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Article

Governance of Urban Green Infrastructure in Informal Settlements of Windhoek, Namibia

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Abstract: Facing increased rural-urban migration, population growth, climate change impacts, and cascading natural, security, and health hazards, many municipalities in sub-Saharan Africa are beginning to consider the benefits of urban green infrastructure for improving the resilience and wellbeing of residents living in informal settlements. However, present governance systems are often ill-equipped to deliver the scale of planning needed. Integration of urban green infrastructure into local government mandates, spatial planning and targeted action plans remains limited, further inhibited by scarce empirical research on the topic in Africa. Taking Windhoek, Namibia, and specifically Moses ||Garoëb, Samora Machel, and Tobias Hainyeko constituencies as a case study, we fitted key informant interview ($n = 23$), focus group ($n = 20$), and participant observation data into existing governance theory to investigate (a) benefits and trade-offs of present urban green infrastructure in Windhoek's informal settlements; (b) urban green infrastructure governance in terms of institutional frameworks, actors and coalitions, resources, and processes; and (c) the key desirable pathways for future urban green infrastructure governance in informal settlements. To this end, we used five green infrastructure initiatives to dissect governance intricacies and found diverse opportunities for innovative governance mechanisms. The urgent need for climate resilience in Namibia offers a policy and practice window to adopt context-specific approaches for multifunctional urban green infrastructure. However, for these initiatives to succeed, collaborative governance platforms and clearly delineated mandates are necessary, with explicit integration of urban green infrastructure into strategies for in-situ informal settlements upgrading and green job growth.

Keywords: green space; inclusive city; informality; local stewardship; participation; peri-urban settlements; policy instruments; self-governance; sub-Saharan Africa; right to the city



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1. Introduction

Sub-Saharan Africa (SSA) is among the world's fastest urbanising regions, and the global proportion of African urban dwellers is projected to rise from 11.3% in 2010 to 20.2% by 2050 [1]. Demographic changes driven by rural-urban migration and natural population growth interact with challenges such as widespread poverty and unplanned informal settlement expansion [2]. These challenges are exacerbated by governance systems ill-equipped to deliver the scale of planning needed to deal with burgeoning informal settlements [3], which feature high densities of temporary structures built with low-cost materials such as corrugated iron sheets. Occupants here usually lack formal employment, secure land rights, food security, good sanitation, and other basic services and infrastructure [4]. At a local government level, the lack of expertise, funds, and data on urbanisation continues to hinder efforts to improve living conditions and implement sustainable natural resource use [5].

Concurrently, cities are social-ecological systems, where development and rapid land use change cause unique disturbance regimes [6]. Urban natural areas provide humans and other species with important ecosystem services [7,8]. With the rise of movements to ‘bring nature back into cities’ [9], new possibilities for planning and managing urban natural areas are emerging. Globally, the increased interest in the nexus between global environmental change, cities, and natural ecosystems [10,11] has brought concepts such as multifunctional urban green infrastructure (UGI) to the fore [12]. However, there remains a research gap in understanding the applicability, utility, and practical implementation of UGI in an SSA context, as its multiple benefits and governance mechanisms are often framed from a predominantly ‘Western’ urban perspective [13,14].

Additionally, projections of climate change indicate precipitation decreases of 10–20%, more days at maximum temperature, longer dry spells, and more frequent extreme events, especially over Namibia, Botswana, northern Zimbabwe, and southern Zambia in southern Africa [15]. Increasing exposure to such climatic and non-climatic changes necessitates urgent interventions to improve the resilience of vulnerable people and ecosystems in peri-urban areas [16,17]. This presents a unique set of challenges [16] but also many opportunities for UGI integration into adaptation and mitigation plans [18,19]. Research on urban climate resilience in peri-urban SSA remains nascent but is critical to provide insights for context-specific pathways forward [5,20–22].

1.1. Governance of Urban Green Infrastructure in SSA’s Informal Settlements

In this paper, we define UGI, following Thorn et al. [5] and Ahern et al. [23] (p. 255), as ‘permeable, multifunctional and interconnected spaces that support environmental, recreational and wellbeing functions within a city, through provisioning, regulating, supporting and cultural ecosystem services.’ Considered cost-effective, especially in the long term [24], and multifunctional in the co-benefits these spaces can provide [25,26], UGI also works effectively with engineered infrastructure as ‘hybrid infrastructures’ [27]. UGI is often referred to as ‘green and blue spaces’ or ‘ecological infrastructure’ [28] and falls under the broader umbrella of nature-based solutions [29]. Many ecosystem services derived from UGI are important for resilience of informal settlement residents, such as microclimate regulation through cooling, filtration of grey water, production of food (urban agriculture and home gardens), air quality improvements, energy supply (fuelwood), support for livelihoods, improved mobility, and better psycho-social wellbeing [18,19,28].

However, unlocking pathways for sustainable and inclusive development [30,31] of UGI relies on good governance. Here, we define governance as the ‘processes, interactions, organisations, and decisions which enable stakeholders to control and coordinate their interconnected needs and desires, while interacting with the environment at different scales’ ([32], as seen in [33] (p. 465)). Governance encompasses both state and non-state actors, formal and informal institutions, rules, mechanisms, processes, and scales [33]. For UGI, ‘governance’ encompasses multi-level interactions between local communities, the private sector, non-governmental actors, and local authorities working together in a polycentric system, and stands in contrast to ‘government’, where actors such as local authorities have the primary, often top-down responsibility for UGI [34].

In SSA, community-led or autonomous adaptations using UGI, implemented as a stress response to environmental changes, are already apparent (e.g., maintenance of home gardens to combat food insecurity [17]), with enormous potential for UGI to alleviate resource and financial constraints faced by municipal authorities in SSA [35,36]. Nevertheless, a pro-grey mindset and conceptualisation of environmental management as ‘luxury’ not ‘necessity’, especially for informal settlements [5,19], coupled with town planning approaches that are often colonial relics with little provision for equitable land and tenure policies [28], perpetuate institutional failures where UGI governance for low-income residents is deprioritised or overlooked. However, there is a growing body of evidence that concerted integration of UGI into settlement planning would simultaneously unlock pathways for inclusivity and social justice [14]. Most studies on UGI governance in SSA

focus on South Africa, creating a distinct geographical bias [18]. We contribute to closing this research gap by examining dryland Windhoek, Namibia, as a case study, as it represents wider changes and governance challenges faced by cities across Africa and the Global South.

1.2. Windhoek, Namibia: Growth of Informality and Impact on Natural Urban Areas

Namibia has undergone an accelerated developmental transformation from a largely rural-based society to 47.9% of the population now living in urban centres [37]. The capital Windhoek has witnessed rapid urbanisation in the last 30 years, but town planning regulations, affordable housing provisioning for low-income groups, and flexible land tenure options have not kept abreast with these developments [38]. This has led to approximately 42.3% of households in Windhoek being temporary shack homes in informal settlements [37]. In-situ upgrading led by the City of Windhoek (CoW) and the Khomas Regional Council has not kept pace with this informal settlement growth.

