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Nature-Based Approaches for a Healthier Planet and Geographical Information Systems

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Abstract: Nature-based solutions (NBS) for a healthier planet refer to methods inspired by nature to tackle environmental problems and manage natural resources sustainably. These solutions often focus on supporting the natural functions of ecosystems and include strategies to minimize the environmental impacts of human activities. Geographic Information Systems (GIS) are technological tools for collecting, storing, analyzing, and displaying geographic data. Combining NBS and GIS can provide a more effective and holistic approach to environmental problems. This study focuses on the potential benefits of GIS-supported NBS in areas such as climate change adaptation strategies, environmental management, disaster management, water resources management, urban planning and green ınfrastructure, and nature conservation. In summary, GIS-supported NBS can be used in various fields to help manage our planet more healthily and effectively. By adopting a holistic approach, this paper evaluates the areas where GIS can contribute to the effective management of geographic data and the implementation of NBS. In this context, solutions on how GIS can be used for NBS are shared.

Keywords: Spatial planning, Disaster management, Climate change, Environmental management

Introduction

Global warming, climate change, natural disasters, and environmental degradation pose threats in today's world. These issues affect human health, ecosystems, and economic stability negatively (Berlemann & Steinhardt, 2017; Capelli et al., 2021). Numerous studies indicate that the frequency and intensity of disasters are increasing, with population growth and unhealthy economic expansion leading to the depletion of critical environmental resources such as vegetation, wetlands, and coral reefs, which serve as vital barriers against disasters (Ibarrarán et al., 2009). It is well-known that climate change-induced natural disasters predominantly manifest as hydro-meteorological events, such as heatwaves and floods, and that traditional engineering solutions and grey infrastructure are unfortunately insufficient to address their root causes. On the contrary, these approaches render both people and ecosystems more vulnerable to such disasters in the long term (Kumar et al., 2020).

Nature-based solutions (NBS), emphasized in international agreements such as the Sendai Framework for Disaster Risk Reduction (Arce-Mojica et al., 2019), offer sustainable solutions to many disaster risks arising from climate change. These approaches aim to provide environmental, social, and economic benefits by utilizing the natural processes and services of ecosystems. According to Kumar et al. (2021), NBS, inspired and supported by nature, develops cost-effective solutions to social and community problems while also protecting human well-being and the environment. However, advanced tools and methodologies are required for the effective planning, implementation, and monitoring of NBS.

This study explores how Geographic Information Systems (GIS), one of the aforementioned advanced tools, plays a critical role in the implementation of NBS. GIS is vital for the collection, analysis, and visualization of spatial data. These technologies provide a scientific and practical basis for planning NBS and assessing their impacts. GIS can be used to map the spatial distribution of ecosystem services, analyze disaster risks, and develop climate adaptation strategies. The study presents examples highlighting the role of GIS in NBS applications and proposes a framework for NBS and GIS integration. Thus, this study aims to develop solutions for the necessary integration of NBS and GIS by focusing on their relatively unexplored intersection.

In conclusion, this paper emphasizes the importance of NBS for a healthier and more sustainable planet while thoroughly examining the capabilities provided by GIS for the effective implementation of these approaches. The ultimate goal is to contribute to the global adoption and application of nature-based solutions.

Nature-Based Solutions

NBS strategies aim to provide sustainable solutions to societal challenges by utilizing natural processes and ecosystem services. The European Commission defines NBS as "solutions that are inspired and supported by nature, are cost-effective, and simultaneously provide environmental, social, and economic benefits while also contributing to resilience" (Kumar et al., 2021). The International Union for Conservation of Nature (IUCN) describes NBS as "actions that are inspired by, supported by, or copied from nature" (Albert et al., 2021).

The concept of NBS was first explored in 2013 as innovative solutions based on natural systems that balance the needs of nature and society (Sowińska-Świerkosz & García, 2022). NBS is a suite of solutions that, rather than opposing nature, work alongside it to support ecosystems, promote sustainability, and benefit biodiversity while making societal life more manageable (Voskamp et al., 2021). With increasing population growth, human interventions in nature have intensified, leading to more frequent natural disasters such as floods, earthquakes, and fires, especially in recent years. In this context, NBS emphasizes concepts like sustainability, resilience, and disaster management to address social and environmental challenges such as climate change adaptation, achieving sustainable development goals, protecting biodiversity, and managing water resources sustainably by observing ecological processes (Voskamp et al., 2021).

