

NATURE-BASED SOLUTIONS FOR CLIMATE CHANGE MITIGATION AND ADAPTATION

SOLUÇÕES BASEADAS NA NATUREZA PARA MITIGAÇÃO E ADAPTAÇÃO À MUDANÇA DO CLIMA

SOLUCIONES BASADAS EN LA NATURALEZA PARA MITIGAR EL CAMBIO CLIMÁTICO Y ADAPTARSE A ÉL

PAULA DE ARAUJO SOUZA, MBA | UFRJ – Universidade Federal do Rio de Janeiro, Brasil

VICTOR HUGO SOUZA DE ABREU, Dr. | UFRJ – Universidade Federal do Rio de Janeiro, Brasil

ABSTRACT

As climate change impacts intensify globally, identifying effective and integrated approaches to mitigation and adaptation is increasingly urgent. This article investigates the potential of Nature-Based Solutions (NbS) as multifunctional strategies capable of simultaneously reducing greenhouse gas emissions and increasing socioecological resilience. Through a structured bibliographic review of peer-reviewed articles, institutional reports, and case studies published between 2018 and 2024, the study synthesizes current scientific evidence on the role of NbS in climate policy and practice. The findings reveal that NbS can contribute up to 30% of the mitigation needed to meet the Paris Agreement targets and reduce climate-related risks by 26%, particularly through ecosystem restoration, urban greening, and sustainable land management. Despite growing recognition, gaps remain in implementation, financing, and policy integration. The article offers actionable recommendations for embedding NbS into national planning, local governance, and urban infrastructure design, emphasizing the need for inclusive, context-specific strategies. By bridging knowledge and practice, this review reinforces the strategic importance of NbS in building a climate-resilient and sustainable future.

KEYWORDS

Nature-Based Solutions; Climate change; Adaptation; Mitigation.

RESUMO

À medida que os impactos da mudança do clima se intensificam globalmente, torna-se cada vez mais urgente identificar abordagens eficazes e integradas para mitigação e adaptação. Este artigo investiga o potencial das Soluções Baseadas na Natureza (SbN) como estratégias multifuncionais capazes de, simultaneamente, reduzir as emissões de gases de efeito estufa e aumentar a resiliência socioecológica. Por meio de uma revisão bibliográfica estruturada de artigos científicos, relatórios institucionais e estudos de caso publicados entre 2018 e 2024, o estudo sintetiza as evidências atuais sobre o papel das SbN nas políticas e práticas climáticas. Os resultados revelam que as SbN podem contribuir com até 30% da mitigação necessária para alcançar as metas do Acordo de Paris e reduzir em 26% os riscos associados ao clima, especialmente por meio da restauração de ecossistemas, infraestrutura verde urbana e manejo sustentável do uso da terra. Apesar do reconhecimento crescente, persistem lacunas em sua implementação, financiamento e integração nas políticas públicas. O artigo apresenta recomendações práticas para incorporar as SbN ao planejamento nacional, à governança local e ao desenho de infraestruturas urbanas, destacando a necessidade de estratégias inclusivas e adaptadas ao contexto. Ao aproximar o conhecimento científico da aplicação prática, esta revisão reforça a importância estratégica das SbN na construção de um futuro resiliente e sustentável frente à mudança climática.



PALAVRAS-CHAVE

Soluções baseadas na natureza; Alterações climáticas; Adaptação; Mitigação.

RESUMEN

A medida que los impactos del cambio climático se intensifican a nivel global, se vuelve cada vez más urgente identificar enfoques eficaces e integrados para la mitigación y la adaptación. Este artículo investiga el potencial de las Soluciones Basadas en la Naturaleza (SbN) como estrategias multifuncionales capaces de reducir simultáneamente las emisiones de gases de efecto invernadero y aumentar la resiliencia socioecológica. A través de una revisión bibliográfica estructurada de artículos científicos, informes institucionales y estudios de caso publicados entre 2018 y 2024, el estudio sintetiza la evidencia científica actual sobre el papel de las SbN en las políticas y prácticas climáticas. Los resultados revelan que las SbN pueden aportar hasta el 30% de la mitigación necesaria para alcanzar los objetivos del Acuerdo de París y reducir los riesgos climáticos en un 26%, especialmente mediante la restauración de ecosistemas, el reverdecimiento urbano y la gestión sostenible del uso del suelo. A pesar del creciente reconocimiento, persisten vacíos en su implementación, financiación e integración en los marcos políticos. El artículo presenta recomendaciones prácticas para incorporar las SbN en la planificación nacional, la gobernanza local y el diseño de infraestructuras urbanas, destacando la necesidad de estrategias inclusivas y adaptadas al contexto. Al conectar el conocimiento científico con la acción práctica, esta revisión refuerza la importancia estratégica de las SbN para construir un futuro sostenible y resiliente frente al cambio climático.

PALABRAS CLAVE

Soluciones basadas en la naturaleza; cambio climático; adaptación; mitigación.

1. INTRODUCTION

Human actions have generated and are likely to continue generating severe consequences for the planet. Since the Industrial Revolution, significant changes have been imposed on the environment, such as increased natural resource consumption, substantial global population growth, and rising greenhouse gas (GHG) emissions, which continue to grow substantially to this day (RODRIGUES et al., 2021; XIMENES & MAGLIO, 2022).

The disordered growth of cities has led to unplanned and uncontrolled urban occupation. This imbalance contributes to environmental degradation as urban centers, for the most part, have been developed by channeling rivers and replacing green areas with concrete and asphalt, disregarding their benefits and making cities impermeable (MARQUES DA SILVA, 2023; FUNDAÇÃO GRUPO BOTICÁRIO, 2024; DOS SANTOS et al., 2024; DE ABREU, ODA & MONTEIRO, 2025). The reduction of permeable areas increases surface runoff, causing floods during periods of intense rainfall, alters the water balance, and reduces water availability. It also affects water quality in bodies of water receiving such waste, with impacts that compromise public health and infrastructure (MARQUES DA SILVA, 2023; FUNDAÇÃO GRUPO BOTICÁRIO, 2020).

According to the Summary for Policymakers (SPM) of the IPCC Sixth Assessment Report (AR6), the misuse of land and energy over more than a century of fossil fuel combustion has caused global warming, leaving over three billion people in countries highly vulnerable to climate change. These impacts are often exacerbated for the poorest populations, which experience precarious infrastructure and lack of access to basic services such as sanitation and housing. Indigenous, riverside, and quilombola communities, which have historically contributed least to climate change, are among the most vulnerable and disproportionately affected groups (IPCC, 2023).

These transformations of nature by humans, coupled with climate impacts such as heatwaves, intense rainfall, rising sea levels, pollution, and wildfires, have already caused irreversible damage to biodiversity and society (PBM/CPES, 2018a; DE ABREU et al., 2024b). In this context, there is a dual possibility: the worsening of climate change impacts in the coming decades due to the current development model that put at risk the resilience of natural systems,

and the potential of biodiversity itself to help create an adaptable and environmentally sustainable society by reducing emissions that contribute to global warming and mitigating the effects of climate change (PBM/CPES, 2018a).

Promoting sustainable development for all involves integrating adaptation and mitigation measures to resiliently address climate challenges, with Nature-Based Solutions (NbS) emerging as transformative measures (XIMENES & MAGLIO, 2022). The International Union for Conservation of Nature (IUCN) pioneered the concept of NbS, defining them as “actions aimed at protecting, managing, and restoring natural or modified ecosystems sustainably, addressing societal challenges such as climate change, food and water security, or natural disasters in an effective and adaptive manner, providing well-being and biodiversity benefits simultaneously” (XIMENES & MAGLIO, 2022).

