



Assessing the Economic and Environmental Benefits of Nature-Based Solutions for Sustainable Infrastructure. A Case of Kumasi, Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Kumasi, Ghana, and most rapidly developing cities in Sub-Saharan Africa are confronted with increasing environmental and infrastructure concerns as a result of rapid urbanization, inadequate land use planning, and climate change. Traditional grey infrastructure has been inadequate in mitigating these problems. This paper assessed the economic and environmental advantages of Nature-Based Solutions for sustainable infrastructure in Kumasi through a systematic review of peer-reviewed articles, reports, and empirical research published from 2006-2025. The paper

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consolidates evidence across four environmental and four economic dimensions, namely climate regulation and air quality enhancement, stormwater and flood control, biodiversity and ecosystem restoration, and soil and water quality enhancement, and cost efficiency and life-cycle savings, enhanced property values and tourism appeal, creation of jobs and green economy prospects, and savings on public health expenditure, respectively. The findings indicate that Nature-Based Solutions provide multifunctional, cost-effective, and ecologically sustainable alternatives to conventional infrastructure, with significant benefits in climate regulation, flood control, and biodiversity enhancement. This paper also proposes actionable recommendations for integrating Nature-Based Solutions into urban planning in Kumasi, with implications for other cities in Sub-Saharan Africa. The paper concludes with specific recommendations, including promoting green infrastructure in spatial plans and investing in community-led reforestation projects to enhance urban resilience.

Keywords: *Nature-based solutions; economic benefits; environmental benefits; sustainable infrastructure; Ghana.*

1. INTRODUCTION

Urbanization is proceeding at an unprecedented level, with more than 55% of the world's population now living in cities, and this is expected to increase to 68% by 2050 (United Nations, 2018). This urbanization puts enormous pressure on infrastructure systems, resulting in higher greenhouse gas emissions, increasing energy needs, and ecological deterioration (Kabisch et al., 2016). As cities grapple with the challenges of population growth while needing to curb climate change and maintain ecosystem services, Nature-Based Solutions have presented themselves as an effective, sustainable complement to traditional gray infrastructure (Cohen-Shacham et al., 2016).

Globally, Nature-Based Solutions are being recognized for their dual economic and environmental benefits. Urban forests, green roofs, permeable pavements, and constructed wetlands, among other Nature-Based Solutions, enhance urban resilience, reduce flood risk, and provide cost-saving services that both benefit biodiversity and human well-being (Raymond et al., 2017). Studies have shown that it can deliver infrastructure services at lower life-cycle costs with co-benefits including air quality improvement, carbon sequestration, and recreational spaces (Faivre et al., 2017). With cities worldwide beset by climate-induced disasters and economic strain, the role of Nature-Based Solutions in urban planning and infrastructure development has drawn increased attention from policymakers, researchers, and international organizations (European Commission, 2021).

In Sub-Saharan Africa, rapid urbanization is outpacing infrastructure development, leading to severe environmental degradation, urban planning challenges, and greater vulnerability to climate change (UN-Habitat, 2014). Although the region is highly exposed to climate hazards like flooding, drought, and heat stress, Nature-Based Solutions are still under-exploited in infrastructure design and policy (Kalantari et al., 2018). Constraints like limited financial capacities, weak institutional capacities, and low levels of public awareness impede the adoption of Nature-Based Solutions in urban planning in African cities (Arsénio et al., 2021). Notwithstanding, some African cities are starting to embrace green infrastructure and ecosystem-based adaptation approaches as effective solutions to urban issues.

The rapid urbanization in Ghana, particularly in metropolitan areas such as Accra, Kumasi, and Tamale, has led to unchecked land use changes, loss of green spaces, and increasing instances of urban flooding (Abass, 2023). Traditional engineering interventions have often been incapable of providing sustainable solutions, particularly in the face of erratic rainfall patterns and intense weather events linked to climate change (Amoako & Inkoom, 2018). Although Ghana's national environmental and climate strategies acknowledge the contribution of ecosystem-based interventions, practical implementation and localized exploration of Nature-Based Solutions remain limited (EPA Ghana, 2020).

Kumasi, which was once renowned as the "Garden City of West Africa" owing to its vegetation cover and ecological balance, is presently suffering from severe environmental

degradation triggered by population growth, deforestation, and unplanned urban expansion (Owusu Ansah & Agyei-Mensah, 2014). The city is confronted with growing risks of flash flooding, poor air quality, and inefficient drainage systems, all of which are compounded by the loss of natural buffers like wetlands and forests. Nonetheless, Kumasi also offers a singular potential to assess and upscale Nature-Based Solutions because of its past incorporation of nature in urban design and the existence of vibrant local initiatives for greening and sustainable development (Mensah et al., 2017).

This paper assessed the economic and environmental advantages of Nature-Based Solutions for sustainable infrastructure in Kumasi, connecting global theory to local practice. Through an evaluation of current Nature-Based Solutions interventions and an investigation of their potential for addressing infrastructural and ecological issues, the study hopes to generate practical recommendations for city planners, policymakers, and stakeholders in pursuit of sustainable and affordable urban solutions in Ghana and elsewhere.

2. LITERATURE REVIEW

Nature-based solutions have emerged as a leading concept over the last several years as a novel and holistic approach to sustainable development, environmental restoration, and infrastructure resilience. The International Union for Conservation of Nature (2016) defines Nature-Based Solutions as "actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits." The definition emphasizes its twofold function in addressing environmental and socio-economic issues. Nature-Based Solutions are often clarified by analogy to similar concepts of green infrastructure, ecosystem-based adaptation, and

ecosystem services. Whereas green infrastructure generally refers to a designed network of natural and semi-natural elements to deliver a wide range of ecosystem services (Benedict & McMahon, 2006), ecosystem-based adaptation refers to the use of biodiversity and ecosystem services to help people adapt to the impacts of climate change (Munang et al., 2013). Nature-Based Solutions is a meta-concept based on these foundations to address several societal challenges simultaneously (Raymond et al., 2017). The theoretical foundations of it in sustainability science, ecological economics, and socio-ecological systems theory. These theories highlight the entwinement of human well-being and ecological well-being (Folke et al., 2010). Additionally, resilience thinking, or a system's capacity to absorb disturbance and reorganize while changing, also guides the adaptive nature of Nature-Based Solutions (Walker & Salt, 2006). Nature-Based Solutions are, then, not simply ecological interventions but strategic, adaptive, and socially embedded solutions to urban complex issues.

