



Urban climate adaptation planning in Windhoek, Namibia: Gaps, challenges, and opportunities for Nature based Solutions

B. Hansen Gaby^{a,*}, A. Breed Christina^b

^a Namibia University of Science and Technology, Namibia

^b University of Pretoria, South Africa

ARTICLE INFO

Keywords:

Land use planning
Policy implementation
Semi-arid cities
Transformative adaptation
Urban planning
Urban resilience

ABSTRACT

Nature based Solutions (NbS) for urban climate adaptation remain underexplored in arid Sub-Saharan African (SSA) cities such as Windhoek, Namibia. This study investigates how national climate adaptation policies translate into local action, identifying gaps, challenges, and opportunities for embedding NbS in urban planning. A qualitative case study combined a review of policy documents with semi-structured stakeholder interviews. Findings reveal that while national policies and the Windhoek Integrated Climate Change Strategy and Action Plan (WICCSAP) set ambitious goals, they lack contextually derived measures and practical NbS targets, such as community-driven resilience or integrated locally tailored dryland strategies, or ecosystem-based water management, leaving the city reliant on grey infrastructure and short-term disaster risk responses. This omission exacerbates urban heat islands, flood risks, and constrains socio-ecological resilience. At the same time, both community-driven practices and municipal champions illustrate alternative pathways. Such initiatives signal early steps toward transformative adaptation where long-term systemic shifts in governance and practice are required. Locally grounded initiatives, including permaculture dryland gardens, rainfall monitoring, and the “Brown is Beautiful” campaign, demonstrate how culturally resonant NbS can integrate water conservation, ecological design, and social cohesion in Windhoek’s deprived, arid context. Within the municipality, individual planners and officials also advocate for NbS, seeking to move beyond grey solutions despite institutional barriers. Realising these opportunities requires capacity building, cross-sectoral coordination, and partnerships to institutionalise NbS in urban governance. The study makes two key contributions: first, it identifies the systemic neglect of NbS in Windhoek and Namibia’s climate policy frameworks; second, it highlights both bottom-up innovations and emerging top-down drivers that can bridge the policy implementation gap. Windhoek’s experience could offer transferable lessons for other rapidly urbanising, water-scarce cities across Sub-Saharan Africa.

1. Introduction

1.1. Climate change and urban vulnerability in Sub-Saharan Africa

Global climate change is projected to raise temperatures by 2–3°C by 2050, intensifying droughts, heatwaves, flooding, and cyclones, disproportionately affecting developing countries, particularly in Sub-Saharan Africa (SSA) (United Nations Environment Programme (UNEP) et al., (2024); World Bank, (2024); Intergovernmental Panel on Climate Change Intergovernmental Panel on Climate Change IPCC (2023)). Semi-arid urban regions in SSA are particularly vulnerable: over 55 % of the population lives in informal settlements, and more than 40 % of households lack reliable access to water, sanitation, or adequate

housing (United Nations Convention to Combat Desertification (UNCCD, 2024; Satterthwaite et al., 2020). Furthermore, semi-arid cities such as Windhoek, face compounded risks from chronic water scarcity, fragile infrastructure and struggle with recurrent flash flooding, illustrating the repercussions of climate impacts across the region (Global Center on Adaptation GCA, 2024; Thorn et al., 2021). In this context, insufficient infrastructure and weak land-use planning further amplify exposure to climate-related hazards, including floods, heatwaves, and droughts (UNCCD, 2024; UN-Habitat, 2022). Together, these pressures underscore the urgent need for integrated and contextual climate adaptation strategies that strengthen urban resilience, restore ecological systems, and improve social well-being.

* Correspondence to: Department of Architecture, Planning and Construction, 13 Jackson Kaujeua Street, Windhoek, Namibia.
E-mail addresses: ghansen@nust.na (B.H. Gaby), idabreed@up.ac.za (A.B. Christina).

<https://doi.org/10.1016/j.landusepol.2025.107877>

Received 30 June 2025; Received in revised form 10 November 2025; Accepted 18 November 2025

Available online 3 December 2025

0264-8377/© 2025 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC license (<http://creativecommons.org/licenses/by-nc/4.0/>).

1.2. Nature based Solutions as an adaptation strategy: operational challenges and opportunities

Nature based Solutions (NbS) are increasingly promoted in global frameworks as actions that protect, sustainably manage, and restore ecosystems to address societal challenges while enhancing human well-being and biodiversity (Convention on Biological Diversity, 2024; International Union for Conservation of Nature International Union for Conservation of Nature IUCN, 2020). The relationship between NbS, land-use planning, and urban resilience is inherently systemic: land-use planning determines the spatial allocation of green and blue infrastructure; NbS provide the ecological and social functions that underpin resilience; and urban resilience frameworks set performance criteria for both planning and NbS implementation (Zhu and Feng, 2025; Albert et al., 2021; Meerow and Newell, 2019). International initiatives, such as the INTERLACE project, demonstrate how NbS in 17 cities across Europe and Latin America can mitigate urban heat, manage stormwater, and enhance biodiversity (Gutiérrez et al., 2024). Yet, without integration into long term urban governance systems, NbS risk being deployed as isolated projects rather than as part of coherent systemic climate adaptation strategies (Albert et al., 2021; Berke and Stevens, 2016).

Such coherent strategies have been redefined as part of “transformative adaptation”, which calls for a deep, long-term systemic shift to address the root causes of complexity, uncertainty, and structural vulnerability. This concept is increasingly emphasised by the UNEP (2025), Intergovernmental Panel on Climate Change IPCC (2023), and scholars such as Pieterse and du Toit (2025) and Frantzeskaki et al. (2019). Unlike immediate risk management (Pieterse and du Toit, 2025), transformative adaptation seeks to reshape social, ecological, and governance systems to enable urban resilience (Birchall et al., 2025; Frantzeskaki et al., 2019). However, governance silos, institutional fragmentation, and limited municipal capacity frequently impede the integration of such systemic transformative adaptation into urban planning (Pieterse and du Toit, 2025; Rogers et al., 2024; Ziervogel et al., 2022), constraining NbS opportunities (Frantzeskaki et al., 2019). Nevertheless, NbS can play a central role in this transformative process, linking ecosystem services to land-use planning while delivering multiple social and ecological co-benefits (Raymond et al., 2017).

Nature based Solutions (NbS) such as water-sensitive urban design, integrated alongside socio-economic priorities in land-use and urban planning (Cilliers et al., 2022; Albert et al., 2021; Kabisch et al., 2017), can bolster urban resilience, which refers to a city’s capacity to prepare for, respond to, and recover from climate-related shocks (Zhu and Feng, 2025; Birchall and Bonnett, 2021; Meerow and Newell, 2019). Practical examples, such as “zai pits” in Burkina Faso, that enhance water retention and livelihoods in arid areas (Danjuma and Mohammed, 2015), illustrate how locally adapted NbS can address environmental degradation while supporting community well-being. Yet, NbS for climate adaptation remain underutilised in urban planning, as countries such as Namibia and Tanzania continue to prioritise engineered solutions that often limit gains in biodiversity, social cohesion, and long-term resilience (Thorn et al., 2021). This reflects broader implementation or operational gaps, such as local knowledge and initiatives that are rarely translated into urban policy and adaptation action plans (Covenant of Mayors in Sub-Saharan Africa (Covenant of Mayors in Sub-Saharan Africa CoM SSA 2024; Deubelli and Mechler, 2021).

1.3. Policy context: the case of Windhoek, Namibia

The NbS, land-use and urban climate adaptation dynamics are clearly visible in Namibia. Namibia’s national climate and urban planning policies provide limited guidance on urban NbS. The National Climate Change Policy (Ministry of Environment, Forestry and Tourism MEFT, 2011) largely focuses on mitigation and agriculture, leaving urban NbS underrepresented (Ministry of Environment, Forestry and Tourism MEFT, 2013). Nationally, limited fiscal allocations for urban

climate adaptation mean that NbS projects remain under-resourced compared to engineered solutions. Similar gaps are evident in other semi-arid countries, where national adaptation plans often overlook the integration of NbS into urban and land-use decision-making (Olgun et al., 2024; Terton et al., 2024; Bizikova et al., 2015). To bridge this gap, national strategies must explicitly connect climate adaptation, biodiversity, and urban planning, while ensuring support through tailored initiatives, monitoring systems, and sustainable financing mechanisms (Birchall and Bonnett, 2021; Berke and Stevens, 2016).

These national dynamics are particularly evident in Windhoek. The Windhoek Integrated Climate Change Strategy and Action Plan (2022–2028) (City of Windhoek CoW, 2023) sets resilience goals, including biodiversity conservation and informal settlement upgrading, yet fiscal constraints, fragmented governance, and tenure insecurity limit implementation (Kohima et al., 2023; Thorn et al., 2021). Implementation of NbS is further constrained by limited municipal budgets, weak data systems, and a preference for engineered solutions over nature-based approaches (Thorn et al., 2021; Du Toit et al., 2025). Sustaining NbS requires long-term stewardship and systemic planning, but municipal capacity often restricts implementation, monitoring, and maintenance (Kiribou et al., 2024; Seddon et al., 2021), which is part of the greater systemic problem. In addition, insecure land tenure, especially in informal settlements, shapes land-use decisions and discourages long-term NbS investments, limiting the integration of green infrastructure into urban and adaptation planning frameworks (GCA, 2024; UNCCD, 2024). Moreover, participatory approaches and local knowledge, which are critical for NbS in arid contexts, remain insufficiently embedded in climate adaptation and urban planning (Kibii et al., 2025; Brink and Wamsler, 2018). Together, these factors limit the operationalisation of NbS in Windhoek’s climate adaptation strategy (Wijesinghe and Thorn, 2021; Thorn et al., 2021). These challenges in Windhoek mirror broader struggles faced by cities in comparable arid and semi-arid regions, where adaptation strategies often underutilise NbS in urban planning (Deubelli and Mechler, 2021; Bizikova et al., 2015). Addressing these challenges calls for aligning climate adaptation, biodiversity, and urban planning at the local level, reinforced through city-specific bylaws, participatory planning instruments, secure tenure arrangements, and locally tailored initiatives that strengthen institutional capacity.

