area, as shown in Figure 2.

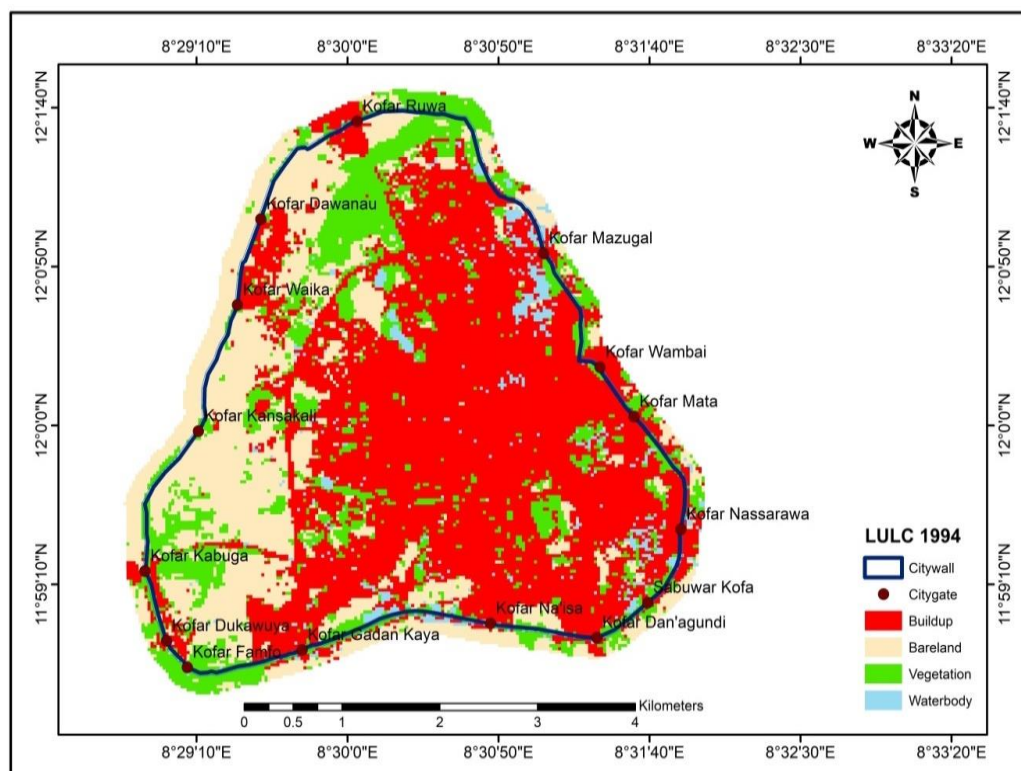


Figure 2: Kano Ancient City Wall Land Use Land Cover (LULC), 1994

Between 1994 and 2004, built-up area increased slightly from 11.75 km² to 12.06 km², indicating a gradual expansion of built-up areas within the Kano Ancient City Wall. Vegetation increased from 4.33 km² to 4.99 km², whereas bare land decreased from 6.22 km² to 5.82 km². Water bodies declined substantially, from 0.74 km² to 0.17 km², indicating a marked reduction in the spatial extent of surface water within the study area, as shown in Figure 3.

