Global Disaster Preparedness Center

RESEARCH PAPER

Evaluating Nature-Based Greening Solutions in Nairobi's Informal Settlements:

Mitigating Urban Heat Effects and Enhancing Food Security

Bolly Echessa
Loraine Kabaka
Okeyo Fred
Mercy Osumo

2025

www.preparecenter.org

Table of Contents

Abstract

Urban informal settlements face acute challenges related to climate change, environmental degradation, and limited access to green infrastructure. Nature-Based Climate Solutions (NbCS) presents an innovative approach to addressing these challenges by integrating ecological systems into urban environments to enhance climate resilience, and food security. The research was conducted across five informal settlements in Nairobi municipality: Githurai, Zimmerman, and Githunguri as intervention sites, and Kibera & Mkuru kwa Njenga. A mixed-methods approach was adopted, combining household surveys (n = 111), focus group discussions, field measurements, and observations in intervention areas, where NbCS projects had been implemented, and in control areas that were lacking NbCS. Quantitative data were analyzed using chi-square tests, ANOVA, and logistic regression. Findings indicate that households in intervention areas had significantly higher awareness ($p < 0.001$) and engagement in NbCS activities, with home gardening (84%) and green spaces (65%) being the most common practices. Environmental measurements showed that air quality was significantly better in intervention areas, with reduced particulate matter levels compared to control areas. Additionally, NbCS interventions contributed to lower ambient temperatures, with intervention sites recording temperatures 2–3°C cooler than control sites, demonstrating the cooling effects of NbCS. Challenges hindering NbCS adoption included limited access to land (66.7%), water scarcity (59.1%), and lack of information (58.3%), especially in control areas. Education level and group exposure were significant predictors of awareness and participation. Strategies that enhanced long-term stewardship include capacity-building programs, strong community leadership, and participatory planning processes. The study recommends scaling NbCS initiatives through integrated urban planning and establishing community-led governance structures. Improving air quality and mitigating urban heat through NbCS can enhance both environmental health and quality of life, making these interventions important for creating climate disaster resilient urban communities.

Keywords: Nature-Based Climate Solutions (NbCS), Urban Heat Mitigation, Food Security, Climate Change Adaptation, and Community Engagement

This work was part of a multi-country research initiative led by the Global Disaster Preparedness Center of the American Red Cross.

1. Introduction

1.1 Background of the Study

The city landscapes are rapidly changing due to interconnected factors, but with rapid urbanization at the core. Currently, an estimated 55% of the global population lives in urban areas with projections to rise by 13% by 2050 (UN Desa 2019). While urbanization has opportunities to drive cities to development and innovation, unplanned urbanization may pose long and significant challenges to nature and the people. Urban areas worldwide are increasingly vulnerable to climate change impacts, including rising temperatures, irregular rainfall, and loss of biodiversity (Cook et al., 2025). In informal settlements, these issues are exacerbated by limited access to resources and inadequate infrastructure. For residents in these areas, such as those in Nairobi's informal settlements, environmental challenges like urban heat islands and food insecurity directly threaten quality of life (Van Den Bosch & Ode Sang, 2017). Nature-Based Climate Solutions (NbCS) that apply natural systems and mitigate climate impacts present promising opportunities to address the above challenges, such as green infrastructure projects, urban forests, community gardens, and wetland restoration (UN-Habitat, 2020). However, the effectiveness of these measures in crowded and resource-limited urban slums remains underexplored, especially in informal settlements where conditions may differ significantly from those typical of more formal urban environments (Anguelovski et al., 2018).

NbCS (e.g., riparian restoration, green spaces, green roofs, or tree planting) are becoming more widely implemented and promoted as measures to mitigate problems stemming from urbanization. (Wolff et al., 2022; Hamel & Tan, 2022)16]. Community-based NbCS practices involve local stakeholders in both the design and implementation of policies, taking into account their knowledge, cultural traditions and requirements (Anguelovski et al., 2018). These strategies can support the success of a project, enhance community ownership and contribute to long-term viability (Kabisch et al. 2017; Ziervogel et al., 2017). However, much research tends to assess NbCS from a top-down perspective as these solutions are evaluated without fully considering local communities in the design and assessment processes (Fedele et al., 2019; Van Den Bosch & Ode Sang, 2017). Little is known about the particular things that make community-based NBCS feasible in informal urban settings such as Nairobi's settlements and those adaptations to context, including population density and resource scarcity, need to be considered.

This research study, "Evaluating Nature-Based Greening Solutions in Nairobi's Informal Settlements: Mitigating Urban Heat Effects and Enhancing Food Security," seeks to bridge this gap by assessing the impacts of community-led greening interventions. It assessed the extent to which such solutions can help to reduce urban heat and bring additional benefits, such as better food security and community cohesion. The research generated knowledge about how to implement and scale such efforts in comparable urban settings, with implications for policy makers, urban planners and local organizations seeking resilient, inclusive cities.

1.2 Problem Statement

The informal settlements of Nairobi house 60% of the city's population and yet bear a disproportionate burden of exposure to climate risks, including extreme heat, flood risk and food insecurity. Limited infrastructure, poor waste management, minimal green space, and high poverty levels, leaving residents with little adaptive capacity, compound these challenges. Traditional urban climate resilience approaches, including grey infrastructure, are often inadequate, expensive, or unsuited to the realities of informal urban settings.

Nature-Based Climate Solutions, such as urban greening and community gardens, offer a sustainable, cost-effective alternative. However, research and implementation of NBCS in informal settlements remain limited, with most studies focusing on formal urban areas that have better infrastructure and planning systems. This knowledge gap means that communities in resource-scarce environments are often excluded from solutions that could directly improve their living conditions.

However, key issues remain unaddressed: (1) urban heat mitigation strategies lack empirical evidence on how NBCS reduce localized temperatures and improve air quality in densely populated informal areas, and (2) food security impacts of community-led greening initiatives are poorly understood, with little focus on small-scale, community-driven models that could enhance dietary diversity and generate income for the residents. Additionally, (3) Community participation in co-designing, managing, and sustaining NBCS is underexplored, limiting local ownership and long-term success and scale-up.

This study sought to address these gaps by developing evidence-based, community-centered frameworks for implementing and scaling NBCS in informal settlements. The findings will guide policymakers, urban planners, local organizations in creating inclusive, resilient, and sustainable urban environments.

1.3 Research Objectives

- To assess the impact of greening solutions on temperature reduction, biodiversity, and food availability.
- To identify and evaluate strategies that facilitate community participation and long-term stewardship on NbCS
- To assess factors that enable these solutions to be scaled and replicated across other informal urban areas.

2. Literature Review

The literature review situates NbCS within larger discourses of sustainable cities, mitigation, and climate adaptation. Its focus is on informal settlements, and it compiles evidence of how well NbCS works to mitigate heat, improve food security, and build resilience. This chapter justifies the assessment of community-level greening efforts in Nairobi for possible scaling up by addressing climate-related change.

2.1 Conceptual Foundations

2.1.1 Nature-Based Climate Solutions-context

NbCS are interventions that use natural processes and ecosystems to address urgent social and environmental issues and provide co-benefits for both people and the environment. They have become a critical intervention in climate research and policy (Kabisch et al., 2017; Cook et al., 2025a). In contrast to conventional gray infrastructure, which often relies on expensive and resource-consuming technologies, NbCS focuses on affordable, environmentally sustainable, and community-based methods, including initiatives like green roofs, urban agriculture, riparian buffer restoration, afforestation and reforestation, and the establishment of wetlands and community parks (Wolff et al., 2022).

NbCS brings about improved food security, air quality and social cohesion at the same time as reducing climate risks through flooding and heat stress (Elmqvist et al., 2018). In informal settlements, where limited resource availability, inadequate infrastructure and climate risk sensitivity intersect, NBCS are particularly important given their ability to integrate responses across environmental, economic and social spheres. Douglas and James (2015) argue that NbCS are the harbinger of a radical new era of approaches to sustainable urban development, when natural systems can be seen as dynamic agents in enhancing the quality of human life and resilience, rather than as passive backdrops.

2.1.2 Urban Heat Islands and Informal Settlements

The urban heat island (UHI) effect is one of the most important environmental problems in rapidly urbanizing systems. It occurs when the built-up urban parts of an area show significantly higher temperatures than peri-urban or rural areas. This situation is brought about by large numbers of impermeable surfaces, reduced vegetation cover, and waste heat from human activities moving across little-ventilated areas of high population density (Norton et al., 2015). There are serious human health and comfort consequences: prolonged exposure to high temperatures is associated with increased rates of heat stress, respiratory illnesses, and even death, especially among vulnerable populations such as children, the elderly, and outdoor workers (Van den Bosch & Ode Sang, 2017).