At present, peri-urban expansion in Windhoek encroaches into natural areas such as riverbeds, hilly slopes, and other marginal lands [39]. Approximately 75% of informal settlement residents depend on riverbeds and peripheral green spaces as areas for open defecation, and the health impacts are evident in recent Hepatitis E outbreaks [5,40,41]. The pollution of water bodies is caused by unregulated dumping of solid waste and heavy metals, agricultural runoff, nutrient loading, and sedimentation [42]. In May 2019, President Hage Geingob declared the drought affecting Namibia, including Windhoek, as a natural disaster [43]. Meanwhile, flooding occurs in the rainy season, where fast currents cause drowning and loss of property in informal settlements. Predicted climate change impacts of drought, heat stress, and flooding may further interact with existing urban poverty, food and water insecurity, lack of sanitation, and disaster risk to perpetuate cycles of vulnerability and inequality [44].

Recognising this need for dryland-specific climate interventions, Windhoek was the first city in Namibia to formulate an Integrated Climate Change Strategy and Action Plan (ICCSAP) [21]. Developed to fill the gap in municipal policies addressing cumulative impacts of climate change on the city and its inhabitants, the ICCSAP is currently in draft form. Encouragingly, it contains explicit sections on 'human settlements' and 'biodiversity and ecosystem goods and services' [21,45]. Since inadequate planning and governance systems are a foremost barrier in implementing UGI in urban SSA [46], such draft plans as the ICCSAP, together with ongoing upgrading efforts, provide the policy and practice windows to integrate UGI more explicitly.

1.3. Conceptual Framework for Analysis of UGI Governance

Lawrence et al. [33] presents a useful framework to analyse governance of UGI in Windhoek's informal settlements. Developed to assess urban forestry governance, the framework draws from the policy arrangements approach [47]. This approach postulates how state and non-state actors work together to fulfil governance functions. The framework emphasises how change in one dimension affects change in another dimension ([34]; Figure 1). Applying this framework to Windhoek, we examine four adapted dimensions. Institutional frameworks relate to governmental policies, laws, and regulations that affect UGI, land ownership, and access rights. Actors and coalitions relate to active and supporting stakeholders, as well as formal partnerships established to deliver the UGI. Resources encompass funding, transfer and access of technical knowledge, and policy tools that support implementation, such as assigned staff or monetary incentives. Finally, processes are the ways in which actors are consulted through participatory mechanisms and include methods for monitoring, evaluation, and learning. Governance occurs along a continuum, ranging from local authorities (state) taking a leading role to collaborative governance with non-state actors and self-governance by non-state actors [33,34].

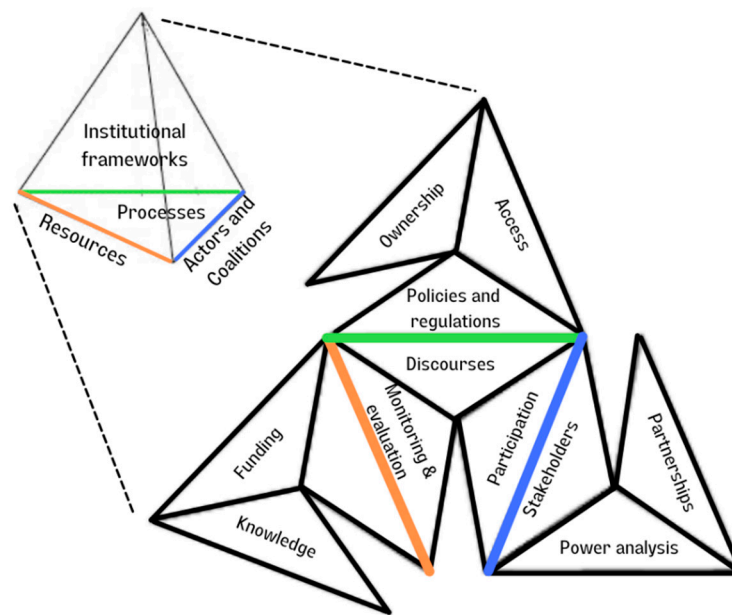


Figure 1. Dimensions of governance arrangements for Windhoek, adapted from Lawrence et al. [33]. If one dimension of the tetrahedron fails, then the integrity of the entire structure is compromised. The top left figure represents an aggregation of the categories shown in the bottom right figure. The colours represent the green, blue, and brown spaces and initiatives that make up urban green infrastructure (UGI), with brown spaces representing drylands.

The overarching aim of this paper is to determine present and potential governance mechanisms for UGI in Windhoek, while drawing out applicable insights for similar SSA informal settlements and dryland environments. We adapt the case study framework described (Figure 1) to investigate (a) benefits and trade-offs of present UGI in Windhoek's informal settlements; (b) UGI governance in terms of institutional frameworks, actors and coalitions, resources, and processes; and (c) the key desirable pathways for future UGI governance in informal settlements.

2. Materials and Methods

2.1. Study Site

Namibia is one of SSA's most arid countries. Approximately 70% of the land area, including its capital Windhoek, is classified as arid to semi-arid [48]. Table 1 provides a demographic and environmental profile of Windhoek. Our study focuses on the peri-urban areas near the northern and north-western boundaries of the city, adjacent to Katutura, the former black township during Namibia's apartheid era (Figure 2). Although segregation based on ethnicity ended with Namibia's independence in 1990, an economic gradient still exists from affluent neighbourhoods in the south to the north west of the city.

2.2. Data Collection

Our empirical research employed key informant interviews ($n = 22$), focus groups ($n = 20$), and rapid participant observation over two months of fieldwork in Windhoek, Namibia, between June and July 2019, which constitute the dry winter months in Central Namibia. Discussions were conducted in English or Oshiwambo with a translator.

Table 1. Basic profile of Windhoek (Sources: [21,37,49,50]).

Variable	Value
Region	Khomas
Area	5133 km ²
Elevation	1655 m
Population (2016)	415,780
Population percentage living in informal settlements (2016)	42.3%
Average rainfall	360 mm/a
Average evaporation	3300 mm/a
Threshold for drought year	<150 mm/a
Average maximum temperatures	28–32 °C
Average minimum temperatures	2–8 °C
Predicted climate change scenarios for Windhoek for 2040	2 °C warmer with twice as many hot days and 1/3 less rainfall 1.5–2 °C warmer with more rain coming later in the rainy season 1–1.5 °C warmer, with average rainfall remaining constant, but becoming more intense



Figure 2. Map of study site in Windhoek, Namibia. The area of interest for this study lies in the informal settlements, which are located on the outskirts of the Moses ||Garoëb, Samora Machel, and Tobias Hainyeko Constituencies. (1) Location of Greenwell Matongo C informal settlement, bordering Goreangab Dam, where one focus group was held. (2) Haka-hana community centre near Havana informal settlement, where another focus group was held. (3) Okuryangava with surrounding informal settlements, one of the areas where transect walks were carried out. The image shows unplanned sprawl extending towards the north and northwest, as well as hilly terrain surrounding the city. (Base map provided by Development Workshop—Namibia, 2019).

2.2.1. Key Informant Interviews

To access key informants for semi-structured interviews, we first conducted actor network analysis and an online search of relevant reports, articles, and staff pages of organisations such as the CoW. Our sampling design employed snowball sampling, i.e., tapping into the network of known informants, and obtaining contact details and introductions through them [51]. Key informants were selected to be a representative cross section of actors with expertise or experiences related to UGI in informal settlements (Table 2). Interviews, which lasted

approximately 45 mins, covered the following areas: diverse actors' understanding of natural ecosystems and their benefits in Windhoek, challenges of UGI implementation in informal settlements, identification of relevant actors and their roles in UGI governance, and optimal governance mechanisms for potential success (schedule in Appendix A).