1.4. Study rationale and objectives

Building on these insights and to strengthen theoretical and operational linkages between policy and practice (Birchall and Bonnett, 2021), our study examines the key strategic gaps, challenges, and opportunities for operationalising or integrating existing NbS knowledge and initiatives in Windhoek. Previous studies in Namibia, such as (Davies et al., 2020; Spear et al., 2018; Crawford and Terton, 2016) highlighted broad governance and capacity barriers to adaptation, while research on rural and peri-urban and governance of NbS in arid environments (Singh and Chudasama, 2021; Thorn et al., 2021; Wijesinghe and Thorn, 2021) demonstrated their potential and hinted at possibilities for mainstreaming. However, there remains limited understanding of how to systematically translate and implement NbS within urban planning and climate adaptation policies (Corgo et al., 2024; Rogers et al., 2023; Wijesinghe and Thorn, 2021), particularly in dryland ecosystems. This gap is particularly acute in semi-arid urban contexts, where water scarcity, fragile infrastructure, and tenure insecurity create distinctive barriers to implementing and sustaining NbS interventions (UNCCD, 2024; Thorn et al., 2021; Satterthwaite et al., 2020). Our study investigates how national adaptation policies in Namibia are (or are not) translated into local implementation, why NbS remain marginal in urban planning, and how existing local NbS knowledge and initiatives can inform more transformative, systemic approaches to urban resilience. By situating Windhoek as a case study, the article could contribute to broader debates on how semi-arid African cities can embed NbS into

climate adaptation and land-use planning.

The article is structured as follows: **Section 2** outlines the methodology; **Section 3** presents results, including a synthesis of policy and stakeholder insights; **Section 4** discusses policy and planning implementation and implications; and **Section 5** provides recommendations and conclusions for arid urban adaptation.

2. Methodology

2.1. Study area

Namibia is an arid to semi-arid country, with approximately 92 % of its land classified as such, facing recurrent droughts, extreme heat, and occasional flooding that exacerbate water scarcity and infrastructure deficits in urban areas (Intergovernmental Panel on Climate Change IPCC, 2022; World Bank Group, 2021). Rapid population growth, particularly in urban areas, intensifies pressure on services, infrastructure, and land-use planning, creating heightened vulnerabilities in informal settlements (UN-Habitat, 2022).

Windhoek, Namibia’s capital, provides a necessary and compelling case study for examining urban climate resilience in this dryland context. The city is home to approximately 486,200 residents, representing half of the country’s urban population (NSA, 2023), and has experienced rapid urbanisation, with a 32.1 % population increase from 2011 to 2023 (NSA, 2023). Informal settlements now house around 40 % of residents, growing at an estimated 6.5–7 % annually, and expanding into ecologically fragile areas with limited infrastructure (Satterthwaite et al., 2020; World Bank, 2024; World Bank Group, 2021; Ziervogel et al., 2022, 2016). These settlements exacerbate exposure to climate stressors such as water scarcity, drought, flooding, and extreme heat, exemplified by the 2015–2017 drought (van Rensburg and Tortajada, 2021; Wijesinghe and Thorn, 2021). Comparable challenges are observed in other dryland SSA cities, such as Gaborone, Botswana (World Bank, 2024; UN-Habitat, 2022).

As Namibia’s only city with an integrated climate strategy and action plan, Windhoek offers a unique lens for examining how national climate

adaptation policies translate into local action, particularly regarding the planning and implementation of NbS to enhance urban resilience. Studying Windhoek allows insights into how climate adaptation strategies interact with governance constraints, socio-environmental vulnerabilities, and resource limitations, providing lessons for other arid urban contexts in SSA.

2.2. Research design

A single-case study design was purposively selected as a critical case (Brink, 2017), focusing on Windhoek to enable an in-depth exploration of the city’s municipal-level adaptation efforts (Yin, 2018; Brink, 2017). The study combined two methods: a desktop review of national and local climate adaptation policy documents and semi-structured interviews with key stakeholders. This approach provided multiple perspectives on the translation of policy into practice and the integration of NbS in urban adaptation planning. Ethical clearance was obtained for the study; all participation was voluntary and with consent.

2.3. Data collection

First, the desktop review systematically analysed national and local-level climate adaptation policies, strategies, and action plans to identify gaps, challenges, and opportunities, with particular attention to NbS. Policy documents were included if they:

- Focused on climate adaptation, urban resilience, water management, or disaster risk reduction.
- Were published between 2010 and 2025 to reflect recent developments.
- Addressed both national-level strategies and local implementation in Windhoek.

A total of six documents were included: five at the national level (e.g., National Policy on Climate Change, Namibia’s Nationally Determined Contribution) and one at the city level (Windhoek Integrated

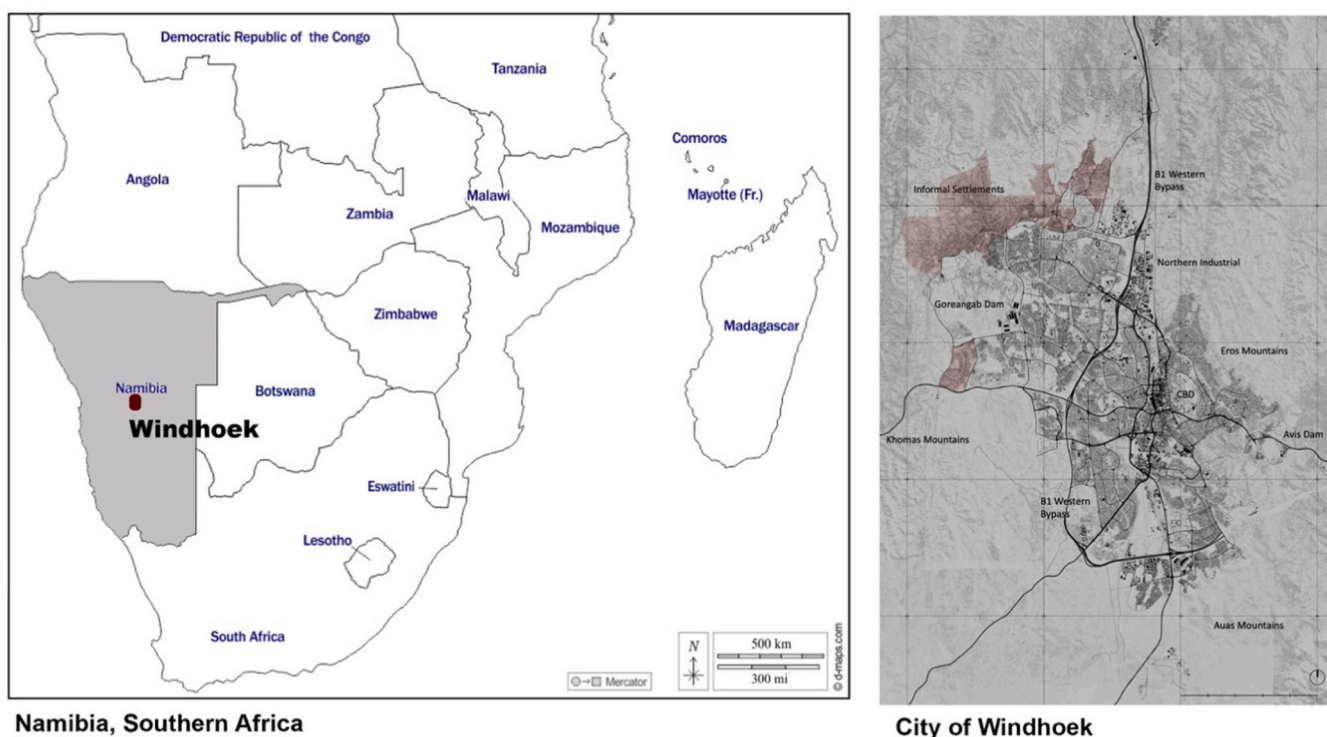


Fig. 1. The City of Windhoek, indicating extensive informal settlement growth (2011–2023) to the north and west, by (Author, 2024).

Climate Change Strategy and Action Plan, WICCSAP 2022–2028). These documents are summarised in [Table 1](#), which also highlights the focus of each document. The desktop review used coding and thematic categorisation ([Washbourne, 2022](#); [Birchall and Bonnett, 2021](#); [Saldaña, 2009](#)) to examine alignment between national policy goals and municipal adaptation strategies.

Following the above, sixteen semi-structured interviews were conducted to capture stakeholder perspectives on climate adaptation processes and NbS implementation in Windhoek. Participants were purposively selected for their expertise or influence in adaptation planning, with snowball sampling ([Flick, 2022](#)) used to include community and NGO representatives.

Participants included (see [Table 2](#), [supplementary material](#)):

- Municipal officials (3): responsible for environmental management, urban planning, and strategic execution.
- Community representatives (2): involved in permaculture and informal settlement upgrading.
- NGO officer (1): focused on informal settlement adaptation programs.
- Urban planners and academics (3): expertise in urban development, land use, and research-informed planning.
- Architects/Urban designers (3): professional perspectives on sustainable, resilient and inclusive urban planning and design separate
- Environmental specialist (1) and diplomat (1): global and environmental policy perspectives.
- Landscape architects (2) and landscaper (1): practitioners engaged in sustainable landscapes and urban greening. The term “landscaper” refers to a professional managing practical aspect of urban green infrastructure, contributing applied knowledge on NbS integration.