The incorporation of Nature-Based Solutions in infrastructure systems is a radical advancement in urban and regional planning. Conventional or "grey" infrastructure, like roads made of concrete, drainage, and flood defense, although functional over the short term, tends to lead to environmental deterioration, rigidity, and expensive maintenance (Palmer et al., 2015). Nature-Based Solutions, on the other hand, deliver infrastructure services by emulating natural processes like infiltration, evapotranspiration, and filtration and thus help ensure sustainability and resilience in urban systems (Kennedy, 2025). A few examples of Nature-Based Solutions for infrastructure systems, as shown in Fig. 1, include pervious pavements for stormwater infiltration, green roofs for urban temperature regulation, and restored wetlands for flood control and biodiversity maintenance (Depietri & McPhearson, 2017).



Fig. 1. Examples of nature-based solutions for infrastructure systems

Source: Depietri & McPhearson, 2017

Nature-based solutions have been applied in cities worldwide, such as Singapore, Rotterdam, and Philadelphia, to reduce urban flooding, heat stress, and improve liveability (Kabisch et al., 2016). The European Commission (2021) views such nature-based interventions as key to long-term infrastructure sustainability and climate resilience aspirations. Realizing this Nature-Based Solution in sustainable infrastructure is a multidisciplinary undertaking, entailing engineering, urban ecology, landscape architecture, and community planning (Frantzeskaki et al., 2019). However much this is, such integration also requires institutional support, regulatory policies, and context-sensitive design, particularly in fast urbanizing areas such as Sub-Saharan Africa.

One of the most common environmental advantages of Nature-Based Solutions, as presented in Fig. 2, is their assistance in climate regulation and air quality improvement. Urban vegetation, i.e., street trees, urban forests, and green roofs, regulates temperature through shading and evapotranspiration and by mitigating the urban heat island effect. This is of particular application in tropical and subtropical climates where excessive heat is a problem of public health (Greksa, 2024). Following Baró et al. (2014), Barcelona's urban trees were discovered to effectively reduce ambient temperatures and remove harmful air pollutants like nitrogen dioxide and particulate matter, hence playing a role in better respiratory health as well as climate change adaptation. Vegetation removes carbon dioxide from the air, thereby reducing greenhouse gas emissions (Forster, 2023). These regulatory services not only enable the cities to attain climate goals but also make the urban centers more habitable for the urban dwellers (Gómez-Baggethun & Barton, 2013). In fast-growing cities such as Kumasi, incorporating vegetation within urban infrastructure can be an affordable and multifunctional approach to mitigate increasing temperatures and declining air quality due to vehicular emissions and industrial processes (Oduro-Ofori, 2025).

Nature-based solutions are being used more and more to solve hydrological issues like urban flooding and poor drainage (Ferreira et al., 2021). Conventional drainage infrastructure, which tends to be pipe- and concrete channel-based, is expensive and has limited ability to buffer extreme rain events, which are increasingly common as a result of climate change (Pluimer, 2023). In contrast, green infrastructure such as

permeable pavements, bioswales, and constructed wetlands replicates natural hydrological processes through the capture, infiltration, and gradual release of stormwater (Masi et al., 2018). These systems minimize surface runoff, soil erosion, and the load on municipal drainage systems. Narayan et al. (2017) point out that natural coastal ecosystems like mangroves and wetlands also act as storm surge buffers, shielding urban settlements from flood losses. For a flood-prone city like Kumasi, which suffers from seasonal flooding and drainage congestion, Nature-Based Solutions can offer effective and sustainable stormwater management solutions while providing aesthetic and ecological value at the same time.

Nature-based solutions are crucial for the restoration and conservation of biodiversity in peri-urban and urban environments (Nair et al., 2025). Urbanization often leads to the loss, fragmentation, and reduction in species richness of habitats. Such impacts could be negated through the introduction of green corridors, native vegetation, and restored wetlands that create habitats and enhance ecological connectivity (Seddon et al., 2020). These interventions underpin a range of taxa, such as birds, pollinators, amphibians, and small mammals that have value to ecosystem function. Beyond fauna, Nature-Based Solutions enable restoration of degraded landscapes through enhanced soil structure, nutrient cycling, and plant succession. Green belts and urban forests, for example, can act as ecological oases in urban development, sustaining habitat for native and migratory species (Gufwan et al., 2025). In Sub-Saharan African cities where land degradation and deforestation are common, ecological restoration by investing in Nature-Based Solutions can greatly help in biodiversity conservation and the preservation of essential ecosystem services (Atuahene, 2025).

An essential ecological advantage of Nature-Based Solutions is that they can improve soil and water quality. Urbanization generally causes sealed surfaces, leading to greater runoff and water body contamination with sediments, heavy metals, and organic pollutants (Qian et al., 2021). Nature-Based Solutions like riparian buffers, rain gardens, and phytoremediation zones are natural filters that absorb and degrade these pollutants before they enter surface or groundwater systems (Depietri & McPhearson, 2017). Enhanced soil health is also attained through organic matter build-up, microbial activity, and

natural soil aeration, which further roots vegetation growth and ecological stability. These functions are especially important in cities such as Kumasi, where uncontrolled development and poor waste disposal threaten water resources and soil fertility (Dalal & Jayaraman, 2025). Through the incorporation of Nature-Based Solutions into urban infrastructure, municipalities can manage such concerns in a holistic way, minimizing environmental pollution and promoting sustainable use of resources (Zarei & Shahab, 2025).

Nature-based solutions tend to be less expensive than traditional grey infrastructure, especially when viewed across their full life cycle. While upfront implementation costs can differ based on the project's size and complexity, Nature-Based Solutions' long-term operational and maintenance costs are significantly less (Bechauf et al., 2022). For instance, a green roof system can be more expensive than conventional roofing upfront but increases the roof's lifespan, lowers energy use, and offers long-term savings on utility bills (Organisation for Economic Co-operation and Development, 2020). In addition, Nature-Based Solutions indirectly cost-save by minimizing extreme weather event damages, lowering the necessity for public spending on disaster recovery, and creating infrastructure resilience. These advantages are particularly valuable in low- and middle-income nations

where city budgets are limited and cost-effectiveness is a key consideration for infrastructure investment (World Bank, 2023).

Access to high-quality green space has been reliably associated with higher property values. Attractively planned parks, greenways, and waterfronts not only add to the beauty of the neighborhood but also to the residents' quality of life, which makes the properties surrounding the area more desirable to buyers and investors (Weaver, 2024). The Economics of Ecosystems and Biodiversity (2011) discusses that properties within proximity to green areas can enjoy premiums as high as 20 percent over comparable properties lacking the proximity. Nature-Based Solutions also have the potential to trigger economic activity through tourism, such as eco-tourism and experience-based recreational tourism in natural or semi-natural ecosystems. In ancient and culturally endowed cities such as Kumasi, incorporating green corridors and botanical gardens into urban planning can make the city more attractive, diversify the local economy, and yield new sources of income from tourism (World Bank Group, 2024).