Table 2. Sectors represented by key informants and focus group participants. The institution type assigned to participants is based on their role at the time of participation in the study, but many also drew insights from past multi-sectoral experiences.

Institution Type	Relevance to Study	<i>n</i>	No. of Females
Residents of informal settlements	Appointed community leaders of informal settlements, and residents who are active in the formal and informal labour force (e.g., food sellers, fodder collectors), as well as members of neighbourhood youth clubs.	20	14
Constituency	Elected head councillors of constituencies who have sections of informal settlements within their jurisdictions.	2	0
Local authority	Officials in City of Windhoek Divisions of Environmental Management and Health Services, Human Settlements, and Parks and Recreation of the City of Windhoek, with direct or indirect responsibility for governance and maintenance of UGI in formal and informal areas of the city.	6	1
NGO/Third Sector	NGOs and Civil Society Organisations (CSOs) who work directly with residents of informal settlements, broader coordinating bodies, and those active in rural areas, namely Shack Dwellers Federation Namibia—Namibia Housing Action Group (SDFN-NHAG), Development Workshop- Namibia, Namibian Chamber of Environment, and Desert Research Foundation of Namibia.	9	4
Private sector	Architects, planning consultants, and businesses that work closely with residents in informal settlements.	4	1
Academia	Lecturers and researchers at the Namibia University of Science and Technology (NUST), in the Department of Architecture and Spatial Planning.	2	0
		43	46.5%

2.2.2. Focus Groups

Two focus group discussions of 2–5 h were held in Greenwell Matongo C ($n = 6$ participants) and Hakahana ($n = 14$ participants) with residents of informal settlements. Introductions to the communities were facilitated by the Shack Dwellers Federation of Namibia and the Namibia Housing Action Group (SDFN-NHAG), an NGO partnership that works closely with residents to facilitate access to tenure and services through a savings group model [52].

2.2.3. Participant Observation

To validate and contextualise findings, qualitative data from focus groups and interviews were combined with rapid participant observation. With the formal permission of constituency councillors, and with a local translator and guide from the community, we conducted transect walks by visiting three informal settlements areas in Greenwell Matongo C and Hakahana in Moses ||Garoëb constituency and Okuryangava in Tobias Hainyeko constituency. Additionally, using an ethnographic approach, the first author spent two months living in Windhoek. While in Windhoek, she embedded herself in the day-to-day activities of residents of a middle-income neighbourhood of Khomasdal in Windhoek. She visited local markets and roadside selling points, attended SDFN-NHAG meetings in informal settlements, and had informal conversations with conservation and

environmental practitioners, town planners, students, and residents across the city. Both authors continued engagement through 2019–2021 using in-person and remote means.

2.3. Analysis

Anonymised interview and focus group transcripts were deductively coded and clustered using NVivo (12.0.0.0) to generate key themes. Through an iterative process, we then assigned these to nodes corresponding to the dimensions of our adapted governance case study framework [53]. Using these themes and insights, and supported by the broader literature on UGI, we present a multi-dimensional snapshot of UGI governance in this complex setting.

3. Results

3.1. UGI in Windhoek's Informal Settlements

3.1.1. Benefits

UGI that holds value for informal settlement residents and other actors is predominantly riparian dryland-adapted vegetation (e.g., grasses, trees, shrubs) adjacent to the ephemeral Arebbusch and Gammams river networks that runs through Windhoek and drains into the Goreangab Dam. Other key forms of UGI are found in meeting areas, sports grounds, hilly slopes, urban farms, small garden plots, and green fences interspersed among dwellings (see also [5]).

Respondents derive several provisioning, regulating, supporting, and cultural ecosystem services from UGI (Figure 3). In terms of provisioning ecosystem services, fuelwood is usually collected from bushes and trees within the city, particularly around riverbeds, by residents who cannot afford gas or electricity in homes, or for informal businesses such as barbecued meat stands. For some residents, these form the basis of their cooking and livelihoods, while others resort to illegally tapping into the grid for energy needs. Grasses and *Acacia* pods are harvested from riverbeds and Camel Thorn trees by a few residents and sold to farmers as livestock feed, either directly on farms or by the roadside. A resident in a focus group mentioned that '*farmers contact these people directly, and then only a few people have this small business*' (June 2019). Urban agriculture, although not widespread, allows individuals to grow vegetables for household consumption and re-sale. Cultivation is usually on small plots near homes. Some residents grow plants for medicines, such as *Aloe vera* for burns and injuries, as well as *Moringa oleifera* (Drumstick Tree). These trees can be seen dotted around the settlements, especially in school yards or church gardens.

Regulating ecosystem services are provided by grasses, trees, and shrubs, by filtering and attenuating water; regulating microclimate; purifying air; and preventing soil erosion of riverbanks and hilly slopes. Intact riparian vegetation buffers against stormwater overflow and slows streamflow velocity. Shade provided by larger trees are prized by residents amidst intense land demands, and these trees are protected even when the surroundings are cleared. These are particularly important as communal meeting points and cooler spaces outside unventilated corrugated iron shacks, which lack electric cooling in summer months. Although they are considered an invasive species, *Prosopis* trees growing in common areas of informal settlements provide these services.

Supporting services include UGI providing habitats for snakes, rats, birds, and baobabs found in dense riparian vegetation, especially around the Goreangab Dam. UGI filters grey water, particularly when well maintained. Residents are also aware that green vegetation captures atmospheric carbon, produces oxygen, and maintains air quality. Other supporting ecosystem services include soil regeneration and nutrient cycling.

UGI in Windhoek has much to provide in terms of cultural ecosystem services, such as recreational spaces, improved psychological wellbeing, and aesthetic beauty, but it has not been optimised or maintained for these services. As described by a CoW official from the Division of Environmental Management and Health Services in an interview: '*During the rainy season, the riverbeds can transform into beautiful water bodies*' (June 2019). Recreational spaces include school football fields and communal meeting areas, and the

largest recreational space easily accessible to residents is the UN Plaza, a green park in Katutura. In addition, the Goreangab Dam offers aesthetic, recreational, and tourism value, as evidenced by operations such as Penduka Village and Lodge (a social enterprise benefitting women, including waterside accommodations and beadmaking). Water from the dam is used by Penduka to irrigate grass on the site, and although they run small-scale hydroponic greenhouses, the water is not used for food production, as it is contaminated.



Figure 3. Examples of ecosystem services in and around informal settlements in Windhoek, Namibia. (a) Riparian vegetation near the Goreangab Dam acts as habitat and corridors for landscape connectivity for biodiversity (supporting services). (b) Penduka is a social enterprise and small guest house located on the edge of the Goreangab Dam – with the potential as a multifunctional recreational area (cultural services). (c) A riverbed in Okuryangava, one of the informal settlements, which has some grasses growing on the slopes, accelerating breakdown of pollutants and providing bank stabilisation (regulating services). (d) Grass harvested from a riverbed in Khomasdal is stacked on the side of the road, with a phone number shown for interested buyers (provisioning services). (e–i) Urban food garden initiative spearheaded by Shack Dwellers Federation Namibia (SDFN) and Eloo Permaculture / Farm Okukuna, deployed in 2020 in response to severe food insecurities brought on by the ongoing COVID-19 crisis. Over 600 plots, growing staples for Namibian cuisine such as spinach, have been established during the last year (images by first author during winter 2019, and SDFN, 2020–2021).