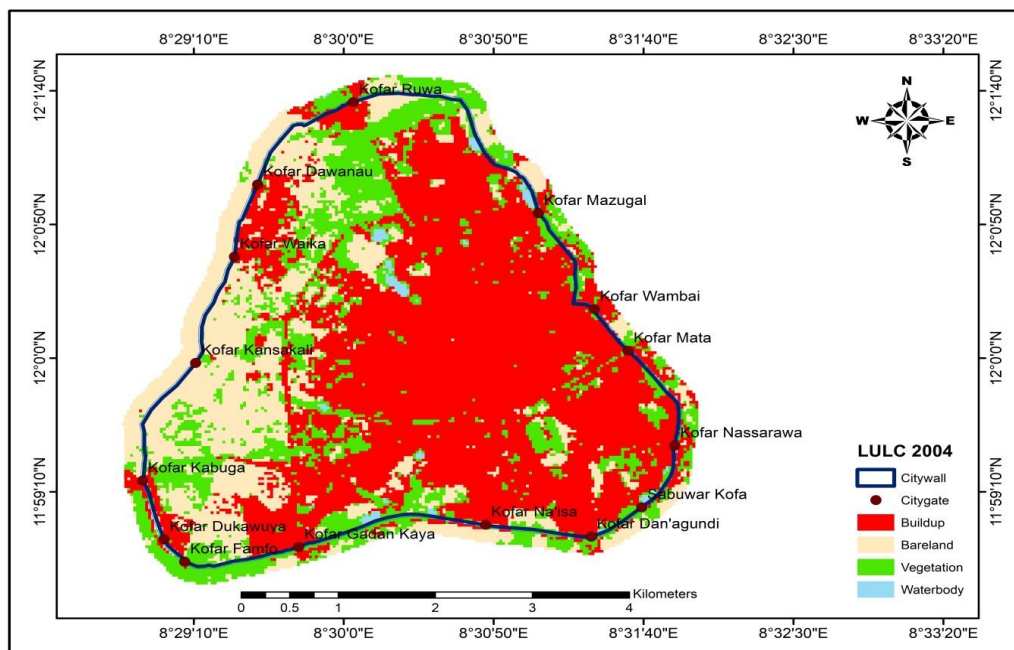


Figure 3: Kano Ancient City Wall Land Use/Land Cover (LULC), 2004

By 2014, built-up area had increased from 12.06 km² (2004) to 13.81 km², indicating continued expansion of built-up areas within the Kano Ancient City Wall. Vegetation decreased from 4.99 km² to 4.12 km², while bare land declined from 5.82 km² to 5.00 km². Water bodies also decreased from 0.17 km² to 0.11 km², further reducing their spatial extent. These changes indicate a progressive transformation of land-cover classes within the study area, as shown in Figure 4.

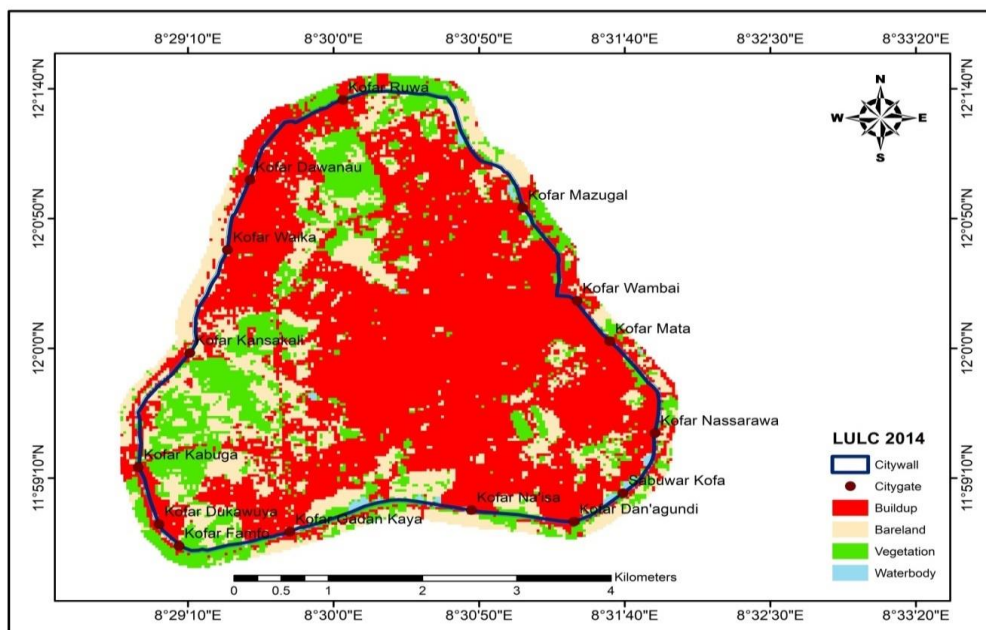


Figure 4: Kano Ancient City Wall Land use/land cover (LULC), 2014

By 2024, built-up area had expanded substantially from 13.81 km² in 2014 to 17.47 km², representing the largest increase recorded during the study period. In contrast, bare land declined from 5.00 km² to 4.17 km², while vegetation decreased sharply from 4.12 km² to 1.36 km². Water bodies also declined from 0.11 km² to 0.04 km², indicating a substantial reduction in natural land-cover classes within the Kano Ancient City Wall. The observed changes reflect the continued transformation of the study area, as shown in Figure 5.