According to Ruangpan et al. (2020), the primary reason for presenting NBS as a crucial solution is the opportunities offered for adapting to future changes, mitigating the impacts of climate change, and enhancing human well-being. NBS provides benefits in various fields, including climate change, water management, biodiversity conservation, urban sustainability, and human well-being, through the preservation, sustainable management, and restoration of natural systems. In this sense, NBS is a concept that serves as an umbrella for many other approaches and related elements that aim to address social and environmental problems by focusing on the benefits offered by natural processes and ecosystem services. Ommer et al. (2022) also introduce NBS as an umbrella concept for ecosystem-based approaches that provide alternatives to traditional engineering solutions in disaster risk reduction.

Principles of Nature-Based Solutions

NBS is based on the principle of protecting and enhancing the services provided by ecosystems (Faivre et al., 2017). These services include water purification, carbon sequestration, soil protection, biodiversity support, and aesthetic values. These approaches ensure that ecosystems continue to deliver these services sustainably. In this respect, NBS supports long-term sustainability and resilience goals, promotes the efficient and sustainable use of natural resources by considering environmental, economic, and social dimensions, and enhances the adaptive capacity of communities by increasing resilience to shocks such as climate change and natural disasters. Due to this comprehensive nature, the planning and implementation of NBS require different expertise, understanding, and support mechanisms. Therefore, stakeholder participation and interdisciplinary collaboration are critical in the development and implementation of NBS. The integration of knowledge from various fields makes these approaches more effective and inclusive in planning and implementation processes. Participatory processes increase the acceptability of solutions by considering the needs and expectations of local communities.

However, the evolution of NBS as an overarching concept encompassing various other concepts over time and the lack of a clear definition still pose uncertainties in outlining the basic principles of NBS (Bona et al., 2022). In this regard, the core principles defined by Albert et al. (2017) for NBS are briefly summarized below. The

authors list examples of practices that meet these criteria, including coastal management solutions aimed at reducing the impacts of climate change and the restoration of floodplains to mitigate flood risks.

- Providing simultaneous benefits for society, the economy, and nature.
- Serving as an umbrella/framework for approaches and concepts addressed by different disciplines, such as blue-green infrastructure, natural capital, and ecosystem services.
- Gradually implementing and evaluating the real-world impacts and forward-looking improvements over time.
- Ensuring effective sustainability over time.

Application Areas of Nature-Based Solutions

As previously mentioned, NBS plays a significant role in combating climate change. Practices such as the conservation and restoration of forests, the rehabilitation of mangroves and wetlands, and the expansion of urban green spaces contribute to reducing greenhouse gas levels in the atmosphere by increasing carbon sequestration. At the same time, these practices enhance resilience to the impacts of climate change. NBS provides effective solutions for the conservation and management of water resources. Practices such as natural water retention areas, green infrastructure, and wetland restoration improve water quality, reduce flood risks, and ensure the sustainability of the water cycle (Carvalho et al., 2022; Ramirez-Agudelo et al., 2020). These approaches promote the sustainable use of water resources and facilitate preventive measures against water crises.

In cities, NBS is used to enhance urban sustainability and quality of life (Raymond et al., 2017). Practices such as green roofs, vertical gardens, urban parks, and green corridors reduce the urban heat island effect, improve air quality, and support biodiversity. At the same time, these solutions positively impact the physical and mental health of urban residents (Bona et al., 2022; La Notte et al., 2021). NBS is critical for the conservation of biodiversity and the sustainable management of ecosystems. Practices such as expanding protected areas, habitat restoration, and connecting natural habitats increase species' survival and reproduction chances. These solutions preserve ecosystem functionality and resilience, ensuring biodiversity sustainability.

Green infrastructure projects in urban areas provide essential examples of sustainable urban development. For instance, green roofs and vertical gardens implemented in Stuttgart, Germany, play a crucial role in reducing the urban heat island effect and improving air quality (Hebbert & Web, 2012). These types of projects contribute to making cities more livable and sustainable (Figure 1).

Figure 1. Roof gardens in Stuttgart (Hebbert & Web, 2012).

The restoration of mangrove ecosystems is an effective example of NBS for both biodiversity conservation and climate change adaptation in coastal areas. In the Philippines, where mangrove areas have significantly declined due to urbanization, fuel provision, and fishing activities, mangrove restoration projects have shown successful results in reducing coastal erosion, sequestering carbon, and preserving fishing resources (Macera et al., 2024).