3.1.2. Trade-Offs Associated with UGI

Some green spaces such as riverbeds are linked to ecosystem disservices, which are functions of natural ecosystems that are perceived to negatively affect human wellbeing [54]. For instance, vegetation conceals criminal activity and increases risks of drowning in waterways during the rainy season, when people cross over makeshift bridges or build structures near watercourses in informal settlements. In general, riverbeds are considered malodorous and dirty, bringing grey water and industrial pollutants from other areas of the city to the informal settlements. Riverbeds are also widely used for open defecation. This causes outbreaks of water- and vector-borne diseases such as cholera and hepatitis E. Speaking about stagnant water in riverbeds, one resident mentioned that: *'When that water remains stuck, you can see the mosquitoes just lying there'* (July 2019). Residents living near the Goreangab Dam also complained of snakes in the riparian vegetation.

3.2. Complexities of UGI Governance in Windhoek's Informal Settlements

We now consider five UGI initiatives to dissect the complexities of governing UGI in and around informal settlements [27] (Table 3). The five case studies are Farm Okukuna, the Community-Led Total Sanitation (CLTS) Programme, existing green recreational spaces Goreangab Dam and UN Plaza, Fruitful Landscape in Katutura, and Windhoek Riverwalk. Farm Okukuna is a partnership between the NGO Eloolo Permaculture and the CoW, set up specifically to enhance food security in informal settlements of Windhoek. Farm Okukuna trainers run urban agriculture and community nutrition programmes, with a particular focus on women. A partnership between Development Workshop—Namibia, UN Children's Emergency Fund (UNICEF), and the Namibian Chamber of Environment, established the CLTS programme, in response to the sanitation crisis in informal settlements. One of the objectives of CLTS is to make riverbeds open defecation-free by installing toilets and cleaning riverbeds. The Goreangab Dam has picnic sites and the Penduka Village on its banks. UN Plaza is a large public park. These are the largest formal green spaces close to the informal settlements and are maintained by the Parks and Recreation Division of CoW. The site previously known as 'Fruitful Landscape' was an arrangement between the Namibia University of Science and Technology (NUST) and a private landholding in Katutura [55]. It was established as an academic training laboratory for NUST students to study integrated techniques for landscape restoration and agriculture. NUST restored 5 ha of land by diverting storm water flow and regenerated vegetation including dryland-adapted trees. The project demonstrated the successful use of contour ditches and bunds to trap rainwater and rehabilitate soil. However, the project has been discontinued. On the other end of the spectrum, the Windhoek Riverwalk is still in planning stages. If implemented, the Riverwalk will see the strategic rehabilitation of riverbeds through the city, creating opportunities for commerce, non-motorised mobility, and recreation.

Table 3. Description of five case studies that can be classified as UGI-related initiatives in and around Windhoek’s informal settlements. Categories are interrelated and non-exhaustive.

Case	Farm Okukuna–Eloolo Permaculture Project	Community-Led Total Sanitation (CLTS)	Green Recreational Spaces (e.g., Goreangab Dam, UN Plaza)	Fruitful Landscape, Katutura	Windhoek Riverwalk
Description	NGO-run permaculture project, in partnership with CoW municipality	Urban sanitation and river rehabilitation programme within informal settlements	Multifunctional green spaces, close to residents in north-western Windhoek	Ecosystem and soil restoration initiative, designed as an academic living laboratory for students	Urban riverbed rehabilitation programme, connecting historically segregated neighbourhoods through green walking and cycling paths
Scale	Single site initiative	Neighbourhoods	Single site initiatives	Private landholding	Citywide
Vegetation	Permaculture project for urban agriculture, vegetables and fruit, and shade trees	Dryland riparian vegetation, shade trees, recreational areas	Dryland riparian vegetation, shade trees, recreational areas	Contour ditches and ponding bunds for rainwater infiltration, supporting dryland grasses and fruit trees	Dryland riparian vegetation, scrub, recreational areas, and economic nodes
Status	Ongoing	Ongoing	Ongoing	Discontinued	Planning

3.2.1. Institutional Frameworks

Policies, Planning, and Regulations

The CoW does not have policies, strategies and plans that explicitly recognise UGI, but UGI components are implicit. For example, the CoW Transformational Strategic Plan 2017–2022 makes provisions for a ‘quality urban environment’. Meanwhile, the CoW’s Development and Upgrading Strategy of 1999 includes planning for green spaces within in-situ informal settlement upgrading plans. Primary responsibility for public spaces and environmental management is in the hands of the CoW, according to the Local Government Act No. 23 of 1992 (amended in 2002). The Water Resource Management Act No. 11 of 2013 gives the CoW the mandate for wastewater management. However, the Act itself does not detail the specific regulations that the CoW should implement [56]. This gap leaves water management open to interpretation by the CoW, and citizens complain that the municipality is taciturn and ambiguous regarding regulations for rainwater harvesting and stormwater diversion. This presents irrigation barriers for urban agriculture. For instance, NUST’s Fruitful Landscapes was discontinued in large part due to the difficulties of adhering to the ambiguous water diversion restrictions and inflexible zoning regulations of the CoW, among other reasons. However, it was a success in terms of ecosystem restoration, as described a researcher from NUST: ‘*it was interesting to see how nature healed itself. We achieved a lot of water infiltration, and the grasses grew so plentifully there. They formed a natural barrier and puffed up the soil underneath*’ (July 2019).

Another regulation related to UGI is the Environmental Management Act No. 7 of 2007. This Act is important for biodiversity conservation and allows the CoW to address habitat fragmentation and loss of green space in cities [57]. The Act stipulates that Environmental Impact Assessments (EIAs) must be carried out prior to settlement upgrading initiatives to assess the potential social, economic, , and ecological impacts of the proposed developments. However, externally appointed consultants usually carry this

out, and public participation in the EIA process is lacking. A housing NGO representative explained, *'if you cannot really identify with the community what are the environmental assets they can use and utilise, environmental impact assessments in upgrading are a useless exercise'* (June 2019).

A separate regulatory mechanism that influences UGI and low-income residents' livelihoods is a permit from the CoW's Division of Health and Environment that allows for harvesting wood. Many residents live on unserviced land, relying on bought or collected fuelwood for cooking. The permit prevents unlawful harvesting of fuelwood and *Acacia* pods. However, the monitoring and enforcement of these regulations are not apparent, and although this footprint is small compared to clearing for developments and housing, it has driven green space reduction in north-western Windhoek in the last 20 years [5]. Consequently, residents now travel much further to the city's periphery to collect wood, even venturing into protected areas such as the Daan Viljoen Reserve. As described by an NGO representative: *'In terms of change, we have seen informal urbanisation spread, and we have seen the indigenous vegetation being cleared to allow that. This has a big local impact on people's quality of life'* (June 2019). Comparatively, grass collection for sale as animal fodder, particularly from riverbeds after the rainy season, does not require a permit, as the CoW prefers grasses to be shorter in riverbeds for security purposes. Therefore, it allows grass sellers to cut these grasses prior to the CoW's dredging activities.