Interviews were conducted in Windhoek between March and October 2024 (14 in-person, 2 virtual), lasting 45–90 min. Audio recordings were transcribed verbatim, and participants were anonymised as R1–R16. The sample size was determined by saturation, while including diverse perspectives across sectors.

2.4. Data analysis

Document and interview data were analysed using descriptive/thematic coding to capture both policy-level and local perspectives on NbS for urban climate adaptation. For document analysis, policies were read and descriptively coded based on climate adaptation key aspects. The codes were grouped into categories: strategic gaps, challenges, and opportunities and synthesised into themes to enable a comparative assessment of national and local-level policy alignment. For interview analysis, data were analysed inductively using ATLAS.ti version 9 following a stepwise procedure by ([Saldaña, 2009](#); [Hsieh and Shannon, 2005](#)): open coding, categorisation of related codes into meaningful groups, and development of broader themes to capture patterns in local

Table 1
Climate Policies, Strategies, and Action Plans at National and Local (Windhoek) Levels.

Level	Reports
National	National Policy on Climate Change (NPCC) 2011
	National Climate Change Strategy and Action Plan (NCCSAP) 2013–2020
	Namibia’s Nationally Determined Contribution (NDC) 2021
	First Adaptation Communication: Namibia’s Climate Change Adaptation Communication to the United Nations Framework Convention on Climate Change (UNFCCC). (2021)
	Namibia’s First Biennial Transparency Report (BTR) and Fifth National Communication (2024)
Local (Windhoek)	Windhoek Integrated Climate Change Strategy and Action Plan (WICCSAP) 2022–2028

adaptation practices. Code co-occurrence analysis was conducted to identify relationships between themes (summarised in [supplementary material](#), [Table 3](#)), and representative quotations were selected to ensure stakeholder voices illustrated the findings. Together, these approaches allowed for an integrated assessment of policy frameworks and local implementation practices for NbS in Windhoek. The identified themes informed the results section, linking procedures explicitly to observed outcomes and ensuring transparency and replicability.

2.5. Limitations

Namibia’s arid climate and low population density limit the number of professionals in climate adaptation and NbS fields; a sample of 16 participants was deemed sufficient to capture relevant perspectives and resulted in data saturation. The study excluded high-level government representatives (e.g., ministers) due to approval delays and election schedules. To limit potential bias from any prior connections with stakeholders, strategies such as member checking and inclusion of diverse perspectives were employed. The policy on climate change is a relatively recent occurrence, which has limited the desktop review to six existing documents.

3. Results

3.1. Overview of climate adaptation at national and local level

The policy framework exhibits ambitious goals but has significant shortcomings in coordination, enforcement, and local implementation, notably concerning NbS. These policy gaps align closely with stakeholder-identified challenges and barriers, including inadequate planning and resource constraints. The interviewees reinforces that Windhoek’s urban area is confronting increasing climate impacts, rapid urbanisation, and a fragmented policy landscape. Climate challenges such as prolonged droughts, high temperatures, and flooding intersect with urban growth pressures, especially in informal settlements, exacerbating vulnerability. However, highlight emerging opportunities, such as community-driven resilience and the integration of NbS. This section sets the stage for a detailed exploration of these gaps, challenges, barriers, and opportunities.

3.2. Policy reviews of Namibia’s National and Windhoek’s’ local climate strategic and action plans: gaps, challenges and opportunities

The desktop review of Namibia’s national and local (Windhoek) climate policies, strategies, and action plans reveals a formal framework aimed at addressing climate change through mitigation and adaptation. This policy landscape signals a commitment to resilience, but implementation is undermined by resource constraints, competing socio-economic priorities, and the limited integration of NbS into land-use and urban planning.

At the national level, the National Policy on Climate Change for Namibia (NPCC, 2011) (Ministry of Environment, Forestry and Tourism ([Ministry of Environment, Forestry and Tourism MEFT, 2011](#))) was the country’s first comprehensive framework for responding to climate change, outlining principles for mitigation, adaptation, and disaster risk reduction. Building on this policy, the National Climate Change Strategy and Action Plan (NCCSAP, 2013–2020) established the strategic foundation for climate action, aiming to develop, implement, and monitor mitigation and adaptation activities while fostering sectoral synergies to reduce vulnerability and promote sustainable development. The NCCSAP calls to “mainstream climate change into policies, legal framework and development planning” ([Ministry of Environment, Forestry and Tourism MEFT, 2013](#), p. 32), yet adaptation efforts have largely targeted rural livelihoods (2013, p. 25), limited mainstreaming and minimal attention to urban centres reflecting a gap in urban planning (2013, p. 17 & 28). The NCCSAP policy predates both the [Paris](#)

Agreement (2015) and Namibia's updated Nationally Determined Contribution (NDC (2021)), it lacks provisions for NbS measures that address water scarcity, biodiversity loss, and capacity development. While the NCCSAP (Ministry of Environment, Forestry and Tourism MEFT, 2013, pp. 12–13, 17) recognises ecosystem-based adaptation by including biodiversity and ecosystems among its priority sectors, it provides limited guidance on operational mechanisms or financing structures, leaving these approaches underdeveloped in practice. Limited coordination across sectors, insufficient local adaptation measures, and inadequate funding for technology transfer have further constrained the strategy's impact.

Similarly, the First Adaptation Communication (Ministry of Environment, Forestry and Tourism MEFT, 2021) to the United Nations Framework Convention on Climate Change (UNFCCC) identifies Namibia's priority for adaptation needs and highlights resource gaps, particularly in urban resilience planning. It notes "in urban areas, there can be a deficit in infrastructure and in the provision of services due to climate change" (Ministry of Environment, Forestry and Tourism MEFT, 2021, p. 15). While the strategy emphasises reducing vulnerability of infrastructure systems, adaptation priorities still focus strongly on broad sectoral infrastructure rather than explicitly on NbS or on targeted urban adaptation measures, indicating a potential rural–urban planning imbalance. Recent national reports, including the First Biennial Transparency Report (BTR) and the Fifth National Communication (2024) to the UNFCCC, reaffirm these systemic issues, particularly the lack of dedicated support for fast-growing urban areas such as Windhoek.

At the local level, the City of Windhoek (CoW) initially relied on the NCCSAP (2013–2020), which lacked city-specific adaptation measures. This gap motivated the development of the Windhoek Integrated Climate Change Strategy and Action Plan (WICCSAP, 2022–2028), released in 2023. The WICCSAP (2022–2028) seeks to embed climate adaptation and mitigation into urban planning, prioritising water security, biodiversity, informal settlement upgrading, and sustainable development in an arid context. The WICCSAP (2022–2028) explicitly notes that "climate action should be integrated into all city departments and functions (City of Windhoek CoW, 2023, p. 12), with "particular attention given to vulnerable communities and groups in the implementation of adaptation actions" (2023, p. 42)." Yet implementation is constrained by limited human, technical, financial resources (2023, p. 38), weak interdepartmental coordination, lack of integration with statutory urban development frameworks, and difficulties in collecting data for evidence-based planning. The same plan (City of Windhoek CoW, 2023, pp. 43 & 47) further mentions that "urban greening, ecological infrastructure and biodiversity conservation should be integrated into city planning and development processes", yet lacks performance indicators or landscape design guidelines for implementation. The WICCSAP (City of Windhoek CoW, 2023, pp. 59, 73) also recognises the value of "partnerships with knowledge institutions," though such collaborations remain limited, highlighting the need for stronger academic–municipal–community linkages. Importantly, WICCSAP does not provide clear guidelines for NbS integration, such as rainwater harvesting, stormwater infiltration systems, or indigenous drought-tolerant planting/ xeriscaping, leaving ecosystem-based approaches under-addressed.

A deeper analysis of these policies reveals systemic weaknesses across national and local levels. The NCCSAP's ambition for sectoral synergies is undermined by vague implementation metrics, while the First Adaptation Communication (Ministry of Environment, Forestry and Tourism MEFT, 2021, pp. 21, 24) acknowledges "limited resources and capacity at regional and local levels" without outlining actionable pathways. In Windhoek, the WICCSAP's water security agenda omits quantifiable NbS targets, such as rainwater harvesting, managed aquifer recharge, or xeriscaping with indigenous drought-tolerant species and water-efficient landscape design. Although xeriscaping defined as landscaping that minimises supplemental irrigation through drought-tolerant vegetation and efficient water management is well

sited to Namibia's arid conditions, it is not integrated into current city-level planning instruments.

Across national and local frameworks, climate responses continue to prioritise engineered or "hard" infrastructure such as, canals and roads over ecosystem-based approaches. Policy analysis shows that neither national nor local-level strategies promote dryland-adaptive measures through regulation or building codes. Techniques such as stormwater harvesting, infiltration ponds, and green corridors along ephemeral rivers (e.g., Goreangab, Arebbusch, Klein Windhoek) are not included in urban planning frameworks, despite their potential to mitigate flash flooding and enhance groundwater recharge. Similarly, urban greening and shade corridors are largely overlooked, even though these measures could reduce urban heat island effects recorded at 5–7 °C higher in dense informal settlements and alleviate health risks for vulnerable populations.

3.3. Stakeholder interviews: gaps, challenges, and opportunities

The policy gaps, challenges, and opportunities related to climate-induced water scarcity, urban planning pressures, biodiversity loss, and the prioritisation of socioeconomic concerns over climate action provide important context for stakeholder experiences. Notably, issues such as poor coordination, weak enforcement, and limited resources reflect the challenges reported by stakeholders, examined in more detail in the following subsections through qualitative findings.