Especially following the Yolanda typhoon in 2013, the Mangrove and Coastal Forest Development Project, initiated in 2015 as part of the National Greening Program, facilitated the restoration of mangrove areas in the country through the participation of various stakeholders (Valenzuela et al., 2020).

Figure 2. Mangrove areas in Del Carmen, Philippines (http-1).

NBS holds significant potential in addressing sustainable development and environmental challenges. GIS is a strategic tool, especially in the effective implementation of NBS, for conducting the necessary spatial analyses and developing planning/design solutions. The broader and more practical application of NBS and GIS integration is essential for both environmental sustainability and societal well-being. In this context, scientific research, policy development processes, and efforts to raise public awareness are essential for the adoption and dissemination of NBS.

Nature-Based Solutions and Physical Planning

NBS is a dynamic interdisciplinary structure with site-based characteristics capable of providing different solutions in every environment (Kauark-Fontes et al., 2023). Therefore, it plays a significant role in physical planning processes. Physical planning encompasses the design, arrangement, and development of settlements and infrastructure. Integrating NBS into these processes is crucial for ensuring environmental sustainability and enhancing the quality of life in communities (Albert et al., 2021). Asare et al. (2023) emphasize that NBS has recently offered innovative measures for solving environmental problems in city centers and improving ecosystems. For example, the creation of small-scale wetlands or ponds helps significantly reduce flood risks while increasing green spaces and vegetation, preventing surface runoff and pollution in cities. Moreover, NBS is beneficial in minimizing natural disaster risks through physical planning and design. These approaches reduce the severity and impacts of disasters, thereby increasing community safety and resilience. Physical planning based on NBS aims to adapt to global climate change, reduce disaster risks, protect natural ecosystems, and minimize the environmental impacts of urbanization and industrialization, thereby preserving long-term ecological balance (Albert et al., 2021; Voskamp et al., 2021).

NBS supports the integration of the benefits obtained from nature and ecosystem services into traditional planning and development processes, addressing environmental, social, and economic challenges (Kauark-Fontes et al., 2023). Practices such as natural water retention areas, forest conservation and restoration, green roofs, and vertical gardens, among others, play a crucial role in reducing greenhouse gas emissions and improving air quality.

Additionally, these solutions increase resilience to the adverse effects of climate change, such as floods, droughts, and the urban heat island effect. The benefits of NBS in physical planning processes are not only social and environmental but also economic. For example, green spaces and parks create recreational areas for people living in urban areas while also having positive effects on mental health. At the same time, these areas support local economies and contribute to economic development through tourism and recreational activities. NBS reduces costs by promoting energy and water savings, thus encouraging economic sustainability.

On the other hand, inadequate physical planning and NBS integration can limit the benefits provided by nature and lead to issues such as ineffective resource use and environmental injustice. In this context, researchers have developed many planning support system proposals centered around NBS (Sarabi et al., 2022). The decision on which NBS to apply in which area is a critical stage in planning and NBS integration. Figure 3 summarizes the steps for determining NBS solutions to be applied in the physical planning process.

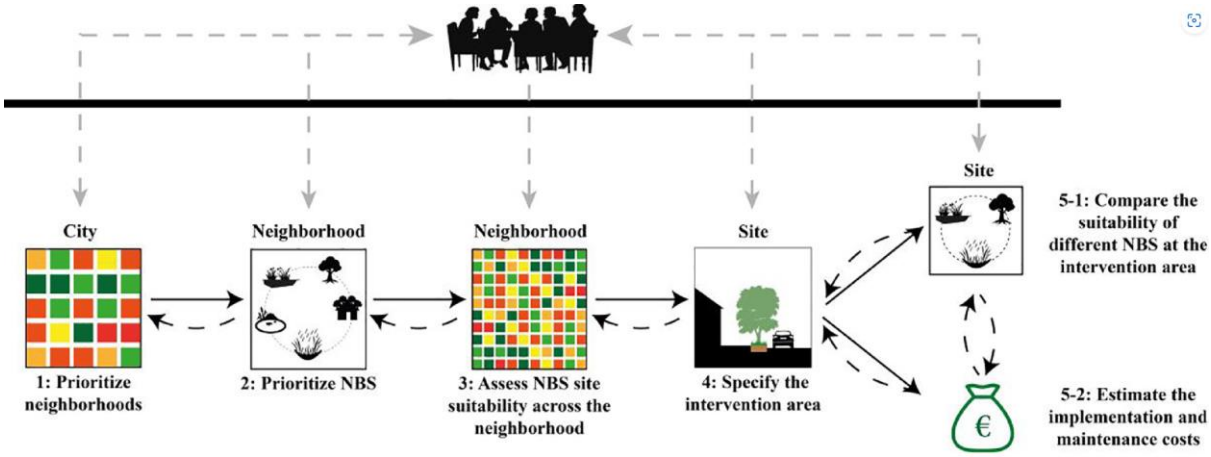

Figure 3. Determining NBS in the physical planning process (Sarabi et al., 2022).

