

Beyond Concrete: Nature-Based Solutions for Climate-Resilient Urban Landscapes in Ilorin, Nigeria

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Abstract

Rapid urban development and the replacement of vegetated and permeable surfaces have increased flood and heat risks in Nigerian cities such as Ilorin, Kwara State. This study assessed the context and location-specific applicability of Nature-Based Solutions (NBS) for improving the city's climate resilience. An applied descriptive-analytical design combined a structured review of literature on NBS, urban flooding, and heat mitigation with qualitative field assessments at five purposively selected locations: the Asa River corridor at the Harmony/Royal Valley Estates axis, the Asa River at Amilengbe, Oloje residential area, Alanamu neighbourhood, and major walkways in Ilorin Central. Field observations examined vegetation cover, surface permeability, drainage conditions, wetland disturbance, waste accumulation, and opportunities for NBS implementation. Evidence from the literature and field observations was integrated through thematic synthesis. The assessment identified wetland encroachment, degraded riverbanks, blocked drainage routes, extensive impervious surfaces, limited vegetation, and solid-waste accumulation as interconnected drivers of flood and heat vulnerability. Published spatial assessments indicate that more than 35% of Ilorin West is highly vulnerable to flooding, while approximately 60.95 km², representing 18% of Ilorin, lies within high flood-risk zones. Evidence from a comparable setting near Ilorin further indicates that permeable pavement can reduce stormwater retention and reduce surface runoff by approximately 50% and lower urban temperatures by 2–4°C in densely built environments. Wetland restoration and riparian buffers are most suitable for the Asa River corridor, while permeable paving and urban trees are recommended for selected residential, commercial, and pedestrian areas. Implementation may be constrained by wetland encroachment, variable soil and infiltration conditions, inadequate maintenance, limited financing, and fragmented institutional responsibilities. The study provides a locally grounded framework for selecting and piloting NBS according to environmental suitability, affordability, and maintenance capacity.

ARTICLE HISTORY

Received: 26 February 2026

Accepted: 14 May 2026

Published: 10 October 2026

KEYWORDS

Climate resilience; Flood risks; Ilorin; Nature-based solutions; Urban heat island effect

Citation: Salami O. O. (2026). Beyond Concrete: Nature-Based Solutions for Climate-Resilient Urban Landscapes in Ilorin, Nigeria. *Journal of Geomatics and Environmental Research*, 9(2), Pp 1-15

1. INTRODUCTION

Urbanisation in Nigeria has come at a steep environmental cost. As cities expand, natural landscapes are rapidly replaced with impermeable concrete, exacerbating flood risks and urban heat islands (UHI) while diminishing biodiversity (Hobbie and Grimm, 2020; Samuel *et al.*, 2025). Ilorin, the capital of Kwara State, Nigeria, exemplifies this challenge, where rapid urban expansion has encroached on critical wetlands, replaced permeable surfaces with impermeable infrastructure, and diminished urban tree cover. In previous studies and from observations, these changes have amplified flood risks during seasonal rains and intensified the urban heat island effect, threatening public health, infrastructure, and social and economic stability (Abubakar, 2023; Rizki *et al.*, 2024; Sekertekin and Zadbagher, 2021). The prevailing reliance on conventional grey infrastructure such as concrete drainage systems and paved surfaces has proven inadequate to address these climate-induced challenges, necessitating a shift toward nature-based solutions (NBS) that harmonise ecological resilience with urban development (Samuel *et al.*, 2025; Worku, 2017). At the national level, the Green Nigeria Initiative under the Renewed Hope Initiative (RHI) underscores this paradigm shift by promoting tree planting, wetland restoration, and sustainable urban greening as core strategies for climate resilience across Nigeria, including North Central states like Kwara (Voice of Nigeria, 2025).

Nigeria's urban population is projected to reach nearly 70% by 2050, intensifying pressure on infrastructure and ecosystems (Aribigbola *et al.*, 2022). Recent studies reveal alarming trends: wetlands in Lagos and Makurdi have declined by over 40% due to rapid urban expansion, undermining their role in flood regulation and biodiversity conservation (Odigie & Obayagbona, 2025; Zahemen *et al.*, 2025). Concurrently, urban heat island effects are escalating, with land surface temperatures in cities such as Kaduna and Lafia rising

significantly as vegetative cover diminishes (Abdullahi *et al.*, 2025; Abimbola *et al.*, 2025). These localised dynamics mirror broader vulnerabilities across sub-Saharan Africa, where reliance on grey infrastructure persists despite mounting evidence that NBS can reduce flood peaks and lower urban temperatures by 2-4°C (Ademosu *et al.*, 2025; Dhyani *et al.*, 2018; WRI & World Bank, 2025). Similar lessons have been documented in other African cities and in Indonesia, where integrating green infrastructure into urban planning has proven vital for resilience, social cohesion and curbing sprawl (Dipeolu *et al.*, 2024; Krisnaputri *et al.*, 2023).