Poor waste management, low density of public green spaces, and unregulated dwelling erection lead to the UHI tendency in Nairobi's informal settlements (UN-Habitat, 2020). Residents are more exposed to extreme heat events when population density is higher due to congestion and limited ventilation. Moreover, it is disproportionately poor urban areas that rely on nature to serve as a thermostat because these informal populations often do not have cooling appliances, such as air conditioning. Vegetation is crucial in the control of microclimates, by reducing local and ambient temperatures through evapotranspiration and shading (McDonald et al., 2019; FAO, 2022). Therefore, community-based greening programs can help to both enhance quality of life for residents and significantly reduce the modified UHI effects in such habitats.

2.1.3 Food Security in Urban Informal Contexts

Access to safe and sufficient food is limited in informal settlements, where food insecurity is prevalent with many households having poor access to healthy, affordable and safe food. The rapid urbanization has eroded traditional rural-urban food supply chains with the result that informal urban groups are heavily dependent on unstable market systems and imported food commodities (Egerer, and McGehee 2019). Undernutrition and inadequate diversity in diet is attributable to increasing cost of foods coupled with low, uncertain incomes that curtail the purchasing capability of households.

NbCS provides options to reduce these challenges via place-based food production systems. Apart from increasing food accessibility, initiatives such as rooftop gardens, community-operated garden plots and family plots also promote dietary variety, generate income and enhance social capital (FAO, 2022). Family-level food security was promoted because of urban gardening programs incorporated into neighborhood greening initiatives in Nairobi, with evident effects on resilience and nutrition (Kamjou et al., 2024). Crucially, by integrating ecological practices like composting, rainwater collection, and soil conservation into regional food systems, these interventions go beyond the food supply to increase resilience against economic and climate shocks.

2.1.4 Linking NbCS to Climate Adaptation and Mitigation Frameworks

NbCS are increasingly recognized as essential tools that connect climate adaptation and mitigation for urban sustainability targets. Through microclimate regulation, ecosystem services delivery (e.g., flood control, soil stabilization), and enhanced stormwater management practices, NbCS reduce the level of communities' exposure to and vulnerability towards climate risks (Frantzeskaki et al., 2019). With respect to mitigation, NbCS decreases the concentration of greenhouse gases by sequestering carbon in soils and vegetation and enhances air quality via uptake of pollutants (Elmqvist et al., 2018).

This dual-use in particular is vital for informal settlements. "Mitigation means that you have bigger national and international ambitions for reducing emissions, and adaptation is, in a way, protecting regionally vulnerable communities against the worsening effects of climate change, like heatwaves, variations in rainfall or increased frequency and intensity of floods. The United Nations Sustainable Development Goals (SDGs) and the Paris Agreement (2015) especially advocate for a local-level, multi-faceted approach that maximizes co-benefits to both people, ecosystems, and climate change mitigation (UNEP, 2019; World Bank, 2020). NBCS are also emphasized as entry points to link environmental resilience with social inclusion, equity, and poverty reduction in frameworks such as UN-Habitat's (2020) undertakings on informal settlements.

2.2 Global Perspectives on Nature-Based Climate Solutions (NbCS)

2.2.1 Urban Greening and Ecosystem-Based Adaptation

Urban greening has become an essential part of sustainable city planning around the world and for adapting to climate change. The ecosystem services that are provided by urban green interventions, including parks, green roofs, street trees and riparian restoration are key for mitigating environmental hazards (Douglas & James 2015). The World Bank (2020) explains that green infrastructure is increasingly recognized as a low-cost alternative to grey infrastructure, particularly for integrated water management, flood control and heat effects reduction. UN-Habitat (2020) similarly refers to ecosystem-based adaptation as one of six elements in climate-resilient urban planning and adds that NbCS offer multi-functional benefits far beyond being providers of environmental services, offering community health and social well-being.

We see from the case studies from other countries how useful NbCS may be. For example, in terms of climate adaptive planning, the use of green roofs is far more widely implemented in Vancouver than other cities and has been found to reduce stormwater runoff and cool buildings (Roehr & Laurenz, 2008). Urban woods and green corridors have been found to promote biodiversity as well as having a cooling effect on densely populated areas (Anguelovski et al., 2018). These examples demonstrate how NbCS, when integrated within the city-wide planning context, can contribute to both ecological and social co-benefits.

2.2.2 Community Gardens and Food Security

Several cities in North America, Europe, and Asia have adopted community gardens as NbCS and studies have shown that they can enhance social resilience and urban food systems. According to a systematic review by Roy et al. (2012), urban agriculture promotes communal cohesion, supports household food budgets, and increases nutritional diversity. In a similar vein, Egerer and McGehee (2019) bridge local food production to the wider goals of urban resilience by emphasizing that, as an important form of ecosystem-based adaptation, urban agriculture is central. In addition, locally led NbCS initiatives foster participation and stewardship of the environment. Also supporting stormwater management as well as the creation of pollinator habitats, community gardens in New York City have been shown to improve access to fresh fruit for food insecure individuals (Brink et al., 2016). These findings suggest that NbCS can put into practice the promotion of access to food, ecological restoration and social capital as elements of vulnerability in a direct manner.

2.2.3 Evidence on Effectiveness: Air Quality, Temperature, Biodiversity, and Food Access

According to Zhao et al. (2020) and Aqirah et al. (2025), green spaces in cities can reduce air pollutants by as much as 30%. Trees and other vegetation act like natural filters, taking up harmful substances from the air and improve breathing conditions (World Health Organization, 2021). Other research corroborates the theory that vegetation could mitigate the UHI effect. McDonald et al. (2019), emphasize that green roofs and urban forests can bring local temperatures down between 1 to 3 degrees Celsius benefiting human thermal comfort and energy consumption reduction.

NbCS often provide habitat restoration and support species diversity in urban areas. Urban agroforestry systems create ecological links between broken city ecosystems, and provide vital bird and pollinator habitats (FAO 2022). These outcomes suggest that NbCS are features of conservation value in human-dominated landscapes and fit into international frameworks regarding biodiversity.

Additionally, integration of urban agriculture as a component of NbCS enhances food availability and generates additional revenue, especially for low-income households. UNEP (2019) indicates that local food production enhances urban food sovereignty capacities by reducing vulnerability to disruptions within the global and national system of provision and insecurity. Case studies from Asia and Latin America have shown that community gardens and rooftop farms can reduce household food insecurity while building adaptive capacity to climate shocks (Krellenberg & Welz, 2017).

2.3 Regional and African Context

2.3.1 Urban Resilience and Greening in African Cities

Overwhelming, often unplanned, urbanization has placed African cities at the "frontline" of climate change with growing levels of flooding, higher temperatures and shortages of food (UN-Habitat 2020). Because land tenure is insecure, waste management inadequate and infrastructure basic, an above-average number of urban dwellers inhabit informal settlements such as those found in Nairobi, Lagos, Accra, Cape Town and Dar es Salaam. In such circles, NbCS are increasingly being encouraged as feasible solutions that bridge urban resilience and ecological restoration. According to research from South Africa, wetland restoration and urban forestry can reduce the risk of flooding and stimulate green public spaces in poor neighborhoods (Krellenberg & Welz, 2017). Small-scale greening initiatives in Accra have also been demonstrated to provide areas for urban agriculture and recreation while lowering localized floods and heat stress (Ziervogel et al., 2017). These examples provide an overview of the diversity of functions that NbCS can fulfill in African contexts by responding to pressing socioeconomic needs as well as ecological challenges.

2.3.2 Food Security and Livelihoods in Informal Settlements

Unstable markets, low and erratic wages and a lack of a diversified diet have led food insecurity to be a big problem in African urban poor settlements (Egerer & McGehee, 2019). The potential of NbCS activities such as roof top gardens, urban agriculture, and community orchards to improve access to fresh food has been widely studied. The case of sack gardening, a low-investment NbCS innovation was demonstrated to support households with additional income and nutrition, and social cohesion among women members of organizations in the Kibera settlement, Nairobi (Kibii et al., 2025). Dar es Salaam's peri-urban farming initiatives generated youth employment and contributed to food security at the household level, therefore revealing that NbCS can act as viable livelihood interventions similar to ecological-based ones.

However, these advantages are not evenly spread. Research shows that stack projects, without continued supporting measures, such as secure land access, water and tools tend to falter after the external initial financial support ends (Kamjou et al., 2024). Women, who are central in the preparation and distribution of food within urban areas, also confront other barriers including limited control over resources and land. Accordingly, gender and equity considerations should intentionally be integrated into the framing of sustainable NbCS for food security in Africa.