As shown in Fig. 3, Nature-based solutions also hold significant potential for the establishment of new jobs in areas such as landscape design, ecological engineering, horticulture,



Fig. 2. Environmental benefits of nature-based solutions

Source: Authors' Construct

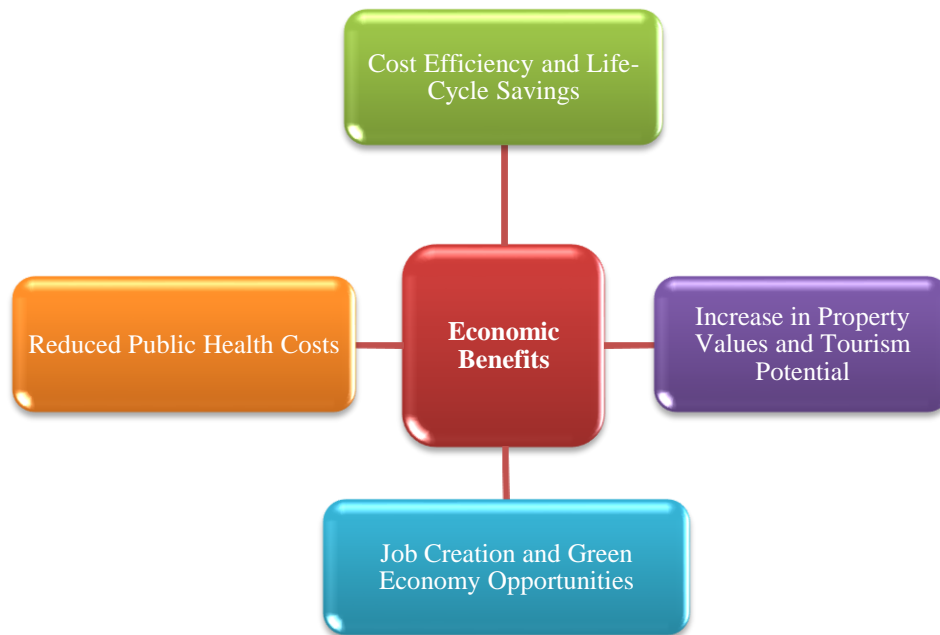


Fig. 3. Economic benefits of nature-based solutions

Source: Authors' Construct

and environmental education (Network for Engineering with Nature, 2025). The transition to a green economy has underlined the need to create "green jobs" that are environmentally friendly and assist in sustainable development. The United Nations Environment Programme (2011) informs us that investments in Nature-Based Solutions can generate more jobs per dollar than conventional infrastructure, especially for labor-intensive initiatives like urban gardening, wetland restoration, and tree planting. In areas of youth unemployment and economic uncertainty, like most of Ghana, these career trajectories are especially beneficial. The establishment of urban tree-planting programs, riverbank stabilization measures, and community gardens can empower communities economically while meeting environmental restoration objectives (Forestry Commission Ghana, 2025).

Nature-Based Solutions indirectly lower the cost of public health by enhancing environmental conditions that affect human well-being. Green spaces enhance physical activity, decrease levels of stress, and reduce the health effects of heatwaves and air pollution (Eliassen, 2024). Urban greenery has also been linked with reduced levels of respiratory disease, cardiovascular disease, and mental illness (Raymond et al., 2017). In addition, through stormwater management and prevention of

urban flooding, Nature-Based Solutions have the potential to avert incidences of waterborne diseases like cholera, which is still a public health issue in most African cities. Chausson et al. (2020) maintain that precautionary investment in environmental infrastructure can lead to considerable savings in government spending on health and emergency response services. In a city such as Kumasi, where health services are usually stretched during the rainy season, these precautionary benefits are not only socially but also economically relevant.

3. METHODOLOGY

This study applied a systematic review approach to investigating the economic and environmental benefits of Nature-Based Solutions for sustainable infrastructure in Kumasi. The systematic review approach was employed due to its strength in accumulating existing knowledge from various sources based on an explicit and reproducible protocol. The review aimed to determine key environmental and economic results of Nature-based Solutions and how these contribute to urban sustainability and resilience.

In an attempt to obtain pertinent literature, an extensive search was carried out on major academic databases, such as Science Direct,

PubMed, Google Scholar, Scopus, and Web of Science, as shown in Fig. 4. The research strategy utilized the application of the following keywords: "Nature-based Solutions," "economic benefits," "environmental benefits," "sustainable infrastructure," "Kumasi," and "Ghana." The application of Boolean operators was utilized to enhance the search parameters' specificity. Only English-language articles were included, and the search was limited to publications from 2006 to 2025 to encompass both older and newer perspectives.

The selection criteria for the studies targeted research that had investigated the economic and environmental benefits of Nature-Based Solutions for sustainable infrastructure, with a priority on Sub-Saharan Africa's urban areas or other comparable developing world cities. The review incorporated peer-reviewed articles, scholarly books, organizational reports, and empirical case studies. Nonetheless, opinion articles, non-academic literature, research that did not meet the general themes, and duplicate articles were not included in the review.

Following the identification of qualifying studies, data were extracted with the assistance of a structured coding scheme. This included the recording of details about each study's author(s), publication year, research objectives, methodology, key findings, and its applicability to the Ghanaian or African urban experience. This was followed by a thematic synthesis of the data that was extracted. The findings were always classified under two broad dimensions: first, the environmental benefits of Nature-Based Solutions, including Climate Regulation and Air Quality Improvement, Storm water and Flood Management, Biodiversity and Ecosystem Restoration, and Soil and Water Quality Improvement; and second, the economic benefits of Nature-Based Solutions, including Cost Efficiency and Life-Cycle Savings, Increase in Property Values and Tourism Potential, Job Creation and Green Economy Opportunities, and Reduced Public Health Costs.

Although the systematic review approach guarantees some degree of academicity and comprehensiveness, some limitations were realized. Most notably, there was the risk of publication bias as a result of the restriction of grey literature and non-English sources. Secondly, even though there is increased interest in nature-based solutions in Ghana, studies specific to Ghana remain scarce. This

gap highlights the necessity for more localized studies exploring the intricate link between nature-based solutions and sustainable infrastructure in Kumasi. Yet the methodological approach taken in this research offers a solid foundation for syntheses of current knowledge and formulating insights that are relevant to both scholars and policymakers. It also enables the identification of key themes and evidence gaps that can guide future research and environmental planning initiatives.

