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A Review of Ecosystem-Based Elements to Mitigate City Vulnerabilities

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Abstract: Ecosystem-based elements (EBE) are considered effective solutions to address adaptation to climate variation and mitigation in urban areas, offering the potential to decrease vulnerability and enhance resilience. This study examines ecosystem-based adaptation (EBA) to mitigate urban vulnerability via a review of the literature. The factors hindering the application of EBE in urban precincts were identified, and their applications to reduce urban risks were explored. Inadequate partnership, limited skills, scarce budgetary provisions, and bureaucratic administrative processes were some significant challenges to the successful adoption of EBE. Some application strategies to mitigate the identified problems include the formulation of robust environmental policies, harmonisation of public and private financing collaboration, as well as monitoring the mechanisms of EBE integration. Abiotic EBE, like water bodies, roof gardens and greenery in cities, offer practical gains which include the reduction of carbon footprint and urban heat island syndrome, improving the ecosystem and promoting community cohesiveness. Thus, to promote the well-being of city dwellers and the adaptive capacity of natural ecosystems, this study stresses the importance of integrated approaches for EBA and mitigation actions known as climate-resilient administration. By tackling extant urban risks and instituting a basis for future environmental and spatio-physical benefits, incorporating EBE could make cities adaptable. Policy-makers, construction industry experts, and property owners could adopt this study's outcomes to build inclusive, intelligently sustainable, and liveable cities.

Keywords: *Adaptation and Mitigation, Climate Change, Ecosystem-Based Elements, Environmental Quality, Urban Resilience and Sustainability, Urban Risks and Vulnerabilities.*

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I. INTRODUCTION

Unregulated human activities have made many urban centres more vulnerable to climate fluctuation, thereby necessitating the mainstreaming of ecosystem-based solutions (EBS) as effective environmental assets. These strategies promote resistance to sustainability issues by using diverse ecological elements to lessen urbanisation-related hazards (Xie & Bulkeley, 2020). According to Castelo et al. (2023), Cortinovis et al. (2022), and Chausson et al. (2020), the use of ecosystem-based adaptation (EBA) has become widely acknowledged as a viable strategy for urban adaptation and mitigation of climate variation, with the potential to reduce risks and increase city resilience. Such remedies can reduce vulnerabilities in diverse ways by making biodiversity less sensitive to the impact of global warming. This is achieved by collaboration with nature to enhance strategies for solving community issues: boosting capacity for adaptation (Woroniecki et al., 2022), increasing public awareness (Seddon et al., 2020), and lowering ecosystem sensitivity to climate effects (Seddon et al., 2020). EBA promote soil preservation, penetration and filtration, regulates urban flooding and enhances the quality of water (Graffiths et al., 2024; Martín Muñoz et al., 2024; Wendling & Holt, 2020). Similarly, networking EBE boosts city resilience and protection against flooding (Palermo et al., 2023). Thus, design and placement factors are determinants for rating EBA worth in an urban setting.

Ecosystem-based elements have the propensity to assuage urban risks and vulnerability, influence climate variability, and make their awareness and knowledge significant. When EBS elements are combined, like water security system integration and urban greenery cultivation, resistance to flooding and high temperatures is enhanced. For instance, endangered folks like the aged, the physically challenged, pregnant women and children who dwell in densely populated areas are more likely to experience the severe effects of urban heat islands, which are aggravated by global warming. Therefore, the presence of plants and water features can significantly lower the Physiological Equivalent Temperature (PET) of and ease urban thermal conduction for senior citizens, according to the Greater Athens survey (Tousi et al., 2025; Semeraro et al., 2024). From the foregoing, Ayo-Odifiri (2024) emphasised that EBS foster resilience in urban residences to improve environmental quality. Furthermore, Strong et al. (2025) and Chersich et al. (2023) underscore how EBE can address maternal and child health during extreme heat and effectively mitigate health risks in other vulnerable demographics. It also reveals the diverse benefits of natural interventions in the planning and design of cities.