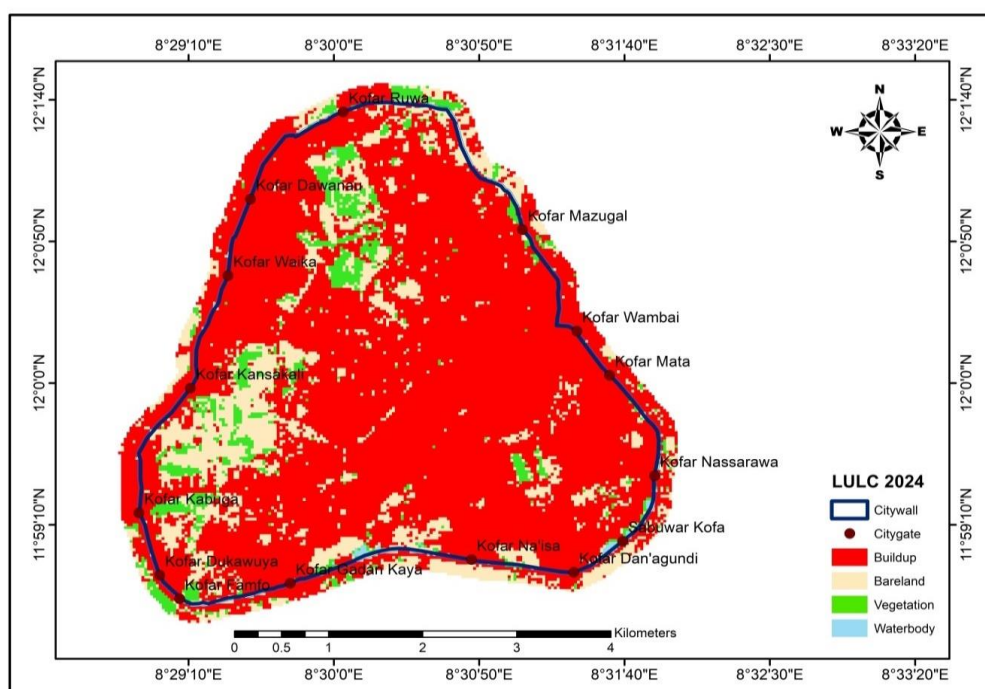


Figure 5: Kano Ancient City Wall Land Use/Land Cover (LULC), 2024

The LULC analysis revealed systematic landscape transformation around the KACW (Table 1). Built-up areas increased across all periods, with the most dramatic change between 2014 and 2024 (from 12.06 km² to 17.47 km²). Vegetation cover declined significantly, dropping from 4.33 km² in 1994 to 1.36 km² (6%) in 2024. The loss was most severe between 2014 and 2024, when vegetation declined from 4.12 km² to 1.36 km². Water bodies nearly disappeared, declining from 0.74 km² in 1994 to 0.04 km² in 2024, representing the largest loss as shown in Table 1.

Table 1: LULC Changes around KACW (1994-2024)

LULC	1994 (km ²)	% Change	2004 (km ²)	% Change	2014 (km ²)	% Change	2024 (km ²)	% Change
Buildup	11.75	0	12.06	-12.67	13.81	17.53	17.47	44.86
Bare land	6.22	0	5.82	16.4	5	-19.61	4.17	-28.35
Vegetation	4.33	0	4.99	21.12	4.12	-4.85	1.36	-72.75
Waterbody	0.74	0	0.17	54.55	0.11	-85.14	0.04	-76.47
Total	23.04		23.046		23.046		23.046	

Built-up density was highest around the central business district, extending from Kofar Ruwa to Sabuwar Kofa and Kofar Danagundi. Southwestern areas, including Kofar Famfo, Kofar Dukawuya, and Kofar Kabuga, showed progressive conversion to built-up land. The spatial pattern indicates radial expansion from the historic core, with the wall increasingly embedded within urban fabric rather than serving as a boundary.

Hydrological Changes and Flood Risk

The near-total loss of water bodies has significantly altered hydrological dynamics. Historical records and field observations documented that the KACW was constructed with side depressions or trenches that filled with water during rainy seasons, functioning as collection points for runoff and domestic effluents, and serving as ponds. Umar et al. (2023) estimated that approximately 138 ponds were located around the wall, covering 40.7 km² and storing 33,084.3 million liters in Kano Metropolis.