3.1 Contextual Focus on Kumasi

Kumasi, the capital of the Ashanti Region and Ghana's second-most populous city, as indicated in Fig. 5, is situated in a wet semi-deciduous area and was formerly dubbed the "Garden City" due to its vegetation. Rapid urbanization since the 1990s has changed land cover, converting green areas to built-up spaces and heightening environmental stresses characteristic of West African cities (Darko et al., 2021). Recent census statistics underscore Kumasi's demographic significance in the Greater Kumasi Metropolitan Area (GKMA), its commercial importance, and the effects of densification on infrastructure and ecosystem services (Ghana Statistical Service [GSS], 2021).

Urban waterscapes indicate evident pressures. The Wiwi, Subin, and Suntre rivers drain the city, flowing through highly populated neighborhoods and industries prior to reaching downstream communities (Dankwa et al., 2024). Evaluations indicate physicochemical, pharmaceutical, as well as petroleum contaminations, with the Subin River frequently noted as a hotspot because of encroachment and emissions (Dankwa et al., 2024). This concurs with 2024 reports attributing Kumasi's growth to riparian encroachment and weakened vegetative buffers along the rivers, recommending stringent 30-metre setbacks for management (Takyi & Amponsah, 2024).

Kumasi's premier water-supply catchments, the Owabi and Barekese reservoirs, exemplify both vulnerability and opportunity for nature-based solutions (NbS). Owabi, a Ramsar site, once provided a significant portion of Kumasi's drinking water and continues to be vital to regional water security; however, land-use and land-cover change analyses reveal edge encroachment, emphasizing the necessity of catchment protection, reforestation, and wetland restoration to ensure flow regulation and water quality (Antwi-Agyei et al., 2019).

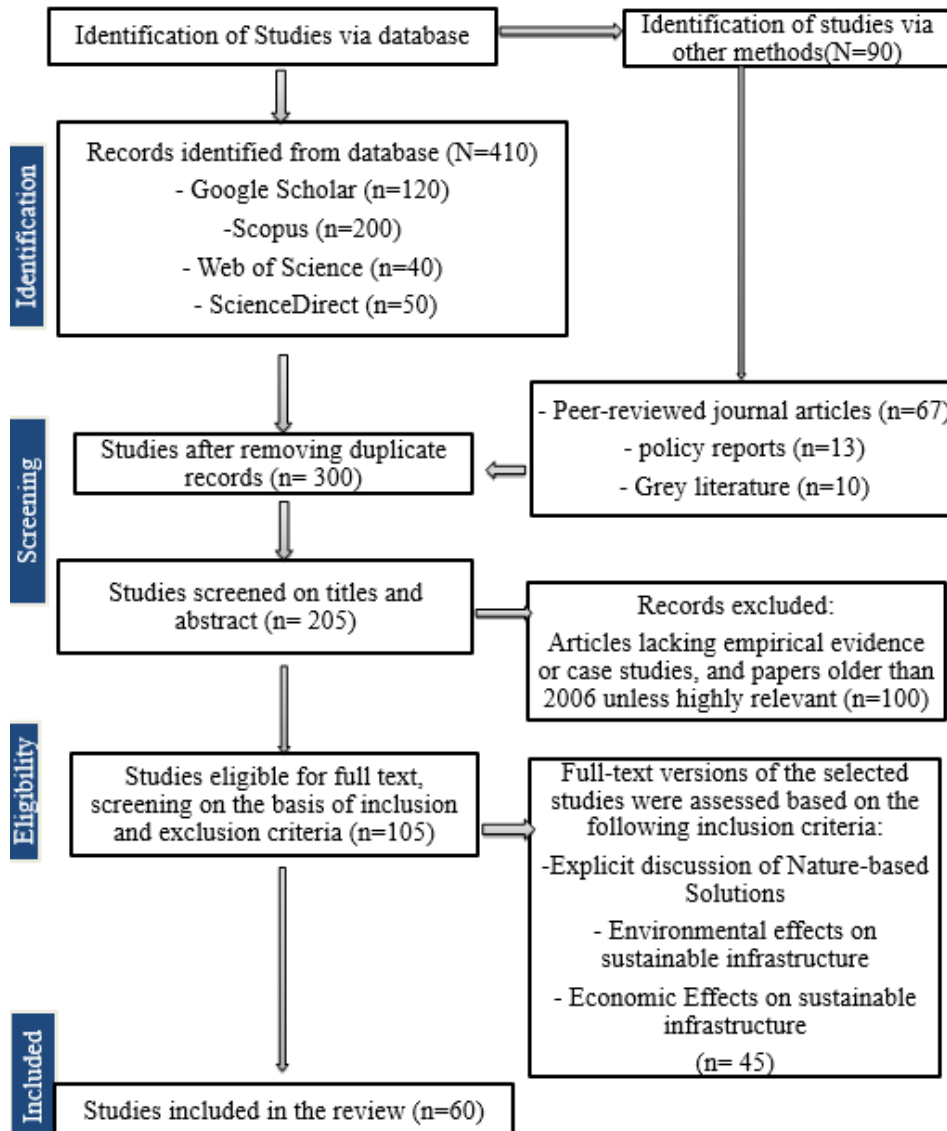


Fig. 4. Systematic review process flow diagram

Source: Authors' construct

Socioeconomic research evidence around these reservoirs also reveals readiness to invest in conservation if benefits are evident, an enabling condition for community-anchored NbS and payment-for-ecosystem-services arrangements (Ayesu et al., 2024). Flood risk is increasing. Analysis attributes flooding to imperviousness, floodplain development, undersized drains, and blocked channels, problems NbS can help solve through peak flow reduction and increased infiltration (Enu et al., 2024). Recent studies of Kumasi's flood exposure demonstrate risk heterogeneity within the GKMA and recommend integrated green-gray solutions such as riparian buffers, urban forests, bioswales, and detention wetlands, coupled with drainage improvement

and more stringent riparian setback regulations (Enu et al., 2024).