The concept has increasingly gained traction in global agendas, such as Agenda 2030, the New Urban Agenda (NAU), the Paris Agreement, the Aichi Targets, and the Sendai Framework for Disaster Risk Reduction. NbS significantly contribute to achieving the Sustainable Development Goals (SDGs), particularly SDGs 3, 6, 11, 12, 13, 15, and 17 (FUNDAÇÃO GRUPO BOTICÁRIO, 2020). When correctly implemented, NbS to address the consequences of climate change can be low-cost and low-risk while preserving essential ecosystems for our survival (RODRIGUES et al., 2021). Additionally, they can be applied on smaller or larger scales, from localized solutions to landscape-level interventions (FUNDAÇÃO GRUPO BOTICÁRIO, 2024; DE ABREU et al., 2024b).

It is widely agreed that NbS need to be developed, implemented, and supervised by local communities and Indigenous peoples, or in close collaboration with them, promoting rights and benefits for local populations (SEDDON, 2022; DE ABREU, SANTOS & MONTEIRO, 2022). NbS can substantially contribute to both mitigation and adaptation, serving as a fundamental component of the global response needed for climate action. According to the IPCC report, they are among the five most effective strategies for mitigating carbon emissions (WWF; IFRC, 2022a). Recognizing that nature can be part of the solution for climate-resilient development makes biodiversity preservation efforts even more urgent.

Therefore, this paper seeks to critically analyze the role of Nature-Based Solutions (NbS) as effective tools for both climate change adaptation and mitigation. Although the concept of NbS has gained significant attention in recent

years, existing academic literature often treats mitigation and adaptation as separate domains, lacking integrative analyses that explore their convergence within practical implementation frameworks. Moreover, there is a scarcity of systematized evidence regarding how NbS perform across different scales, territories, and socioeconomic contexts—particularly in terms of effectiveness, replicability, and cost-benefit trade-offs when compared to conventional engineered approaches.

In this context, the central research questions guiding this review are:

- (i) How have NbS been applied to simultaneously address climate change mitigation and adaptation goals?
- (ii) What are the main barriers and opportunities for scaling NbS in urban, rural, and coastal environments?
- (iii) To what extent do the reviewed cases demonstrate the multifunctionality and socioecological co-benefits of NbS?

By addressing these questions, this article aims to fill a gap in the academic debate by offering a structured synthesis of recent studies and institutional reports, with an emphasis on the dual functionality of NbS in facing the escalating challenges of the climate crisis. The selection of sources was guided by this analytical framework, focusing on peer-reviewed articles, international guidelines, and practical case studies that demonstrate the real-world implications of NbS. Ultimately, the article intends to promote a more critical and comprehensive understanding of NbS, fostering their informed adoption by policymakers, planners, environmental managers, and civil society, while reinforcing the need for integrated, inclusive, and context-sensitive planning. The study is structured as follows: Section 1 provides a contextualization, the problem, and the objectives of the work. Section 2 presents the methodology used for the bibliographic review. Section 3 addresses the theoretical framework through bibliographic support, and Section 4 presents the final considerations.

2. METHODOLOGY

The methodology adopted in this article consists of a bibliographic review structured in four stages: (I) Study Definition; (II) Data Collection; (III) Reading of Articles; (IV) Development of the Theoretical Framework (Figure 1).



Figure 1: Research Development Methodology.

Source: The authors.

The first stage, called “Study Definition,” involves selecting the research topic and defining its scope. This process includes identifying the research problem, establishing objectives, and determining relevant keywords.

The second stage, referred to as “Data Collection,” is characterized by the careful and objective selection of articles. This was achieved through direct searches on academic research platforms such as Capes, SciELO, and Google Scholar, using keywords like “nature-based solutions” and “climate change”.

Additionally, documents from reputable institutions, such as the International Union for Conservation of Nature (IUCN), WRI Brasil, and the Intergovernmental Panel on Climate Change (IPCC), were consulted. Cross-referencing was also applied, including studies cited in works obtained through direct searches.

The third stage focused on reading and thoroughly analyzing the articles and documents selected during the data collection process. This step aimed to provide a robust foundation for the study.

Finally, the fourth stage involved the development of the theoretical framework. The objective was to compile and integrate the relevant information gathered, cross-referencing the data to present concepts and findings related to the proposed topic.

To enhance the transparency and replicability of the bibliographic review, a set of explicit criteria was adopted for the selection and analysis of the literature. The review included peer-reviewed articles, institutional technical reports, and case studies published between 2018 and 2024, with emphasis on documents that addressed NbS in the context of climate change adaptation, mitigation, or both. Sources that lacked methodological clarity or empirical support were excluded from the final sample to ensure the robustness of the findings. Preference

was given to studies with clearly defined outcomes, quantified indicators (e.g., GHG reduction, area restored), and replicable methodologies.

The prioritization of NbS strategies in the analysis was based on three main criteria: (i) their proven or estimated effectiveness in reducing climate-related risks or GHG emissions; (ii) the range of ecosystem services and co-benefits provided (e.g., biodiversity conservation, water regulation, social inclusion); and (iii) the feasibility of implementation across different governance and territorial contexts. Strategies such as mangrove restoration, urban green infrastructure, agroforestry, and watershed protection were emphasized due to their recurrence in the literature and documented positive outcomes.

Although the scope of the review was global, special attention was given to examples from Latin America—particularly Brazil—due to the region's socioenvironmental vulnerabilities, high biodiversity, and emerging policy initiatives involving NbS. Studies covering urban, rural, coastal, and forest ecosystems were included to ensure the diversity of biogeographical contexts.

3. THEORETICAL FRAMEWORK

This section examines the timeline of climate change progression and the role of NbS in this context. It explores their mechanisms for mitigation and adaptation, highlighting case studies that illustrate the practical application of these solutions and their benefits across various global contexts.

3.1. Global Climate Change Context

Since 1970, the average global surface temperature has risen more rapidly than at any other 50-year interval in at least the past two millennia. Greenhouse gas (GHG) emissions have continued to grow globally, driven by historical and current inequalities caused by unsustainable energy exploitation, inadequate land management, and changes in its use, alongside distinct consumption and production patterns between regions (IPCC, 2023).

The IPCC's AR6 Synthesis Report (SYR) notes that human influence on climate change has produced impacts across the planet, affecting the atmosphere, cryosphere, biosphere, and oceans, resulting in environmental and human losses. This includes increased frequency of heatwaves, droughts, intense rainfall, and tropical cyclones, subjecting millions to food and water

insecurity. In the short term, associated dangers are expected to include mental health issues, flooding in low-lying and coastal areas, biodiversity loss, and reduced food production in certain regions (IPCC, 2023).

The Paris Agreement calls for efforts to limit warming to 1.5°C. Beyond this threshold, the risks of extreme climate events and ecosystem collapse increase substantially. Every additional 0.5°C of global warming exacerbates these risks (WWF; IFRC, 2022b). According to the IPCC's modeled scenarios, even with very low GHG emissions, it is more likely than not that global warming will reach 1.5°C in the short term (2021–2040) (IPCC, 2023).

CO₂ concentrations in the atmosphere were higher in 2019 than at any point in at least 2 million years. This is corroborated by data showing that fossil fuel combustion accounted for significant GHG emissions. In the same year, approximately 79% of global GHG emissions originated from the energy, transport, and building sectors, while 22% came from agriculture and other land uses (AFOLU) (IPCC, 2023).