Ownership

UGI in informal settlements is generally found in land with contested land tenure rights, and according to results of a study by Thorn et al. [5], 98% of informal residents in Windhoek do not have formal tenure. This 'undeclared' or 'unzoned' nature of informal settlements is particularly problematic for CoW divisions such as Parks and Recreation, Disaster Risk Management, and Roads and Stormwater, which manage various components of public open spaces in formal areas of the city. According to the Local Government Act of 1992 and the Windhoek Town Planning Scheme, these divisions do not have the mandate for acting in 'undesigned areas', leaving a gap in management, irrigation, maintenance, and monitoring of green spaces in informal settlements. Often, one-off attempts at planting street trees are undermined by instances of vandalism because non-state actors do not have the human resource and financial capacity for long term maintenance. Furthermore, there is no evidence of environmental NGOs active in informal settlements in Windhoek. This factor has prompted NGOs such as SDFN-NHAG and Development Workshop—Namibia to take the environmental mandate upon themselves, expanding their current work in land and housing.

Ownership has been shown in other studies to have a strong connection to sense of place as well [13]. In Windhoek, the lack of secure land tenure and affordable housing options and unstable income streams lead to a diminished sense of ownership and belonging. This demotivates informal residents from investing scarce financial resources to maintain or restore UGI (see also [58]).

Access

In neighbouring South Africa, a 'green apartheid' has occurred, where more affluent, historically white-designated areas have significantly more green spaces than historically predominant Black African, Coloured, or Indian areas, with little indication of this trend being reversed [28]. Windhoek underwent the same physical apartheid segregation [52] and shows a similar pattern of greening across the city. It is apparent that there is need for green spaces to act as freely accessible social enablers [28], further explored in sections on the Riverwalk. However, where UGI is publicly available and accessible in Windhoek (Table 4), ecosystem disservices are common (Section 3.1.2) and negatively impact recreational and other cultural benefits [59].

Table 4. Comparison of institutional frameworks that underpin initiatives that can be classified as UGI-related in and around Windhoek’s informal settlements. Categories are interrelated and non-exhaustive.

Case	Farm Okukuna—Eloolo Permaculture Project	Community-Led Total Sanitation (CLTS)	Green Recreational Spaces (e.g., Goreangab Dam, UN Plaza)	Fruitful Landscape, Katutura	Windhoek Riverwalk
Policies	CoW Transformational Strategic Plan 2017–2022	CoW Development and Upgrading Strategy, 1999	CoW Transformational Strategic Plan 2017–2022	CoW Transformational Strategic Plan 2017–2022	CoW Sustainable Urban Transport Master Plan
Planning and regulations	CoW drainage and stormwater regulations	Riverbeds in formal areas are under the mandates of Parks and Recreation, Environmental Management, Human Settlements, and Roads and Stormwater Divisions of CoW	These spaces in formal areas are under the mandate of Parks and Recreation Division of CoW	CoW drainage and stormwater regulations, and zoning regulations	CoW zoning regulations
Ownership	Mixed: NGO lease of land from CoW	Mixed: Riverbeds are under CoW, with resident management and NGO expertise in this instance	Public: CoW	Private: agreement between university and private landholding	Public: CoW
Access and use rights	Private: Restricted access through organised trainings or tours	Public access	Public access	Private: Restricted access	Public access

3.2.2. Actors and Coalitions Stakeholders and Partnerships

The unplanned, transient, and heterogeneous nature of peri-urban areas [17] means that a variety of actors assume responsibility for maintaining different types of UGI (Table 5). For instance, neighbourhood groups of twenty houses often self-govern as ‘blocks’ to carry out functions like mending fences, reinforcing slopes, and maintaining meeting areas marked by larger trees. Many private households informally manage UGI, such as flower gardens and fences surrounding homes. Some schools and clinics maintain playgrounds and gardens, and few elected constituency councillors have urban food gardens in their office premises. A community-appointed water point committee oversees the maintenance and management of the public taps and associated tariffs, endorsed by the CoW.

In 2020, a non-state collaborative partnership was formed to address growing food insecurity during COVID-19 lockdowns. The SDFN joined with Farm Okukuna and philanthropic donors to train residents in urban gardening techniques. The partnership established over 600 garden plots near informal residents’ homes, starting March 2020. A key enabler was the free provisioning of water for informal settlements by the CoW to mitigate impacts of unhygienic practices during the pandemic, whereas previously there were water tariffs. Residents use permaculture and water-sparing techniques taught by Farm Okukuna trainers to grow produce such as spinach, tomatoes, carrots, and lemons for household consumption and resale (Figure 3e–i).

Table 5. Comparison of actors and coalitions within initiatives that can be classified as UGI-related in and around Windhoek’s informal settlements. Categories are interrelated and non-exhaustive.

Case	Farm Okukuna—Eloolo Permaculture Project	Community-Led Total Sanitation (CLTS)	Green Recreational Spaces (e.g., Goreangab Dam, UN Plaza)	Fruitful Landscape, Katutura	Windhoek Riverwalk
Primary stakeholders	Eloolo Permaculture Initiative NGO, CoW	Residents of informal settlements, CoW, NGOs	Residents, CoW, especially Parks and Recreation Division	Namibia University of Science and Technology (NUST), landowners	CoW, NUST, Environmental NGOs, business owners (for economic nodes), private architecture firm, citizens
Partnerships	Between NGO and CoW, where municipality provides land and water	Numerous, e.g., youth organisations, volunteer network, and NGOs	Future partnerships could include CoW and Riverwalk, for instance	Informal agreements to sell produce to intermediaries	Public private partnership twinned with Riverwalk in City of Austin, Texas, USA
Power analysis (those with high influence)	Led by Eloolo Permaculture Initiative, oversight by CoW	High influence of elected councillors and community leaders for resident buy-in	Management could be through voluntary citizen committees, requires CoW leadership	Privately led, but discouraged by CoW due to conflicts on water regulations	Conceptualised by private entity, now transferred to CoW for public ownership

Initiatives around Windhoek’s main dams also offer examples of partnerships for UGI management, albeit with differing levels of success. Avis Dam, in the city’s southern extent, is maintained by a voluntary non-profit NGO named Greenspace [60]. The NGO provides readily accessible recreational opportunities to residents in southern Windhoek. Goreangab Dam in the northwest is an area of scenic beauty. Yet the lack of strategic governance hampers the equitable sharing of the dam’s recreational benefits to low-income residents. A public private coalition for the management of this dam, the Goreangab Action Committee, used to exist but is now defunct due to coordination difficulties. There remains potential to resurrect such partnerships, with citizens and industry working together with the CoW Parks and Recreation Division. However, current plans to develop a Goreangab Waterfront as a leisure centre and property development risks gentrification [61].