Against this backdrop, several streams of policy and practice create a receptive environment for NbS. Nationally, the Ghana Roadmap for Resilient Infrastructure in a Changing Climate promotes NbS as cost-effective complements to conventional investments, citing co-benefits for cooling, air quality, and biodiversity alongside avoided damages (Global Center on Adaptation [GCA], 2022). Locally, sanitation and water programs scaled to the GKMA aim to reduce pollution loads and expand equitable services, which can be paired with green infrastructure to improve stormwater performance

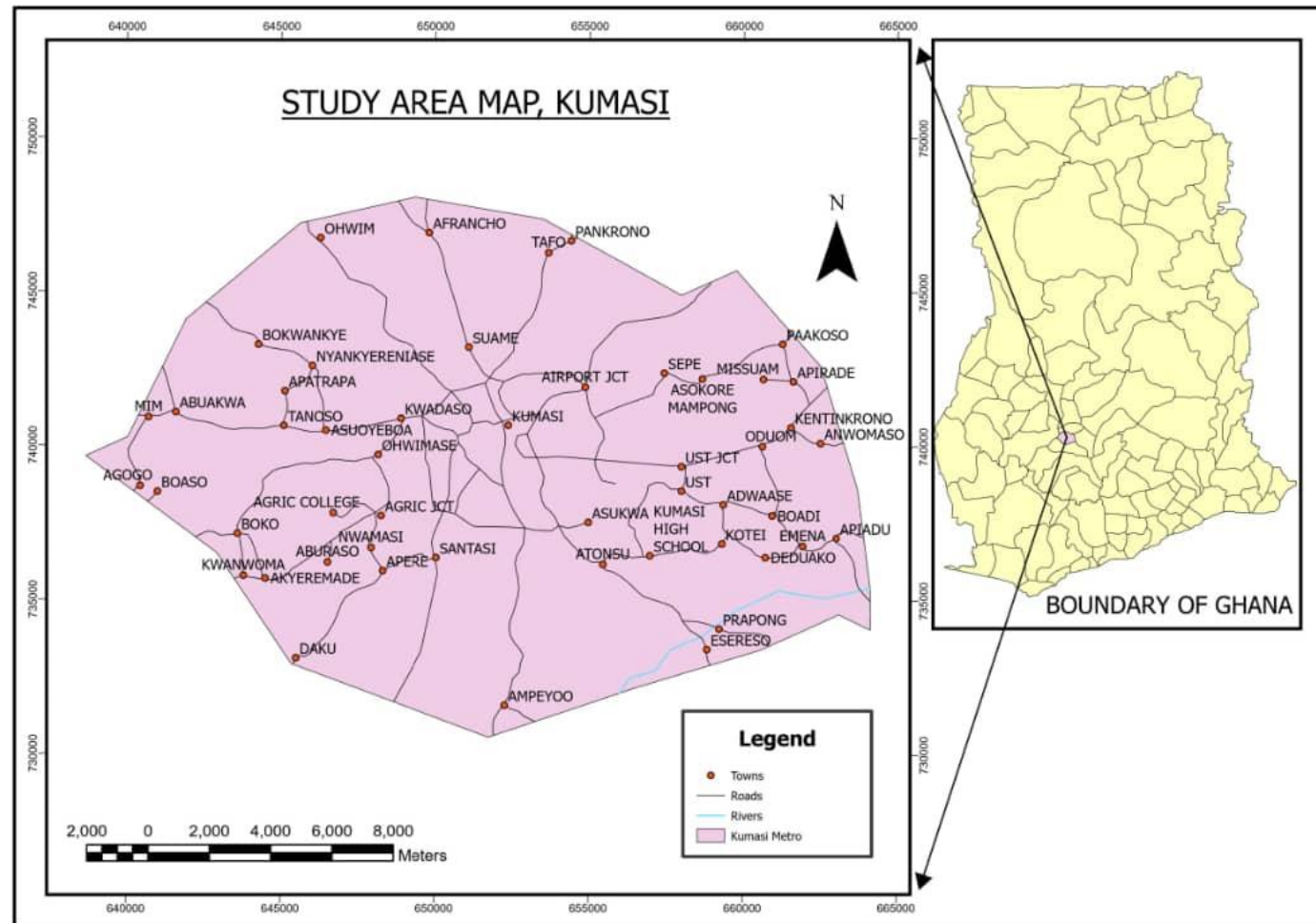


Fig. 5. Map of the study area
Source: Authors' construct

and water quality (World Bank/MSWR, 2023). Recent Kumasi-focused research also identifies barriers (awareness, financing, coordination) and pathways (stakeholder literacy, community stewardship, policy alignment) for mainstreaming NbS into urban climate resilience strategies (Boateng, 2023).

Green-space dynamics within the urban area suggest where NbS can deliver environmental and economic gains. Parks in Greater Kumasi are decreasing in number and function, with Rattray Park suffering from maintenance problems; local people value convenient, well-managed green space for recreation and health, supplemented by street trees, pocket parks, and riparian greenways (Gagakuma et al., 2025). In a city where forests and rivers sustain water security and climate resilience, it is essential to incorporate NbS into land-use regulation and infrastructure development to ensure sustainability in Kumasi.

4. RESULTS AND DISCUSSION

4.1 Environmental Benefits of Nature-Based Solutions

Tables 1, 2, 3, and 4 summarize the scholarly articles that were directly related to the environmental benefits of Nature-based Solutions, based on a thorough search and evaluation. The following analysis and discussion are based on the empirical, theoretical, and conceptual underpinnings of these investigations. Nature-Based Solutions are central to the regulation of urban microclimates and

improvement of air quality. Various studies indicate that vegetation such as trees, green roofs, and urban forests reduce the urban heat island effect and decrease levels of air pollutants. Greksa et al. (2024) emphasize the environmental management multifunctionality of vegetation, demonstrating urban greenery advantages through shading, evapotranspiration, and absorption of pollutants. Their extensive research is particularly important for tropical cities where public health is endangered by extreme heat. This is consistent with Baró et al. (2014), whose study in Barcelona proves urban trees reduce temperatures significantly and eliminate pollutants such as nitrogen dioxide and particulate matter. Unlike Greksa, Baró et al. present quantitative proof, grounding their research in measured data and air quality indices. Forster (2023) directs attention to carbon sequestration, demonstrating that trees reduce greenhouse gas levels through carbon dioxide absorption, particularly valuable for cities experiencing growing emissions. Gómez-Baggethun and Barton (2013) contend air purification and climate regulation are crucial urban ecosystem services, essential for urban planning. Oduro-Ofori et al. (2025) offer a Ghana-specific perspective, disclosing Kumasi, the former "Garden City," is affected by environmental degradation due to urban sprawl, yet green infrastructure can reverse these tendencies. Their localized focus reaffirms the scientific consensus and demonstrates that NBS are effectively implementable in low- and middle-income countries. The sources unite in findings but vary in approach, such as case studies, policy analysis, and theoretical evaluations.