Wetland restoration can serve as a natural sponge to absorb excess stormwater while sequestering carbon (Tang *et al.*, 2021). Similarly, any alternative to traditional concrete, such as permeable pavements, could allow rainwater infiltration, reducing surface runoff and replenishing groundwater (Samuel *et al.*, 2025). Urban greening strategies, such as restoring tree cover along highways and public spaces, can significantly lower ambient temperatures and improve air quality (Raihan, 2023; Rizki *et al.*, 2024). Despite these benefits, the adoption of NBS in Nigerian cities remains limited due to fragmented urban policies, competing land-use priorities, insufficient financing and lack of political will (Effiong, 2025). Globally, over 60% of wetland areas have been converted for residential or commercial use (Adeleke, 2022). Similar figures can be predicted for Ilorin metropolis, while existing regulations may lack enforcement mechanisms to protect these ecosystems.

Although the literature on urban climate risk in Nigeria is expanding, important knowledge gaps remain. Existing studies relevant to Ilorin have predominantly examined flood susceptibility, river-basin characteristics, water quality, rainfall variability, ecological pressure, or land-use change as separate concerns. These studies provide valuable evidence on the spatial extent and drivers of environmental risk but offer limited integration of flooding and urban heat as interconnected consequences of wetland degradation, vegetation loss, and surface sealing. Moreover, relatively little research has translated these risks into location-specific NBS options while simultaneously considering land-use constraints, soil and surface conditions, affordability, institutional coordination, community acceptance, and long-term maintenance. This gap is particularly evident in secondary cities such as Ilorin, which receive less attention than larger Nigerian metropolitan areas despite experiencing rapid urban expansion and increasing climate vulnerability.

This study addresses the identified gap by integrating evidence from a structured literature review with qualitative field assessments of selected river corridors, flood-prone neighbourhoods, and highly impervious public spaces in Ilorin. Its unique contribution lies in connecting observed urban environmental challenges to context-appropriate NBS interventions and the institutional barriers affecting their implementation. It further develops a thematic intervention matrix and a multi-sectoral implementation framework linking environmental challenges, recommended interventions, institutional responsibilities, financing actors, and community participation. The study is guided by the following research question: How can context-appropriate nature-based solutions be integrated into Ilorin's urban planning and governance systems to reduce flood and urban heat risks?

2. MATERIALS AND METHODS

This study adopts an applied research design using a descriptive-analytical approach to examine the potential of nature-based solutions (NBS) in enhancing flood and heat resilience in Ilorin, Kwara State. The study focuses on two key sites: areas of wetland degradation along the Asa River and high-density urban zones experiencing intensified UHI effects due to increased concrete surface development. Field assessments were conducted at five purposively selected locations (Figure 1) representing river and wetland corridors, flood-prone residential neighbourhoods, and highly impervious public spaces: the Asa River wetland along the Harmony/Royal Valley Estates axis, the Asa River corridor at Amilengbe, Oloje residential area, Alanamu neighbourhood, and major walkways in Ilorin Central.