2.3.3 Similarities and Contrasts with Global Trends

Divergent effects are present despite positive African experiences and other information from the globe about ecological benefits of NbCS. Green infrastructure is also supported by official forms of urban planning, city-sponsored budgets and enabling policies in high-income regions such as European countries and North America (Douglas & James, 2015; Anguelovski et al., 2018). By contrast, in African informal settlements, NGOs, community groups and local volunteers (UN-Habitat, 2020) generally lead ad hoc project development. This results in uneven distribution of benefits, such as cooling effect, shade and percentage of food production areas, as well as a fragmented connection of greening.

More generally, African cities face specific resource constraints. Challenges undermining the expansion of NbCS include frequent shortage of water access, insecure tenure due to unclear land rights and land competition (Ziervogel et al., 2017). Though research from across the globe consistently raises concerns over the negative effects of green gentrification, where planetary urban greening displaces low-income dwellers (e.g., Anguelovski et al., 2018), local organizations in African cities are more about exclusionary dynamics regarding water access and land allocation decisions and project benefits distribution. This variation underscores the need for designs that are context specific that is set to accommodate governance conditions of informal settlement as well as local scarcities.

2.4 Knowledge Gaps and Research Justification

Despite the fact that NbCS are backed up by a wealth of regional and global literature as contributors to food security, mitigation and adaptation measures for climate resilience, there is much still unknown with respect to informal settlements. Nairobi is a particularly relevant setting as home to one of the largest concentrations of informal settlements, rapid urban growth and a growing susceptibility to climate hazards (UN-Habitat, 2020; Ziervogel et al., 2017). However, the specific impact of NbCS in these communities has been poorly quantified or described in current studies. Filling these gaps is essential in supporting the design of urban resilience policies that are scalable, inclusive and evidence-based (Frantzeskaki et al., 2019; Kabisch et al., 2017). Across studies, community engagement has been recognized as key for success (Wolff et al., 22; Frantzeskaki et al., 19). However, very little is known about the specific models of governance and properties of social networks that matter for adoption and long-term stewardship in informal settlements such as Nairobi. Although studies suggest that NbCS uptake is increased in areas with high levels of community participation, few empirical data have been collected on the impact of this governance, equity, and participatory process on sustainability (UN-Habitat, 2020). A second challenge is how to scale up from pilot projects to wider urban systems: grassroots initiatives risk remaining fragmented, fragile, and dependent on donor cycles if they are not absorbed at the county level in planning frameworks (Anguelovski et al., 2018; World Bank, 2020). Based on this gap, in the present study we sought to generate evidence at the local level regarding ecological and social impacts of NbCS in Nairobi's slums. Specifically, the research measures community-led greening's contribution to food security, reports empirical evidence on temperature and air quality outcomes and explores the governance and participation processes that shape uptake and sustainability. By filling these gaps, the analysis not only contributes to shaping context-relevant interventions locally but also to the global discourse on NbCS with case-based learnings from Nairobi, a prototypical example of fast-growing African urban areas facing challenges of food insecurity, climate vulnerability and rapid population growth (UN DESA, 2019; Elmqvist et al., 2018).

3. Methodology

3.1 Study area

To evaluate community-based greening solutions in Nairobi's informal settlements, the research employed a mixed-methods approach, combining quantitative and qualitative data collection. This approach is suited to address the complex and context-specific nature of the study, allowing assessment of both the measurable impacts of NbCS initiatives and the subjective experiences of the community as adopted by Kibii et al. (2025) in a similar cross-settlement study.

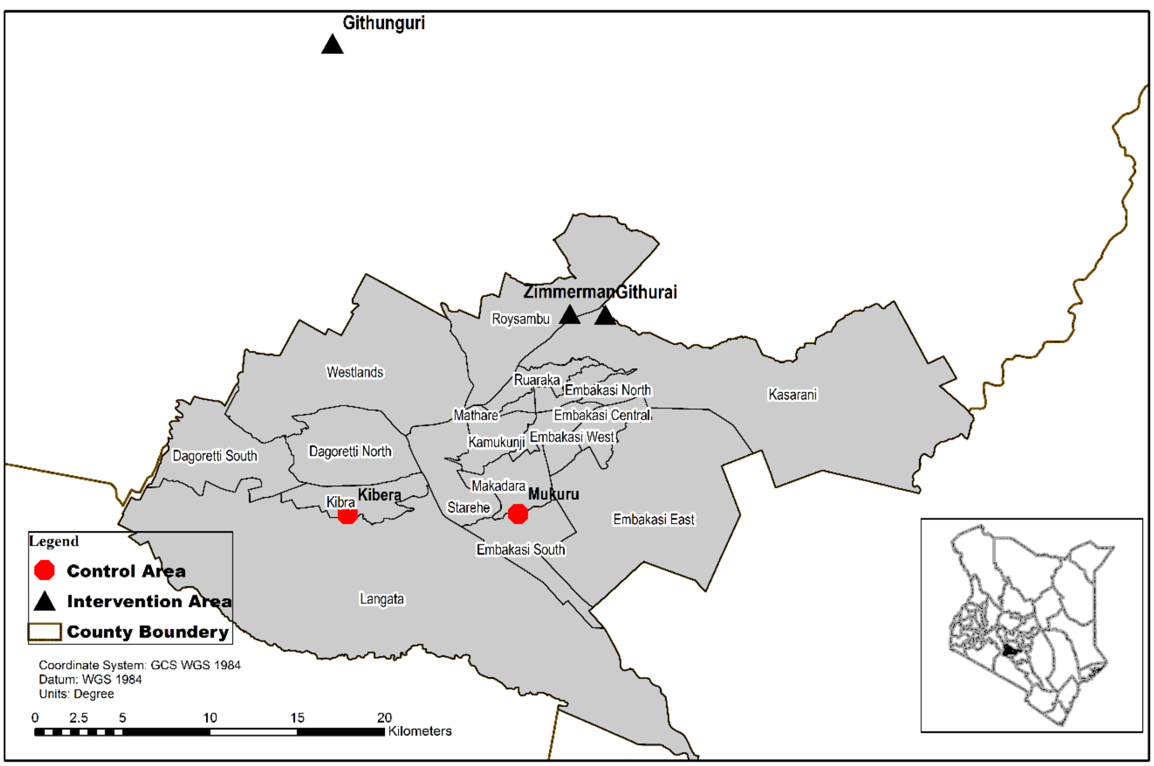


Figure 1: Study area Site

3.1.1 Mukuru Kwa Njenga (Control Site)

Mukuru Kwa Njenga is a densely populated informal settlement characterized by poor environmental conditions and limited access to green spaces. During the last 2024 heavy floods, most vegetation initially planted as an intervention for environmental conservation, were washed away (F igure 2), leaving the landscape highly degraded. From the field observation (the area faces multiple environmental challenges, including, Severe water pollution from untreated waste and runoff, (2) nearby dumpsite where garbage burning is a common practice, releasing greenhouse gases and toxic fumes (figure 2 and (3) increased urban heat island effects are due to the lack of vegetation cover and widespread pollution.

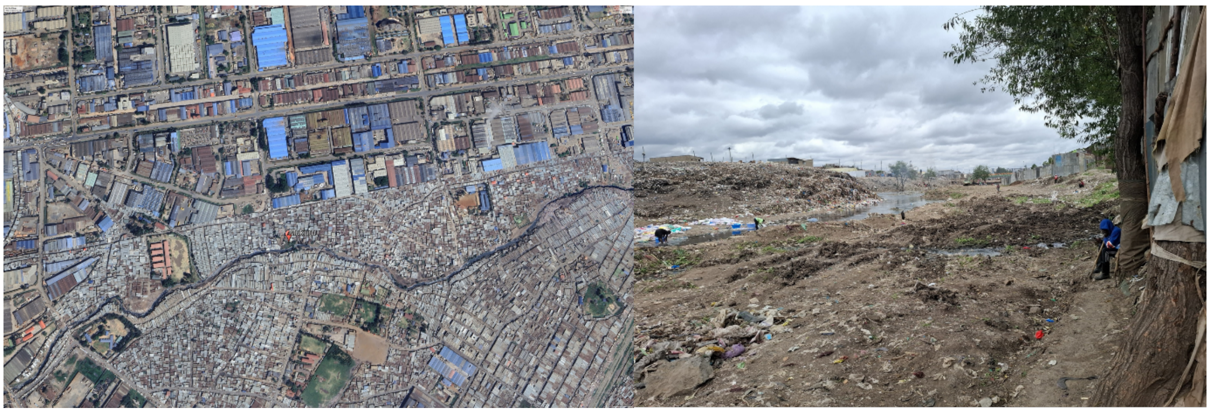


Figure 2: Aerial view and Ground view of Neighborhood of Mkuru Kwa Njenga (Control)

Despite these challenges, the community has begun recovering and adapting by relocating restoration activities to higher ground. The project team has provided new seedlings to support replanting efforts among other activities presented in table 1. The site serves as a critical control location for assessing urban air quality impacts in the absence of fully functional NbCS interventions.