By working in harmony with nature, it is possible to reduce emissions by up to 11.7 gigatons of CO₂ equivalent annually by 2030. This amount represents more than 40% of what is necessary to curb global warming. Despite the climate crisis and unchecked exploitation of natural resources, the protection, sustainable management, and restoration of ecosystems offer a pathway to tackle social challenges, ensure human well-being, and enhance biodiversity benefits (UNEP, 2024a).

3.2. Nature-Based Solutions: Origins and Definitions

NbS are measures that utilize nature and its ecosystem services to generate multiple environmental, social, and economic benefits (PELLEGRINI et al., 2023; ; DE ABREU et al., 2024a). These solutions play a fundamental role in addressing issues such as food and water security and poverty and have gained prominence for their potential to tackle climate change (SEDDON et al., 2021; GÓMEZ MARTÍN et al., 2021).

Several studies have demonstrated that NbS can reduce direct exposure to climate impacts and play a significant role in national mitigation and adaptation plans (CHAUSSEON et al., 2020; SEDDON, 2022). It has been found that 59% of NbS contribute to mitigating climate effects such as flooding, soil erosion, and reduced food production. Among 386 studies analyzed, only ten

reported no impact of NbS on climate effects (CHAUSSEON et al., 2020).

NbS can combat climate change in several ways: by reducing greenhouse gas emissions associated with deforestation and land use; capturing and storing atmospheric carbon dioxide; and strengthening ecosystem resilience, thereby assisting societies in adapting to climate risks (IUCN, 2023b).

These solutions can reduce the intensity of climate and meteorological hazards by up to 26% (WWF; IFRC, 2022a). By helping reduce disaster risks and enabling climate adaptation, NbS directly support several Sustainable Development Goals (SDGs) (Figure 2). Ten out of the 17 SDGs include targets related to disaster risk reduction (WWF; IFRC, 2022b).

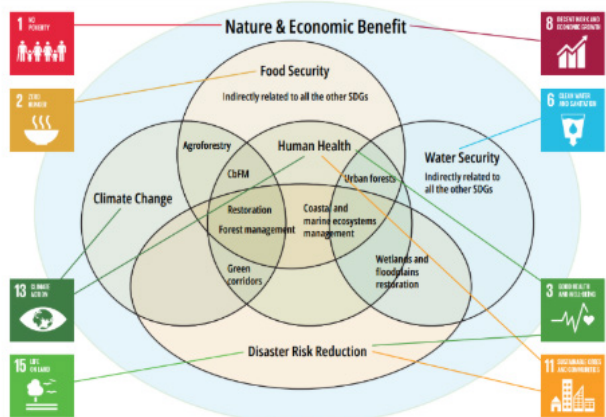


Figure 2: Sustainable Development Goals supported by NbS.

Source: WWF; IFRC, 2022b.

In urban contexts, NbS are viewed as an umbrella concept encompassing approaches such as “green-blue infrastructure” and “ecosystem-based adaptation” (FRANTZESKAKI et al., 2019; IUCN, 2023a). These solutions can complement engineering approaches for climate mitigation and adaptation, offering several advantages. As dynamic living systems, NbS have the potential for self-repair and adaptation, aligning with evolving climate change. While few studies directly contrast the efficacy of nature-based approaches with traditional methods, research indicates that nature-based infrastructure can cost 50% less than equivalent gray infrastructure and provide an additional 28% in value, delivering benefits such as pollution reduction, carbon capture, recreational spaces, and tourism promotion. Moreover, these solutions are ready for large-scale implementation (UNEP; GLOBAL EBA FUND, 2022).

A Global Standard for NbS, led by the IUCN, aims to establish a rigorous framework to guide the design,

implementation, and evaluation of interventions (IUCN, 2023a). This standard includes eight criteria and 28 indicators supported by guiding questions to help users develop effective solutions. For an initiative to qualify as an NbS, it must deliver simultaneous benefits for biodiversity and human populations (PBMC/BPBES, 2018b).

NbS are referenced in the adaptation plans of all 30 nations classified as low-income by the World Bank. Conversely, only nine (27%) of the 33 high-income nations include NbS actions. However, national intentions to implement NbS vary according to economic development levels, regions, and habitat types, and rarely translate into measurable, science-based targets (SEDDON et al., 2019).

In 2019, the richest 1% of the world’s population was responsible for 16% of global CO₂ emissions, equivalent to the emissions of approximately 5 billion people, representing 66% of the global population (KHALFAN et al., 2023). Although climate financing has been increasing globally, only 1.5% of these resources were allocated to NbS for adaptation in 2018 (EVERS et al., 2022). Currently, about \$130 billion per year is directed toward NbS, with public funds accounting for 86% and private financing 14%. However, urgent action is still needed (UNEP, 2024a).

To ensure the development of effective solutions, it is essential to plan with strong local community participation. This allows for the identification of priority areas and the obstacles and facilitators for implementation. To create more resilient and inclusive cities and achieve more accurate environmental, social, and economic outcomes, it is crucial to address the greater vulnerability of groups such as women, Indigenous peoples, the elderly, individuals living in poverty, and communities that depend directly on natural resources or are physically exposed to climate impacts (EVERS et al., 2022).

Scientific consensus indicates that achieving the Paris Agreement’s goal of limiting average temperature increases to 1.5°C requires rapid and significant reductions in global GHG emissions. NbS are vital for reducing emissions in the agricultural, forestry, and land-use sectors and for protecting and enhancing carbon sinks on land and at sea. However, these solutions must be implemented alongside rapid reductions in GHG emissions (SEDDON, 2022).

A study revealed that if peak warming is limited to a 1.5°C increase by 2055, the adoption of NbS could reduce this warming by 0.1°C. Furthermore, these solutions could continue cooling the atmosphere, provided there is an effective reduction in emissions (GIRARDIN et al., 2021). According to a Coalition for Urban Transitions

study, implementing NbS for basic infrastructure, such as sanitation and drainage, is part of a set of actions that could reduce urban GHG emissions by up to 88% by 2050 (WWF; IFRC, 2022b).

Nevertheless, the effectiveness of NbS in combating climate change depends on ecosystems' ability to withstand the impacts of these changes (UNEP, 2021). These solutions should not be seen as isolated measures for nature protection or recovery but rather as an integration of societal and natural systems into a unified framework (GÓMEZ MARTÍN et al., 2021; DE ABREU et al., 2023a, b).

NbS emerge as a tool to accelerate the transition to a global vision that values quality of life, human well-being, and connection with nature while promoting resilience, adaptation, and mitigation of climate change and preserving biodiversity (SEDDON, 2022).

3.3. Nature-Based Solutions for Climate Change Mitigation

Natural ecosystems are important sources and sinks of greenhouse gases (GHGs) (SEDDON et al., 2020). Approximately 30% of the climate mitigation needed by 2030 to meet the goals established by the Paris Agreement can be achieved through NbS (IUCN, 2023b). Nature-based mitigation solutions include measures to preserve ecosystems from damage, restore ecosystems that have undergone degradation, and adopt more sustainable practices in land management (UNEP, 2021).

One of the great advantages of NbS in mitigating climate change is their ability to offer multiple simultaneous benefits, including improvements in public health through air pollution reduction, the promotion of active mobility such as walking and cycling, and the adoption of healthy and sustainable diets (IPCC, 2023). NbS have the potential to expand carbon absorption areas on land and at sea, as well as reduce GHG emissions from human activities in agriculture, forestry, and other land use (AFOLU) (SEDDON et al., 2021).

The NbS with the greatest mitigation potential fall into three main groups. The reduction of emissions through the prevention of loss or degradation of natural ecosystems is more economical and faster than restoring carbon in already degraded ecosystems. The preservation of intact ecosystems, such as forests, wetlands (e.g., peatlands and mangroves), seaweed forests, and seagrass meadows, has the potential to limit CO₂ emissions.