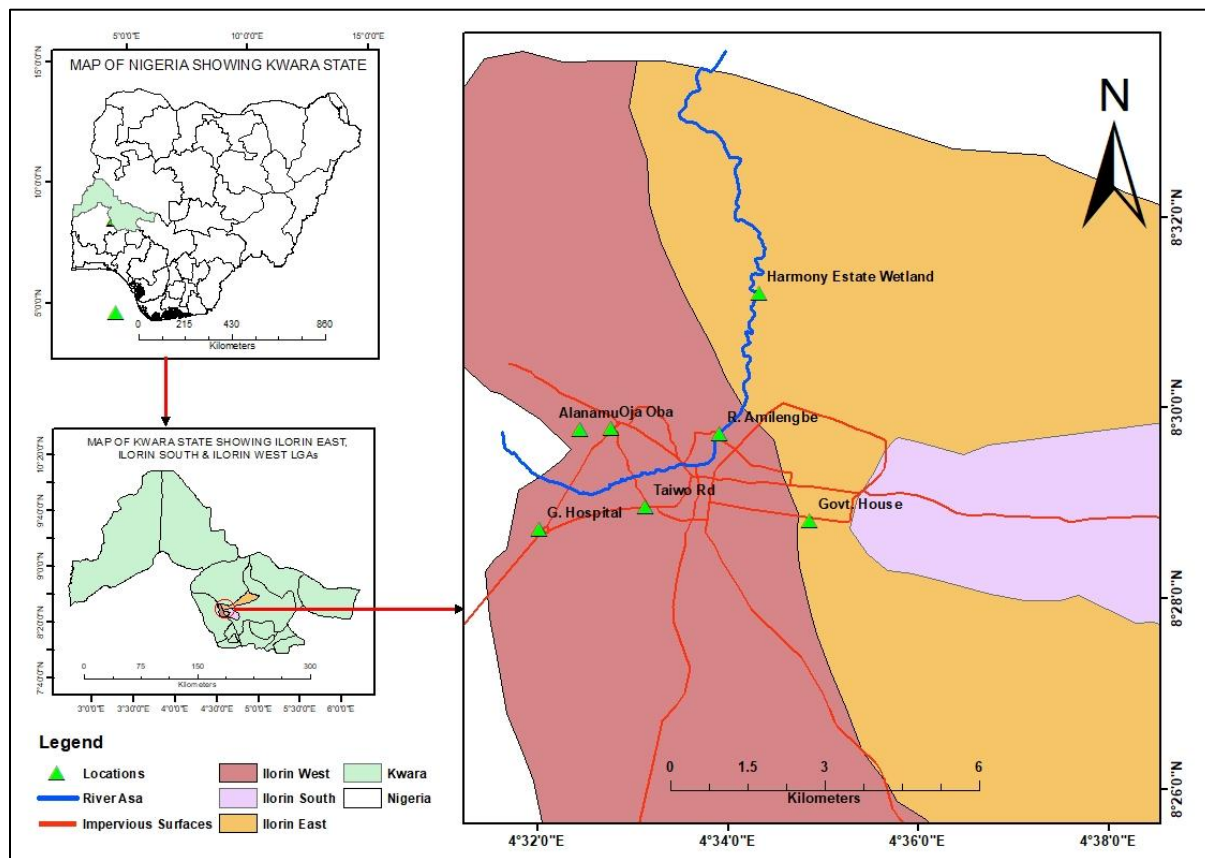


Figure 1. Location of the selected field-assessment sites in Ilorin, Nigeria. The map identifies the Asa River corridor at the Harmony/Royal Valley Estates axis, the Amilengbe Riverbank, Oloje Residential Area, Alanamu neighbourhood, and selected major walkways in Ilorin Central.

Data were collected through a mixed-methods approach comprising three components. First, a systematic literature review was conducted using Google Scholar and relevant institutional repositories, guided by predefined inclusion criteria such as relevance to NBS, urban flooding, and heat mitigation in comparable contexts. The search was conducted using combinations of the keywords: 'nature-based solutions', 'urban climate resilience', 'urban flooding', 'urban heat island', 'wetland restoration', 'permeable pavements', 'urban greening', 'Ilorin', 'Nigeria', and 'sustainable drainage systems'. Studies were included if they were peer-reviewed publications published between 2015 and 2025, addressed nature-based solutions for urban flooding or heat mitigation, and focused on developing countries or comparable urban contexts. Studies lacking empirical evidence, unrelated to urban climate resilience, or published outside the specified period were excluded.

Second, field observations were documented using structured field notes organised around predefined assessment parameters, including site type, vegetation cover, surface permeability, drainage condition, evidence of flooding or water stagnation, wetland or riverbank disturbance, solid-waste accumulation, and potential opportunities for NBS implementation. The credibility of the observations was strengthened through cross-site comparison with published studies, spatial assessments, and institutional reports concerning flooding, land-use change, wetland degradation, and urban heat conditions in Ilorin. Only conditions directly observed during the assessments or corroborated by relevant documentary evidence were incorporated into the thematic findings. Observations without sufficient supporting evidence were interpreted cautiously and reported as indicative conditions rather than verified causal relationships.

The literature and field evidence were analysed through thematic synthesis. Field notes were first organised according to the predefined observational categories, after which recurring environmental conditions and implementation constraints were identified across the assessed locations. These themes were compared

with findings from the reviewed literature to examine areas of convergence, divergence, and local specificity. The final themes were organised around urban flooding, wetland and riverbank degradation, impervious-surface expansion, urban heat exposure, NBS suitability, and institutional barriers. The integrated findings were then used to develop the thematic intervention matrix and the proposed governance and implementation framework for NBS in Ilorin.

2.1 The Study Area

Field assessments were conducted at five purposively selected locations across Ilorin, representing wetlands, river corridors, residential neighbourhoods, and public infrastructure areas (Table 1). The Asa River wetlands, especially the stretch near Harmony and Royal Valley Estates Road, which has seen significant encroachment for housing and refuse dumping, serve as a focal point for assessing flood risks. Equally critical are the recently constructed concrete walkways (2020–2023) in high-traffic zones like Oja Oba Market, Unity, Ibrahim Taiwo and Government Roads, where permeable surfaces were replaced with impermeable materials, altering local hydrological regimes. These sites were selected due to their accessibility, climate vulnerabilities, and representation of broader Nigerian urban trends.

Table 1. Summary of Field Assessment Locations in Ilorin

Location		Site Type	Site Category		Baseline Ecological Condition	Observed Environmental Issues		NBS Opportunities Identified
Asa River Corridor (Harmony/Royal Valley Estates axis)	River	Wetland/ River channel	Public	river	Previously vegetated wetland, now largely encroached	Flooding, water stagnation, wetland loss, unregulated agricultural activities, waste dumping		Wetland restoration, buffer zone creation, riparian vegetation, sustainable vegetable farming
		Riverbank/ Urban interface	Public	urban riverbank	Degraded riverbank with reduced vegetation	Waste pollution, poor water quality		Riverbank rehabilitation and revegetation, community-led clean-up, vegetative buffers, bioswales.
Oloje Residential Area		High-density residential	Residential	neighbourhood	High impervious surface coverage	Poor drainage, frequent flooding		Permeable pavements, rain gardens, improved drainage
Alanamu Neighborhood		Low-lying urban zone	Residential	neighbourhood	Limited green cover, compacted soil	Flood vulnerability, runoff accumulation		Urban greening, community green spaces, infiltration trenches
Major Walkways (Ilorin central areas)		Public infrastructure	Public	infrastructure	Fully paved concrete surfaces	Heat retention, rapid runoff, drainage overflow due to extensive concrete paving and inadequate drain capacity.		Permeable paving, Tree-lined corridors, green infrastructure retrofits

3. RESULTS AND DISCUSSION

Field assessments at the five selected locations identified recurring environmental conditions relevant to NBS implementation in Ilorin. These included wetland and riverbank degradation, inadequate drainage, water stagnation, extensive impervious-surface coverage, limited vegetation, solid-waste accumulation, and encroachment on environmentally sensitive areas. The conditions varied across the assessed locations. The findings are derived from the on-site assessments unless otherwise indicated. Evidence from previous studies is introduced separately to contextualise, corroborate, or contrast the field observations.