3.3.1. Escalating climate change impacts and urbanisation pressures

Stakeholder interviews revealed critical environmental and social pressures—such as prolonged drought and rapid urban expansion—that were driving the need for climate adaptation in Windhoek. Respondents identified significant gaps, including limited financial and institutional capacity for resilience planning, which increased the city's vulnerability to climate-related impacts. Water scarcity, intensified by recurring droughts and extreme weather events, was frequently cited as a primary concern. As one respondent (R10) explained:

Historically, Namibia experienced droughts every fourth or fifth year, but from 2015 to 2017, we had consecutive droughts—nearly three seasons. That's not normal. We've seen the same pattern again from 2022 to 2024, with prolonged droughts now interspersed with extreme wet seasons. In December 2022, parts of Windhoek flooded, recording nearly 100 millimetres of rainfall in an hour. Here in arid regions like Windhoek, water scarcity remains the primary climate change impact.

Climate challenges were compounded by rapid urbanisation, which placed increasing pressure on urban areas. This growth was largely driven by the expansion of informal settlements, as people migrated in search of improved livelihoods. Respondents noted that this expansion contributed to water scarcity and biodiversity loss and added strain to already limited natural resources. Urban planners faced significant challenges in responding to this growth, while residents in water-stressed areas remained vulnerable to extreme heat and flooding. One respondent referred to data from the Namibia Statistics Agency (NSA, 2023), stating that informal settlements were expanding at a rate of 6.5–7 % per year, surpassing the formal city's growth rate of 4 %. R10 elaborated:

Most of this growth happens in informal settlements, complicating efforts to tackle climate change and sustain urban resilience. That flooding episode overwhelmed our drainage systems, highlighting the gap between rapid expansion and infrastructure capacity.

3.3.2. Key gaps and challenges in climate adaptation efforts

Stakeholder interviews revealed significant gaps that hinder effective climate adaptation, noting the absence of NbS such as sustainable water management and ecosystem-based interventions, which could improve water availability, protect river processes, and reduce erosion

in informal areas, but are often overlooked in favour of conventional engineered solutions. The absence of these NbS practices heightens Windhoek's arid-urban risks, as evidenced by recent droughts depleting aquifers and floods overwhelming informal settlements. Stakeholders suggested that integrating NbS could foster interconnected ecosystems and enhance local resilience, helping to better align observed practice with policy intentions. Furthermore, the difficulty in engaging communities in informal areas to adopt environmental sustainability practices, such as protecting open spaces and planting trees, intensifies urban heat and exposes vulnerable populations to greater heat stress during droughts. As stated by (R10):

As you know, ecosystem-based adaptation strategies are very critical for us, especially in a dry city like Windhoek. We want to ensure that all the public open spaces and areas that were left for conservation purposes are protected and create that interconnectedness of different ecological systems, river processes, open spaces, and so on. Furthermore, it's very difficult now to get people, especially in the informal areas, on board. To talk about environmental sustainability, planting trees, protecting the environment, and not building near river courses.

A recurring concern was the limited practical implementation of NbS, which remains largely confined to rural agriculture and livestock initiatives, while urban contexts are neglected. Respondents pointed to policy and governance inertia, alongside weak enforcement mechanisms, as major barriers. These concerns mirror existing policy gaps, including the "lack of comprehensive indicators" in the WICCSAP and "insufficient funding for implementation" in the NPCC. Together, these shortcomings highlight the need for more inclusive and actionable NbS adaptation frameworks. As R14 expressed:

The lack of execution stems from a cumbersome civil service unaccustomed to implementation. There's no funding or allocated funding for implementation either.

This challenge is further exacerbated by a fragmented urban planning system. While the Urban and Regional Planning Act (Act 5 of 2018) mandates the development of sustainable strategies to address climate-related issues, there is no cohesive policy framework that effectively integrates legislation, climate adaptation, and urban planning. As a result, urban areas are often overlooked, with poorly aligned policies and a lack of implementation strategies contributing to significant delays. These issues reflect broader policy findings, such as "limited co-ordination across sectors" (NCCSAP) and "urban areas neglected" (Windhoek Structure Plan). R8 elaborated:

Policies at the national level should incorporate climate adaptation, but they lack clear strategies for urban areas. Rural- agricultural areas get the focus, while urban areas are pretty much ignored.

Resource constraints further exacerbate the issue, particularly the lack of funding and technical expertise needed to implement effective actions, especially for ecosystem-based approaches such as NbS. This aligns with the UNFCCC report's observation of "limited resources for environmental or ecosystem approaches," highlighting a critical gap in Namibia's capacity to operationalise climate adaptation strategies. R14 added:

There's no funding for execution, and we lack the expertise too.

Moreover, inconsistent collection and monitoring of climate data, particularly at the local level, hinders progress in tracking adaptation efforts and informing evidence-based planning. R16 explained:

Climate change-related data, for example, isn't consistently captured, even at the national level.

In addition to technical gaps, climate challenges are often deprioritised in urban areas, especially within vulnerable dryland ecosystems. In informal settlements, communities tend to resist engagement with climate issues when basic needs, such as access to water, electricity, and

secure land tenure remain unmet. This reflects a broader lack of awareness around climate change and adaptation. In contrast, residents in formal urban areas, where basic services are more readily available, are increasingly engaging with climate action through private initiatives and projects. This disparity highlights a critical awareness gap and underscores policy barriers such as the "lack of comprehensive need-based community adaptation planning" (WICCSAP). R9 highlighted this tension:

Depending on how you present climate issues, you can get pushback from the community saying, 'We can't talk about climate change when we don't have water, electricity, or our own plots.'

These challenges, including poor implementation, urban neglect, resource shortages, data gaps, and competing socio-economic priorities, reflect broader policy issues such as "gaps in data collection for climate monitoring" (WICCSAP) and "socio-economic priorities" overshadowing climate action (NCCSAP). They highlight the urgent need for integrated, community-responsive adaptation strategies and localised NbS.

3.3.3. Emerging NbS opportunities for advancing climate adaptation

Stakeholders identified actionable opportunities to enhance climate adaptation through practical NbS measures, such as xeriscaping measures to reduce water needs and the reintroduction of native, drought-tolerant species that can also tolerate temporary flooding. This approach could reduce urban heat islands by 5–7°C in informal settlements, mitigating heat stress during prolonged droughts as dense urban areas amplify heat stress. Several respondents highlighted the need to prioritise and promote such approaches within national and local policies to strengthen urban resilience. R6 emphasised their relevance in an arid urban context:

There is mostly xeriscape planting, reintroduction of natives that are dropped to the ground because of their adaptation to the climate. With the planting design, not only are these plants selected for their drought-tolerant and indigenous characteristics, but they are also able to withstand being submerged in water for temporary amounts of time.

To support these initiatives and strengthen local capacity, respondents advocated for ongoing co-creation workshops and community education programs. These efforts seek to build expertise, raise awareness, and develop grassroots guidelines for climate adaptation and NbS. Permaculture uniquely addresses both urbanisation pressures and water scarcity in Windhoek's arid context, offering a scalable model for low-income arid cities. R3 highlighted how informal settlements are already contributing through bottom-up approaches, such as permaculture practices:

Permaculture gardens provide adaptive strategies that help town planners by reducing pressure on resources and demonstrating sustainable land use.

Enhancing this community engagement, stakeholders proposed awareness campaigns to reframe perceptions of arid landscape aesthetics and function. Such campaigns, using smaller group meetings and larger platforms, could shift mindsets towards valuing indigenous, low-water designs, an approach aligning with policies advocating for NbS (e.g., WICCSAP). R6 elaborated:

We need to retrain people's mindsets to see that brown is beautiful. Brown is living, there are stunning brown plants and infrastructure. Highlighting arid designs with indigenous species can reshape this conversation.

Further opportunities lie in strengthening NbS and community engagement through cross-sectoral partnerships, including private-sector and corporate involvement. Respondents revealed a willingness to collaborate but stressed the need for coordinated stakeholder identification strategies to harness diverse funding and ensure accountability. This could be supported by integrated, flexible policies tailored to unique regional needs. R9 illustrated this with an example:

Okahandja’s new strategic plan embraces participatory approaches to housing and land delivery. This builds community resilience, making them more adaptive to climate challenges and helping planners understand local climate-related issues.

Together, these opportunities, leveraging NbS, fostering community-driven solutions, reframing cultural attitudes, and enhancing partnerships address urban neglect, resource shortages, and awareness gaps, offering a cohesive pathway to integrated climate adaptation.

3.4. Synthesis: integrating Nature based Solutions for Windhoek’s urban climate adaptation

Windhoek’s urban climate adaptation faces compounded challenges driven by rapid informal settlement growth, recurrent droughts, and flooding, which strain infrastructure and exacerbate urban heat islands and water scarcity. National and local policies, including NCCSAP, NAP, and WICCSAP, provide a formal framework but remain limited in operational guidance, urban-specific measures, and integration of NbS. Stakeholders reinforced these gaps, highlighting inadequate local climate data, weak enforcement, socio-economic priorities overshadowing climate action, and limited institutional partnerships. As one respondent noted, “Most of this growth happens in informal settlements, complicating efforts to tackle climate change and sustain urban resilience” (R10). Missing NbS interventions such as stormwater harvesting, xeriscaping, drought-tolerant vegetation, permaculture gardens, and community co-creation hubs—contribute to heightened vulnerability, with impacts including increased flooding and urban heat islands of 5–7°C in dense settlements (R3, R6, R10). Opportunities to enhance adaptation include embedding NbS into statutory urban plans, leveraging citizen-science monitoring to strengthen local data systems (R16), scaling community-led initiatives from Okahandja and the Kambashu Institute (R8, R14), and fostering stronger collaborations between city departments, academia, and communities. A respondent emphasised the potential of community-driven approaches:

“Permaculture gardens provide adaptive strategies that help town planners by reducing pressure on resources and demonstrating sustainable land use” (R3). Collectively, these insights summarised in Table 4, highlight pathways to bridge policy implementation gaps and advance resilient, equitable, and NbS-informed urban climate adaptation in Windhoek’s arid context.