Coalitions also exist to implement city-wide UGI projects, such as the proposed Riverwalk Initiative. The initiative aims to connect southeast to northwest Windhoek by rehabilitating 200 ha of riverbeds to frame a 20 km green recreational biking and walking corridor, with strategic economic nodes in between. Riverwalk brings together the CoW, NUST, Barnard Mutua Architects, NGOs, and citizens to form a public private partnership. The Goreangab Dam is proposed as the western-most point of the initiative, but the planned initiative does not include informal settlements. However, implementation of the Riverwalk is hampered by the competing priorities of land necessary for motorised transport, ambiguity of responsibility for management of riverbeds, funding gaps, and fears of compromised security.

Power Analysis

By their very nature of operation outside formal administrative systems, power structures prove difficult to decipher in informal settlements [17,62]. Stakeholders have differing degrees of power and agency to influence decision making and associated access to green spaces. Residents have agency over their immediate surroundings in terms of daily maintenance (e.g., planting, irrigation, soil management). Beyond the household level, religious leaders, schools, members of Constituency Development Committees (CDCs), and

nominated community leaders have a significant influence on residents' behaviours and perceptions. The food garden initiative (in section on Stakeholders and Partnerships above) is an example of collective action by non-state actors overcoming the lack of individual agency within informal settlements. Additionally, resource management programmes such as CLTS have been championed by elected constituency councillors and the CoW, which is critical for community buy-in and longevity.

Despite these examples, the illegality of residents' occupation makes them vulnerable to eviction, which is a major barrier to investment in UGI. We found that residents generally expect municipal guidance and action for public services such as solid waste management, sanitation, and UGI implementation. However, the CoW's divisions that should be responsible for these services do not have clear mandates or strategies for actions in informal settlements. This frustrates residents and leads to conflicts over unmet needs and lack of momentum.

3.2.3. Resources

Funding

Individuals frequently report a lack of funding to restore and maintain UGI, such as to obtain irrigation water, specialised equipment, seeds, pesticides, and cold storage facilities for perishable agricultural produce, in addition to lack of land. At the local authority level, the CoW is financially autonomous from the central government [56] and uses rates and income tax to maintain green spaces and dredge riverbeds in formal parts of the city. The CoW Human Settlements Division estimates that NAD 3–4 billion (c. USD 200–300 million) would be required for complete servicing and upgrading of the informal settlement areas, but this estimate only includes provisioning of land tenure and basic services and excludes ecosystem restoration and maintenance. Officials emphasised that informal settlement residents do not pay rates and taxes. Because of the political and economic influence associated with such payments, and despite acknowledged equity concerns, UGI restoration is generally prioritised for wealthier areas.

Nevertheless, other governance approaches exist that prevent the financial burden from falling solely on residents or the CoW, such as the mixed financing model Eloo Permaculture (Table 6). The NGO runs Farm Okukuna as a social enterprise with donor and CoW support. Meanwhile, SDFN-NHAG savings groups have monetary mechanisms that could be adapted for UGI investment [52]. Examples exist of smaller NGOs, such as Family of Hope Services nursery school in Moses ||Garoëb, using donations to install and maintain drip irrigation for an urban food garden, feeding children daily through meal programmes. Riverwalk hopes to obtain private investment and donations, while using rental income and public funds. In the long term, there is significant potential for UGI to support informal livelihoods, as evidenced by one resident taking part in the SDFN food garden initiative: *'Since I started growing spinach outside my shack, I have had neighbours begging me to sell them some of my produce. I have sold more than 300 NAD worth of spinach so far, and I used some of that money to buy more seeds and tools for my garden'* (May 2021).

Table 6. Comparison of resources and types of knowledge within initiatives that can be classified as UGI-related in and around Windhoek’s informal settlements. Categories are interrelated and non-exhaustive.

Case	Farm Okukuna—Eloolo Permaculture Project	Community-Led Total Sanitation (CLTS)	Green Recreational Spaces (e.g., Goreangab Dam, UN Plaza)	Fruitful Landscape, Katutura	Windhoek Riverwalk
Funding	CoW, external fundraising, income from produce and some training programmes	Current financial support from European Union funding	Presently CoW; Could include philanthropy, CSR, nominal access fees	University	CoW, private donations, businesses hiring premises
Knowledge	Knowledge of permaculture practices specific to dryland areas	Knowledge of riparian ecosystem restoration, floodlines, and disaster risk reduction techniques are required, but not applied	Landscape architecture and ecology, and sustainable management models are required	Expertise on land restoration, contours and drainage, urban agriculture, including dryland techniques	Expertise on landscape architecture and ecology, innovative business model for economic nodes

Knowledge and Information

Scaling UGI requires knowledge of the local community social structures, as well as ecological processes underpinning the landscape. Scaling UGI also requires scientific and non-scientific expertise and experiences of diverse actors [63]. The national government and CoW Disaster Risk Management and Environmental Management divisions have assessed climate risks and vulnerabilities in informal settlements, although this data is not publicly available yet. These efforts have also not been linked to potential UGI initiatives. Recently, programmes such as Future Resilience for African Cities and Landscapes (FRAC-TAL) have made advances in mainstreaming climate change, including ecosystem-based adaptation, into local government planning [21]. Meanwhile Urban Ecolution and Peri Urban Resilient Ecosystems were the first research programmes to focus on UGI and climate risk in informal settlements [5,22]. Despite these initiatives, engineered solutions, such as bunds and culverts for flooding, and electronic cooling solutions for higher temperatures take prominence over nature-based solutions. This is further inhibited by a lack of data on UGI efficacy in this context. Encouragingly, the initiatives mentioned above demonstrate that expertise in Windhoek on soil restoration, climate resilience, and urban agriculture exists.

The modes of disseminating knowledge and raising awareness in informal settlements represent another barrier. CDCs, with members nominated by residents and councillors, are meant to be conduits of information between the residents, councillors, and the CoW. However, residents say that influence and power dynamics surrounding these CDCs hinder true representation, instead making them gatekeepers of information, forming information bottlenecks. Ad hoc community meetings take place in the absence of more formal platforms.

3.2.4. Processes

Discourses

The discourse on UGI, urban ecosystem services, and nature-based solutions in Windhoek’s informal settlements is nascent at best and, perhaps justifiably, overshadowed by the crippling issues of land tenure and service provision in peri-urban areas (Table 7). The discourse is also strongly centred on the leadership being provided by the CoW, with NGOs, the private sector, and residents playing a supporting role. The current discourse on water security and water as a ‘right’ or ‘commodity’ [64] has significant implications

for UGI. One of the city's most pressing issues relates to projected changes in climate and their impact on already strained water resources [20,65]. Windhoek depends on a combination of water reclamation, dams, surface reservoirs, and boreholes to supply water to its inhabitants. By 2042, it is projected that the annual rainfall will decline [20,21,65]. The ongoing considerations for water security interact with the discourse on food insecurity, housing, land, and resilience. The cultural services discourse is also prominent, where residents emphasise the need for recreational spaces such as football fields. More recently, as we have shown, the discourse landscape on UGI governance has started to shift from local governmental regulation to collaborative, community-driven governance models for urban agriculture and open defecation-free riverbed initiatives.

Table 7. Comparison of processes driving or inhibiting initiatives that can be classified as UGI-related in and around Windhoek's informal settlements. Categories are interrelated and non-exhaustive.