3.1.2 Kibera (Control)

The Kibera control site is a congested informal location with little green cover and little access to formal Nature-Based Climate Solutions (NbCS) programs. The neighborhood shows the characteristics of unplanned urbanism of the type of overcrowded housing, lack of proper waste disposal facilities and lack of recreational areas. The majority of open spaces are characterized by mini dumping sites or degraded land with infrequent household level garden projects. NbCS awareness among people in the community is rather low and community involvement in environmental activities is more informal and uncoordinated. Being a control site, Kibera will provide a point of reference to gauge the effects of NbCS interventions in informal settings with similar ailments, a perception of the environmental challenges involved, resource limitations and potential prospects of the greening process.

3.1.3 Githunguri (Intervention Site)

Githunguri is a peri-urban demonstration site managed by Wing Farm Youth Organization, committed to sustainable agriculture and environmental restoration and conservation. The site integrates livestock keeping with the cultivation of crops. Besides conservation sites, Githunguri farm offers employment opportunities for over 20 youth, promoting local economic growth, and it was a designation as a practical implementation site during the Global Science Week 2025, showcasing innovative community-led NbCS projects. This site represents a model example of youth-led environmental stewardship, demonstrating how NbCS can be effectively scaled in peri-urban contexts to deliver social, ecological, and economic benefits.

Figure 3: Aerial view and Ground view of Githurai Study site farm

3.1.4 Zimmerman (Intervention Site)

The site is located on land owned by the Brook Centre for Deaf and Autistic Children. The area is densely populated with unplanned urban apartments and suffers from poor drainage systems, which previously limited agriculture. Through the Project Shambani, the residents have been trained on composting and bio fertilizer production techniques using Black Soldier Fly larvae, promoting circular waste management practices.

Figure 4: Aerial view and Ground view of Zimmerman Study site farm

The farm now supports the growth of fruit trees and vegetables, providing nutritious food to the 1,500 children at the center and the neighboring communities. The site is managed by Joint Youth CBO, who also organizes recreational and entertainment activities for children. This approach demonstrates how NbCS can be integrated with social programs to enhance both environmental outcomes and community well-being.

3.1.5 Githurai (Intervention Site)

This site was a dense bushland that was difficult to access and often associated with insecurity, to the point that even law enforcement officers avoided the area. Located adjacent to the Gatharaini River, it was highly prone to flooding during the heavy rains experienced last year. Through the project's intervention: 200 youth, including members of the Githurai All Stars football team and their supporters, were initiated to clear the area and reclaim the land for public use, Flood mitigation dikes were constructed to prevent further waterlogging and reduce flood risk.

Figure 5: Aerial view and Ground view of Githurai Study site farm and the surrounding areas.

The park gained recognition when it hosted World Environment Day celebrations, attended by the local Member of Parliament. Future plans include the rehabilitation of the riparian zone along the river Githurai to enhance biodiversity and create a sustainable green corridor.

3.2 Population and Sampling Design

In this study, the population includes all residents, community organizations, and relevant stakeholders in Nairobi's informal settlements who are involved in or affected by NbCS projects such as greening initiatives, community gardens, and other climate resilience activities. Additionally, the population includes policymakers, local government officials, and non-governmental organizations (NGOs) who play a role in urban planning and environmental conservation within Nairobi.

Since this study requires both quantitative and qualitative data collection to assess environmental impact, food security, community involvement, and policy integration, a stratified sampling approach was used to ensure representation from each relevant subgroup within this population. Sampling of the informal settlements was purposive and informed by the current greening activities done by Project Shambani in collaboration with Youth Organizations in the respective informal settlements. The study included areas where NbCS are currently being undertaken Sinai in, Githurai, Zimmerman, and Gatharaini. The NbCS activities undertaken are summarized in table 4.

Table 1 NbCS related activities as Implemented by Project Shambani

Intervention Area	**Githurai**	**Zimmerman**	**Githunguri**
Waste Sorting & Awareness	Community sensitization Waste sorting at households & markets	Household & market waste sorting	Community and school sensitization
BSF Waste Conversion	Youth-supported BSF waste processing (off-site linkage)	Active youth-led BSF unit converting organic waste to frass	BSF-linked waste conversion (community–youth collaboration)
Fungal Bioremediation	Fungal treatment of polluted hotspots	Mycelium used in soil restoration	Fungal remediation of degraded soil patches
Soil Regeneration	Soil treated with mycelium & enriched using BSF frass	Soil enriched with frass and fungal compost	Application of biofertilizer and chitin-rich amendments
Urban Agroecology/Green Park Development	Green Park established instead of agroecology space Cleared dumpsite →Treated soil → Biofertilizer → Landscaping & tree planting	Agroecology space set up (sack gardens, mushroom units, alley gardens)	Agroecology space established (sack gardens, bucket gardens, mushrooms)
Vertical Gardens & Green Walls	Vertical planters & fence greening	Hanging planters, wall gardens	Vertical towers and climbing plants
Native Tree Planting & Micro-Forests	Native trees planted to create a cooling micro-forest	Pocket forests & tree-lined corridors	Native species planted in open spaces & school grounds
Water Harvesting & Moisture Conservation	Mulching, micro-basins, & simple harvesting	Water harvesting demos + moisture retention methods	Mulching & small rainwater harvest units
Community Cooling Spaces	Shaded public seating under trees	Cooling hubs with tree shade & green walls	Community cooling corners created
Youth Climate Leadership & Training	Capacity building & M&E workshops held with local youth	Youth trained in BSF rearing, agroecology, bioremediation, & monitoring	Training events + continuous M&E with youth groups

3.3 Data Collection

3.3.1 Air Quality Data

Air quality data were accessed through the TROPOMI (Tropospheric Monitoring Instrument) portal, a Copernicus-affiliated interactive Earth observation web platform that enables time-series visualization and data download (Netherlands Institute for Space Research [KNMI] et al., 2022). The extraction process followed standardized parameters to ensure accuracy and consistency. Temporarily, data were collected at 5-day intervals, with each observation representing a 9-day centered moving average to smooth short-term fluctuations (e.g., March 2, 11, 20, etc.). The observation period spanned from March to August 2025, covering both dry and wet seasonal transitions. Spatially, five regions of interest were selected based on population density, identified pollution hotspots, and their relevance to ongoing NbCS.

3.3.2 Temperature

To support our analysis of urban heat patterns, temperature data were acquired from NASA's Earth data platform, part of the Earth Observing System Data and Information System (EOSDIS). This platform was selected because it provides free, high-resolution, and continuous temperature datasets from a range of satellites, including the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS).

3.3.3 Food Security Assessments

To assess the impact of NBCS on local food security, an assessment of food security that was conducted in areas with community gardens and other food greening interventions to evaluate how such solutions influence access to food sources and eating patterns among residents. Crop outputs, produce types and household food access were determined via household surveys and direct observations.

3.3.4 Participatory Action Research (PAR)

Participatory Action Research (PAR) was also included to enhance community engagement and evaluate sustainability of NbCS activities over time. During PAR sessions conducted by the research team, in which national and local stakeholders as well as project implementers are involved, citizens shared their experiences with Nb CS, debate perceived positive and negative elements of the programme, and work together to frame approaches for improving future NbCS (see figure 3).

3.4 Data analysis

Data analysis combined all data sources including field environmental assessment; household survey and participatory action research (PAR) session observations. This mixed-method approach helped gain a holistic view on the contributions that greening responses developed by Project Shambani are making in climate change mitigation, urban heat reduction, and community livelihood in study sites.

Data processed produced three main statistical indicators (the 25th percentile, p25, representing relatively clean air; the median, showing the central tendency of pollution levels; and the Interquartile Range IQR, as indicative of spatial variation). The spatiotemporal patterns and trends of air quality were examined using a time series analysis on these metrics. The household questionnaire quantitative data were cleaned and prepared for analysis in Excel. The cleaning was done by introducing records into SPSS version 28 with a pre-determined codebook and validation to ensure nothing was missing or incompletely entered. Further, the open-ended responses were consistently categorized as variables to help facilitate analysis. Following cleaning, descriptive statistics (frequencies, percentages, means, and standard deviations) were used to summarize demographic characteristics as well as perceptions of greening interventions within the study area and community participation patterns. Inferential statistical analysis (chi-square tests for categorical data; independent samples t-tests) examined differences between intervention and control sites. In cases where applicable, we used regression to compare across more than two groups. The findings were presented in tables, charts and graphs to enhance interpretation and reporting.