Table 1. Theme 1 - Climate regulation and air quality improvement

Author(s)	Objectives	Methodology	Key Findings	Relevance
Baró et al. (2014)	To examine urban trees' role in air pollution removal and climate mitigation in Barcelona	Empirical case study	Urban trees reduce pollutants and heat, aiding climate adaptation	Supports integrating green infrastructure into city planning
Forster (2023)	To highlight how trees help mitigate climate change	Expert commentary	Trees sequester carbon dioxide, reducing greenhouse gases	Justifies carbon-reducing urban policies
Gómez-Baggethun & Barton (2013)	To classify and value ecosystem services for urban planning	Review & analytical framework	Ecosystem services enhance city climate goals and livability	Important for urban environmental planning
Greksa et al. (2024)	To explore the role of vegetation in managing environmental and climate-related problems	Literature synthesis	Vegetation helps regulate temperature and air quality, particularly in hot climates	Applicable to urban centers in tropical climates like Kumasi
Oduro-Ofori et al. (2025)	To discuss strategies for promoting green infrastructure in Kumasi	Contextual policy review	Green infrastructure can improve air and climate resilience in Kumasi	Direct relevance to Ghana's urban sustainability

Source: Authors Construct

Table 2. Theme 2 - Stormwater and flood management

Author(s)	Objectives	Methodology	Key Findings	Relevance
Ferreira et al. (2021)	To assess Nature-Based Solutions for urban flood resilience	Book chapter analysis	Green infrastructure buffers stormwater and improves resilience	Supports use of natural systems in urban water management
Masi et al. (2018)	To discuss role of wetlands in circular economy and stormwater control	Conceptual research	Constructed wetlands filter and manage stormwater	Applies to integrated urban water design
Narayan et al. (2017)	To quantify coastal wetland benefits for flood damage reduction	Quantitative modeling	Coastal ecosystems significantly buffer storm surges	Encourages wetland preservation near urban coastlines
Oduro-Ofori et al. (2025)	To discuss strategies for promoting green infrastructure in Kumasi	Contextual policy review	Green infrastructure can improve air and climate resilience in Kumasi	Direct relevance to Ghana's urban sustainability
Pluimer (2023)	To evaluate sustainability of drainage structures under climate change	Technical assessment	Traditional infrastructure lacks resilience to extreme rain	Highlights need for Nature-Based Solutions over conventional systems

Source: Authors' Construct

Together, they contend that urban greenery is essential for climate regulation and air quality at every scale.

Nature-Based Solutions effectively address urban hydrological problems such as flooding, poor drainage, and stormwater runoff. These issues exacerbate globally with climate change, particularly in cities like Kumasi, where poor infrastructure and unplanned development heighten vulnerability. Ferreira et al. (2021) describe green infrastructure tools such as bioswales, permeable pavements, and constructed wetlands for flood resilience. Their research demonstrates these systems replicate natural processes, reducing surface runoff and soil erosion. This confirms Masi et al. (2018), who emphasize wetlands' contribution to the circular economy for stormwater retention, nutrient filtering, and ecological services. Both papers concur that green infrastructure prevents

flooding and enhances resource efficiency and ecosystem restoration. Narayan et al. (2017) expand analysis to coastal wetlands minimizing storm surges. Their paper contends that nature-based flood mitigation achieves superior cost-benefit results to conventional structures. Though based in the northeastern U.S., its principles are transferable to flood-prone West African regions. Contrarily, Pluimer (2023) criticizes grey infrastructure's sustainability under climate change, uncovering that buried drainage frequently fails under heavy rainfall, necessitating nature-based solutions. Pluimer's critique and endorsement of NBS by other researcher's mirror expanding consensus on traditional drainage systems' insufficiency. Finally, Oduro-Ofori et al. (2025) are directly applicable to Kumasi. Their study illustrates the city's vulnerability to seasonal flooding and argues that incorporating green infrastructure, like urban wetlands and green belts, into planning can reduce

Table 3. Theme 3 - Biodiversity and ecosystem restoration

Author(s)	Objectives	Methodology	Key Findings	Relevance
Atuahene et al. (2025)	To review green ecology management in sub-Saharan Africa	Regional review	Nature-Based Solutions support biodiversity and ecological services	Important for African cities like Kumasi
Gufwan et al. (2025)	To investigate microbial ecosystems' role in soil health	Empirical study	Biocrusts enhance soil function and ecosystem recovery	Encourages use of soil-based Nature-Based Solutions
Nair et al. (2025)	To introduce Nature-Based Solutions for urban sustainability	Book introduction	Green infrastructure restores degraded urban ecosystems	Key for designing resilient urban environments
Seddon et al. (2020)	To establish NBS as a global climate change solution	Global synthesis	Ecological restoration is central to Nature-Based Solutions impact	Frames Nature-Based Solutions as a biodiversity safeguard

Source: Authors Construct

disaster risk. Their findings confirm and contextualize the arguments from the broader literature, validating NBS as viable and necessary in Ghana's urban landscape.

Urbanization has led to habitat fragmentation and decreased species richness, and restoring biodiversity is essential in all areas. Nature-Based Solutions (NBS) achieve this by developing green corridors, rehabilitating wetlands, and incorporating local flora and fauna within urban development. Seddon et al. (2020) synthesize the ecological advantages of NBS, positing that biodiversity targets in climate adaptation enhance ecological and social co-benefits. Nair et al. (2025) endorse NBS in cities, citing it promotes sustainability and resilience. Both highlight NBS's promise, but Seddon et al. do so for global climate policy, whereas Nair et al. do so for urban infrastructure. Gufwan et al. (2025) are unique in bringing attention to microbial ecosystems such as biocrusts, demonstrating restoration can be done at micro scales, impacting nutrient cycling and soil fertility. This adds to macro-level discussions on ecological restoration. Atuahene et al. (2025) contribute a Sub-Saharan African perspective, citing deforestation and institutional weakness as NBS barriers but identifying recovery prospects with investment in green infrastructure. Their work substantiates ecological theories at large within African contexts. Together, these sources present a multi-scalar, interdisciplinary analysis, from policy to microbial ecology, illustrating that NBS are essential for urban biodiversity conservation.