Case	Farm Okukuna–Eloolo Permaculture Project	Community-Led Total Sanitation (CLTS)	Green Recreational Spaces (e.g., Goreangab Dam, UN Plaza)	Fruitful Landscape, Katutura	Windhoek Riverwalk
Discourses	In danger of discontinuation due to developmental pressures for alternative land uses; cultural attitudes that agriculture is difficult in the city	Concerns whether riverbeds can be rehabilitated from the level of solid waste disposal, sanitation, encroachment taking place; open defecation-free status achieved in some areas	Concerns due to lack of political willingness to promote green spaces	Perception that Windhoek conditions are unsuitable for agriculture; feasibility of restoration	A green vision for a connected, prosperous, and healthy city
Participation	NGO active in planning, management, and advocacy programmes, working with housing NGOs and resident groups	Local community groups, with momentum from councillors and NGOs; door-to-door volunteers; supported by CoW	Participatory method of management would mean communities' needs are considered in implementation of these green and blue spaces	Conflicts and low acceptance of ideas by peripheral actors, lack of support from CoW, vandalism and theft are barriers to participation	Citizen groups, businesses, and town planners have been consulted; lack of engagement of peri-urban residents
Monitoring and evaluation	Annual reporting; CoW supervision	Public meetings in community areas; quarterly reporting	Annual reporting	Site assessments by university	Actors' meetings

Participation and Monitoring and Evaluation

Legitimised forms of community participation in decision-making about informal settlement green spaces is scant. However, the sustained efforts of Eloolo through Farm Okukuna offer an example of how technical advice and consistent advocacy over a longer period have encouraged uptake of urban garden plots among informal settlement residents, particularly women, by training organisations such as SDFN to engage their savings' group members in deploying gardens. Historically, many perceived the CoW as adopting a top-down approach with limited willingness to engage with informal settlements, but this precedent has also started changing since 2017. The intent to improve engagement is represented in that Human Settlements Division of the CoW now has a section for 'public engagement'. However, the formulation of the ICCSAP has only minimally engaged

informal settlement actors so far, primarily through constituency councillors, and there remains a pressing need to facilitate building of accountability, transparency, and access to information. Monitoring and evaluation is another key challenge, especially for long-term mitigation of UGI encroachment, open defecation, and solid waste disposal.

4. Discussion

Our objective in this paper was to analyse current governance mechanisms for UGI in Windhoek. Using a case study analysis framework, we isolated five examples of UGI implementation. In doing this, we address the paucity of empirical research on UGI and ecosystem services governance outside South Africa in SSA [13,18], and in informal settlement or dryland contexts [13]. Moreover, with its focus on equity and inclusivity of residents in peri-urban areas, our study contributes to ensuring that the mainstreaming of UGI does not perpetuate historical inequalities in access to nature and green spaces in cities [66].

This research is timely, given the urgent need for governments to adopt innovative, local solutions to combat the pervasive impacts of climate change and urban expansion [67]. The challenges and opportunities presented by complex governance configurations need to be part of this discussion [68], where UGI offers a suite of benefits to mitigate climate change [69], alleviate flood risk [70], improve public health [71], be economically affordable [14], and be delivered at a scale accounting for administrative and ecological boundaries [72–74]. For municipality planners and managers, UGI measures often prove more cost-effective than grey infrastructural measures, with options for more citizen-centred, collaborative governance configurations that are uniquely suited to SSA [14,27]. Our study provides insights that fill critical gaps in this scholarship.

In the following section, using this reflection of the past and present, we distil key desirable pathways for future UGI governance in peri-urban areas.

4.1. *The Need for Collaborative Governance Platforms for UGI*

Information asymmetry, lack of community consultation, and absence of collaborative governance are major barriers for settlement planning, including integration of UGI and ecosystem services. Community participation and stewardship are essential for UGI schemes in Windhoek's informal settlements to succeed, not only to account for benefits that residents perceive (e.g., trees acting as barriers against wind and dust, snakes eliminating rodents) but also to reflect the true dynamics of how the informal economy and survival strategies relate to the natural environment. Cognition of ecosystem services is an enabler of participation, and therefore, awareness and capacity development programmes, as well as environmental education, should form the bedrock of UGI [27].

A window of opportunity exists to enhance UGI consideration through public private partnerships. For example, SDFN-NHAG is in the process of updating its strategies for upcoming work in Windhoek, together with the CoW. SDFN-NHAG has existing participatory mechanisms in place across Namibia to directly engage residents in upgrading and securing tenure through the Community Land Information Programme [52], and other co-production processes involving green space design [75]. Processes such as these could complement EIAs for in-situ upgrading and consultation for climate resilience. More active engagement of environmental NGOs in Windhoek's peri-urban areas would also help raise awareness of biodiversity conservation in urban centres, which is currently a gap in Namibia [76], while linking to global discourse and actions on the UN Decade for Ecosystem Restoration 2021–30 [77].

To this end, an opportunity lies in establishing a focal body for UGI coordination - whether community-driven, municipality-driven, or using a hybrid strategy - to help shift perspectives to viewing informality as an opportunity to deploy innovative UGI approaches that are not possible in formal areas of the city [70]. Reviving multi-stakeholder partnerships could help promote inclusivity and accessibility in the planning, design and management of UGI, while improving local stewardship and valuing of green spaces -

as seen in the case of informal settlements in Nairobi [27]. Political leadership from the CoW will continue to underpin UGI implementation [19], but this must be coupled with an involved, informed community and supported by NGOs, the private sector, universities such as NUST, and others who work through purpose-built collaborative governance platforms. Local committees for UGI, like existing self-organised water point committees, will be important for maintenance. For Windhoek, these will also operationalise principles espoused in the Sustainable Development Goals, especially Goal 17 on partnerships [78], as shown by Cumming et al. [79] for South Africa's National Development Plan.

4.2. The Need to Integrate Informal Settlements and UGI into Municipal Climate Change Strategies

Windhoek is now poised to implement a multi-scale climate adaptation plan through the ICCSAP [21]. The ICCSAP provides an ideal opportunity for UGI to be mainstreamed into policy at the local authority level. The disaster risk reduction potential of UGI identified in this study is supported by a growing body of evidence worldwide, such as slope stabilisation, stormwater management [70,80], microclimate regulation [81], urban agriculture [82], and swales [83]. These not only increase the resilience of informal settlement residents to climate change but also feed into wider benefits by improving quality of life, while making the entire city more accessible and inclusive [71].

Furthermore, novel funding could be sought from sources such as the Green Climate Fund, the Global Environmental Facility, other governments, or private capital. Nationally, niche schemes such as the First Lady's 'One Nation Fund'—a microfinancing scheme for low-income entrepreneurs—can be leveraged for urban agriculture schemes. Various sustainability and climate change related projects have already been funded in rural Namibia, but peri-urban areas have often been overlooked. Another way to provide financial momentum is through committees formed by informal residents that could charge a mutually agreed upon contribution in cash or kind. For instance, constituency councillors emphasized the potential of nominal fee-based access rights for future recreational spaces to generate funds to maintain these spaces. Success of future UGI and climate adaptation programmes would hinge on local support, including CoW recognition and legitimisation, as well as partnerships with new actors such as the private sector through corporate social responsibility. Most importantly, clarifying mandates, roles, and modes for collaborative UGI governance in peri-urban, informal areas, and formalising these in future policies, strategies, plans, and programmes remains paramount.