3.1 Field-assessment findings

Field observations conducted in this study reveal that rapid urban expansion in Ilorin has significantly altered the natural hydrological and thermal systems, particularly through the encroachment of wetlands and the increasing dominance of impervious surfaces. At key locations along the Asa River corridor, including areas around Harmony and Royal Valley Estates and adjoining settlements, direct site assessments show extensive residential development on previously functional wetland zones. These areas now exhibit clear signs of hydrological disruption, including blocked drainage pathways, persistent water stagnation which eventually destroys the roads and other infrastructure, and visible flood marks on buildings during peak rainfall events. In several instances, water levels were observed to reach building foundations and, in more severe cases, window lintel height, indicating recurrent and intensified flood exposure (Figure 2). These observations demonstrate that the natural buffering capacity of the wetland system has been substantially compromised, supporting the position that wetland loss and floodplain encroachment are central drivers of increasing flood risk in Ilorin.



Figure 2. Waterlogged conditions around selected buildings within the Asa River wetland corridor, Ilorin. The photographs document saturated ground and visible indications of previous water exposure on structures located close to the wetland. Source: Author's field photographs, [25 August, 2025]

3.2 Flooding and river-corridor degradation

Weighted overlay assessments further identify rainfall intensity and land-use change as dominant drivers of flood susceptibility, with highly vulnerable zones accounting for more than 35% of Ilorin West (Ipadeola *et al.*, 2025). Morphometric evaluations confirm that the Asa River Basin retains a dendritic drainage pattern and low drainage density, characteristics of a system originally efficient for water conveyance and infiltration (Ocheri *et al.*, 2025). However, this natural efficiency has been severely compromised by rapid urbanisation and wetland encroachment. Hydraulic modelling and vulnerability mapping show that residential developments along floodplains, such as Harmony and Royal Valley Estates and adjoining corridors, have significantly amplified flood hazards (Ojo *et al.*, 2023; Idrees *et al.*, 2022). Recent assessments estimate that over 14% of the catchment is highly vulnerable, with at least 425 buildings directly at risk.

These findings align with and support existing hydraulic and geospatial analyses of the Asa River basin. Previous studies show that the river frequently overtops its banks during heavy rainfall, affecting adjacent communities and infrastructure (Ojo *et al.*, 2023). Flood modelling integrating HEC-RAS and GIS further estimates that approximately 60.95 km² (18%) of Ilorin falls within high flood-risk zones concentrated along the river channel (Ojo *et al.*, 2023). Complementary multi-criteria spatial analyses identify low-lying neighbourhoods such as Alanamu and Oloje as highly vulnerable due to a combination of topographic exposure, impervious surfaces, and inadequate drainage infrastructure (Ipadeola *et al.*, 2025). While these

studies establish the extent of flood vulnerability, the present study provides additional context-specific evidence by demonstrating how recent land-use practices, particularly the expansion of residential structures into wetland areas, are actively intensifying flood risks at the micro-scale. Field data indicate that the disruption of natural infiltration processes has accelerated surface runoff and reduced the overall stormwater retention capacity of the system.

Beyond hydrological impacts, the study identifies significant environmental degradation within the Asa River wetland corridor, further compounding flood vulnerability. Direct field observations reveal widespread waste dumping, unregulated agricultural activity, and general ecosystem disturbance in areas adjacent to the river (Figure 3). These activities have contributed to declining water quality and reduced ecological functionality, as evidenced by visible pollution and degradation of vegetative cover. This observation is consistent with the findings of Solihu and Bilewu (2022), who report that water quality in downstream sections of the Asa River has deteriorated to levels considered unfit for domestic use.



Figure 3. Wetland disturbance along the Asa River corridor at the Harmony/Royal Valley Estates axis, Ilorin. The photograph documents waste accumulation and adjacent land-use pressure observed during the field assessment. Photograph taken by the author on [25 August, 2025].

Building on this, the present study demonstrates that continued anthropogenic pressure is not only degrading environmental quality but also weakening the wetland's capacity to perform pressure critical ecosystem services such as water filtration, flood attenuation, and habitat provision (Figure 4). This reinforces the argument that environmental degradation and flood risk are closely interconnected within the Ilorin context.



Figure 4. Remnant wetland vegetation along the Asa River corridor in Ilorin showing an open wetland landscape with established vegetation and undeveloped surfaces that may support water retention, water filtration, habitat provision, and local cooling. Source: Author's field photographs, [August 2025].