Field observations revealed that ponds between Kofar Dan Agundi and Kofar Na'isa have ceased to exist, with only a few remaining between Kofar Na'isa and Gadon Kaya. Filling these ponds for urban expansion has eliminated critical groundwater recharge zones. Mohammed et al. (2019) reported that static water levels have declined by 4-27.6 meters in certain areas of Kano Metropolis, directly correlating with loss of recharge sites. Groundwater-dependent water sources, including hand-dug wells historically used by residents, have experienced declining yields.

The loss of water bodies and expansion of impervious surfaces (filling stations, story buildings) have increased surface runoff and flood risk. Field observations confirmed that clogged drainage systems cannot handle runoff during heavy rains, causing neighborhood flooding, and this was evident during flooding around Kofar Dan Agundi in 2023, as stated by Tijjani and Aliyu (2017). The demolition of wall sections for infrastructure development has exacerbated drainage disruption, even though these walls historically provided flood management functions.

Thermal Changes and Urban Heat Island

Studies from the late 1990s and early 2000s documented a 1.3°C temperature difference between Kano ancient city (surrounded by the wall) and Minjibir LGA (40 km away) in 1993 (Mohammed et al., 2019). Recent meteorological data show temperature gaps of 2-4°C between Kano ancient city and Mariri suburb, confirming intensification of Urban Heat Island (UHI) effects over three decades (Usman, Nichol, Abdallah, & Bilal, 2025).

The loss of vegetation cover significantly contributes to UHI intensification. LULC analysis shows vegetation declined from 4.33 km² in 1994 to 1.36 km² in 2024 (Table 1), eliminating natural cooling mechanisms such as shade provision and evaporative cooling. Interviews with museum custodians confirmed observations of temperature increases, reduced rainfall, and altered local climate patterns associated with vegetation loss. Removing trees and other plant life disrupts natural cooling, leading to higher temperatures and altered climate patterns (Muhammad et al., 2024).

Vegetation and Biodiversity Loss

The reduction in vegetation cover by 1.36 km² in 2024, as shown in Table 1, has significant implications for biodiversity and ecosystem services. The study area is historically characterized by Sudan savannah vegetation, including *Acacia albedea*, *Parkia biglobosa*, and *Adansonia digitata*, and has experienced extensive deforestation (Muhammad et al., 2024). Field observations show that the vegetation is primarily cultural (introduced by humans), with very few native species, and indicate



that vegetation clearance has accelerated erosion and contributed to encroachment in the wider region around the city wall.

The loss of green spaces has eliminated important ecosystem services, including soil stabilization, air purification, microclimate regulation, and wildlife habitat. The remaining vegetation cover around the wall (1.36 km²), as shown in Table 1, is inadequate to protect ecosystem services effectively. This aligns with Barau's (2005) finding that urban Kano's biodiversity has progressively declined due to urbanization.

Socio-Environmental Consequences

The environmental changes documented have significant socioeconomic consequences. Increased flooding risk threatens lives and property, as evident in the Kofar Dan Agundi flooding in 2023. Groundwater depletion affects water supply for domestic and commercial users, with declining well yields forcing reliance on more expensive water sources. Mohammed et al. (2019) stated that UHI increases energy consumption for cooling and reduces thermal comfort, particularly affecting vulnerable populations.

The destruction of the KACW has also impacted tourism potential. LULC analysis shows increasing urban encroachment and loss of green spaces around the wall, leading to physical degradation and reduced historical appeal. The wall's damaged status discourages both domestic and international tourists. Tourism revenue data from Kano State Tourism Management Board KSTMB shows a decline from N10,018,590.83 million in 2013 to N6,575,173.27 million in 2015 (Muhammad et al., 2024). The loss of open spaces around the wall limits opportunities for developing tourism infrastructure.

DISCUSSION

Drivers of LULC Transformation

The systematic LULC transformation around the KACW reflects multiple interacting drivers. Population growth (3.2% as at 2023) has increased demand for housing and commercial space, driving conversion of open land to built-up areas. This is compounded by weak enforcement of planning regulations, as evidenced by field observations around KACW. Interviews revealed that government agencies themselves have facilitated encroachment through plot allocation and building approvals near the city wall.