However, it is noteworthy that EBEs themselves are vulnerable to changes in climate patterns (Chausson et al., 2020; Seddon et al., 2020), necessitating adaptive management strategies (Kauark-Fontes et al., 2023a; Van der Meulen et al., 2023). To enhance the adaptation of EBE to mitigate urban vulnerabilities, some areas that require specific attention according to Frantzeskaki et al. (2022), Chausson et al. (2020), and Frantzeskaki (2019) include evidence-based relevance of EBA to alleviate climate risks and improved application techniques to awaken city residents' consciousness. Adams et al. (2025) and Van der Jagt (2021) said the challenges of EBS implementation can be tackled via reflexive ways that offer stakeholders cooperation. Along with Allen et al. (2023), Kauark-Fontes et al. (2023b), the Intergovernmental Panel on Climate Change (IPCC, 2021) and Pörtner et al. (2021), the IPCC report highlighted the significance of EBA integration to manage climate variability effects. Thus, viewing EBE perception against a larger climate-resilient development context, it is aimed to ensure that city dwellers have a sustainable future in their natural environment. So, the relationship between urban vulnerability and EBA becomes indispensable for offering feasible policy frameworks that initiate resilience and sustainability in built-up environments.

Notably, many researchers have validated the advantages of EBE on environmental air quality (Ascenso et al., 2021), biodiversity conservation (Xie & Bulkeley, 2020), reduced risks of disaster (De Silva et al., 2022; Ommer et al., 2022), low carbon footprint (Yin et al., 2024; Pan et al., 2023), social wellbeing (Liu et al., 2021), as well as urban inclusivity (Bush & Doyon, 2019), which are factors that promote urban sustainability. Nilsson et al. (2024) report that Nairobi underpinned the benefit of implementing EBS in informal settlements. Furthermore, demonstrates EBA's potential to offer a competitive alternative to traditional grey surfaces while improving flood resilience. Therefore, deploying EBE in urban design is critical to developing cities that are viable, inclusive and resilient. Based on the above, there are methodological and knowledge gaps, hence, this paper reviews ecosystem-based elements to mitigate city vulnerabilities via the following objectives;

- Identify the challenges facing ecosystem-based solutions in cities; and
- Examine ecosystem-based adaptation to reduce urban risks.

Evaluating the stated objectives, EBE can effectively adjust cities to their adaptation and mitigation strategies, ensure social equity and leverage technological tools for monitoring and evaluation to enhance urban resilience and sustainability.

II. MATERIALS AND METHODS

This adopted system of appraisal of literature helps to explore comprehensively extant studies on EBS practices and challenges, urban risks and vulnerability. The review outlined the research's selection criteria, sources of data, elicitation period, search strings and process for synthesising the findings. Only English-based published articles were the materials for this research. Two research concerns extracted from the general objective were examined, thus;

- RQ1. What are the challenges facing ecosystem-based solutions in cities?

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- RQ2. How does ecosystem-based adaptation reduce urban risks?

Published papers on the challenges, significance and adaptation of EBS, and causes of urban risks and vulnerability were revised to address the research questions. Studies on rural areas and those not related to climate change were excluded. This study's approach coheres with Chigbu et al. (2023) and Ayo-Odifiri et al. (2022), where literature review signifies a process social scientists engage in, inquiring and obtaining rapid and doable outcomes for broad information operationalisation. The study used a data collection process at five stages (Salman et al., 2024; Mohamed Shaffril et al., 2021; Snyder, 2019), comprising research question formulation, search and extraction of related research, quality evaluation of the papers, and findings and discussion of results. Thus, papers that were relevant to the research questions published from 2011 to 2025 (15 years) and sourced from Google Scholar and Scopus databases were considered adequate in line with Ayo-Odifiri (2024).

The literature search string included "ecosystem-based solutions" OR "ecosystem-based elements" OR "ecosystem-based adaptation" OR "nature-based solutions" AND "urban vulnerability" OR "urban risks" AND "climate change." Three hundred and twenty-two (322) peer-reviewed papers were selected from the 2 databases (Google Scholar =278, Scopus = 22). The abstracts were revised for relevance to the study at a 3-scale of 'very significant' (3) to 'insignificant' (1), and the quality of the studies included was evaluated by two environmental experts. Thereafter, 37 papers were used to conduct this research, and the outcomes were appropriately discussed.