3.3 Impervious surfaces and urban heat exposure

Closely linked to these processes is the increasing prevalence of impervious surfaces across the urban landscape, which emerges as a key driver of both flood intensification and altered hydrological dynamics. Field assessments across high-density areas reveal extensive use of concrete materials for roads, walkways, and residential compounds, significantly reducing surface permeability (Figure 5). These impervious surfaces function as rapid runoff conduits, channelling stormwater at increased velocity into drainage systems that ultimately discharge into the Asa River. This process contributes to the rapid accumulation of water within the river channel, thereby increasing the likelihood of overflow during peak rainfall events. These were predicted by the flood vulnerability models of Alimi *et al.* (2023) and Ipadeola Salami, 2026

et al. (2025). Supporting evidence from Abubakar (2023), based on studies conducted in Malete, a town close to Ilorin, demonstrates that permeable pavement systems can reduce stormwater generation by approximately 50%, highlighting the magnitude of the impact associated with surface sealing. The study also demonstrated that permeable pavement was the most effective Low Impact Development (LID) practice. In this regard, the present study establishes a direct causal relationship between infrastructure design choices and increased flood vulnerability, showing that the expansion of concrete surfaces has significantly altered the natural hydrological balance of the city.



Figure 5. Comparison of contrasting pavement types at selected urban locations in Ilorin: (a) a recently constructed concrete surface that restricts direct stormwater infiltration; and (b) an unpaved vegetated surface that permits greater opportunities for infiltration. The comparison illustrates differences in surface permeability rather than measured runoff performance. Source: Author's field photographs, [August, 2025].

In addition to its hydrological implications, the loss of permeable and vegetated surfaces has contributed to the intensification of urban heat conditions within Ilorin. Field observations indicate that highly built-up areas characterised by dense concrete coverage and limited vegetation exhibit increased heat retention, consistent with established UHI dynamics. These areas lack the cooling benefits associated with evapotranspiration and shading, leading to elevated surface and ambient temperatures. This observation is supported by regional studies which show that urban environments with high concentrations of impervious materials can experience temperature increases of between 5-7°C compared to surrounding vegetated areas (Ikuemonisan *et al.*, 2025). It also aligns perfectly with the broader sustainability crisis in Ilorin identified by Fadeyibi *et al.* (2021), who calculated a significant ecological deficit, largely driven by high energy consumption. A preserved wetland would have offered a vital cooling effect through evapotranspiration, mitigating UHI effects and reducing the energy burden of the city for cooling. The current trajectory, however, creates a vicious cycle: heat increases demand for air conditioning, which consumes more energy (often from fossil fuels), releasing waste heat that further intensifies the UHI. The present study provides localised validation of this phenomenon, demonstrating that the transformation of wetlands and green spaces into built environments has diminished natural cooling mechanisms and contributed to rising thermal stress within the city.

These localised environmental changes occur within a broader context of climatic variability, which further amplifies the risks identified in this study. Evidence from the Lower Niger Basin indicates a trend toward increasing temperature variability and rainfall anomalies in recent decades (Onyeisi, 2022). Such shifts suggest a growing likelihood of extreme weather events, including intense rainfall and prolonged heat periods. When considered alongside the patterns observed in Ilorin, it becomes evident that current urban development practices are poorly aligned with emerging climate realities. The continued prioritisation of grey infrastructure over nature-based approaches can therefore be interpreted as maladaptive, as it increases exposure to both flood hazards and thermal stress rather than mitigating them.

At the same time, community-level observations highlight the complex socio-economic dimensions shaping environmental outcomes in Ilorin. Residents in wetland-adjacent areas expressed resistance to conservation or relocation measures due to concerns related to housing affordability and livelihood stability. Similarly, traders in Oja Oba Market and urban residents in high-density areas acknowledged the environmental limitations of paved walkways but emphasised their functional benefits, including improved accessibility and cleanliness. These perspectives reveal a critical tension between immediate socio-economic needs and long-term environmental sustainability. They also underscore the importance of adopting context-sensitive and socially inclusive approaches when promoting nature-based solutions, as

policy interventions that fail to consider local realities are unlikely to achieve effective implementation. This mirrors findings from Kisumu in Kenya, where Corporate Social Responsibility-driven beautification projects improved urban identity but faced sustainability challenges without strong governance and community frameworks (K'oyoo, 2024).

3.4 Contextual suitability of selected NBS interventions and implementation barriers

To consolidate the qualitative findings and translate them into an actionable implementation framework, Table 2 links the principal urban environmental challenges identified in Ilorin with their spatial contexts, corresponding NBS interventions, expected results, institutional barriers, and responsible actors. It demonstrates that NBS selection should respond to variations in flood exposure, land use, soil and surface conditions, urban density, affordability, and maintenance capacity rather than follow a uniform city-wide approach.

Although site conditions influence the suitability of wetlands, permeable pavements and urban vegetation, implementation also depends on land-use enforcement, inter-agency coordination, financing, community participation, and long-term maintenance. Consequently, while interventions such as wetland restoration and riparian buffers require stronger protection of river corridors, permeable paving requires infiltration testing and defined maintenance arrangements, and urban greening requires locally adapted vegetation and dry-season establishment support.

3.5 Context-Specific Applicability of NBS in Ilorin

The effectiveness of NBS in Ilorin must be considered against the marked wet and dry seasons. During the wet season, intense rainfall and extensive impervious cover generate rapid runoff into the Asa River and adjoining low-lying neighbourhoods, while the dry season is characterised by higher temperatures and limited rainfall. Wetland restoration, riparian revegetation, rain gardens, and permeable surfaces are therefore most relevant for attenuating wet-season runoff, whereas urban vegetation must also withstand dry-season water stress. Planting should be timed toward the onset of the rainy season and prioritise locally adapted, drought-tolerant species, supported by mulching, rainwater harvesting, and limited establishment-phase irrigation. This is important because tree-cooling performance varies with background climate, urban form, vegetation characteristics, and water availability rather than vegetation cover alone (Li *et al.*, 2024; Alonzo *et al.*, 2025).