4. Discussion

The findings highlight the urgent need for integrated, locally tailored strategies to strengthen resilience in arid regions, offering valuable lessons for other arid urban contexts globally. The discussion explores four core complexities in Namibia’s urban climate adaptation planning: climate impacts and urbanisation challenges, climate data gaps, policy-implementation disconnect, and the tension between socio-economic and climate priorities. It also identifies two key opportunities for advancing adaptation: enhanced coordination and capacity building, and partnerships for implementing NbS.

4.1. Gaps and challenges

4.1.1. Climate impacts, urbanisation and NbS challenges

Climate adaptation, urbanisation, and biodiversity have often been treated as separate planning domains, yet their intersection in rapidly growing cities like Windhoek poses urgent challenges (Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change IPCC, 2022; UN-Habitat, 2020). Informal settlements, growing at an estimated 6.5–7 % annually, exacerbate climate-related stressors such as water scarcity, droughts, and flooding, particularly in ecologically fragile and infrastructure-poor environments (Satterthwaite et al., 2020; Ziervogel et al., 2016). Recent floods in Windhoek exposed drainage deficiencies across both formal and informal neighbourhoods, revealing the limits of siloed planning frameworks and highlighting the need for more context-sensitive interventions (Ampaire et al., 2017). These compounding risks call for integrated adaptation strategies such

Table 4
Synthesis of Key Policy and Stakeholder Insights: Challenges and Opportunities for Windhoek’s Climate Adaptation.

Challenge	Description	Specific Missing NbS	Exacerbated Climate Impacts	Opportunities	Overlaps / compliment or contradictions	Data Source(s)
Climate Impacts, Urbanisation, and NbS Challenges	Rapid informal settlement growth and flood risks strain infrastructure (e.g., drainage systems overwhelmed).	Stormwater harvesting, xeriscaping, use of drought-tolerant vegetation	Increased flooding and urban heat islands (5–7°C in informal settlements)	Integrate NbS like stormwater harvesting and xeriscaping into Windhoek’s Structure Plan, urban or land-use planning, and WICCSAP	Complementary – Policies and interviews both identify infrastructure stress and lack of NbS	Policy Review (WICCSAP, NCCSAP) Stakeholder Interviews, Field Observation
Insufficient Climate Data and NbS Evidence	Inconsistent local data collection hinders climate monitoring and flood preparedness	Citizen-science-led monitoring, rainfall tracking, community NbS mapping	Hindered preparedness for flood events	Develop local data systems via citizen science to support NbS planning	Partial Complementarity – Interviews confirm data gaps; policies acknowledge but lack mechanisms	Policy Review (WICCSAP, NCCSAP) Stakeholder Interviews
Policy–Implementation Challenges	Weak NbS integration in WICCSAP (2022–2028) due to limited funding and coordination	Xeriscaping, permeable surfaces	Amplified runoff and erosion in informal settlements during wet seasons	Embed NbS and locally led initiatives from Okahandja and Kambashu Institute into municipal bylaws and structure plans	Complementary – Both policy and interviews cite lack of implementation; Contradictory – Policies claim mainstreaming while interviews show limited evidence	Policy Review, Stakeholder Interviews
Socio-Economic Priorities	Basic needs (water, electricity, land) overshadow climate action in informal settlements	Permaculture gardens	Limited resilience to drought-induced water scarcity	Promote community-driven permaculture and “Brown is Beautiful” campaigns to align climate and socio-economic goals	Complementary – Interviews confirm socio-economic priorities overshadow climate; policies acknowledge but under-address	Stakeholder Interviews, Field Observation
Institutional Partnerships	Limited partnerships between city departments, academia, and communities	NbS research collaborations, community co-creation hubs	Weak knowledge transfer, fragmented learning	Strengthen partnerships via living labs and university–municipality projects	Partial Complementarity – Policies mention partnerships; interviews note lack of implementation	Policy Review, Stakeholder Interviews

as NbS that connect climate action with biodiversity and urban development goals (Johnson et al., 2022; Cilliers, 2020; Cohen-Shacham et al., 2019). Embedding NbS in Windhoek's WICCSAP, urban and land-use planning through urban greening, xeriscaping, and community-based water management, could enhance systemic resilience, supported by monitoring frameworks to track impacts such as reduced flooding, lower urban heat, and improved ecosystem services (Zhu and Feng, 2025; Lin et al., 2021). In the case of Windhoek, while locally tailored strategies exist, they are not acknowledged or supported by policy, which fails to support the growth of local NbS interventions that are practical, inclusive, and sustainable.

4.1.2. Climate data and NbS evidence gaps hindering effective adaptation

Inconsistent and outdated climate data is a critical barrier to adaptation in Windhoek, where rapid urbanisation demands timely, localised information (United Nations Framework Convention on Climate Change United Nations Framework Convention on Climate Change UNFCCC, 2020). The lack of real-time rainfall and settlement data contributed to unpreparedness during the 2022 and 2025 floods, reflecting a broader Sub-Saharan African trend that limits anticipatory planning (Ampaire et al., 2017). Community-driven citizen science, such as training residents to track rainfall and temperature, can address data gaps in a cost-effective and locally grounded manner (Loglisci et al., 2024; Pasgaard et al., 2023; Tipaldo and Allamano, 2017). Successful examples from Cape Town highlight how such efforts can improve flood forecasting and response (Ziervogel et al., 2022). Building on results from this study, we propose leveraging local knowledge, including neighbourhood initiatives and campaigns such as "Brown is Beautiful," to raise awareness, enhance data collection, and inform urban and land use planning in line with strategic action plans such as the WICCSAP. However, scaling these approaches will require balancing training and technological investments against other pressing urban needs (Cilliers et al., 2022).

4.1.3. Disconnect between policy and local NbS implementation

Despite progressive national strategies like the National Climate Change Strategy and Action Plan (NCCSAP) and the National Policy on Climate Change (NPCC, 2011), implementation at the local level remains weak (Bulkeley and Tuts, 2013) limiting the uptake of NbS in urban contexts. These policies often prioritise rural agricultural adaptation, neglecting urban vulnerabilities, especially in informal settlements (Sibiya et al., 2023) where NbS could address heat stress, flooding, and water scarcity. Systemic obstacles such as outdated regulations, limited expertise, and fragmented coordination hinder the execution of local authority plans like WICCSAP, further constraining NbS integration (Birchall and Bonnett, 2021). Similar disconnects are seen in other African cities like Nairobi, where climate policy rarely translates into action (Titz and Chiotha, 2019). Bridging this gap requires multi-level governance that explicitly incorporates NbS, with meaningful roles for local communities in planning and implementation processes (Fila et al., 2023; Ziervogel et al., 2022). We propose building on locally grounded initiatives, such as Okahandja's and Kambashu Institute community-led adaptation model and updating NCCSAP and WICCSAP to include urban-specific strategies, to strengthen policy alignment and pioneer NbS implementation and operationalisation in Windhoek.

4.1.4. Tension between socio-economic priorities and NbS climate goals

In Windhoek's urban context, immediate socio-economic needs often overshadow long-term climate goals. Residents in informal settlements, housing 40 % of the population, prioritize water, electricity, and land tenure over adaptation efforts (Sibiya et al., 2023; Ampaire et al., 2017). Insecure land tenure restricts NbS implementation, such as permaculture gardens, by limiting long-term urban planning investments in informal areas (Global Center on Adaptation GCA, 2024; United Nations Convention to Combat Desertification UNCCD, 2022). This reflects as

spatial inequalities, where communities in informal settlements specifically are sidelined in planning processes (Kohima et al., 2023). Integrating NbS into land use policies, like tenure regularisation and the Windhoek Structure Plan, can align climate resilience with socio-economic goals, as seen in climate-resilient housing initiatives (AfDB, 2024; Prall et al., 2023) to address strategic vulnerabilities. These spatial inequalities certainly hold implications for climate adaptation. Participatory scenario planning, used successfully in Windhoek, shows how inclusive processes reconcile priorities (Thorn et al., 2021). Our findings illustrate that sustained political will, inter-sectoral coordination, and community empowerment are vital to bridge this current divide.

4.2. Opportunities

4.2.1. Coordination and capacity building as enablers for NbS

Effective adaptation, including the implementation of NbS, depends on cross-sectoral coordination and capacity development, yet Namibia continues to face challenges in both areas. National plans like NCCSAP and local efforts like WICCSAP are hindered by limited collaboration and institutional silos, which constrain the integration and scaling of NbS in urban planning and climate adaptation projects. Resource constraints, outdated technology, and a lack of skilled personnel further impede progress (Davies et al., 2020; Ampaire et al., 2017). Communication gaps between government, experts, and communities also stall context-sensitive adaptation, limiting opportunities to co-create NbS that are locally relevant and cost-effective. Addressing these issues requires a transformative, transdisciplinary approach, where stakeholders co-create solutions and share knowledge (Tran et al., 2024; Ziervogel et al., 2022). Workshops and co-production that bring together planners, technical experts, and residents (Wolff et al., 2022) as seen in Kibera, Nairobi, can foster mutual learning and inform practical micro-scale NbS interventions (Kibii et al., 2025). We propose institutionalising such coordination through local climate adaptation units and integrating NbS into these processes, while aligning with climate finance opportunities, which will help overcome structural barriers with possibility of building lasting resilience. (McEvoy et al., 2024).