III. RESULTS AND DISCUSSION

The outcomes based on the literature search regarding challenges facing ecosystem-based solutions in cities and ecosystem-based adaptation to reduce urban risks were discussed in this section. The inclusion criteria elicited 37 papers used as representative samples of the range of diverse urban risks, vulnerabilities and ecosystem-based solutions implemented.

➢ *The Challenges of Ecosystem-Based Solutions in Cities*

The review identified diverse ecosystem-based solutions (biotic and abiotic elements), including green infrastructure, green roofs, green spaces, vertical greens, and constructed wetlands, each focusing on specific climate-related vulnerabilities in urban areas. However, several management challenges inhibit the effective adaptation of ecosystem-based solutions in cities. They include poor collaborative governance as a significant inhibition. The complex nature of EBE requires collaborative monitoring by stakeholders, including government agencies, the private sector, and citizens. Van Der Jagt et al. (2021) agreed that fragmented decision-making processes and siloed approaches often hindered effective collaboration. But the absence of a unified framework to plan and manage EBA complicates the governance landscape (Castellar et al., 2024; Albert et al., 2019). Therefore, scarce knowledge of EBS concepts among stakeholders poses another challenge. Likewise, variation in the definition and scope of EBS leads to ambiguity in their application (Li et al., 2025), yet attains relevance as a viable tool for addressing urban sustainability and resilience. This knowledge gap extends to policymakers and urban planners, who may struggle to integrate EBE into existing urban development frameworks (Castellar et al., 2024). Financial constraints and limited funding availability are persistent obstacles to EBA. The long-standing benefits of EBS are habitually overlooked in favour of short-term economic gains, making it difficult to attract sufficient funds to execute EBS projects (Van Der Jagt et al., 2021), particularly in public spaces.

Funding options are further complicated by the absence of standardised techniques to determine the financial benefit of ecosystem services offered (Li et al., 2025). The integration of EBS is hampered by administrative obstacles such as strict regulatory frameworks and antiquated urban planning laws. The multipurpose characteristics of EBS are not considered by many extant regulations, which makes it difficult to introduce EBA into urban planning and development processes (Castellar et al., 2024; Frantzeskaki, 2019). As a result, a holistic policy thrust that targets the various urban facilities framework is required to deal with these issues. This emphasises the necessity of developing strategic policies at the national and sub-national levels to identify previous obstacles to governance and make it easier for EBE to be widely adopted in urban areas.

The examined studies showed that the different ecosystem-based solutions varied in their ability to manage flood runoff, improve ecosystems, and lessen the consequences of urban heat islands. Coordinating collaboration between the private and public sector, funding methods, however, should encourage shared financial responsibilities from stakeholders like turban inhabitants, property owners and developers who benefit from EBE. Tools to address the organisational framework, access to resources and shared planning and management are inadequate, despite the availability of instruments to help overcome a lack of expertise in EBS implementation (Albert et al., 2019). This implies that the creation of instruments and approaches to resolve the aforementioned issues should be given top priority in the outlines for regulation. Hence, adapting monitoring mechanisms toward improved support of EBS incorporation deserves a multi-stakeholder approach. This involves the conceptualisation of robust outlines to tackle ecosystem-based elements' intricate challenges and improve the procedures to assess and justify EBS benefits. Furthermore, the advancement of private sector initiatives for public interest and developing tools to foster institutional capacity and collective governance. By focusing on these elements, policy-makers can advance better conditions to mainstream EBE in urban locales.

➢ *Ecosystem-Based Adaptation to Reduce Urban Risks*

Many cities confronted with flooding, loss of biodiversity and extreme temperatures require some innovative approaches to gain resilience. Ecosystem-based

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solutions represent a strategic method to mitigate urban risks and vulnerabilities using natural elements on built-up infrastructure. These include creating green roofs, restoring urban wetlands and enhancing urban forests to provide both socio-economic and environmental benefits. In agreement with Martín Muñoz et al. (2024) and Palermo et al. (2023), Ranasinghe et al. (2024) highlighted the significance of zoning using environmentally conscious techniques to conserve wetlands, which is vital for flood retention and climate adaptation. The cost-effectiveness and competitive advantages of integrating EBS to enhance flood management over the traditional grey space agree with the study of Nilsson et al. (2024) in Nairobi. Consequently, Albert et al. (2019) revealed that integrating EBS into the built environment not only mitigates vulnerabilities but also fosters urban sustainability.