NbS that promote better management of agricultural lands often lead to increased productivity while generating climate benefits. Improving the management of lands in use (such as plantations, croplands, and pastures) can result in a significant reduction of CO₂ and other emissions, as well as enable carbon capture. The restoration of ecosystems is a crucial component for protecting intact ecosystems. Recovering native vegetation cover contributes to increasing CO₂ absorption from the atmosphere (UNEP, 2021; Busch et al., 2019; Friedlingstein et al., 2019; Girardin et al., 2021; Griscom et al., 2017; Lewis et al., 2019, as cited in SEDDON et al., 2021).

In all analyses, the total mitigation potential of NbS depends significantly on the decarbonization of the global economy. If the global average temperature exceeds 1.5°C, many ecosystems may lose their capacity to act as carbon sinks and become net GHG sources (SEDDON et al., 2021). Therefore, all forms of mitigation must be implemented at their maximum potential (UNEP, 2021). Assuming decarbonization occurs, NbS can still contribute to reducing warming (GIRARDIN et al., 2021).

Girardin et al.'s model estimates that NbS that avoid emissions will see rapid adoption by 2025 and absorb carbon, achieving a mitigation of 10 gigatons of CO₂ annually (Gt CO₂ yr⁻¹). This ambitious scenario involves halting ecosystem degradation globally, restoring approximately 700 million hectares of ecosystems, and improving the management and use of 2.5 billion hectares of land by mid-century.

Studies suggest that various tropical nations can mitigate over 50% of their national emissions through NbS, particularly by preventing deforestation, at a cost of up to \$100 per ton of CO₂. This value has served as the basis for estimating "viable" mitigation potential (GRISCOM, as cited in SEDDON et al., 2021; UNEP, 2021). The IPCC estimates the mitigation potential of avoided deforestation between 0.4–5.8 Gt CO₂ yr⁻¹ and carbon sequestration in vegetation and soil through afforestation and reforestation practices between 0.5–10.1 Gt CO₂ yr⁻¹ (SEDDON et al., 2020).

Restoring 350 million hectares of forest by 2030 could sequester up to 1.6 Gt CO₂ yr⁻¹, representing 14% of global carbon emissions (SEDDON et al., 2019). The most cost-effective contributions to CO₂ emissions reductions are expected to come from preserving intact forests, wetlands, and grasslands, avoiding emissions of 4 Gt CO₂ annually. Conversely, the highest potential for carbon absorption in biodiversity comes from sustainably managing forests, agricultural lands, and grasslands,

absorbing 4 Gt CO₂ annually, as well as restoring native forests and wetlands, capturing 2 Gt CO₂ annually (GRISCOM, as cited in SEDDON et al., 2021).

These actions could reduce global warming by 0.1°C if warming peaks at 1.5°C by mid-century. However, if the warming peak reaches 2°C by the end of the century, there will be more time for NbS benefits to accumulate, reducing the warming peak by 0.3°C. Nonetheless, the total potential of NbS is relatively small compared to what can be achieved by eliminating fossil fuels (GIRARDIN et al., 2021).

Brazil, among Latin American and Caribbean countries, has the greatest mitigation potential—approximately 50%, equivalent to 1.7 ± 0.5 Gt CO₂ eq yr⁻¹ (ROE et al., 2021). As a country with continental dimensions, representing 47% of South America's territory and hosting 15-20% of the world's biodiversity, Brazil bears significant responsibility for global environmental preservation. Its degradation impacts on the integrity of the entire biosphere. Combined with the elimination of illegal and legal deforestation and large-scale native vegetation restoration, NbS can mitigate approximately 80% of Brazil's net zero GHG commitment over the next 20 years (SOTERRONI et al., 2023).

Soterroni's scenarios estimate that restoration solutions would mitigate 10-19% of emissions during 2020–2050, while afforestation (commercial planting) would have limited reach. Natural forest recovery could retain 40 times more carbon than commercial plantations and seven times more than agroforestry (LEWIS, as cited in SEDDON et al., 2020). However, commercial plantations, often monocultures, pose challenges due to their reliance on a single species, which may negatively affect biodiversity (SEDDON et al., 2020).

Analyses indicate that although NbS will play a crucial role in combating climate change through 2050, their most significant impact will occur in the latter half of this century. To capitalize on this potential, it is essential to immediately begin ecosystem protection, management, and restoration processes (SEDDON et al., 2021). Delaying mitigation measures will contribute to increased global warming, causing greater damage to natural and human systems, which are nearing their adaptation limits. Many NbS aimed at climate change mitigation also hold the potential for adaptation, and vice versa, though few studies address both aspects simultaneously (IPCC, 2023).

It is imperative to strengthen political structures to ensure that NbS can deliver multiple benefits for both climate change mitigation and adaptation, as well as other

essential ecosystem services supported by biodiversity (SEDDON et al., 2020).

3.4. Nature-Based Solutions for Climate Change Adaptation

Mitigation measures aimed at alleviating climate change will have a significant impact on reducing the severity of effects that nations, societies, and ecosystems will face. However, reducing greenhouse gas (GHG) emissions alone is not enough to halt these impacts. Even if actions to limit temperature increases to 1.5°C are effective, some impacts are likely to persist and intensify. Therefore, it is essential to invest in strategies for climate change adaptation (CHAUSSON et al., 2020).

NbS helps communities adapt to the impacts of climate change, such as heatwaves, floods, and even wildfires (CHAUSSON et al., 2020). To maximize the benefits of NbS as an adaptation strategy, a landscape-scale approach must be adopted, including the protection, restoration, and management of urban, rural, coastal, and marine ecosystems. Ecosystem integrity and connectivity are essential to maintaining biodiversity and ensuring the resilience of NbS against future climate impacts (EVERS et al., 2022).

Some studies report difficulties in implementing adaptation strategies and a lack of consolidated data on the impacts of NbS focused on adaptation (EVERS et al., 2022). Owen, cited by Seddon (2019), argues that there are no metrics capable of capturing the effects of interventions—whether nature-based or not—on the adaptation process. In other words, there is no equivalent metric to the gigaton (Gt) of CO₂ used to measure GHG reductions.

Improving the monitoring of NbS effectiveness for adaptation is crucial to expanding access to financing for these projects (EVERS et al., 2022). The main obstacles to climate change adaptation include limited resources, lack of private sector and population engagement, low climate awareness, weak political commitment, scarce and slow research, and a reduced sense of urgency. There is a growing gap between the predicted costs of adaptation and the resources available, which are primarily public funds directed mainly toward mitigation efforts.

Global financial flows for adaptation, from both public and private sources, are insufficient, especially in developing countries where international financial support for climate issues is lacking, resulting in adaptation costs five to ten times higher than current public funding

levels. The implementation of NbS can significantly help bridge this gap (IPCC, 2023; SEDDON, 2022).

The vulnerability framework for socioecological systems, formalized by the IPCC, which links ecosystem vulnerability with socioeconomic system vulnerability, serves as a conceptual model for understanding how nature supports human adaptation to climate change. NbS can reduce the vulnerability of socioecological systems in three ways: by decreasing exposure to climate hazards, reducing sensitivity to adverse impacts, and increasing adaptive capacity (SEDDON et al., 2020, 2021).

A specific type of NbS known as Ecosystem-Based Adaptation (EbA) has proven effective in helping human adaptation to climate change. This strategy has been widely recognized for its ability to reduce flood and heat risks in urban areas (SEDDON et al., 2019; IPCC, 2023). For example, the restoration and protection of coastal ecosystems, such as mangroves, offer natural defenses against floods; reforestation can combat desertification and improve water security; and wetlands play a crucial role in natural drainage, reducing floods, soil erosion, and landslides (UNEP, 2024b; SEDDON et al., 2021).