4.2.2. Nature based Solutions for climate adaptation

Nature based Solutions (NbS) offer a transformative approach, aligning ecological restoration with socio-economic development in Namibia's arid urban contexts. Practical implementations in Windhoek, such as permaculture gardens, xeriscaping, and dryland revegetation, demonstrate how community-led or public NbS initiatives can improve water management, enhance biodiversity, and strengthen urban resilience. The Windhoek Integrated Climate Change Strategy and Action Plan (WICCSAP 2022–2028) attempts to incorporate ecosystem-based approaches, such as revegetation, to enhance urban resilience. WICCSAP's focus on short-term disaster mitigation, and combined with limited funding and governance challenges, constrains the broader uptake of cost-effective (Birchall et al., 2025), culturally embedded NbS tailored to arid adaptation (Çetin et al., 2018; Cinar and Aktas, 2018) that can take small steps towards long term transformative adaptation. Building on these findings, we propose leveraging locally tailored community-led practices that have the potential to support the "Brown is Beautiful" campaign, but require dedicated communication platforms (Wolff et al., 2022) to promote the mainstreaming of arid-adapted landscaping not only improving resilience, but also social cohesion (Singh and Chudasama, 2021). Embedding permaculture and "Brown is Beautiful" in the WICCSAP, in addition, the Windhoek Urban Structure Plan and municipal bylaws, supported by tenure regularisation and monitoring frameworks, can scale these NbS to address critical water scarcity in the city (Zhu and Feng, 2025; United Nations Convention to Combat Desertification UNCCD, 2022).

The WICCSAP (2022–2028) signals potential entry points for mainstreaming NbS in urban planning to tackle water scarcity and

biodiversity loss while enhancing community-driven resilience. Nationally, developing an NbS framework linked to the Climate Change Strategy and Action Plan, advocating for NbS within Green Climate Fund and Adaptation Fund proposals, and piloting NbS projects across urban, peri-urban, and rural contexts could provide momentum. Reframing NbS in Namibia's national reports to highlight their role in food security, water access, biodiversity, and income generation would strengthen the case for international support. Furthermore, updating outdated policies (e.g., NPCC 2011) and embedding NbS in both statutory urban plans and climate action strategies are critical steps toward building resilience in Namibia's arid urban environments

Despite their potential, NbS face resistance due to entrenched preferences for hard infrastructure solutions often perceived as more reliable and familiar (Thorn et al., 2021). This resistance is further compounded by limited funding and a lack of locally relevant case studies (Kibii et al., 2025; Seddon et al., 2020; Sarabi et al., 2019). Pilot projects, such as permaculture gardens, not only demonstrate practical NbS benefits but also provide evidence to attract investment and build momentum for broader implementation (McEvoy et al., 2024), as demonstrated by international examples of xeriscaping initiatives in Tucson (Gerlak et al., 2021). Such projects can then be developed for best practice and local contextual standards.

To fully realise the potential of NbS, we propose that policy frameworks could prioritise localised, flexible strategies, integrating NbS into urban planning, and operationalising support through cross-sectoral coordination (Corgo et al., 2024; Adams et al., 2023). In addition, fostering partnerships between governments, NGOs, businesses, and donors is required for implementation and scale-up efforts (Sousa et al., 2024; Davies and Laforteza, 2019). By leveraging pilot projects and community-driven practices, NbS can simultaneously address pressing challenges like water scarcity and urban heat while generating socio-economic co-benefits and increasing public engagement in climate adaptation (Wolff et al., 2022; Cohen-Shacham et al., 2016) in small, local and incremental ways, while keeping a long-term systemic outlook.

5. Conclusion

This study highlights the critical gaps, challenges and opportunities shaping Windhoek's urban climate adaptation and offers guidelines for integrating NbS in arid cities across Sub-Saharan Africa. This study highlights five key lessons for advancing NbS in Windhoek and other arid cities. Firstly, integrated responses to climate risks are urgent, as droughts, floods, and informal settlement growth exacerbate water scarcity and heat islands, highlighting the need for holistic adaptation strategies such as xeriscaping and stormwater harvesting. Secondly, community-driven initiatives provide proof of concept, with locally led practices like permaculture gardens and the "Brown is Beautiful" campaign restoring degraded landscapes, enhancing food security, and fostering social cohesion, demonstrating scalable models tailored to local needs. Thirdly, embedding NbS in statutory frameworks is essential, since integrating ecological approaches in the WICCSAP is emphasised, in addition, the Windhoek Urban Structure Plan and municipal bylaws can further bridge the gap between high-level policy ambitions and practical implementation. Fourthly, co-creation and local knowledge are central to effectiveness, as participatory workshops and citizen-led experiments align policy with lived realities, producing context-sensitive solutions that enhance legitimacy and uptake. Finally, Windhoek's experience could offer transferable lessons, with comparative learning from other arid cities, informing the scalability, equity, and effectiveness of dryland NbS, while awareness campaigns can shift cultural perceptions toward valuing arid-adapted landscapes.

Based on the study focus and findings, several policy recommendations emerge to advance the implementation of NbS in Windhoek and other arid cities:

- Enhance institutional coordination: Establish a cross-departmental *Climate and Environment Taskforce* to align land-use planning, water management, and infrastructure development.
- Mainstream NbS in planning instruments: Incorporate measurable NbS indicators into all Climate adaptation reports, spatial structure reports and related bylaws, including ecological corridors, permeable surfaces, and water-sensitive design standards.
- Reinstate ecological overlays: Update outdated reports and apply environmental mapping to guide spatial decisions and protect key ecosystem services.
- Support locally led initiatives: Provide technical and financial support—such as micro-grants and inclusion in municipal programmes—for community-driven NbS projects.
- Invest in capacity building: Strengthen NbS awareness, education, and technical training across municipal departments, universities, and community organisations to foster cross-sectoral collaboration.
- Leverage monitoring and data systems: Develop citizen-science-led monitoring programmes for rainfall, flooding, and vegetation. Address local data gaps that currently hinder urban adaptation planning
- Promote cross-sectoral partnerships: Encourage collaboration between government, academia, NGOs, and private sector actors to support co-design, funding, and scaling of NbS. Build on existing community-led initiatives, such as Kambashu Institute and Okahandja.

While the study provides valuable qualitative insights, its limitations include the scarcity of existing policy documents and experts in the field. Future research could expand stakeholder participation and incorporate quantitative surveys. Studies employing mixed method approaches that combine spatial, ecological, and socio-economic data could be useful for assessing NbS performance more comprehensively and providing more detailed recommendations for operationalisation.

Our study emphasises that resilient and equitable adaptation in dryland cities requires integrated land-use planning, institutional commitment, and community leadership. Advancing NbS through this lens highlights their potential as drivers of transformative adaptation, shifting responses from risk management fixes to deep, systemic change.

Statement

During the preparation of this work the author used Grammarly as a tool/service to check grammar. The author(s) wrote, reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

CRedit authorship contribution statement

Gaby Bianca Hansen: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Christina A Breed:** Writing – review & editing, Supervision.

Declaration of Generative AI and AI-assisted technologies in the writing process

None.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We express our sincere gratitude to the University of Pretoria for

providing the bursary that supported this study and to all the interviewees who generously participated.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.landusepol.2025.107877](https://doi.org/10.1016/j.landusepol.2025.107877).

Data Availability

Data will be made available on request. Available on request, once the degree is conferred