Permeable paving is potentially suitable for walkways, parking areas, residential compounds, and low-traffic public spaces in Ilorin, but its performance should not be assumed to be uniform across the city. Lateritic soils in and around Ilorin vary in particle composition, plasticity, compaction, and permeability; consequently, heavily compacted or relatively impermeable subsoils may restrict direct infiltration and create waterlogging beneath the pavement. Site-specific infiltration and geotechnical tests should therefore precede installation. Where infiltration is limited, permeable paving should incorporate an aggregate storage layer, a controlled underdrain, and a safe overflow connection to the existing drainage system. Sediment and solid-waste accumulation must also be addressed because clogging progressively reduces pavement infiltration and requires periodic sweeping and cleaning (Sousa *et al.*, 2024; Rahman *et al.*, 2025). Evidence from monitored applications confirms that permeable paving can reduce peak discharge, but performance remains dependent on local design, substrate conditions, rainfall, and maintenance (Lee *et al.*, 2023).

These local environmental and socioeconomic conditions suggest that NBS should be implemented as a differentiated portfolio rather than as a uniform city-wide prescription. Wetland restoration and riparian buffers are most appropriate along the Asa River and its degraded floodplain; permeable paving and rain gardens are better suited to selected public spaces and residential areas following infiltration testing; and tree planting should target heat-exposed roads, markets, schools, and pedestrian corridors where maintenance can be secured. Lower-cost community greening and wetland stewardship should be prioritised in resource-constrained neighbourhoods, while comparatively capital-intensive interventions, including engineered permeable pavements, should initially be introduced through monitored pilot projects and institutional partnerships (Effiong, 2025; Dipeolu *et al.*, 2024).

Table 2. Linking Urban Environmental Challenges, NBS Interventions, and Institutional Barriers in Ilorin

Environmental challenge	Location or local context	Recommended NBS intervention	Expected outcome	Key institutional or implementation barriers	Priority institutional actors
Flash flooding, wetland loss, and riverbank degradation	Asa River corridor, including the Harmony/Royal Valley Estates and Amilengbe area	Wetland restoration, riparian buffers, floodplain revegetation, and constructed wetlands	Increase temporary stormwater retention, reduce runoff velocity, stabilise riverbanks, and improve water quality	Encroachment on wetlands and setbacks; waste dumping; weak enforcement of development controls; competing agricultural and residential land uses; fragmented institutional roles.	Kwara State Ministry of Environment, Ilorin West and Ilorin South local governments, urban planning agencies, community associations, and environmental NGOs
Runoff accumulation and recurrent residential flooding	Low-lying and densely developed neighbourhoods, including Oloje and Alanamu	Rain gardens, bioswales, infiltration trenches, vegetated drainage edges, and household rainwater harvesting	Capture runoff near its source, increase local infiltration and storage, reduce pressure on conventional drains,	Limited public space; inadequate drainage and maintenance; affordability constraints; solid-waste obstruction	Local government authorities, residents' associations, property owners, and community-based organisations
High impervious-surface coverage and rapid runoff	Major walkways, park areas, markets, institutional compounds and other public spaces	Permeable interlocking pavement, porous pavement, and tree-pit infiltration systems	Reduce surface runoff, support groundwater infiltration where soil conditions permit	Variable subsoil permeability; soil compaction; sediment and waste clogging; installation; maintenance	Public works agencies, planning authorities, market associations, and private developers
Rising land-surface temperatures and limited shade	Dense commercial and transport corridors, markets, schools, and major pedestrian routes in Ilorin Central	Street-tree planting, shaded pedestrian corridors, pocket parks, and vegetated public spaces	Reduce local solar exposure and local temperatures, improve human comfort, add to urban biodiversity	Limited planting space; dry-season water stress; damage to vegetation; weak funding; conflict with underground or overhead infrastructure	Urban planning agencies, local councils, market associations, schools, private businesses, and community groups

Environmental challenge	Location or local context	Recommended NBS intervention	Expected outcome	Key institutional or implementation barriers	Priority institutional actors
Loss and fragmentation of urban green spaces	Rapidly developing residential estates and built-up neighbourhoods	Protection of existing vegetation, community green spaces, and development-related greening requirements	Maintain ecological connectivity, reduce heat exposure, support biodiversity and recreation	Development/land ownership issues; poor open-space standards; preference for built development over ecological functions; weak enforcement;	Physical planning and land administration agencies, estate developers, resident associations, and traditional institutions
Water pollution and solid-waste accumulation in urban waterways	Asa River, tributary channels, markets, and densely populated river-adjacent communities	Vegetated buffer strips, constructed wetlands, riverbank restoration, and community-based waste interception	Filter sediments and pollutants, improve river-edge conditions, and reduce waste dumping	Inadequate waste collection; persistent dumping; weak monitoring; unclear institutional mandates; limited community ownership	Waste-management authorities, environmental agencies, market associations, community groups, and NGOs
Weak coordination and limited financing for NBS implementation	City-wide institutional and governance context	Multi-stakeholder NBS coordination; pilot projects, green finance, public-private partners, community stewardship	Achievement of SDG goals and Green Nigeria Initiative	Fragmented institutional responsibilities; limited funding; weak technical capacity; maintenance budgets; insufficient monitoring data	State and local authorities, financial institutes, private investors, universities, civil society, community reps