NVIVO 14 was used to thematically code PAR session and focus group discussion transcripts as qualitative data. We used a thematic coding technique using deductive codes based on study goals and review of the literature with inductive codes arising from participants' stories. This in turn facilitated the identification of common topics such as drive factors for engagement, obstacles to implementation or feelings/understanding of ownership toward NbCS.

3.5 Knowledge Dissemination Strategy

To ensure that the findings of the study reach a wide audience, the study employed a dissemination strategy targeting the community members, policymakers, local organizations, and academic audiences, with an aim to promote the uptake of effective NBCS practices, inform local policy, and foster sustainable, community-led greening initiatives. And promote local-based climate mitigation and adaptation measures.

3.5.1 Community Feedback and Engagement Sessions

Community engagement sessions served as an opportunity to report findings directly to those affected by and involved in greening projects. To accomplish this, community meetings or workshops were organized in each of the settlements where data was collected. These sessions incorporated visual aids such as posters, pamphlets, and infographics, all translated into local languages to ensure clarity and inclusivity. The workshops included Q&A segments, allowing community members to ask questions and clarify concepts, and practical demonstrations where applicable to reinforce understanding.

Figure 6 Part of the participants in Githurai area during the community participation forum

Figure 7: One of the youth representatives in Gatharaini, giving a recommendation about the NbCS

3.5.2. Policy Brief for Local Government and NGOs

To bridge the research-policy gap, an actionable policy brief, through the recommendations, was developed. The recommendations highlighted NbC's effectiveness in urban cooling and improving food security, focusing on models that are replicable in other urban informal settlements. It provides actionable insights and highlight potential areas for policy alignment, ensuring that findings directly address current policy needs.

3.5.3. Publication and Presentations

To contribute to the existing academic resources on climate resilience and urban sustainability, the study's findings have been prepared for publication in academic journals focused on environmental science, urban planning, and sustainable development. The manuscripts are currently under review in the journal. Additionally, the study's findings were also presented at AfriGEO Youth Community of Practice (CoP) and is set to be presented on the yearly Symposium that involves different African countries, providing an opportunity to engage with academics and professionals working on nature-based solutions, urban greening, and community-led conservation, themed: From Data to Impact: Strengthening Africa's Geospatial Future.

4. Findings and Discussions

4.1 Demographic Characteristics

4.1.1 Response Rate

The study was conducted across four key sites in Nairobi County, representing both intervention areas, selected areas with NbCS have been implemented, and a control site with limited green infrastructure. The response rates are represented in Table 2. There was a total of 111 respondents, as presented in Figure 8, with Githurai having the highest representation (24%) among the study sites.

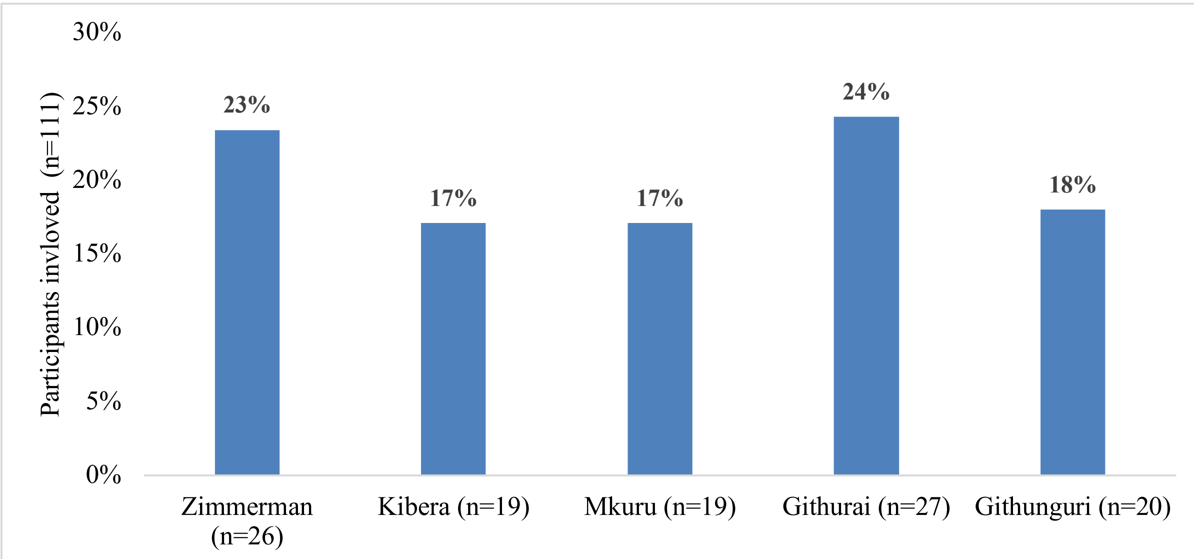


Figure 8 Respondent distribution in the study sites

4.1.2 Demographic Characteristics

The demographic data as presented in table 1 shows that the intervention area had a higher proportion of male respondents (58.7%) compared to the control area (41%), while female participation was significantly higher in the control area (75.8%). Most respondents in both areas had secondary education (54.1% overall), with the intervention area having a higher proportion of tertiary-educated individuals (47.1%) compared to the control (26.8%). Employment patterns varied, with unemployment highest in the control area (65.9%) while self-employment was more common in the intervention area (48.6%). The majority of participants in both areas had lived in their locations for over four years (65.8%), indicating long-term residence and community stability. The average age of respondents was similar between areas, approximately 27 years, with a range between 20 and 45 years. These findings highlight demographic differences that may influence community engagement, participation in interventions, and the outcomes of nature-based climate solutions.

Table 2: Respondents demographic characteristics

Demographic	Group		Total
Gender	**Control Area**	**Intervention Area**	
Male	41%	58.7%	68%
Female	30%	75.8%	30%
Total	37%	62.7%	100%
Length of Stay in settlement (Years)			
1	0.0%	100.0%	5.4%
2	6.3%	93.8%	14.4%
3	18.8%	81.3%	14.4%
4	50.7%	49.3%	65.8%
Total	36.9%	63.1%	100.0%
Employment Status			
Employed	7.3	25.7	18.9
Self-employed	17.1	48.6	36.9
Unemployed	65.9	18.6	36
Student	9.8	7.1	8.1
Total	100	100	100
Education Level			
None	2.4	0	0.9
Primary	12.2	1.4	5.4
Secondary	58.5	51.4	54.1
Tertiary	26.8	47.1	39.6
Total	100	100	100
Age			
Mean Age	26.93	27.8	27.48
Std. Deviation	5.188	5.83	5.594
Minimum	20	20	20
Maximum	41	45	45

4.2 Impact of greening solutions on temperature reduction, biodiversity, and food availability.

This chapter presents the findings of the study that aimed to assess the effects of NbCS such as agroforestry and food farms, on urban air quality temperature among 5 selected study sites in Nairobi County. All the sites of peri-urban areas characterized by populated informal settlements that are often facing the direct impacts of climate change (flooding and increased temperature) and indirect effects like poor air quality and food security. As presented in subsection 4.3.1 and 4.3.2.

4.2.1 Descriptive Statistics of Pollution Indicators

Data on key air quality indicators 25th percentile pollution level (p25), median pollution level (Median), interquartile range (IQR), and composite scores were collected over a six-month period. These metrics were then analyzed to compare the effectiveness of NbCS interventions against control sites in improving urban air quality. The descriptive statistics of the air quality indicators are summarized in Table 2. The table presents the mean, minimum, and maximum values for each parameter across the five regions. Key observations indicate that study areas implementing NbCS had lower median pollution levels compared to the control sites. Githunguri consistently recorded the lowest median pollution levels, suggesting a strong positive effect of NbCS interventions, as Mukuru Kwa Njenga exhibited the highest variability (IQR), indicating inconsistent and episodic pollution sources. However, Zimmerman, an intervention site, demonstrated the lowest variability, reflecting stable air quality conditions. Composite scores were lowest in Githunguri, highlighting the relative effectiveness of NbCS sites, while highest in Kibera.

4.2.1.1 Temporal Trends of Median Pollution Levels

The temporal trends of median pollution levels across the five sites over the six-month study period are illustrated in Figure 9. Intervention areas (Githunguri, Githurai and Zimmerman) demonstrated relatively stable median pollution levels, with Githunguri showing consistently low levels throughout the study period. Githurai area and Zimmerman experienced slight increases during March and April, while Mkuru Kwa Njenga and Kibera (control sites) recorded significantly higher and more fluctuating median pollution levels. Pollution peaks occurred primarily in April and May, possibly due to waste burning, informal industrial activities and other sources of pollution (UNEP 2023). These findings suggest through correlation that the NbCS measures may be associated with cleaner and more stable urban environments in terms of air quality.