References

- Adams, C., Frantzeskaki, N., Moglia, M., 2023. Mainstreaming nature-based solutions in cities: A systematic literature review and a proposal for facilitating urban transitions. *Land Use Policy* 130, 106661. <https://doi.org/10.1016/j.landusepol.2023.106661>.
- AfDB, 2024. UNCCD COP16: Mobilizing Global Action for the African Great Green Wall Initiative [WWW Document]. African Development Bank Group. (<https://www.afdb.org/en/news-and-events/press-releases/unccd-cop16-mobilizing-global-action-african-great-green-wall-initiative-79474>) (accessed 5.20.25).
- Albert, C., Brillinger, M., Guerrero, P., Gottwald, S., Henze, J., Schmidt, S., Ott, E., Schröter, B., 2021. Planning nature-based solutions: principles, steps, and insights. *Ambio* 50, 1446–1461. <https://doi.org/10.1007/s13280-020-01365-1>.
- UN-Habitat (Ed.), 2020. *The value of sustainable urbanization, World cities report*. UN-Habitat, Nairobi, Kenya.
- Ampaire, E.L., Jassogne, L., Providence, H., Acosta, M., Twyman, J., Winowiecki, L., van Asten, P., 2017. Institutional challenges to climate change adaptation: a case study on policy action gaps in Uganda. *Environ. Sci. Policy* 75, 81–90. <https://doi.org/10.1016/j.envsci.2017.05.013>.
- Berke, P.R., Stevens, M.R., 2016. Land use planning for climate adaptation: theory and practice. *J. Plan. Educ. Res.* 36, 283–289. <https://doi.org/10.1177/0739456X16660714>.
- Birchall, S.J., Bonnett, N., 2021. Climate change adaptation policy and practice: the role of agents, institutions and systems. *Cities* 108, 103001. <https://doi.org/10.1016/j.cities.2020.103001>.
- Birchall, S.J., Kehler, S., Weissenberger, S., 2025b. Sometimes, I just want to scream*: Institutional barriers limiting adaptive capacity and resilience to extreme events. *Glob. Environ. Change* 91, 102967. <https://doi.org/10.1016/j.gloenvcha.2025.102967>.
- Bizikova, L., Parry, J.-E., Karami, J., Echeverría, D., 2015. Review of key initiatives and approaches to adaptation planning at the national level in semi-arid areas. *Reg. Environ. Change* 15, 837–850. <https://doi.org/10.1007/s10113-014-0710-0>.
- Brink, E., Wamsler, C., 2018. Collaborative Governance for Climate Change Adaptation: Mapping citizen-municipality interactions: collaborative governance for climate change adaptation. *Env. Pol. Gov.* 28, 82–97. <https://doi.org/10.1002/et.1795>.
- Bulkeley, H., Tuts, R., 2013. Understanding urban vulnerability, adaptation and resilience in the context of climate change. *Local Environ.* 18, 646–662. <https://doi.org/10.1080/13549839.2013.788479>.
- Çetin, N., Mansuroğlu, S., Önaç, A., 2018. Xeriscaping feasibility as an urban adaptation method for global warming: a case study from Turkey. *Pol. J. Environ. Stud.* 27, 1009–1018. <https://doi.org/10.15244/pjoes/76678>.
- Cilliers, E.J., 2020. Reflecting on Global South planning and planning literature. *Dev. South. Afr.* 37, 105–129. <https://doi.org/10.1080/0376835X.2019.1637717>.
- Cilliers, E.J., Timmermans, W., Rohr, H., Goosen, H., 2022. Scaling up of nature-based solutions to guide climate adaptation planning: evidence from two case studies. *Front. Sustain. Cities* 4, 624046. <https://doi.org/10.3389/frsc.2022.624046>.
- Cinar, H.S., Aktas, N.K., 2018. XERISCAPE analysis: a case study in a residential garden in Istanbul. *J. Environ. Prot. Ecol.* 4 (19), 1904–1917.
- City of Windhoek (CoW), 2023. *WINDHOEK INTEGRATED CLIMATE CHANGE STRATEGY AND ACTION PLAN 2022-2028*.
- Cohen-Shacham, E., Andrade, A., Dalton, J., Dudley, N., Jones, M., Kumar, C., Maginnis, S., Maynard, S., Nelson, C.R., Renaud, F.G., Welling, R., Walters, G., 2019. Core principles for successfully implementing and upscaling Nature-based Solutions. *Environ. Sci. Policy* 98, 20–29. <https://doi.org/10.1016/j.envsci.2019.04.014>.
- Convention on Biological Diversity, 2024. *Kunming Monit. Glob. Biodivers. Framew.* [WWW Doc.]. (<https://www.cbd.int/gbf/>) (accessed 8.25.25).
- Corgo, J., Cruz, S.S., Conceição, P., 2024. Nature-based solutions in spatial planning and policies for climate change adaptation: a literature review. *Ambio* 53, 1599–1617. <https://doi.org/10.1007/s13280-024-02052-1>.
- Covenant of Mayors in Sub-Saharan Africa (CoM SSA), 2024. *Embu County's Dallas Settlement Launches Green Infrastructure Plan to Tackle Climate Change*. [WWW Document]. URL (<https://comssa.org/en/news/press-release-embu-county-dallas-settlement-launches-green-infrastructure-plan-to-tackle-climate-change>) (accessed 9.3.25).
- Crawford, A., Terton, A., 2016. *Review of Current and Planned Adaptation Action in Namibia*.
- Danjuma, M.N., Mohammed, S., 2015. Zai Pits system: a catalyst for restoration in the dry lands. *Journal Agriculture Veterinary Science (IOSRJAVS)* 8, 01–04. <https://doi.org/10.9790/2380-08210104>.
- Davies, C., Laforteza, R., 2019. Transitional path to the adoption of nature-based solutions. *Land Use Policy* 80, 406–409. <https://doi.org/10.1016/j.landusepol.2018.09.020>.
- Davies, J.E., Spear, D., Ziervogel, G., Hegga, S., Ndapewa Angula, M., Kunamwene, I., Togarepi, C., 2020. Avenues of understanding: mapping the intersecting barriers to adaptation in Namibia. *Clim. Dev.* 12, 268–280. <https://doi.org/10.1080/17565529.2019.1613952>.
- Deubelli, T.M., Mechler, R., 2021. Perspectives on transformational change in climate risk management and adaptation. *Environ. Res. Lett.* 16, 053002. <https://doi.org/10.1088/1748-9326/abd42d>.
- Fila, D., Fünfgeld, H., Dahlmann, H., 2023. Climate change adaptation with limited resources: adaptive capacity and action in small- and medium-sized municipalities. *Environ. Dev. Sustain* 26, 5607–5627. <https://doi.org/10.1007/s10668-023-02999-3>.
- Frantzeskaki, N., McPhearson, T., Collier, M.J., Kendal, D., Bulkeley, H., Dumitru, A., Walsh, C., Noble, K., van Wyk, E., Ordóñez, C., Oke, C., Pintér, L., 2019. Nature-based solutions for urban climate change adaptation: linking science, policy, and practice communities for evidence-based decision-making. *BioScience* 69, 455–466. <https://doi.org/10.1093/biosci/biz042>.
- Gerlak, A.K., Elder, A., Thomure, T., Shipek, C., Zuniga-Teran, A., Pavao-Zuckerman, M., Gupta, N., Matsler, M., Berger, L., Henry, A.D., Yang, B., Murrieta-Saldivar, J., Meixner, T., 2021. Green infrastructure: lessons in governance and collaboration from Tucson. *Environment Science Policy Sustainable Development* 63, 15–24. <https://doi.org/10.1080/00139157.2021.1898894>.
- Global Center on Adaptation (GCA), 2024. *AFRICA ADAPTATION ACCELERATION PROGRAM*.
- Gutiérrez, M.M., Felthöfer, C., Knoblauch, D., 2024. *Integrating Nature-Based Solutions in Policy and Planning: Findings and Lessons from INTERLACE Cities*. *Transversal City Impulse Paper*. INTERLACE Deliv. 2, 5.
- Hsieh, H.-F., Shannon, S.E., 2005. Three approaches to qualitative content analysis. *Qual. Health Res* 15, 1277–1288. <https://doi.org/10.1177/1049732305276687>.
- Intergovernmental Panel on Climate Change (IPCC), 2022. *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, First ed. Cambridge University Press. <https://doi.org/10.1017/9781009325844>.
- Intergovernmental Panel on Climate Change (IPCC), 2023. *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, First ed. Cambridge University Press. <https://doi.org/10.1017/9781009325844>.
- International Union for Conservation of Nature (IUCN), 2020. *IUCN Global Standard for Nature-based Solutions: a user-friendly framework for the verification, design and scaling up of Nbs: first edition*, First ed. IUCN, International Union for Conservation of Nature. <https://doi.org/10.2305/IUCN.CH.2020.08.en>.
- Johnson, B.A., Kumar, P., Okano, N., Dasgupta, R., Shivakoti, B.R., 2022. Nature-based solutions for climate change adaptation: a systematic review of systematic reviews. *Nat. Based Solut.* 2, 100042. <https://doi.org/10.1016/j.nbsj.2022.100042>.
- Kabisch, N., Korn, H., Stadler, J., Bonn, A., 2017. *Nature-Based Solutions to Climate Change Adaptation in Urban Areas—Linkages Between Science, Policy and Practice*. In: Kabisch, N., Korn, H., Stadler, J., Bonn, A. (Eds.), *Nature-Based Solutions to Climate Change Adaptation in Urban Areas, Theory and Practice of Urban Sustainability Transitions*. Springer International Publishing, Cham, pp. 1–11. https://doi.org/10.1007/978-3-319-56091-5_1.
- Kibii, C., Guerra, F., Bananayo, P.B., Sandholz, S., 2025a. Nature-based solutions for climate change adaptation and resilience in urban informal settlements: insights from kibera, kenya and Villa 20, Argentina. *Nat. Based Solut.* 7, 100216. <https://doi.org/10.1016/j.nbsj.2025.100216>.
- Kiribou, R., Djene, S., Bedadi, B., Ntirenganya, E., Ndemere, J., Dimobe, K., 2024. *Urban climate resilience in Africa: a review of nature-based solution in African cities' adaptation plans*. *Discov. Sustain* 5, 94. <https://doi.org/10.1007/s43621-024-00275-6>.
- Kohima, J.M., Chigbu, U.E., Mazambani, M.L., Mabakeng, M.R., 2023. Neo-)segregation, (neo-)racism, and one-city two-system planning in Windhoek, Namibia: What can a new national urban policy do? *Land Use Policy* 125, 106480. <https://doi.org/10.1016/j.landusepol.2022.106480>.
- Lin, B.B., Ossola, A., Alberti, M., Andersson, E., Bai, X., Dobbs, C., Elmqvist, T., Evans, K.L., Frantzeskaki, N., Fuller, R.A., Gaston, K.J., Haase, D., Jim, C.Y., Konijnendijk, C., Nagendra, H., Niemelä, J., McPhearson, T., Moomaw, W.R., Parnell, S., Pataki, D., Ripple, W.J., Tan, P.Y., 2021. Integrating solutions to adapt cities for climate change. *Lancet Planet. Health* 5, e479–e486. [https://doi.org/10.1016/S2542-5196\(21\)00135-2](https://doi.org/10.1016/S2542-5196(21)00135-2).
- Loglisci, N., Milelli, M., Iurato, J., Galia, T., Galizia, A., Parodi, A., 2024. Validation of citizen science meteorological data: can they be considered a valid help in weather understanding and community engagement? *Sensors* 24, 4598. <https://doi.org/10.3390/s24144598>.
- McEvoy, D., Tara, A., Vahanvati, M., Ho, S., Gordon, K., Trundle, A., Rachman, C., Qomariyah, Y., 2024. Localized nature-based solutions for enhanced climate resilience and community wellbeing in urban informal settlements. *Clim. Dev.* 16, 600–612. <https://doi.org/10.1080/17565529.2023.2277248>.
- Meerow, S., Newell, J.P., 2019. Urban resilience for whom, what, when, where, and why? *Urban Geogr.* 40, 309–329. <https://doi.org/10.1080/02723638.2016.1206395>.
- Ministry of Environment, Forestry & Tourism (MEFT), 2013. *NATIONAL CLIMATE CHANGE STRATEGY & ACTION PLAN (NCCSAP)*.
- Ministry of Environment, Forestry and Tourism (MEFT), 2011. *National Policy Climate Change Namibia*.