Urbanization often results in sealed surfaces that increase runoff and degrade soil and water quality. Nature-Based Solutions, through natural

filtration mechanisms and soil rehabilitation practices, offer practical solutions to these challenges. Qian et al. (2021) provide empirical data on how urban pavements contribute to water pollution through the release of sediments and heavy metals. Their work establishes the problem, paving the way for solutions offered by others. Depietri and McPhearson (2017) propose integrating green, blue, and grey infrastructure to mitigate such problems. Their work is more theoretical but important in showing how ecosystem-based design can transform polluted cities. Zarei and Shahab (2025) take a systematic review approach to identify success factors and implementation barriers. They find that although NBS significantly improve soil and water quality, they are often constrained by institutional and financial challenges. This tempered perspective contrasts with the more enthusiastic endorsements by other scholars, but it enhances the discussion by addressing practical constraints. Dalal and Jayaraman (2025) emphasize the context of Kumasi, where poor urban planning and unregulated waste disposal threaten both soil fertility and freshwater bodies. Their findings confirm the relevance of NBS in Sub-Saharan African cities, particularly in terms of riparian restoration, phytoremediation, and rain garden development.

4.2 Economic Benefits of Nature-Based Solutions

Tables 5, 6, 7, and 8 summarize the scholarly articles that were directly related to the economic benefits of Nature-based Solutions, based on a thorough search and evaluation. The following analysis and discussion are based on the empirical, theoretical, and conceptual underpinnings of these investigations.

Table 4. Theme 4- Soil and water quality improvement

Author(s)	Objectives	Methodology	Key Findings	Relevance
Qian et al. (2021)	To study runoff pollution on urban pavements	Laboratory and field testing	Urbanization increases pollutant runoff	Provides rationale for natural filtration systems
Depietri & McPhearson (2017)	To explore integrating green, grey, and blue infrastructure	Theoretical framework	Vegetation filters pollutants before reaching water bodies	Offers strategies for NBS in polluted urban areas
Dalal & Jayaraman (2025)	To assess threats to water quality from poor urban planning	Empirical review	Uncontrolled development harms soil and water	Calls for holistic NBS integration in cities
Zarei & Shahab (2025)	To identify success factors for NBS in green infrastructure	Systematic review	NBS enhance soil quality and resilience	Useful for Ghanaian urban policy design

Source: Authors Construct

Table 5. Theme 1- Cost efficiency and life-cycle savings

Author(s)	Objectives	Methodology	Key Findings	Relevance
Bechauf et al. (2022)	To evaluate Nature-Based Solutions in infrastructure planning	Cost-benefit analysis	Nature-based solutions are cheaper in the long term than grey infrastructure	Applicable to budget-constrained cities
OECD (2020)	To explore development cooperation for resilient infrastructure	International report	Nature-Based Solutions reduce operational costs and prolong infrastructure life	Useful for climate-adaptive urban planning
World Bank (2023)	To assess the financial viability of Nature-Based Solutions for resilience	Guideline for developers	Long-term savings through resilience	Provides financial justification for Nature-Based Solutions in LMICs

Source: Authors' Construct

A consistent theme across the literature is that Nature-Based Solutions, while occasionally demanding higher upfront investment, prove more cost-efficient over time. Bechauf et al. (2022) argue that green infrastructure, such as green roofs and permeable surfaces, reduces long-term operational costs, including energy bills and maintenance. This perspective is reinforced by the OECD (2020), which frames NBS as resilient investments capable of withstanding climate shocks better than conventional infrastructure. Adding a development finance angle, the World Bank (2023) provides a practical guideline for developers, illustrating how NBS reduce project risks by lowering future repair and replacement costs. The three sources confirm each other's findings, though they approach the topic from different vantage points: research, policy, and implementation. Together, they establish NBS as a smart financial strategy for infrastructure planning, especially in resource-constrained cities.

The economic potential of NBS to enhance urban land values and attract tourism is well supported. Weaver (2024) demonstrates that properties

located near parks, greenways, or waterfronts often command higher prices due to improved aesthetics and livability. This finding is echoed by TEEB (2011), which outlines how ecological restoration and well-managed green spaces contribute to both direct and indirect economic growth. World Bank Group (2024) links these benefits to the tourism sector, suggesting that NBS can turn urban green zones into attractions that stimulate the local economy. This is especially relevant for culturally rich cities like Kumasi, where blending urban greenery with heritage can promote eco-tourism. The sources, though addressing different economic pathways, converge on the idea that NBS create value not only for residents and investors but also for cities at large.

Nature-Based Solutions are recognized as catalysts for green employment, especially in sectors tied to ecological restoration and sustainability. Network for Engineering with Nature (2025) emphasizes job opportunities in horticulture, environmental education, and urban ecosystem management. UNEP (2011) offers broader statistical evidence, stating that investments in NBS produce more jobs per dollar

Table 6. Theme 2- Increase in property values and tourism potential

Author(s)	Objectives	Methodology	Key Findings	Relevance
Weaver (2024)	To assess impact of green spaces on property values	Market analysis	Proximity to green spaces increases real estate value	Encourages city beautification through Nature-Based Solutions
The Economics of Ecosystems and Biodiversity (TEEB) (2011)	To quantify biodiversity's economic benefits	Global synthesis	Green spaces boost both property value and tourism	Demonstrates financial return from Nature-Based Solutions
World Bank Group (2024)	To explore Nature-Based Solutions and nature tourism linkages	Policy brief	Urban green areas foster tourism and jobs	Relevant for Kumasi's tourism and cultural potential

Source: Authors' Construct

Table 7. Theme 3 - Job creation and green economy opportunities

Author(s)	Objectives	Methodology	Key Findings	Relevance
Network for Engineering with Nature (2025)	To promote green jobs through Nature-Based Solutions	Program analysis	Jobs can be created in ecological fields	Addresses unemployment in Ghanaian cities
UNEP (2011)	To advocate for decent green jobs in sustainability	Global policy report	Nature-Based Solutions investments create more jobs per dollar than grey infrastructure	Key to economic development and social equity
Forestry Commission Ghana (2025)	To highlight the benefits of the "Tree for Life" reforestation	Project profile	Tree planting supports livelihoods and ecosystems	Relevant to Ghana's national programs

Source: Authors' Construct

Table 8. Theme 4 - Reduced public health costs

Author(s)	Objectives	Methodology	Key Findings	Relevance
Chausson et al. (2020)	To map the effectiveness of Nature-Based Solutions for climate adaptation	Global review	Nature-Based Solutions help reduce disease risks and health expenses	Particularly important during seasonal floods in Kumasi
Eliassen (2024)	To examine the health benefits of nature exposure	Public health commentary	Nature reduces stress and improves well-being	Justifies Nature-Based Solutions for public health improvement
Raymond et al. (2017)	To create a framework for Nature-Based Solutions co-benefits	Conceptual paper	Nature-Based Solutions reduce air pollution and health issues	Integrates Nature-Based Solutions into health policy planning

Source: Authors Construct

than grey alternatives. Forestry Commission Ghana (2025) grounds these insights in local reality, showing how Ghana's tree-planting and reforestation programs are already creating meaningful work, particularly for youth and marginalized communities. These three sources align on the point that NBS not only offer environmental gains but also play a vital role in advancing inclusive and sustainable economic development.