Research indicates that protecting coastal ecosystems can benefit over 500 million people worldwide, generating more than \$100 billion annually. For inland ecosystems, reforestation, afforestation, and sustainable forest management promote climate adaptation benefits for more than 25 million people, while reducing deforestation benefits between 1 and 25 million people (SMITH et al., 2019, as cited in SEDDON et al., 2021). Mangroves, for instance, prevent \$57 billion in annual flood damage across countries like China, India, Mexico, the United States, and Vietnam (IUCN, 2023a).

The effectiveness of adaptation strategies, including ecosystem-based approaches, tends to decrease as global warming increases (IPCC, 2023). While primarily adaptive in nature, EbAs also have the potential to mitigate climate change by reducing emissions resulting from habitat loss and ecosystem degradation (UNEP, 2024b). Ecosystems are inherently dynamic, possessing the ability to self-organize and adapt, making them more resilient to disturbances compared to engineered interventions (SEDDON et al., 2019).

Deep, rapid, and consistent mitigation efforts combined with accelerated implementation of adaptation measures this decade could significantly reduce future climate damages for people and ecosystems while bringing numerous additional benefits. Considering that

adaptation strategies generally require long timelines for execution, it is essential to intensify such actions this decade to close existing adaptation gaps (IPCC, 2023).

3.5. Effectiveness of Nature-Based Solutions in the Context of Climate Change

To demonstrate the effectiveness of NbS in combating climate change, it is essential to analyze concrete examples of projects implemented globally. Table 1 presents several practical cases showcasing how different NbS initiatives have been successfully applied across various regions of the world, highlighting their positive impacts on greenhouse gas (GHG) emissions mitigation, climate adaptation, and biodiversity promotion. These cases provide valuable insights and evidence of the potential and feasibility of NbS in addressing current climate challenges.

1. Restoration of Coastal Mangrove Forests (Vida Manglar – Colombia)
• Objective: Restore and protect 11,000 hectares of mangroves along the Caribbean coast. • Results: Mitigation: Positive. Issued 67,000 tCO₂e in credits (2015–2018). Expected to avoid 1 million tCO₂e over 30 years. Adaptation: Positive. Protects against coastal erosion, storms, and flooding. Ecological Effect: Positive. Improves habitat quality and extent. Food Security: Positive. Local Economy: Positive. Disaster Risk Reduction: Positive. Conflict and Security: Positive.
2. Pasture Management (Northern Rangelands Trust – Kenya)
• Objective: Improve pasture health in 14 pastoralist communities. • Results: Mitigation: Positive. Captures and stores 50 million tons of carbon over 30 years. Adaptation: Positive. Communities limit land degradation through rotational grazing techniques. Ecological Effect: Positive. Protects habitats and three endangered species. Water Security: Positive. Local Economy: Positive. Livelihoods: Positive.
3. River Restoration (Eddleston Water – United Kingdom)
• Objective: Reconnect the river to its floodplain, create storage ponds and wetlands to enhance natural flood management and restore biodiversity. • Results: Mitigation: Positive. Carbon storage benefits estimated at £717,000 over 100 years. Adaptation: Positive. Reduces flood peaks by 30%. Ecological Effect: Positive. Water Security: Positive. Disaster Risk Reduction: Positive. Socioeconomic Outcomes: Positive. Collaboration with farmers and foresters ensures local profitability while reducing flood risks and economic damages to communities.

4. Ecosystem Conservation (Bale Ecoregion – Ethiopia)
• Objective: Reduce overgrazing pressure and restore ecosystems, combined with agroforestry. • Results: Mitigation: Positive. Reduces deforestation by 62%. Adaptation: Positive. Resilient crop varieties and better water access. Ecological Effect: Positive. Protects 500,000 hectares of forest, increasing tree density. Food Security: Positive. Water Security: Positive. Local Economy: Positive. Disaster Risk Reduction: Positive. Conflict and Security: Positive. Socioeconomic Outcomes: Improves household income and food security.
5. Filter Gardens (General Motors Factory – Joinville, Brazil)
• Objective: Treat wastewater through filtering gardens using locally adapted vegetation integrated into the landscape. • Results: Reuses 26,000 m³ of water annually, reducing potable water consumption by 20%. Removes 90% of pollutants and reduces solid waste generation.
6. Urban Agriculture (Urban Farm in Cajuru – Brazil)
• Objective: Supply fresh, pesticide-free products to meet the needs of the local population. • Results: Sustainability; Use of renewable energy sources (solar and wind); Rainwater harvesting for irrigation; Utilization of recycled materials.
7. Rain Gardens (New York – USA)
• Objective: Manage stormwater and increase green areas. • Results: Reduces air pollution; Adds 2.4 billion m² of green spaces (2010–2018); Improves quality of life; Decreases flood probability; Reduces 1.9 billion liters of water entering the sewage system, saving on wastewater treatment costs.
8. Urban River Renaturalization (Cheonggyecheon Stream – South Korea)
• Objective: Create a sustainable urban ecosystem by restoring a stream. • Results: Attracts tourism; Increases biodiversity; Reduces temperatures; Improves air quality; Mitigates flooding; Decreases automobile traffic and increases public transport use.
9. Sponge City (Yanweizhou Park – China)
• Objective: Retain and infiltrate rainwater. • Results: Climate resilience; Increased biodiversity; Flood reduction; Improved quality of life; Lower flood risks.
10. Vertical Garden (Green Wall at Quai Branly Museum – France)
• Objective: Improve microclimate and protect the building from climate change. • Results: Reduces indoor climate control needs; Retains rainwater; Improves sound environment; Sequesters carbon and other pollutants; Shields against UV rays.

11. Ecological and Green Corridors (Green Corridor in Recreio dos Bandeirantes – Brazil)
• Objective: Conserve and connect 320.76 hectares of protected areas while adding 60.73 hectares of public areas and parks. • Results: Protects biodiversity; Connects and expands conservation areas; Promotes clean mobility; Improves public transport.
12. Coral Reef Restoration (Coral Vita – Bahamas)
• Objective: Restore degraded coral reefs using fragmentation and assisted evolution techniques to produce more resilient corals in a few months. • Results: Creates new jobs; Boosts tourism; Protects coastal areas from storms and wave force; Improves water quality.
13. Urban Park (High Line – USA)
• Objective: Revitalize degraded spaces by creating parks. • Results: Attracts tourism; Serves as a sustainability benchmark; Recovers and plants native species.

Table 1: Examples of NbS Projects in Practice Worldwide.
Source: Observatory of Innovation for Sustainable Cities, 2024; NbS Initiative, 2024.

3.6 POLICY AND FINANCING FOR NATURE-BASED SOLUTIONS

Although the severe threats posed by climate change to the global economy are well recognized, less than 5% of climate funding is allocated to addressing its impacts. Additionally, less than 1% of this funding is directed toward coastal protection, infrastructure, and disaster risk management, including NbS. Financing for NbS comes from various public and private funds at national and international levels (SEDDON et al., 2020).

The Paris Agreement, the Aichi Targets, and the Sustainable Development Goals (SDGs) have been firmly integrated into national policies and laws, establishing a consistent legal and policy foundation to potentially become the world's largest ecosystem-based climate adaptation program if adequately implemented. However, many countries still have sectoral environmental and development policies that often lack integration (PBM/ BPBES, 2018a). NbS frequently involve multiple actions over large terrestrial and marine areas, crossing legal boundaries and requiring joint decision-making among various governmental spheres and ministries. Therefore, the success of NbS depends on governance that encourages active collaboration and coordinated action among stakeholders, even amid potential conflicts of interest and priorities (SEDDON et al., 2020).