- Ministry of Environment, Forestry and Tourism (MEFT), 2021. First Adaptation Communication: Namibia's Climate Change Adaptation Communication to the United Nations Framework Convention on Climate Change (UNFCCC). Ministry of Environment, Forestry and Tourism, Department of Environmental Affairs and Forestry, Division of Multilateral Environmental Agreements.
- NSA, 2023. The National Strategy for the Development of Statistics (2023/24-2026/27). Brink, A. van den (Ed.), 2017. *Research in landscape architecture: methods and methodology*. Routledge/Taylor & Francis Group, London; New York, NY.
- Olgun, R., Cheng, C., Coseo, P., 2024. Nature-based solutions scenario planning for climate change adaptation in arid and semi-arid regions. *Land* 13, 1464. <https://doi.org/10.3390/land13091464>.
- Paris Agreement, 2015. The Paris Agreement | UNFCCC [WWW Document]. URL (<https://unfccc.int/process-and-meetings/the-paris-agreement>) (accessed 5.21.25).
- Pasgaard, M., Breed, C., Heines, M., Knudsen, L., Brom, P., Schmidt, A., Engemann, K., 2023. Citizen science beyond science: a collaborative approach for transformative sustainable development. *Citizen Science Theory Practice* 8, 41. <https://doi.org/10.5334/cstp.574>.
- Pieterse, A., du Toit, J., 2025. Local responses to climate change: navigating mainstreaming and transformative adaptation. *Cities* 157, 105606. <https://doi.org/10.1016/j.cities.2024.105606>.
- Prall, M., Olazabal, M., Lehmann, M., 2023. Socio-economic projections in urban climate change adaptation planning: practices and prospects for just adaptation. *Habitat Int.* 142, 102946. <https://doi.org/10.1016/j.habitatint.2023.102946>.
- Raymond, C.M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M.R., Geneletti, D., Calfapietra, C., 2017. A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environ. Sci. Policy* 77, 15–24. <https://doi.org/10.1016/j.envsci.2017.07.008>.
- van Rensburg, P., Tortajada, C., 2021. An Assessment of the 2015–2017 Drought in Windhoek. *Front. Clim.* 3, 602962. <https://doi.org/10.3389/fclim.2021.602962>.
- Rogers, N.J.L., Adams, V.M., Byrne, J.A., 2024. Agenda-setting and policy leadership for municipal climate change adaptation. *Environ. Sci. Policy* 161, 103869. <https://doi.org/10.1016/j.envsci.2024.103869>.
- Saldana, J., 2009. *The Coding manual for qualitative researchers*. First published 2009. ed. Sage, Los Angeles London New Delhi.
- Sarabi, Han, Romme, Vries, Wendling, 2019. Key enablers of and barriers to the uptake and implementation of nature-based solutions in urban settings: a review. *Resources* 8, 121. <https://doi.org/10.3390/resources8030121>.
- Satterthwaite, D., Archer, D., Colenbrander, S., Dodman, D., Hardoy, J., Mitlin, D., Patel, S., 2020. Building resilience to climate change in informal settlements. *One Earth* 2, 143–156. <https://doi.org/10.1016/j.oneear.2020.02.002>.
- Seddon, N., Chausson, A., Berry, P., Girardin, C.A.J., Smith, A., Turner, B., 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philos. Trans. R. Soc. B* 375, 20190120. <https://doi.org/10.1098/rstb.2019.0120>.
- Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., House, J., Srivastava, S., Turner, B., 2021. Getting the message right on nature-based solutions to climate change. *Glob. Change Biol.* 27, 1518–1546. <https://doi.org/10.1111/gcb.15513>.
- Sibiya, N.P., Das, D.K., Vogel, C., Mazinyo, S.P., Zhou, L., Kalumba, M.A., Sithole, M., Adom, R.K., Simatele, M.D., 2023. Overcoming bureaucratic resistance: an analysis of barriers to climate change adaptation in South Africa. *Climate* 11, 145. <https://doi.org/10.3390/cli11070145>.
- Singh, P.K., Chudasama, H., 2021. Pathways for climate change adaptations in arid and semi-arid regions. *J. Clean. Prod.* 284, 124744. <https://doi.org/10.1016/j.jclepro.2020.124744>.
- Sousa, A.R., Cruz, S.S., Breda-Vázquez, I., 2024. Understanding transformative capacity to boost urban climate adaptation: a semi-systematic literature review. *Ambio* 53, 276–291. <https://doi.org/10.1007/s13280-023-01940-2>.
- Spear, D., Zaroug, M.A.H., Daron, J.D., Ziervogel, G., Angula, M.N., Haimbili, E.N., Hegga, S.S., Baudoin, M.-A., New, M., Kunamwene, I., Togarepi, C., Davies, J.E., 2018. *Vulnerability and responses to climate change in drylands: the case of Namibia*. CARIAAASSAR Work. Pap. 41.
- Terton, A., Qi, J., Jang, N., 2024. Tracking Progress on the Integration of Nature-based Solutions and Ecosystem-Based Adaptation in National Adaptation Plan Processes.
- Thorn, J.P.R., Biancardi Aleu, R., Wijesinghe, A., Mdongwe, M., Marchant, R.A., Shackleton, S., 2021. Mainstreaming nature-based solutions for climate resilient infrastructure in peri-urban sub-Saharan Africa. *Landscape Urban Plan.* 216, 104235. <https://doi.org/10.1016/j.landurbplan.2021.104235>.
- Tipaldo, G., Allamano, P., 2017. Citizen science and community-based rain monitoring initiatives: an interdisciplinary approach across sociology and water science. *WIREs Water* 4, e1200. <https://doi.org/10.1002/wat2.1200>.
- Titz, A., Chiotha, S.S., 2019. Pathways for sustainable and inclusive cities in Southern and Eastern Africa through Urban green infrastructure? *Sustainability* 11, 2729. <https://doi.org/10.3390/su11102729>.
- Tran, J.H., Little, V.J., Tran, T.D., McClelland, R., 2024. Strategic opportunities for nature-based solutions: lessons for policy and practice from cross-city comparisons. *Nat. Based Solut.* 5, 100132. <https://doi.org/10.1016/j.nbsj.2024.100132>.
- UN-Habitat, 2022. UNITED NATIONS HUMAN SETTLEMENT PROGRAMME (UN-HABITAT) ANNUAL REPORT 2022.
- United Nations Convention to Combat Desertification (UNCCD), 2022. Desertification and Drought Day 2022 [WWW Document]. UNCCD. URL (<https://www.unccd.int/events/desertification-drought-day/2022>) (accessed 8.25.25).
- United Nations Convention to Combat Desertification (UNCCD), 2024a. Desertification and Drought Day 2024 [WWW Document]. UNCCD. URL (<https://www.unccd.int/events/desertification-drought-day/2024>) (accessed 8.25.25).
- United Nations Convention to Combat Desertification (UNCCD), 2024b. THIRD NATIONAL ACTION PROGRAMME FOR NAMIBIA TO IMPLEMENT THE UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION 2014-2024.
- United Nations Environment Programme (UNEP), Bueno Rubial, M.D.P., Mangan, A., Christiansen, L., Neufeldt, H., Hammill, A., Niles, K., Dale, T., Leiter, T., Njuguna, L., Singh, C., Bours, D., Butera, B., Canales, N., Chapagain, D., England, K., Pauw, P., Watkiss, P., Harvey, B., Charlery, L., Cundill-Kemp, G., Traerup, S., Sankam, J., 2024. Adaptation Gap Report 2024: Come hell and high water - As fires and floods hit the poor hardest, it is time for the world to step up adaptation actions. United Nations Environment Programme. <https://doi.org/10.59117/20.500.11822/46497>.
- United Nations Framework Convention on Climate Change (UNFCCC), 2020. United Nations Climate Change Annual Report.
- Washbourne, C.-L., 2022. Environmental policy narratives and urban green infrastructure: Reflections from five major cities in South Africa and the UK. *Environ. Sci. Policy* 129, 96–106. <https://doi.org/10.1016/j.envsci.2021.12.016>.
- Wijesinghe, A., Thorn, J.P.R., 2021. Governance of urban green infrastructure in informal settlements of Windhoek, Namibia. *Sustainability* 13, 8937. <https://doi.org/10.3390/su13168937>.
- Wolff, E., Rauf, H.A., Diep, L., Natakun, B., Kelly, K., Hamel, P., 2022. Implementing participatory nature-based solutions in the Global South. *Front. Sustain. Cities* 4, 956534. <https://doi.org/10.3389/frsc.2022.956534>.
- World Bank, 2024. (<https://www.worldbank.org/en/country/namibia/overview>). URL (<https://www.worldbank.org/en/country/namibia/overview>).
- World Bank Group, 2021. Climate Risk Profile: Namibia.
- Yin, R.K., 2018. *Case study research and applications: design and methods*, Sixth edition. ed. SAGE, Los Angeles London New Delhi Singapore Washington DC Melbourne.
- Zhu, S., Feng, H., 2025. Strengthening climate resilience through urban policy: a mixed-method framework with case study insights. *Land* 14, 890. <https://doi.org/10.3390/land14040890>.
- Ziervogel, G., Cowen, A., Ziniades, J., 2016. Moving from adaptive to transformative capacity: building foundations for inclusive, thriving, and regenerative urban settlements. *Sustainability* 8, 955. <https://doi.org/10.3390/su8090955>.
- Ziervogel, G., Enqvist, J., Metelerkamp, L., Van Breda, J., 2022. Supporting transformative climate adaptation: community-level capacity building and knowledge co-creation in South Africa. *Clim. Policy* 22, 607–622. <https://doi.org/10.1080/14693062.2020.1863180>.