There is strong agreement across the literature that NBS contribute to improved public health and reduced healthcare spending. Eliassen (2024) outlines how access to green spaces can improve mental well-being and encourage physical activity, while Raymond et al. (2017) provide a structured framework showing that NBS reduce exposure to urban stressors like air pollution and heatwaves. Chausson et al. (2020) extend the discussion to disease prevention, emphasizing that green infrastructure helps prevent flood-related illnesses, such as cholera, which are still common in African cities. Collectively, these studies complement each other, painting a comprehensive picture of how NBS support human health, directly through environmental improvements and indirectly through reduced pressure on public health systems.

5. CONCLUSION

This paper has brought to the fore the multifaceted value of Nature-Based Solutions for confronting both environmental and economic issues of rapidly urbanizing cities, especially in Sub-Saharan Africa. Based on an extensive body of literature, this study confirms that Nature-Based Solutions, including urban forests, green roofs, riparian buffers, bioswales, and constructed wetlands, present credible alternatives to traditional infrastructure. These nature-embedded interventions are beneficial for climate regulation, air and water quality improvement, biodiversity support, urban flood reduction, and rehabilitation of degraded ecosystems. Economically, they are life-cycle cost-effective, stimulate green jobs, enhance property values, and indirectly save public health spending. Notwithstanding increasing awareness of these benefits, implementation across most African cities remains low due to institutional inertia, fragmented urban planning systems, budgetary limitations, and limited localized technical capacity. If cities like Kumasi are to achieve resilient and sustainable urban futures, Nature-Based Solutions need to be mainstreamed into policy, planning, and practice in a coherent and context-sensitive fashion. Towards this, some concrete steps are

suggested. First, it is necessary that city planning authorities in Kumasi directly integrate Nature-Based Solutions into the city's Metropolitan Spatial Development Framework. Such key strategies should involve the creation of green corridors, replenishing urban forests, and repurposing drainage systems to incorporate bioswales and retention landscapes. Integrating these elements into official urban planning documents will help ensure their formal acceptance and long-term internalization within future land use and infrastructural investments.

Secondly, attempts should be made to create a specialized reforestation partnership that involves the Forestry Commission of Ghana, private sector developers, and civil society organizations. The partnership should aim at the regeneration of peri-urban ecological buffer zones with native plant species, in addition to offering livelihood incentives for local communities. Such multi-stakeholder arrangements are able to integrate environmental objectives with socio-economic empowerment, enhancing the sustainability and ownership of such interventions. Furthermore, specific Nature-Based Solutions for flood mitigation need to be put in place in recognized high-risk areas within Kumasi, such as Atonsu, Asokwa, and Dakodwom. These localities need to be prioritized for interventions such as constructed wetlands, vegetated retention ponds, and floodplain restoration. Integration of such interventions should also be supported by localized hydrological monitoring systems and the involvement of community-based maintenance teams to facilitate functionality and adaptation to seasonal dynamics.

The Government of Ghana, through its fiscal authorities and environmental agencies, should establish a tax rebate or financial incentive program for real estate developers that incorporate green infrastructure elements in their construction ventures. These elements can range from green roofs, permeable pavements, and rain gardens. Such economic tools would motivate the private sector to adopt environmentally friendly designs and enhance broad-based adoption of Nature-Based Solutions within the urban construction sector. In support of employment and capacity building, a formal training and certification program in green infrastructure management should be established under the regulation of technical and vocational education councils. The program should equip youth with hands-on skills in

ecological landscaping, urban horticulture, environmental monitoring, and maintenance of green systems. Establishing a formal green jobs pipeline will not only decrease youth unemployment but also develop the technical workforce essential to maintain urban Nature-Based Solutions. The Environmental Protection Agency of Ghana should update its Environmental Impact Assessment guidelines to expressly compel developers to consider and include Nature-Based Solutions as preferred mitigation options. This regulatory improvement would guarantee that nature-based options are not disregarded in urban development and their benefits considered during initial phases of project design and approval.

To quantify the ecological impacts of Nature-Based Solutions over time, biodiversity monitoring stations should be placed in strategic urban green areas, such as restored wetlands and urban parks. Such monitoring stations could be maintained in collaboration with academic institutions like the Kwame Nkrumah University of Science and Technology. They would yield empirical evidence on ecological indicators such as diversity in flora and fauna, soil health, and air purity, facilitating evidence-based management and adaptation of interventions. Nature-Based Solutions are not just a conceptual fad but a practical, cost-effective, and ecologically responsible pathway to sustainable urban development. Their potential to respond to multiple environmental and socio-economic issues simultaneously makes them especially appropriate to complex urban realities like those of Kumasi. Their success, however, requires deliberate policy integration, institutional innovation, and active community engagement. By implementing the specific recommendations detailed above, Ghanaian and other cities can tap into the full potential of Nature-Based Solutions to create resilient, inclusive, and ecologically vibrant urban futures.

6. LIMITATION OF THE STUDY

While this study provides a comprehensive synthesis of the economic and environmental benefits of Nature-Based Solutions (NBS) for sustainable infrastructure in Kumasi, several limitations should be acknowledged. First, the research relied primarily on secondary data obtained from peer-reviewed literature, reports, and case studies, with a focus on English-language sources. This approach, while ensuring academic rigor, may have introduced publication

bias by excluding relevant grey literature, non-English publications, and community-level experiential knowledge that could offer additional contextual insights. Despite the increasing interest in NBS within Ghana, the availability of “localized empirical studies specific to Kumasi” remains limited. Much of the evidence base was drawn from broader Sub-Saharan African or international contexts, which, although valuable, may not fully capture the unique socio-ecological, cultural, and governance dynamics of Kumasi. Consequently, certain recommendations in this paper, while theoretically sound, should be interpreted with caution until further localized research validates their applicability. The synthesis of findings from diverse methodological approaches, ranging from empirical field studies to conceptual frameworks, introduced potential challenges in ensuring full comparability across studies. Variations in study design, measurement indicators, and spatial scales may influence the extent to which the findings can be directly compared or generalized. Finally, the study did not incorporate primary field data such as stakeholder interviews, site-specific ecological measurements, or cost-benefit analyses of ongoing NBS initiatives in Kumasi. Such data could have provided a richer, more grounded understanding of local feasibility, performance, and socio-economic trade-offs. Future research would benefit from mixed-methods approaches that combine systematic literature reviews with empirical fieldwork to validate and refine these findings in real-world settings.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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