The inclusion of NbS in public policies related to health, security, development, energy efficiency, restoration, and environmental conservation is fundamental to promoting actions at all levels of government and making them an essential part of urban infrastructure. These solutions can be integrated through existing sectoral policies, specific regulations, economic incentives, and infrastructure projects such as roadworks, housing, and drainage systems (FUNDAÇÃO GRUPO BOTICÁRIO, 2020). Despite their benefits, traditional approaches and a lack of awareness of ecosystem services often hinder innovation. Overcoming these challenges requires strong institutions and well-structured planning to ensure the benefits of NbS (SEDDON et al., 2020). Incorporating NbS into urban policies is crucial for climate adaptation and resilience, although significant institutional challenges remain in coordinating efforts across different governmental bodies (EVERS et al., 2022).

For communities and ecosystems to adapt effectively, policies based on NbS must be grounded in scientific and local knowledge. Scientists and policymakers need to collaborate to identify knowledge gaps and translate ecosystem resilience science into accessible and relevant information. This requires research and professional communities to synthesize and disseminate scientific findings, considering the effectiveness of NbS at different scales and contexts. Decision-makers require clear and accessible evidence to address climate change and biodiversity issues. Mechanisms must be developed to evaluate and compare various approaches and monitor the impact of NbS on future climate change, supported by robust regulatory policies (IPCC, 2023; SEDDON et al., 2019).

3.7. PRACTICAL RECOMMENDATIONS AND POLICY INTEGRATION

The findings of this review underscore the potential of NbS to serve as effective and multifunctional tools for climate change adaptation and mitigation. However, to translate this scientific knowledge into concrete, impactful actions, it is essential to move beyond the conceptual recognition of NbS and promote their structured and systemic integration into public policies, urban planning, and territorial management strategies. Based on the evidence gathered, the following recommendations are proposed:

3.7.1. Institutionalize NbS through national and local policies

Governments should embed NbS into climate, environmental, infrastructure, and development policies by defining clear goals, indicators, and financing mechanisms. These solutions should be treated as essential components of urban infrastructure, equivalent in importance to transportation or sanitation systems. For instance, urban master plans and climate adaptation plans should explicitly prioritize the restoration of natural ecosystems, creation of green-blue corridors, and conservation of coastal and riparian buffers.

3.7.2. Foster intersectoral governance and participatory planning

Effective implementation of NbS requires coordination among different governmental sectors (e.g., environment, housing, public works, health, and education) and levels (national, regional, local). Participatory approaches involving Indigenous communities, local residents, academia, and the private sector should be prioritized to ensure socially just and context-appropriate interventions. NbS planning must reflect local vulnerabilities, cultural values, and resource availability.

3.7.3. Redirect and increase funding toward NbS projects

Despite the growing recognition of NbS, they still receive a minimal fraction of climate-related investments. International climate finance, national green funds, and public-private partnerships must allocate dedicated resources to NbS implementation, maintenance, and monitoring. Funding mechanisms should include incentives for landowners, municipalities, and businesses that adopt ecosystem-based approaches in their operations or territories.

3.7.4. Adopt NbS standards and effectiveness metrics

To enhance transparency and promote large-scale replication, NbS initiatives should follow internationally recognized standards—such as those developed by the

IUCN—and include mechanisms for evaluating their socio-environmental effectiveness. Metrics should cover not only carbon sequestration, but also risk reduction, biodiversity gains, and social co-benefits such as improved well-being, employment, and food security.

3.7.5. Promote the integration of NbS into urban resilience strategies

Urban environments—especially in developing countries—must incorporate NbS as core elements of resilience strategies. Actions such as expanding urban parks, restoring wetlands, and implementing green roofs and rain gardens can contribute significantly to flood mitigation, temperature regulation, and air quality improvement. These measures should be incorporated into the design and retrofitting of public infrastructure, affordable housing programs, and sustainable mobility plans.

3.7.6. Invest in education, capacity building, and communication

Strengthening the technical capacity of public servants, planners, engineers, and community leaders is crucial to the successful adoption of NbS. Public awareness campaigns and environmental education programs can also foster cultural change, encouraging behaviors aligned with nature-based practices and increasing social support for their implementation.

4. CONCLUSION

Nature-Based Solutions (NbS) emerge from this comprehensive review as scientifically supported, socially inclusive, and ecologically effective strategies for simultaneously addressing climate change mitigation and adaptation. The findings presented demonstrate not only the capacity of NbS to reduce greenhouse gas emissions and enhance carbon sinks, but also their ability to promote biodiversity conservation, reduce vulnerability to climate hazards, and deliver co-benefits such as improved water regulation, food security, public health, and local livelihoods. Thus, NbS go beyond isolated environmental interventions and represent a paradigm shift in how societies can reconcile development and sustainability goals through integrated, low-impact, and participatory approaches.

To effectively translate these findings into practical action, it is essential to bridge the gap between scientific evidence and decision-making processes. The first step in this direction involves the institutional integration of NbS into climate and development policies. Governments at all levels—federal, state, and municipal—should incorporate NbS explicitly into climate action plans, national adaptation strategies, land-use regulations, and urban planning instruments. Rather than being treated as optional or supplementary, NbS must become structural components of policy frameworks aimed at increasing resilience and reducing emissions. For example, ecological restoration actions such as riparian forest recovery, wetland rehabilitation, or reforestation of degraded areas should be systematically included in territorial and infrastructure planning, not as compensatory measures, but as cost-effective and multifunctional interventions with measurable climate impact.

In parallel, local governments and environmental managers should be empowered to lead the implementation of NbS through technical capacity building, access to financial resources, and institutional autonomy. Successful application depends on the ability to tailor strategies to specific regional characteristics, ecosystem conditions, and social dynamics. In this context, the role of communities—especially traditional, Indigenous, and marginalized populations—is central. Their participation in all stages of planning, execution, and monitoring ensures that projects reflect local priorities and values, while also leveraging traditional knowledge systems and fostering social inclusion. Promoting participatory mapping, community-based monitoring, and collaborative governance arrangements helps to strengthen the legitimacy and effectiveness of NbS and increases the likelihood of long-term maintenance.

Financing is a crucial dimension for turning the potential of NbS into reality. Although these solutions are often less costly than conventional infrastructure in the long run, they remain underfunded. Redirecting climate finance to prioritize NbS—both from public sources and international cooperation mechanisms—is an urgent need. Investment strategies should promote scalable models that can be replicated in different contexts and encourage synergies between public policies, private initiatives, and community-based projects. Innovative financial mechanisms, such as green bonds, payment for ecosystem services, and blended finance models, can help overcome resource limitations and stimulate cross-sector collaboration.

Equally important is the development and adoption of robust evaluation frameworks that allow for the systematic monitoring of NbS performance. Beyond biophysical indicators, such as carbon sequestration or flood reduction, it is necessary to consider social and economic outcomes, including improvements in quality of life, equity in resource access, and the generation of sustainable livelihoods. The use of internationally recognized standards, like those proposed by the IUCN, should be adapted to local realities and used to guide the planning, implementation, and scaling of interventions. Transparent evaluation not only strengthens accountability and institutional learning but also builds confidence among stakeholders and investors.

Ultimately, this study reinforces the idea that NbS should not be viewed as secondary or symbolic interventions, but as core components of sustainable development strategies capable of reshaping how societies interact with nature. By demonstrating their versatility and effectiveness, this review offers a knowledge base that can support policymakers, environmental professionals, and civil society in making informed decisions toward a more resilient, equitable, and ecologically balanced future. For this to materialize, there must be political commitment, intersectoral coordination, and an intentional shift in values—placing nature and communities at the center of climate action.