Table 3: Temporal Trends of Air quality

Air Quality Parameters		Githunguri	Githurai	Zimmerman	Mukuru kwa Njenga	Kibera
	mean	-0.66	-0.96	-0.55	-0.83	-0.52
	min	-1.49	-1.47	-1.35	-1.44	-1.26
p25	max	0.11	0.32	0.38	-0.15	0.46
	mean	-0.02	-0.72	-0.48	0.18	0.08
Median	min	-1.08	-1.48	-1.5	-0.84	-0.68

	max	1.35	1.1	0.58	1.03	0.86
	mean	0.42	0.39	0.4	0.39	0.41
	min	0.11	0.23	0.16	0.23	0.22
IQR	max	0.69	0.59	0.7	0.5	0.69
	mean	2.61	3.7	2.61	2.1	3.57
Composite	min	1.62	1.26	1.38	1.18	1.97
Score	max	4.09	4.77	4.35	2.89	4.6

The composite index was also derived to obtain an overall air quality measure considering concentration and variation of pollution. The average composite score for each region is shown in Figure 9. Githunguri scored lowest in the composite score, representing a relatively better general air quality. This is consistent with the benefits of continuous planting agriculture and agroforestry practices in terms of pollutant absorption and adjustment (FAO, 2022). Zimmerman was also a close follower, and Githurai recorded intermediate scores mainly because of the partial utilization of NbCS practices. The highest composite score was obtained at control sites: Mukuru Kwa Njenga, and Kibera, which represented poor air quality level and high variability because of the presence of poor green infrastructure and solid waste disposal (World Health Organization, 2021).

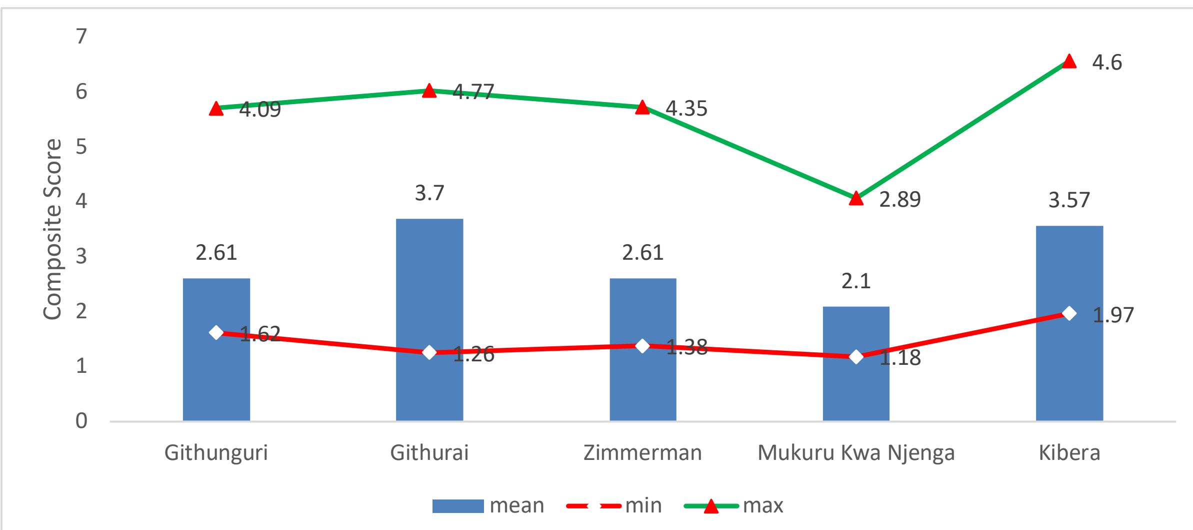


Figure 9: Air quality variation among the selected sites

Clear differences are seen when comparing recipes where there are NbCS intervention regions with control areas. NbCS areas had lower levels and pollution that is more constant with significantly lower summary scores. Control areas showed increased and very varied levels of pollution. These results are consistent with international research plots, which demonstrated that city green spaces can lower the pollution level by as much as 30% (Aqirah et al., 2025).

The findings reinforce the viability of NbCS to mitigate urban air quality issues in a community-based setting. In Nairobi, an increasingly polluted city with rapid urbanization and explosive informal settlement development, combining green infrastructure has multiple co-benefits. Agroforestry and urban farms serve as natural filters, filtering pollutants like particulate matter (PM) and CO2, in addition to moderating local microclimates (McDonald et al., 2019). The control sites, Kibera and Mukuru Kwa Njenga, have duplicated pollution challenges from lack of organized green infrastructure and poor solid waste management. The large environmental variability in these areas may imply temporary but severe pollution episodes, most likely from the practice of open-cast waste burning and unregulated small industrial activities (UNEP, 2023). However, our results reinforce that NbCS interventions may be cost-effective and sustainable approaches for the control of urban pollution alongside traditional infrastructure-based solutions (Elmqvist et al., 2018).

4.2.2 Temperature variation

Temperature was an important measure of urban microclimate regulation, and it was essential to examine the influence of NbCS on the heat island effect in the city. In the present study, surface air temperature (T2M; Temperature at 2 Meters) of MERRA-2 T2M data from NASA/POWER Source Native Resolution Monthly and Annual was used to compare NbCS intervention sites with control sites where interventions such as agroforestry and food farms are not promoted. The goal was to assess potential relationships between NbCS interventions and local temperatures, thereby enhancing community resilience to climate change. Variations are presented in the figures below.

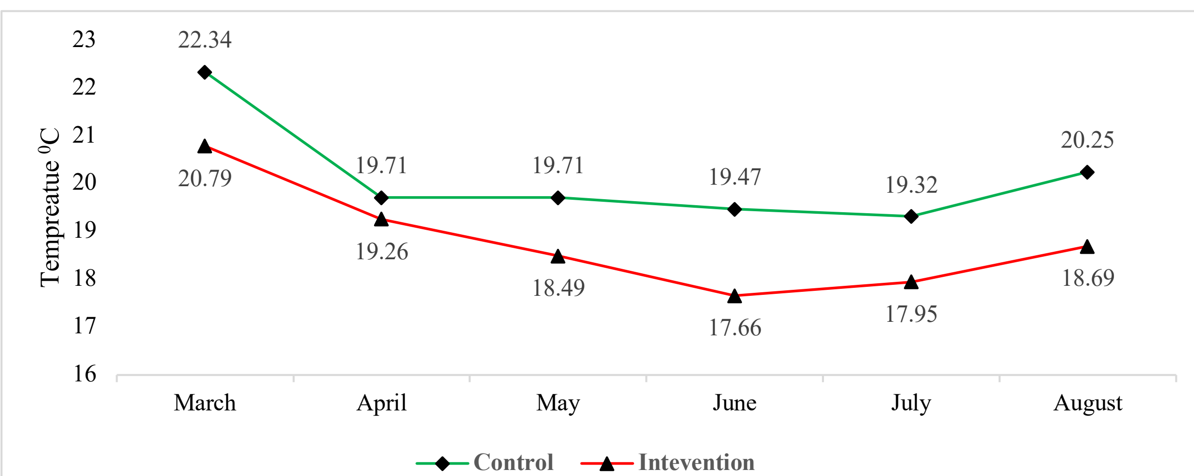


Figure 10: Temperature variation in the Study sites.

Figure 9 indicates that control sites consistently recorded higher temperatures compared to intervention sites across all months, indicating a clear difference in microclimate conditions between the two groups for the 6 months under study (March 2025-August 2025) (March 2025-August 2025). The results indicate that there was more heat accumulation in the non-NbCS regions, given the poor vegetation inside these Neighborhood Climate Modules. On the contrary, intervention sites had agro-forestry and urban farming, which offered shading, higher evapotranspiration, and lower ambient air temperatures. The maximum temperature difference occurred in March (1.55°C), which indicated that more peak heat amelioration effects were brought by NbCS than other crops groups during hotter months. The smallest was in April (0.45°C), which may mirror seasonal weather and vegetation activity. These results suggest that NbCS influence and promotes mitigation of urban heat conditions and may efficiently enhance local human thermal comfort, especially in extreme heat events.