Economic factors, including commercial expansion around markets (particularly Kofar Ruwa market) and establishment of filling stations, shops, and other temporary structures, have accelerated conversion of open spaces. The perception of the wall as an obstacle to development rather than a heritage asset has driven direct demolition, as observed during road construction projects, including demolition of >1 km in 2000 and the Kofar Na'isa and Dan Agundi gates in April 2010 and around June 2014, respectively (Tijjani & Aliyu, 2017).

Climate change likely interacts with these drivers, with rainfall variability affecting vegetation regeneration and erosion patterns. However, anthropogenic drivers clearly dominate LULC change in this study, confirming patterns observed across sub-Saharan African cities (UNESCO, 2022).

Environmental Implications

The environmental implications of LULC transformation extend beyond the immediate study area. The loss of water bodies and reduction of pervious surfaces have increased flood risks for

communities downstream of the wall. Groundwater depletion affects water security for an expanding urban population. These findings align with Li et al. (2021), who emphasized the protective role of urban vegetation in reducing environmental deterioration of historic city walls. In the KACW, substantial vegetation loss, declining water bodies, and increasing built-up surfaces have reduced natural environmental protection and increased surface runoff and flood risks. The reduction of pervious surfaces may also limit groundwater recharge, contributing to water-security challenges. These findings show that effective conservation of the KACW requires managing the surrounding environmental landscape in addition to protecting the wall structure.

The hydrological changes observed align with broader concerns about water security in the Sahel region. Mohammed et al. (2019) documented similar groundwater declines across Kano Metropolis, attributing them to urbanization, over-extraction, and reduced recharge. The loss of ponds around the KACW represents a loss of local adaptation infrastructure that historically provided water storage during dry seasons for domestic use and economic activities such as brick-making (Umar et al., 2023).

The loss of vegetation and associated ecosystem services also affects the structural integrity of the KACW. Vegetation cover stabilizes soil and reduces undercutting of the wall's foundation. Interviews with museum custodians indicated that accelerated erosion of the wall has been linked to vegetation removal. This creates a negative feedback loop in which urbanization drives vegetation loss, which accelerates wall degradation and further reduces its cultural and environmental value.

Implications for Heritage Conservation

Field observations around KACW observed that the loss of ponds and vegetation around the wall has removed cultural and environmental buffers that historically protected the structure. Filling ponds increased erosion and drainage problems, while vegetation loss reduced soil stabilization and moisture regulation. Conservation strategies must therefore address both the wall structure and its environmental context, integrating heritage management with broader urban environmental planning.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates that rapid urbanization around the KACW has transformed LULC patterns, with significant environmental consequences including loss of water bodies (0.04km²), vegetation decline (1.36km²), and expansion of built-up areas (17.47km²). These changes have contributed to increased flood risk, groundwater depletion, UHI intensification, biodiversity loss, and reduced tourism potential. The near-total loss of ponds and green spaces has eliminated critical ecosystem services that historically supported both the local environment and the preservation of the wall itself. The environmental degradation documented in this study represents not only a loss of heritage value but also a loss of ecological function that affects urban residents' well-being. Addressing these challenges requires integrated approaches that recognize heritage sites as environmental infrastructure deserving protection for both cultural and ecological reasons.

To address these challenges, the study recommends:

1. **Integrated Environmental-Heritage Planning:** Develop comprehensive management plans addressing both heritage conservation and environmental protection, recognizing that vegetation loss, water body depletion, and built-up expansion are interconnected processes requiring integrated solutions.



2. Green Infrastructure Restoration: Restore vegetation cover around the study area, including planting of native species adapted to local conditions; rehabilitate ponds and water bodies to restore hydrological functions and groundwater recharge.
3. Flood Risk Management: Improve drainage systems, enforce regulations on impervious surface coverage and restore natural drainage patterns where possible.
4. Climate-Resilient Conservation: Integrate climate change considerations into conservation strategies; implement monitoring systems for temperature, rainfall, and erosion patterns; develop adaptive management approaches.
5. Community Engagement: Engage local communities in environmental restoration efforts; provide economic incentives for green infrastructure maintenance; establish community-based monitoring programs.
6. Policy Strengthening: Enforce existing environmental regulations; strengthen penalties for buffer zone violations; mandate Heritage Impact Assessments for all development near heritage sites. Despite the NCMM Act mandating a 30-meter buffer zone, government actions have systematically undermined regulations, including plot allocations by LGAs, indiscriminate building approvals by KNUPDA, and direct demolitions.

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