As a pathway for future research, it is recommended that scenario-based models be developed to evaluate the long-term performance of NbS under different climate, ecological, and socioeconomic conditions. Comparative studies between NbS and traditional engineering solutions, particularly in terms of cost-efficiency, durability, and social impact, can also generate valuable evidence to guide investments and policy design. Such efforts will be fundamental to ensuring that the next generation of climate policies moves beyond rhetoric and embraces transformative, nature-based pathways to sustainability.

REFERENCES

CHAUSSEON, A. et al. **Mapping the effectiveness of nature-based solutions for climate change adaptation**. *Global Change Biology*, v. 26, n. 11, p. 6134–6155, 9 set. 2020. Available at: <https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15310?af=R> Accessed on Feb. 10, 2024.

COALITION FOR URBAN TRANSITIONS 2021 **Seizing the Urban Opportunity**. Available at: <https://urbantransitions.global/en/publication/seizing-the-urban-opportunity/>. Accessed on Apr. 14, 2024.

DE ABREU, Victor Hugo Souza; SANTOS, Andrea Souza; MONTEIRO, Thaís Guedes Máximo. Climate change impacts on the road transport infrastructure: A systematic review on adaptation measures. **Sustainability**, v. 14, n. 14, p. 8864, 2022. Available at: <https://doi.org/10.3390/su14148864>.

DE ABREU, Victor Hugo Souza et al. Climate change adaptation strategies for road transportation infrastructure: A systematic review on flooding events. **Transportation Systems Technology and Integrated Management**, p. 5-30, 2023. Available at: https://doi.org/10.1007/978-981-99-1517-0_2.

DE ABREU, Victor Hugo Souza et al. Implications of Climate Change for the Brazilian Road Infrastructure. In: **COVID-19 and Climate Change in BRICS Nations**. Routledge, 2023. p. 80-99. eBook: ISBN9781032643182.

DE ABREU, Victor Hugo Souza et al. Análise de riscos climáticos em infraestruturas de transportes: uma exploração metodológica. **Boletim do Observatório Ambiental Alberto Ribeiro Lamego**, v. 18, n. 1, p. 28-44, 2024a. Available at: <https://doi.org/10.19180/2177-4560.v18n12024p28-44>.

DE ABREU, Victor Hugo Souza et al. Nature-Based Solutions to Reduce Carbon Footprint and Increase Resilience of Road Transportation Infrastructure. In: **Carbon Footprint Assessments: Case Studies & Best Practices**. Cham: Springer Nature Switzerland, 2024b. p. 159-176. Available at: https://doi.org/10.1007/978-3-031-70262-4_7.

DE ABREU, Victor Hugo Souza; ODA, Sandra; MONTEIRO, Thaís Guedes Máximo. Strategic Decisions: A Support Model For Prioritizing Projects In The Brazilian Transport Infrastructure. **MIX Sustentável**, 11(1), 107-118, 2025. Available at: <https://doi.org/10.29183/2447-3073.MIX2025.v11.n1.107-118>.

DOS SANTOS, Rafael Ferraz et al. Climate Response and Nature-Based Solutions: Evaluating the Impact

of the Belt and Road Initiative in Latin America. In: **Carbon Footprint Assessments: Case Studies & Best Practices**. Cham: Springer Nature Switzerland, 2024. p. 273-288. Available at: https://doi.org/10.1007/978-3-031-70262-4_11.

EVERS, H. et al. **Soluções baseadas na natureza para adaptação em cidades: o que são e por que implementá-las**. www.wribrasil.org.br, 6 fev. 2022. Available at: <https://www.wribrasil.org.br/noticias/solucoes-baseadas-na-natureza-para-adaptacao-em-cidades-o-que-sao-e-por-que-implementa-las> Accessed on Apr. 29, 2024.

FRANTZESKAKI, N. et al. **Nature-Based Solutions for Urban Climate Change Adaptation: Linking Science, Policy, and Practice Communities for Evidence-Based Decision-Making**. *BioScience*, v. 69, n. 6, p. 455–466, 29 maio 2019.

Fundação Grupo Boticário **CIDADES BASEADAS NA NATUREZA Infraestrutura Natural para Resiliência Urbana**. 2020. [s.l.: s.n.]. Available at: <https://www.fundacaogrupoboticario.org.br/pt/solucoes-inovadoras/Paginas/Inicial.aspx> Accessed on: Jan. 20, 2024.

Fundação Grupo Boticário **CIDADES DO FUTURO As Soluções Baseadas na Natureza ajudando a enfrentar a emergência climática**. 2024 [s.l.: s.n.]. Available at: <https://www.fundacaogrupoboticario.org.br/pt/solucoes-inovadoras/Paginas/Inicial.aspx> Accessed on Jan. 20, 2024.

GIRARDIN, C. A. J. et al. **Nature-based solutions can help cool the planet — if we act now**. *Nature*, v. 593, n. 7858, p. 191–194, 1 maio 2021. Available at: <https://www.nature.com/articles/d41586-021-01241-2> Accessed on Feb. 04, 2024.

GÓMEZ MARTÍN, E. et al. **Assessing the long-term effectiveness of Nature-Based Solutions under different climate change scenarios**. *Science of The Total Environment*, v. 794, p. 148515, nov. 2021. Available at: <https://doi.org/10.1016/j.scitotenv.2021.148515>. Accessed on Mar. 21, 2024.

IPCC Sections In: Climate Change 2023: Synthesis Report. **Contribution of Working Groups I, II**

and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 35-115, doi: 10.59327/IPCC/AR6-978929169164

IUCN 2023a **Nature-based Solutions**. Available at: <https://www.iucn.org/our-work/nature-based-solutions>. Accessed on Feb. 27, 2024.

IUCN 2023b **Nature-based Solutions for climate**. Available at: <https://www.iucn.org/our-work/topic/nature-based-solutions-climate>. Accessed on Feb. 27, 2024.

KHALFAN, A. et al. **Igualdade climática: um planeta para os 99%**. OXFAM Internacional. 2023 DOI 10.21201/2023.000001 Available at: <https://policy-practice.oxfam.org/resources/climate-equality-a-planet-for-the-99-621551/>. Accessed on Mar. 09, 2024.

MARQUES DA SILVA, A. M. **R E V I S Ã O SISTEMÁTICA DE LITERATURA SOBRE SOLUÇÕES BASEADAS NA NATUREZA NO CONTEXTO DAS CIDADES**. Euro Elecs 2023; Available at: <https://eventos.antac.org.br/index.php/euroelecs/article/view/3503/4443>. Accessed on Mar. 21, 2024.

NbS Initiative; **Case Study Platform**. 2024. Available at: <https://casestudies.naturebasedsolutionsinitiative.org/case-search/>. Accessed on May 29, 2024.

Observatório de Inovação para Cidades Sustentáveis **Estudos de Caso**. 2024. Available at: <https://oics.cgee.org.br/solucoes-e-casos/casos?tema=5b8e9ab0f543305390d41e96>. Accessed on May 29, 2024.

PBMC/BPBES, 2018a: **Potência Ambiental da Biodiversidade: um caminho inovador para o Brasil. Relatório Especial do Painel Brasileiro de Mudanças Climáticas e da Plataforma Brasileira de Biodiversidade e Serviços Ecossistêmicos. Sumário para Tomadores de Decisão**. 1ª edição [Scarano, F.R., Santos, A.S. (Eds.)]. PBMC, COPPE–UFRJ. Rio de Janeiro, Brasil. 14p. Available at: <https://www.fundacaogrupoboticario.org.br/pt/Biblioteca/Pot%C3%Aancia-Ambiental-da-Biodiversidade-um-caminho-inovador-para-o-Brasil.pdf>. Accessed on Feb. 15, 2024.