4.3. The Need to Include UGI in Integrated Development Plans such as the Human Settlements Upgrading Policy

The Human Settlements Division of the CoW was established in 2017 with the aim of strategically coordinating the in-situ upgrading of informal settlements. It is currently in the process of updating its Human Settlements Upgrading Strategy to create a policy. This presents an opportunity to include explicit provisions for UGI within settlement upgrading policy. Some priority areas hold promise, namely UGI-based recreational opportunities, riparian restoration, urban agriculture, and dryland-specific techniques. As trees and vegetation surrounding the peri-urban areas dwindle, the need for pre-emptive action and planning is evident. Schemes have been considered but not implemented at scale. Initiatives such as planting indigenous street trees for mitigating urban heating (replacing invasive species), greywater reclamation for irrigation, sunken planting pits, and using shade structures for seedlings to reduce moisture loss through evapotranspiration should be explored [84,85].

The riverbeds which turn into ephemeral rivers in the rainy season, form an intersection between health, climate adaptation, and ecological outcomes. They must urgently be cleaned, restored, and maintained as multifunctional ecological assets. Encouragingly, the CLTS programme that has succeeded in making some parts of the Moses ||Garoëb and Samora Machel constituencies open defecation-free [86] is government-supported and aligns with the Harambee Prosperity Plan II (2021-2025). Taking CLTS as an example, there

are opportunities to convert riverbeds to multifunctional UGI, while improving walkability and creating recreational areas [87].

Furthermore, financially viable alternatives for cooking with firewood are needed to curb the overharvesting of vegetation, and examples could include solar heaters or subsidised gas provisions, leveraging existing platforms such as the 'Think Namibia' climate-smart campaign operating in rural areas [88].

Food insecurity and malnutrition is widespread in Windhoek. Urban agriculture is only adopted by a small percentage of the population for fear of theft of produce, lack of land, or lack of skill or interest in urban agricultural activities [58]. Even in our study, the servicing, upgrading, and provisioning of secure tenure was the highest priority for all informants from informal settlements. 'Once land is serviced, then the constituency can say ok now you can grow tomatoes or spinach' (June 2019), said a constituency councillor. The feasibility of urban agriculture must be carefully assessed [89], not least due to a dismissive attitude seen towards urban agriculture [90]. However, a precedent has been set by initiatives such as the SDFN food gardens and the Eloo Permaculture Initiative, showing that training and advocacy are critical. A recent study by Shikangalah and Mapani [65] found that precipitation in Windhoek follows an approximate pattern of showing years with high rainfall, followed by drought years, indicating that rainwater harvesting in peak rainfall years is viable to help irrigate urban agriculture, in tandem with greywater reclamation. Therefore, we recommend the CoW revise and clearly communicate stormwater and grey water regulations for households to further enable urban agriculture schemes.

Going beyond policy mainstreaming, innovative approaches such as starting small, 'safe-to-fail' pilot schemes within a learning-by-doing approach [23], collaboratively developed with informal residents through 'urban learning labs' used elsewhere in Namibia, Southern Africa [21,91], and SSA [92], will be important in this dynamic setting. Digital messaging platforms can also help overcome information bottlenecks and achieve wider innovation.

4.4. The Need to Consider UGI in the Informal Economy and for Green Jobs

Previous studies in Windhoek have mainly focused on the contribution of ecosystem services in the informal food economy [58,93], but our findings show that trade in firewood, grasses, *Acacia* pods, and reeds harvested from the surroundings forms a part of many residents' livelihoods. Green job creation is a significant opportunity that can be explored for Windhoek, as involving residents in UGI implementation, maintenance, and management could provide consistent sources of low-skill employment through initiatives such as public works programmes [94].

More recently, there is a growing movement to greening the recovery from COVID-19 [95,96]. South African cities, for instance, have committed to green urban recovery post COVID-19, with explicit provisions for nature-based solutions including UGI in these strategies [97]. Namibian national and local governments, working collaboratively with communities, have a unique opportunity to model UGI initiatives in a similar way.

5. Conclusions

This paper analysed the ecosystem services, benefits, trade-offs, and governance structures of UGI in and around Windhoek's informal settlements. Our results reveal that Windhoek is facing an escalating crisis of unplanned urban sprawl, climate change, and lack of basic infrastructure in peri-urban areas, and residents are disproportionately exposed to social and environmental risks. Opportunities exist to leverage UGI for climate resilience and to enhance socio-economic wellbeing and quality of life. UGI initiatives are often most effective when deployed in a complementary manner with grey or engineered solutions, but much greater recognition of UGI's multiple benefits needs to be mainstreamed in decision-making [27]. Collaborative governance platforms and clearly delineated mandates are necessary, with explicit integration of UGI into strategies for climate adaptation, informal settlement upgrading, and green job growth.

This research contributes much needed empirical evidence from Africa to the growing global body of research on nature-based solutions for cities [98]. Future research could focus on the impact of climate change on the natural environment of Windhoek and how this would interact with the sustainability, governance, and feasibility of UGI initiatives. Further research is needed to determine which governance configurations will allow the most inclusive and participatory approach for UGI in peri-urban Windhoek, with a particular focus on gender [62]. Research institutions have a role to play as knowledge brokers in this context [99]. As rural-urban migration accelerates and climate impacts intensify, it is ever more critical that local authorities and other actors with the responsibility to meet decentralised developmental commitments integrate agendas of equitable development and environmental justice through UGI in policy, planning, and urban design.

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Appendix A Themes and Open-Ended Questions from Semi-Structured Interviews and Focus Groups (Survey Tool)

Give a brief description of your role/job in Windhoek?

What are the changes in climate that you have observed in Windhoek over the last twenty years? If there are any, what are the main impacts of these changes?

Do you think that natural ecosystems can play a part in helping people in the informal settlements? If yes, how do natural ecosystems play a part in helping people? Please give examples.

Are you aware of a concept called ecosystem services?

Here's my definition of ecosystem services: [give definition]. What do you think are the most important ecosystem services received by residents living in Windhoek?

Are there any that are particularly vital to the wellbeing of the informal settlement residents?

What will be the most pressing issues (non-climatic) within the informal settlements in the next 30 years?

Do you think any of these issues can be feasibly addressed by using natural ecosystems? What would the alternatives be? Please describe any examples that come to mind.

Are you aware of any green space and natural ecosystem management plans currently being carried out in Windhoek, particularly focused on informal settlements?

Can you describe them briefly, and tell me who oversees their implementation?

What are some of the important opportunities for development within the informal settlements in the next 30 years?

What are the strengths within (a) the community (b) the authorities (c) broader stakeholders to incorporate ecosystem-based strategies?

Community ownership of the initiatives is vital to the success of multifunctional green spaces. Who do you think will be most likely to accept and work towards conserving ecosystems in order to gain adaptation benefits?

Are there any barriers that you can think of in the short-term (2030) which will challenge implementation of urban green spaces and urban green infrastructure? Any in the long term (2063)?

What is your view about the impact that climate change may have on Windhoek in the short-term (e.g., 2030) and long-term (e.g., 2063)?

What would be the impact of climate change on the informal settlements in the peri-urban areas of Windhoek, and how does this differ from other formal areas?

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