3.6 Policy Implications

The findings suggest the need for targeted and implementable policy actions to enhance urban climate resilience in Kwara State. First, rather than broad regulatory overhaul, incremental revisions to existing Urban Development Guidelines are recommended. These should prioritise the phased introduction of permeable materials in new public infrastructure projects, beginning with high-risk flood zones, while pilot wetland restoration schemes can be implemented in selected locations where encroachment is already evident. Such a phased approach improves feasibility by aligning implementation with available technical capacity and budgetary constraints. These actions are consistent with national frameworks such as the Green Nigeria Initiative, which promotes integrated green infrastructure and afforestation programs (Voice of Nigeria, 2025).

Second, the study highlights the potential of small-scale, community-based nature-based solution pilots in high-risk areas such as the Harmony and Royal Valley Estates corridor. Instead of large-scale relocation or redevelopment, which may face resistance, pilot interventions could include community-managed sustainable drainage corridors, localised rain gardens, and flood-resilient landscaping. These interventions are relatively low-cost, easier to implement, and more socially acceptable, particularly when co-designed

with residents. Aligning such initiatives with existing National Floodplain Management Guidelines (NEMA, 2023) can further enhance institutional support while maintaining local adaptability.

Third, urban heat mitigation strategies should be gradually integrated into existing infrastructure planning processes rather than introduced as standalone regulatory requirements. For instance, heat-sensitive design principles, such as increasing vegetation cover, using reflective materials, and introducing shaded public spaces, can be incorporated into ongoing and future projects. The use of measurable indicators, such as vegetation density or surface reflectivity, provides a practical basis for monitoring progress without imposing unrealistic compliance burdens. Frameworks such as the Heat Mitigation Index (HMI) and the Universal Thermal Climate Index (UTCI) offer useful reference points but should be adapted to local data availability and technical capacity (Sulaiman *et al.*, 2025; Setiawati *et al.*, 2021).

In addition to these measures, the findings underscore the importance of developing feasible financial mechanisms to support implementation. Rather than establishing entirely new funding structures, the study recommends leveraging existing financial channels and introducing targeted incentives. For example, a modest state-supported Climate Resilience Fund could be developed incrementally, drawing on budget reallocations, environmental levies on high-impact developments, and partnerships with development finance institutions such as the Bank of Industry and existing programs such as the World Bank-supported ACRoSAL project (Nigeria ACRoSAL, 2025). This fund could prioritise small-scale interventions, including retrofitting of impermeable surfaces, drainage improvements, and community-based greening projects. Providing micro-grants or concessional loans to households and local contractors would further enhance uptake while maintaining financial sustainability.

Furthermore, cost-sharing arrangements can improve feasibility, where government agencies such as the Town Planning and Development Authority and the Ministry of Lands, Housing and Urban Development provide technical support and partial funding, while communities contribute labour or local knowledge. This approach reduces the financial burden on the state while fostering local ownership. Existing federal initiatives, including the Green Nigeria Initiative, can also be leveraged to attract external funding and technical assistance, ensuring alignment between state and national priorities (Voice of Nigeria, 2025). While broader fiscal instruments such as carbon taxes may offer long-term potential (Kabundu *et al.*, 2022), their immediate applicability at the state level may be limited; therefore, more practical and context-appropriate financing tools should be prioritised in the short term.

3.7 Integrated thematic matrix

Figure 6 presents the proposed multi-sectoral governance and financing framework for implementing nature-based solutions in Ilorin. The framework positions relevant government institutions as providers of policy direction, regulation, and institutional coordination, while financial institutions and private investors support project financing and implementation. Technical partners, civil society organisations, and local communities contribute research, local knowledge, project co-design, monitoring, and long-term stewardship. These actors are connected through an NBS coordinating platform responsible for project prioritisation, resource mobilisation, stakeholder engagement, and performance evaluation. Monitoring and feedback mechanisms support adaptive management and inform the scaling of successful interventions.