PBMC/BPBES, 2018b: **Potência Ambiental da Biodiversidade: um caminho inovador para o Brasil. Relatório Especial do Painel Brasileiro de Mudanças Climáticas e da Plataforma Brasileira de Biodiversidade e Serviços Ecossistêmicos**. 1ª edição [Scarano, F.R., Santos, A.S. (Eds.)]. PBMC, COPPE – UFRJ. Rio de Janeiro, Brasil. Available at: <https://www.bpbes.net.br/wp-content/uploads/2019/01/RelatorioTematico_ClimaCompleto.pdf>. Accessed on Feb. 15, 2024.

PELLEGRINI I. U. et al. **Soluções Baseadas na Natureza para a adaptação ao aumento do nível do mar: uma revisão sistemática**. Paranoá, n. 34, p. 1–18, 15 set. 2023. Available at: <<https://periodicos.unb.br/index.php/paranoa/article/view/47348/38542>>. Accessed on Feb. 18, 2024.

RODRIGUES, P. N. et al. **APRENDENDO COM A NATUREZA: UMA REVISÃO SOBRE NATURE-BASED SOLUTIONS (NBS)**. Revista Gestão & Sustentabilidade Ambiental, v. 10, n. 1, p. 417, 31 maio 2021. Available at: <<https://www.wribrasil.org.br/noticias/solucoes-baseadas-na-natureza-para-adaptacao-em-cidades-o-que-sao-e-por-que-implementa-las>>. Accessed on Feb. 12, 2024.

ROE, S. et al. **Land-based measures to mitigate climate change: Potential and feasibility by country**. Global Change Biology, v. 27, n. 23, p. 6025–6058, 11 out. 2021. Available at: <<https://doi.org/10.1111/gcb.15873>>. Accessed on Feb. 16, 2024.

SEDDON, N. et al. **Global Recognition of the Importance of Nature-Based Solutions to Climate Change Impacts**. 14 set. 2019. Available at: <<https://doi.org/10.20944/preprints201810.0203.v2>>. Accessed on Mar. 01, 2024.

SEDDON, N. et al. **Understanding the Value and Limits of Nature-Based Solutions to Climate Change and Other Global Challenges**. Philosophical Transactions of the Royal Society B: Biological Sciences, v. 375, n. 1794, p. 20190120, 27 jan. 2020. Available at: <<https://royalsocietypublishing.org/doi/10.1098/rstb.2019.0120>> Accessed on: Mar. 02, 2024.

SEDDON, N. et al. **Getting the Message Right on Nature-based Solutions to Climate Change**. Global Change Biology, v. 27, n. 8, p. 1518–1546, fev.

2021. Available at: <<https://onlinelibrary.wiley.com/doi/10.1111/gcb.15513>>. Accessed on Mar. 02, 2024.

SEDDON, N. **Harnessing the potential of nature-based solutions for mitigating and adapting to climate change**. Science, v. 376, n. 6600, p. 1410–1416, 24 jun. 2022. Available at: <<https://www.science.org/doi/10.1126/science.abn9668>>. Accessed on Mar. 01, 2024.

SOTERRONI, A. C. et al. **Nature-based solutions are critical for putting Brazil on track towards net-zero emissions by 2050**. Global Change Biology, v. 29, n. 24, p. 7085–7101, 31 out. 2023. Available at: <<https://onlinelibrary.wiley.com/doi/10.1111/gcb.16984>>. Accessed on Feb. 20, 2024.

UNEP, 2021 **Nature-based solutions for climate change mitigation**. Nairobi and Gland Available at: <<https://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/37318/NBSCCM.pdf>>. Accessed on Mar. 02, 2024.

UNEP, 2024a **PNUMA e soluções baseadas na natureza**. Available at: <<https://www.unep.org/pt-br/pnuma-e-solucoes-baseadas-na-natureza>>. Accessed on Mar. 08, 2024.

UNEP 2024b **Climate action**. Available at: <<https://www.unep.org/topics/climate-action>>. Accessed on Mar. 02, 2024.

UNEP; GLOBALEBA FUND. **Harnessing Nature to build Climate Resilience: Scaling up the use of Ecosystem-based Adaptation** - Executive Summary. Unep. org, 2022 Available at: <<https://wedocs.unep.org/handle/20.500.11822/40415?jsessionid=2D85D35C9FA4D3>> Accessed on Mar. 08, 2024.

XIMENES, D. S. S.; MAGLIO, I. C. **Soluções Baseadas na Natureza e adaptação climática no Brasil: estudo de cidades costeiras vulneráveis**. Revista LABVERDE, v. 12, n. 1, p. 183–206, 21 nov. 2022. Available at: <<https://www.revistas.usp.br/revistalabverde/article/view/188817/188282>>. Accessed on Feb. 15, 2024.

WWF; IFRC, 2022a IFRC - International Federation of Red Cross and Red Crescent Societies and WWF – World Wide Fund For Nature (Formerly World Wildlife Fund) **Working With Nature to Protect People** | IFRC.

Available at: <<https://www.ifrc.org/document/working-nature-protect-people>>. Accessed on Feb. 25, 2024.

WWF; IFRC, 2022b IFRC - International Federation of Red Cross and Red Crescent Societies and WWF – World Wide Fund For Nature (Formerly World Wildlife Fund) **Working With Nature to Protect People How Nature based Solutions reduce climate change and weather-related disasters** Implementing nature-based solutions to protect people and nature. [s.l: s.n.]. Available at: <https://www.ifrc.org/sites/default/files/2022-05/IFRC_%26_WWF_V_6-LR.pdf>. Accessed on Feb. 25, 2024.

AUTHORS

ORCID: [0009-0005-3454-2857](https://orcid.org/0009-0005-3454-2857)

PAULA DE ARAUJO SOUZA | MBA em Meio Ambiente pelo Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia da Universidade Federal do Rio de Janeiro | Meio Ambiente
e-mail: pauladearaujo12@gmail.com

ORCID: [0000-0002-2557-2721](https://orcid.org/0000-0002-2557-2721)

VICTOR HUGO SOUZA DE ABREU | Pesquisador de Pós-Doutorado | Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia da Universidade Federal do Rio de Janeiro | Engenharia de Transportes | Correspondência para: Av. Horácio Macedo, 2030, 101 – Cidade Universitária – Rio de Janeiro, RJ, Brasil
e-mail: victor@pet.coppe.ufrj.br

HOW TO CITE THIS ARTICLE:

SOUZA, P. A.; ABREU, V. H. Nature-based solutions for climate change mitigation and adaptation. **MIX Sustentável**, v.11, n.2, p.47-62. ISSN 2447-3073. Disponível em: <<http://www.nexos.ufsc.br/index.php/mixsustentavel>>. Acesso em: _/_/_.

SUBMITTED ON: 15/01/2025

ACCEPTED ON: 19/08/2025

PUBLISHED ON: 02/09/2025

RESPONSIBLE EDITORS: Lisiane Ilha Librelotto e Paulo Cesar Machado Ferroli

Record of authorship contribution:

CRedit Taxonomy (<http://credit.niso.org/>)

PAS: conceptualization, data curation, investigation, methodology, visualization, writing - original draft and writing - review & editing.

VHS: conceptualization, supervision, validation and writing - review & editing.

Conflict declaration: nothing to declare.