Incorporating EBS into urban areas offers multi-dimensional profits beyond mere aesthetic enhancement, directly addressing urban risks and vulnerability. These include roof gardens, urban greenery and pervious pavement, which are critical to moderate urban environmental heat effects, hence reducing energy consumption and improving residents' overall health and well-being. Additionally, EBS facilitate stormwater management through natural filtration and attenuation and effectively minimises flood risks, which are increasingly frequent because of climate change. Therefore, adopting such strategies not only contributes to a more resilient urban ecosystem but also fosters community engagement and social cohesion, as well as vital components for sustainable urban living. De Silva et al. (2022) and Ommer et al. (2022) emphasised the relevance of blending adaptive measures with emissions reduction strategies for carbon sequestration, which Yin et al. (2024) and Pan et al. (2023) identified, thereby promoting climate-resilient development that combines urban health with the resilience of natural habitats.

The adaptation of ecosystem-based solutions to mitigate urban vulnerabilities not only confronts issues of the environment but also reveals vital socioeconomic advantages. By fostering roof gardens, urban greenery and wetlands, cities can enhance biodiversity while simultaneously minimising the urban heat island effect, and also tackle issues of air quality and stormwater management more effectively. This approach contributes to climate resilience and promotes ecological health, aligning with the findings of Allan et al. (2023), Kauark-Fontes et al. (2023b) and IPCC (2021), which highlights adaptation strategies with mitigation efforts, termed climate-resilient development. Furthermore, these solutions often engage local communities, fostering social cohesion and improving public well-being through increased access to green spaces. Economically, the adoption of EBS can lead to cost savings in urban infrastructure maintenance and reduce the financial burden associated with climate-related disasters, thus providing cities with a sustainable pathway which coheres with the advocacy of Kauark-Fontes et al. (2023a) and Chausson et al. (2020) for adaptive management to tackle urban vulnerability to climate risks via EBS. Embracing these solutions can yield natural habitats natural habitats numerous benefits, transforming urban landscapes into more resilient environments. In addition, vertical gardens on building facades and rooftop urban agriculture are some innovative approaches to integrating EBS into urban fabrics.

IV. CONCLUSION AND RECOMMENDATION

Conclusively, the adaptation of EBS represents a pivotal mechanism to mitigate urban vulnerability during escalating climate challenges. Introducing natural elements into the urban design planning process offers cities more resilience to social, economic and environmental stresses, and motivates defensible urban ecosystems. Allan et al. (2023), IPCC (2021), and Pörtner et al. (2021) revealed that such an approach was reinforced by the accounts that emerged from the IPCC report, which validated the overwhelming linkages between human societies, ecosystems, and climate. In addition, the report highlights the justifiable evidence-based policies to adopt these solutions and reinforces their reliability in producing flexible urban surroundings.

As cities emerge, preference for EBS strategies not only tackles instant vulnerabilities and risks but also presents a long-term basis for social, psychological and ecological benefits, and guarantees an achievable future for city dwellers amidst eventual climate uncertainties. The preferential advocacy for incorporating EBE into existing urban policies can be adopted via diverse key approaches of a viable framework. EBS consequences on the public space provide environmentally friendly benefits, enhance the urban fabrics, social inclusivity and equity, and community health and safety. Furthermore, cautious planning and implementation that aligns land-use and urban activities and circulation strategies through integrated actions could offer better interaction between climate adaptation and mitigation, thereby supporting urban resilience against anticipated environmental and climatic risks (Agrawal et al., 2020). These inclusive indulgences are crucial for nurturing urban areas that can withstand varying environmental situations to thrive.

This study provides invaluable insight into creating inclusive, sustainable and resilient cities by professionals in the construction industry, researchers, property developers, house owners, stakeholders, policymakers, and the application of industrial revolution technologies. Significantly, the outcomes underscore the necessity for multidisciplinary teamwork between architects, planners and natural scientists to optimise the planning, design and execution of EBS in urban environments. Future studies should assess the performance index and cost-benefit analysis of ecosystem-based solutions in metropolitan areas.

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