The integration of NBS into physical planning processes should begin at the strategic planning and policy development stages. Policies and strategic plans that highlight the benefits and potential of NBS facilitate the adoption and implementation of these approaches. These processes should encourage stakeholder participation and consider the needs and expectations of different sectors and communities.

In spatial planning and design processes integrated with NBS, the characteristics and potential of local ecosystems should be analyzed, and NBS that are most suitable for the physical characteristics of the planning/design area, disaster risks, and stakeholder expectations should be implemented. In this process, the integration of nature-based elements such as green infrastructure networks, ecological corridors, and natural water management systems enhances environmental sustainability and societal benefits.

Monitoring and evaluation processes are also important to ensure the effectiveness of NBS in physical planning processes. The performance and impacts of implemented nature-based solutions should be regularly monitored and evaluated. These processes are crucial for identifying successful practices and areas that need improvement. Additionally, these evaluations provide information and experience for future planning processes, promoting the more effective and widespread implementation of nature-based approaches.

Nature-Based Solutions and Geographic Information Systems

NBS aims to develop sustainable and resilient environmental solutions by utilizing ecosystem services. GIS is a critical tool in the planning, implementation, and monitoring of these approaches. GIS enhances NBS's effectiveness and applicability through its capabilities in spatial data collection, analysis, modeling, and visualization.

GIS plays a vital role in spatial analysis and modeling processes for NBS. Analyzing the spatial distribution of natural ecosystems, water resources, vegetation, and land use provides critical information for the planning and implementation of NBS. Applications for NBS vary depending on the problem under investigation, and GIS-based analyses and mapping, which are conducted during decision-making processes regarding the suitability and applicability of the targeted solution, are used to predict the potential impacts of nature-based solutions and determine the most appropriate strategies (Sowińska-Świerkosz & García, 2022). In short, GIS-based models are advanced tools used to predict the potential impacts of nature-based solutions and determine the most appropriate strategies.

For many years, GIS has been effectively used by researchers and scientists to assess natural disaster risks and the impacts of climate change. NBS, to provide resistance against floods, droughts, erosion, and other natural disasters, has developed databases for NBS projects on open-source and licensed platforms such as ThinkNature, Eklipse, Oppla, Unalab, Urbangreenup, Growgreen, Naturvation, Nature4Cities, Climatekic ACT on NBS (Memisoglu, 2022). The goals of these platforms include using GIS to spatially identify and analyze risks, determine the regions where NBS are most effective, and take necessary preventive measures.

While NBS protects against disaster risks, it also supports the sustainable management and conservation of natural resources. Again, in this process, GIS is known to be an essential system for conducting inventory,

analysis, management, and forecasting studies related to natural resources. Many projects use GIS-supported models and methods to monitor and manage natural resources such as water resources, forests, agricultural lands, and biodiversity. GIS-based maps and databases visualize the current status and changes of resources, aiding in the development of conservation and management strategies (Memisoglu, 2022).

GIS is a critical element in physical planning, and planning requirements have been an essential pillar in the historical development of GIS. In this respect, GIS facilitates the integration of NBS into participatory planning processes. GIS-based tools and platforms enable stakeholders and communities to visualize and analyze spatial data. In this way, it supports more inclusive and informative decision-making by bringing together the knowledge and opinions of different stakeholders. Moreover, continuous monitoring and evaluation are necessary to ensure the effectiveness of NBS. GIS provides comprehensive data for monitoring and evaluating the performance of implemented NBS. GIS-based monitoring systems regularly monitor changes in ecosystems and the impacts of nature-based solutions, allowing for necessary improvements and corrective measures to be taken.

In conclusion, GIS is an indispensable tool in the planning, implementation, and monitoring of NBS. The spatial analysis, modeling, risk assessment, resource management, participatory planning, and monitoring capabilities provided by GIS enhance the effectiveness and sustainability of nature-based solutions. The integration of GIS and NBS contributes significantly to the development and implementation of sustainable and resilient environmental solutions.