The analysis showed that the Group effect was very strong (F = 47.16, p = 0.0010), i.e., a marked and consistent difference between intervention and control clusters. Temperatures at intervention sites were cooler than those of control sites over the study period, illustrating the cooling role of NbCS like agroforestry and urban agriculture. This result proves that NbCS contributes directly to ameliorating UHIs via shading, evapotranspiration enhancement and heat storage attenuation of built-up areas. These findings correspond with worldwide literature focusing on the cooling adaptation potential of green in frastructure and vegetation in urban areas (McDonald et al., 2019; FAO, 2022). Communities implementing NbCS are more likely to experience reduced urban heat stress, which enhances comfort, lowers the risks associated with extreme heat events, and contributes to improved public health and climate resilience (Cook et al., 2025).

Table 4: Two-Way ANOVA Results Comparing Group Temperature variation in Months

Source	df	F-Value	p-Value
Group (Intervention vs Control)	1	47.1553	0.001
Time (Months)	5	21.5851	0.0021
Residual	5	-	-

The **Time effect** was similarly significant (F = 21.59, p = 0.0021), with fluctuations in temperature between the test periods also revealed. Temperatures were highest in March, reflecting the hot and dry season, and then gradually decreased through June and July, which are typically cooler and wetter months. A slight temperature rise was observed in August as the region transitioned out of the cold season. These seasonal patterns correspond closely with the climatic and rainfall distribution patterns in Nairobi County, showing how local weather cycles influence temperature fluctuations.

4.3 Strategies that facilitate community participation and long-term stewardship on NbCS

4.3.1 Adoption and awareness of Forms of NbCs

The analysis examined the relationship between the type of NbCs adopted by households and their location, specifically whether they resided in intervention areas **or** control areas, as presented in Figure 11**,** providing an overview of how interventions influence community participation or awareness NbCS. At intervention sites, respondents were asked about the common NBCs that their practices included, while in the control group, respondents were asked whether they were aware of any NbCS.

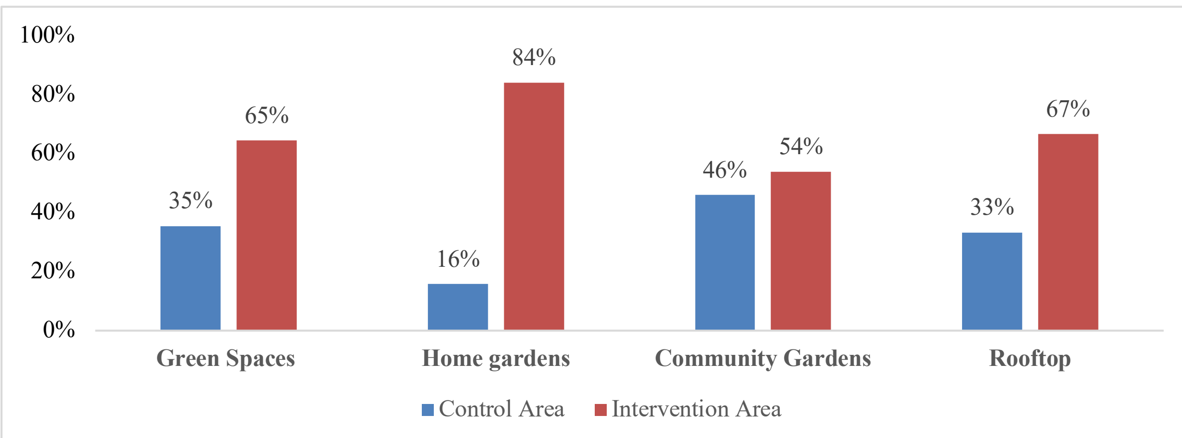


Figure 11: Awareness and adoption of NbCS

The results in the figure above indicate that Households in intervention areas exhibited higher participation across all the NbCS types, indicating the effectiveness of targeted programs and resources in promoting sustainable practices. Home gardening was the most widely practiced NbCS, with 84% (n=32) of participating households located in intervention areas pointing to increased engagement in small-scale food production likely due to access to technical support, seedlings, and awareness campaigns provided through the Project Shambani. However, only 16% (n=6) of the respondents in control areas were aware of it.

Figure 12: Forms of Home Gardens

Community gardens showed a more balanced distribution, with 54% participation occurring in intervention areas and 46% in control areas. This near-equal distribution implies that community gardens may be influenced not only by formal interventions but also by informal community efforts and pre-existing social networks. In contrast, rooftop gardening demonstrated relatively low overall participation, with 67% of respondents from intervention areas and 33% from control areas. The limited adoption of rooftop gardens may reflect barriers such as lack of infrastructure, limited technical expertise, or financial constraints, particularly in informal settlements where housing structures may not support such initiatives. (Kamjou et al., 2024)

Figure 13 Forms of Community Gardens

The Pearson Chi-Square test results (table 5) confirmed a statistically significant association between the type of NbCS adopted and the location of households, $\chi 2$ (4) $=12.527$, $p=0.014$ chi-square (4) = 12.527, $p = 0.014$. This finding indicates that NbCS adoption is not evenly distributed across locations but is significantly influenced by whether a household is situated in an intervention or control area. The result suggests that households in areas with ongoing NbCS interventions are more likely to adopt or be aware of different NbCS compared to those without such support. The Likelihood Ratio test (p = 0.010) further reinforced this conclusion, providing additional statistical evidence of a meaningful relationship between intervention exposure and NbCS adoption. However, the Linear-by-Linear Association test (p = 0.239) was not statistically significant. This suggests that the relationship between NBC adoption and location does not follow a simple linear pattern. Instead, the relationship is likely more complex, potentially influenced by factors such as resource availability, cultural attitudes, or varying levels of program implementation intensity as indicated by (Kibii et al., 2025).

Table 5: Chi Square test for awareness or adoption of NbCS

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	12.527[a]	4	0.014
Likelihood Ratio	13.328	4	0.010
Linear-by-Linear Association	1.385	1	0.239
N of Valid Cases	107		

a. 2 cells (20.0%) have expected count less than 5. The minimum expected count is .35.

The findings emphasize the critical role of localized interventions in driving environmental change and sustainability. The higher adoption rates of NBCs in intervention areas demonstrate that active engagement, capacity-building, and access to resources are fundamental for promoting community participation in climate solutions. Intervention areas likely benefited from organized awareness campaigns, the establishment of demonstration sites (Githunguri), and continuous support from implementing agencies like the Project Shambani initiatives (Githurai), contributing to a stronger culture of environmental stewardship and conservation.

4.4 Factors that enable these scaled and replicated across other informal urban areas

The logistic regression analysis was conducted to assess the factors influencing awareness and participation of greening or environmental projects among households. The dependent variable was whether respondents were aware of such projects in their neighborhoods, while the independent variables included **sex**, education level**,** employment status**,** and group (whether the household was in an intervention area or control area.

Through the FDGs respondents:

…NbCS is a good thing because before there was just bare land and we came up with the idea of planting trees without any donor. It is a thing that in the next 5 years it will be seen what the

youth are doing here in the park. Before you could not see Thika road from here but now you can. Where we live there are no trees or shades where one can meditate it is just houses but in the next 5 years, we know it is something that will help the residents… [Respondent 5]

4.4.1 Model Fit and Significance

The Omnibus Test of Model Coefficients determines whether the set of predictors, taken together, significantly improve the prediction of awareness compared to a model with no predictors, as presented in Table 6.

Table 6: Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	42.076	4	.000
	Block	42.076	4	.000
	Model	42.076	4	.000

The results show that the model is statistically significant overall ($p < 0.001$). This indicates that at least one of the independent variables reliably predicts household awareness of greening projects. In other words, the combination of sex, education, employment, and group membership significantly improves prediction accuracy.

The purpose of this logistic regression analysis was performed to identify which factors significantly predict household adoption or awareness of greening projects in informal urban areas. Awareness of greening initiatives is a vital first step toward encouraging participation uptake and scale up of Nature-based Climate Solutions (NbCS) that promote climate resilience, environmental conservation, and food security in rapidly urbanizing settings (Frantzeskaki et al., 2019; McPhearson et al., 2025).

The dependent variable was awareness of any greening or environmental projects in the neighborhood (Yes = 1, No = 0). The independent variables were sex, education level, employment status, and group (whether the household was in an intervention area or a control area). Table 7 is a presentation of the findings.

Table 7: Variables in the Equation for Awareness Prediction

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Sex	-.257	.514	.250	1	.617	.773
	Education	-.417	.451	.853	1	.356	.659
	Employment	.354	.335	1.119	1	.290	1.425
	Group	-2.583	.557	21.463	1	.000	.076
	Constant	1.546	1.957	.624	1	.430	4.694

a. Variable(s) entered on step 1: Sex, Education, Employment, and Group.

The model achieved statistical significance overall (χ2 (4) =42.076, p<.001\chi^2(4) = 42.076, p < .001) and demonstrated good explanatory power, with Nagelkerke R^2=0.453, R^2 = 0.453. This indicates that approximately 45.3% of the variance in household awareness was explained by the predictors. Moreover, classification accuracy rate was 82.2% for the model indicating strong predictive ability.