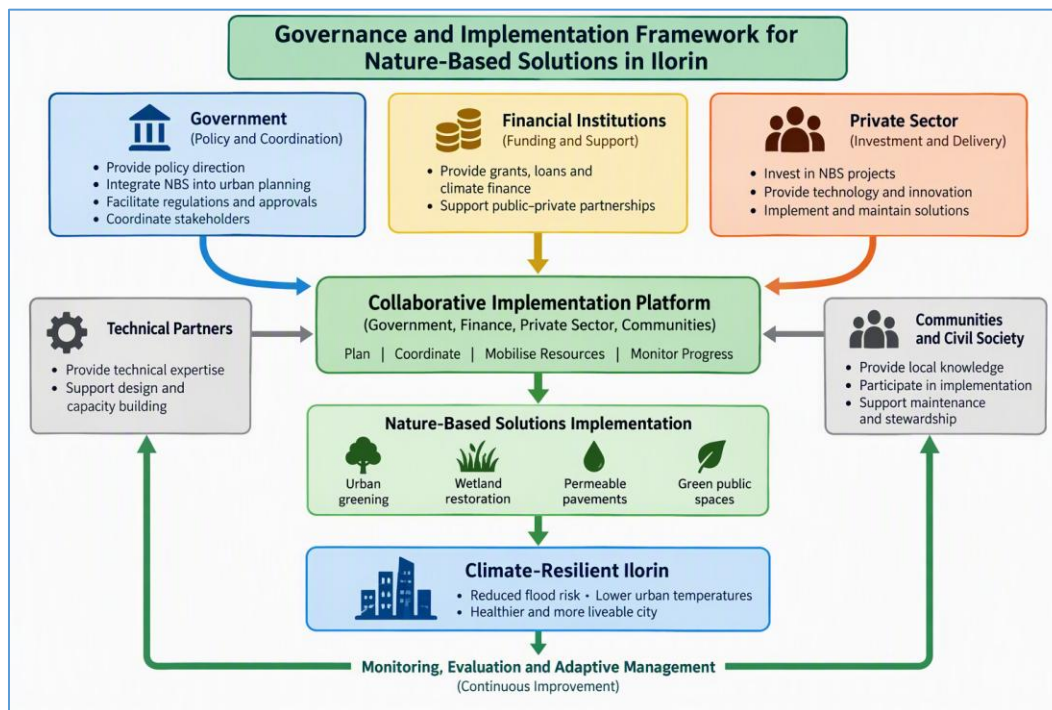


Figure 6: Multi-Sectoral Implementation Framework for Nature-Based Solutions in Ilorin illustrating the proposed relationships among government institutions, financing actors, technical partners, communities, NBS implementation activities, and monitoring processes. Source: Author's conceptualisation based on the study findings, 2026.

4. CONCLUSION

This study concludes that the frequent flooding and increasing heat in Ilorin are direct results of the city's expansion over its natural landscapes. The construction of homes and concrete infrastructure on the Asa River wetland has destroyed a vital natural sponge, while the widespread use of impermeable surfaces such as concrete walkways redirects rainwater into drainage systems instead of allowing infiltration. The dual failure of urban planning, encroaching on floodplains and sealing the ground surface, has transformed a naturally regulated river system into a source of recurrent flooding and has intensified urban heat conditions, reducing overall urban liveability.

To reverse this trend, Ilorin must begin to prioritize practical and context-sensitive nature-based solutions. The Town Planning and Development Authority of Kwara State should halt new construction approvals within ecologically sensitive buffer zones along the Asa River, while the Ministry of Environment should implement targeted clean-up and restoration programs in pollution hotspots such as the Amilengbe area, in collaboration with local community groups. In addition, urban planning regulations should progressively incorporate permeable paving materials in public infrastructure, alongside the legal protection of remaining wetlands. Financially, these interventions can be supported through a combination of state ecological funds and partnerships with institutions and existing programs, with targeted support mechanisms such as low-interest loans for household-level rainwater harvesting and community grants for urban greening initiatives.

Notwithstanding these contributions, this study has limitations. Although field observations were triangulated with published and institutional evidence, they were geographically constrained to selected high-risk areas, which may not fully capture spatial variability across the entire city. In addition, the study relied primarily on qualitative observational methods and secondary data sources, limiting the extent of independently validated repeated instrumental measurements. Temporal limitations also apply, as observations were conducted within a specific timeframe and may not reflect seasonal or long-term climatic

variations. These constraints suggest that the findings should be interpreted as indicative rather than fully exhaustive.

Despite these limitations, the insights generated in this study have broader relevance beyond Ilorin. The patterns identified – wetland encroachment, expansion of impervious surfaces, and the resulting combined flood and heat risks – are characteristic of many rapidly urbanizing secondary cities across Nigeria and sub-Saharan Africa. As such, the study offers a transferable framework for understanding how land-use changes interact with climate risks in similar urban contexts. However, the application of these findings to other cities should be adapted to local environmental conditions, governance structures, and socio-economic realities.

Building on these findings, future research should focus on strengthening empirical and analytical depth. There is a need for longitudinal studies that examine seasonal and long-term climate impacts on flood and heat dynamics in Ilorin. Quantitative modelling of nature-based solutions, including their cost-benefit implications and performance under different climate scenarios, would provide stronger evidence for policy integration. Further research should also explore socio-economic dimensions, particularly community willingness to adopt nature-based interventions and the effectiveness of participatory governance models. In addition, integrating high-resolution geospatial and remote sensing data could enhance the precision of urban heat and flood risk mapping, thereby supporting more targeted planning interventions.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the residents, traders, and community stakeholders within the assessed locations in Ilorin, particularly along the Asa River corridor, the Harmony and Royal Valley Estates axis, and Oja Oba Market, for facilitating site access and providing relevant local insights during the field assessments. Appreciation is also extended to the public institutions, researchers, and organisations whose published data, reports, and scholarly works contributed to this study. The author also appreciates Mr Saheed Ishaq of the Department of Environmental Management and Toxicology, Kwara State University, Malete for his assistance in creating the map of the study area. His contribution in preparing the illustration greatly enhanced the presentation of this work.

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