Conclusion

This study aims to emphasize the importance of NBS in physical planning processes, using different steps and frameworks from the past to the present, and to highlight the benefits of GIS technology and methods at this stage. The integration of NBS and GIS is crucial in developing sustainable and resilient social and environmental solutions and is indispensable in physical planning. While NBS offers innovative solutions to environmental problems by utilizing ecosystem services, the spatial analysis, modeling, and monitoring capabilities provided by GIS enhance the effectiveness and applicability of these approaches.

The main contributions of the information provided in the study are summarized below:

- The connection between NBS, physical planning, and GIS is clearly explained, providing a primary motivation for the planning and implementation of nature-based solutions in future studies.
- Practical suggestions and methods for the effective use of GIS in relation to NBS are provided. This can help improve spatial data collection, analysis, and visualization processes in future research.
- The role of NBS in creating sustainable and resilient cities is emphasized. This is important for urban planners, local governments, and policymakers.

Based on the fundamental information presented in this study, research and applications on the following topics can be pursued:

- Pilot projects testing the applicability of NBS and GIS in different geographical regions and environmental conditions can be developed. These projects can evaluate the general applicability of nature-based solutions by offering customized solutions for different ecosystems and communities.
- Research examining the role of NBS and GIS in developing resilient solutions against climate change and natural disasters can be conducted.
- Studies evaluating the economic and social impacts of NBS can help better understand the contributions of these approaches to sustainable development goals. Research focusing on their impacts on vulnerable communities and disadvantaged areas is fundamental.
- Research on new technologies and data integration methods supporting the integration of GIS and NBS can be conducted. This enables more precise and comprehensive analyses, increasing the effectiveness of nature-based solutions.

This paper demonstrates the potential of NBS and GIS integration to ensure environmental sustainability and resilience. It is believed that this integration will provide theoretical and practical contributions to future studies. Future research will further advance the integration of nature-based solutions and GIS, enriching knowledge on developing sustainable and resilient environmental solutions.

Discussion and Recommendations

GIS offers unique capabilities in collecting, analyzing, and visualizing spatial data for nature-based solutions. These technologies can help tackle various environmental problems more effectively. The theoretical impacts of this study include strengthening the scientific foundations of NBS and developing new methods and models to ensure the integration of GIS with nature-based solutions. However, uncertainties regarding how NBS should be conceptually addressed, the relationship between different practices and approaches with NBS, the challenges in evaluating and monitoring the long-term benefits of NBS, and the challenges brought by the multidisciplinary and stakeholder processes in determining the correct NBS applications are significant issues raised by many researchers. On the other hand, the fact that GIS technologies, which emerged to provide effective responses to planning requirements, are still not adequately used in practical planning processes and that GIS-based studies are concentrated in academic and project-based processes indicate that some measures need to be taken regarding the integration of NBS solutions into physical planning studies with GIS support. In this context, the following key areas should be addressed to ensure the more accurate integration of NBS into physical planning studies and to support the effective use of GIS technologies.

Education and Capacity Building: Training programs on GIS and NBS should be organized, and expertise in these areas should be increased. Universities and research institutions can enhance knowledge accumulation by adding new courses on these topics to their curricula.

*Policy and Strategy Development***:** Local and national policies and strategies should be developed supporting the integration of nature-based solutions and GIS. These policies should include financial and technical support mechanisms to encourage the implementation of NBS.

*Data Sharing and Collaboration***:** Platforms that facilitate the sharing of GIS data and information related to NBS should be established. Collaboration between public institutions, the private sector, and civil society organizations should be increased.

*Research and Development***:** More research should be conducted on the integration of NBS and GIS, and innovative solutions in this field should be supported. Research projects can be used to evaluate the applicability and impacts of nature-based solutions.

*Pilot Projects and Applications***:** Pilot projects and applications demonstrating the integration of NBS and GIS should be implemented. By providing successful application examples, these projects can promote the adoption of similar solutions in other regions.

In conclusion, this study presents a framework suggesting that GIS should be used as a strategic tool to enhance the effectiveness of NBS. This framework is essential for both the academic community and practical applications. The integration of nature-based solutions and GIS is an essential step toward a healthier and more sustainable planet.

Scientific Ethics Declaration

The authors declare that they are responsible for the scientific, ethical, and legal aspects of this article published in EPESS.

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