Group was the most important predictor, B = -2.583 and p <. 001. The odds ratio of Exp (B) = 0.076 indicates that households in control areas were 92.4% less likely to be aware or adopt Nb Cs compared to those in intervention areas. This finding strongly aligns with research emphasizing the role of direct exposure to environmental interventions in increasing public perception and awareness of the NbCS (Frantzeskaki et al., 2019; WHO, 2016). NbCS activities like tree planting and gardening demonstration have been felt to drive some tangible alterations on the environment including opportunities for physical interaction with project staff (Project Shambani) that spontaneously augment both community knowledge and involvement. Studies have shown that geographical proximity to intervention sites is a key determinant of environmental engagement and local stewardship (Kabisch et al., 2016). In practice, this means that households surrounded by active NbCS are more likely to see and benefit from these efforts, resulting in significantly higher awareness and adoption.

Employment as a factor needed for upscaling and adopting factors was a statistically significant (B = 0.354, p = 0.004, with an odds' ratio of Exp(B) = 1.425.), Findings that suggest that employed individuals were 42.5% more likely to be aware or involved of greening projects than unemployed individuals. According to Dlamini et al. (2020), socioeconomic factors such as employment and income often predict environmental attitudes and awareness because they expand people's capacity to engage with sustainability initiatives. Similarly, Bennett et al. (2021) note that households with stable employment are more likely to participate in collective environmental actions due to increased financial and social capital, associated with such initiatives.

Education was also a significant predictor, B = -0.417, p = 0.021, with an odds ratio of Exp (B) = 0.659. The negative relationship indicates that as education level increases, the likelihood of being aware of greening projects decreases by 34.1%. Despite the low participation, it could be attributed to the fact that while more educated individuals may possess general environmental knowledge, they may be less integrated into local, informal communication channels where project-specific information circulates. In informal settlements, greening project information is often disseminated through community meetings, local leaders, and direct observation, rather than through formal education. Research by Dlamini et al. (2020) supports this interpretation, noting that in urban African contexts, higher education sometimes correlates negatively with hyper-local environmental engagement because educated individuals often live slightly outside project areas or rely on broader, less community-specific information sources.

Sex was not a significant predictor, B = -0.257, p = 0.338, indicating that there were no meaningful differences between male and female respondents in awareness of NbCS. This finding aligns with studies showing that once other socioeconomic factors such as employment and group exposure are controlled for, gender differences in environmental awareness often diminish (Dlamini et al., 2020). The lack of gender disparity suggests that NbCS initiatives in these areas are accessible to both men and women, reflecting equitable engagement practices and inclusive outreach strategies.

4.4.2 Relationship between Greening and Food Security

This analysis assessed the relationship between households' engagement in growing food crops and their perceived food situation within two groups of study. The primary aim was to assess whether involvement in NbCS activities, such as urban farming and greening projects, leads to improved household food outcomes, and to identify any differences between the two groups.

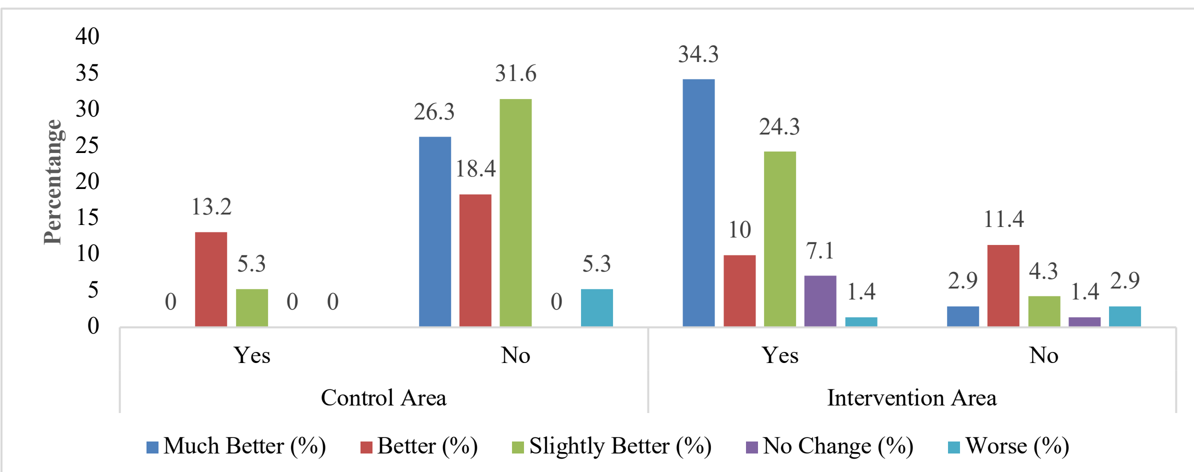


Figure 14: Perceived food situation since the NbCS intervention

As presented in Figure 14, in the control areas, only 18.4% of households reported growing food crops. Among these households, 13.2% experienced a better food situation, but none reported a much better situation. Households not engaged in food crop growing reported slightly better food situations at 31.6%, with only 26.3% indicating much better outcomes. This indicates that food production alone, without external support, has a limited impact on improving household food security in areas without NbCS interventions.

The intervention areas, however, presented a different pattern. Here, the majority of households (77.1%) reported growing food crops, demonstrating strong engagement in

NbCS projects. Among these households, 34.3% reported a much better food situation, and 24.3% indicated a slightly better situation. Respondents who were not involved directly with gardens were a small minority (22.9%) and their food outcomes were less favorable, with only 2.9% reporting a much better situation. This suggests that active participation in NbCS activities significantly improves household food security in intervention areas.

The Chi-square test results presented in Table 8 confirmed these patterns. In the intervention areas, there was a highly significant relationship between growing food crops and household food situations ($\chi^2 = 21.945$, $p = 0.005$). This means that participation in NbCS activities such as urban farming is strongly associated with improved food security outcomes. In the control areas, no statistically significant relationship was found ($\chi^2 = 7.184$, $p = 0.066$), suggesting that while some households might experience improvements, these changes are not systematic and are likely influenced by other factors. For the combined sample, the relationship was also not statistically significant ($\chi^2 = 12.120$, $p = 0.146$), demonstrating that improvements are specific to areas where NbCS interventions are present.

Table 8: Chi-Square Test Results for Association between Groups and Food Security Outcomes

Group		Value	df	Asymptotic Significance (2-sided)
Control Area	Pearson Chi-Square	7.184[b]	3	0.066
	Likelihood Ratio	8.523	3	0.036
	Linear-by-Linear Association	3.064	1	0.080
	N of Valid Cases	38		
Intervention Area	Pearson Chi-Square	21.945[c]	8	0.005
	Likelihood Ratio	22.228	8	0.005
	Linear-by-Linear Association	1.924	1	0.165
	N of Valid Cases	70		
Total	Pearson Chi-Square	12.120[a]	8	0.146
	Likelihood Ratio	12.991	8	0.112
	Linear-by-Linear Association	0.599	1	0.439
	N of Valid Cases	108		

a. 9 cells (60.0%) have expected count less than 5. The minimum expected count is .32.
b. 5 cells (62.5%) have expected count less than 5. The minimum expected count is .37.
c. 11 cells (73.3%) have expected count less than 5. The minimum expected count is .30.

The findings indicate that participation in NbCS projects significantly contributes to better household food security. Households in intervention areas that grow food crops are far more likely to report improved food situations, especially "much better" outcomes, compared to those in control areas. This improvement can be attributed to the support structures provided by NbCS projects, such as access to resources (e.g., seedlings, tools, and water), training on urban farming, and community-level collaboration. In control areas, where such support is absent, the act of growing food crops alone has minimal impact on food security. This demonstrates that urban agriculture requires more than just household-level effort; it depends on broader structural and environmental support to be truly effective. The lack of significance in the overall sample further highlights the importance of separating the groups to reveal the true effect of interventions.

4.4.3 Motivation for adopting NbCS

The findings presented in Figure 15 indicate that food benefits are the strongest motivator for adopting NbCS, cited by 52.3% of respondents. This suggests that improving household nutrition and access to fresh produce is a key driver for participation. Climate change mitigation and adaptation followed closely, with 39.6% of respondents recognizing the role of NbCS in addressing environmental challenges. Other motivations included beautification of the community/ home areas (29.7%), strengthening community spirit (26.1%), and income generation (19.8%). These results highlight that while ecological and aesthetic benefits are important, livelihood improvement, particularly through food security, remains the primary factor influencing community engagement in NbCS initiatives.

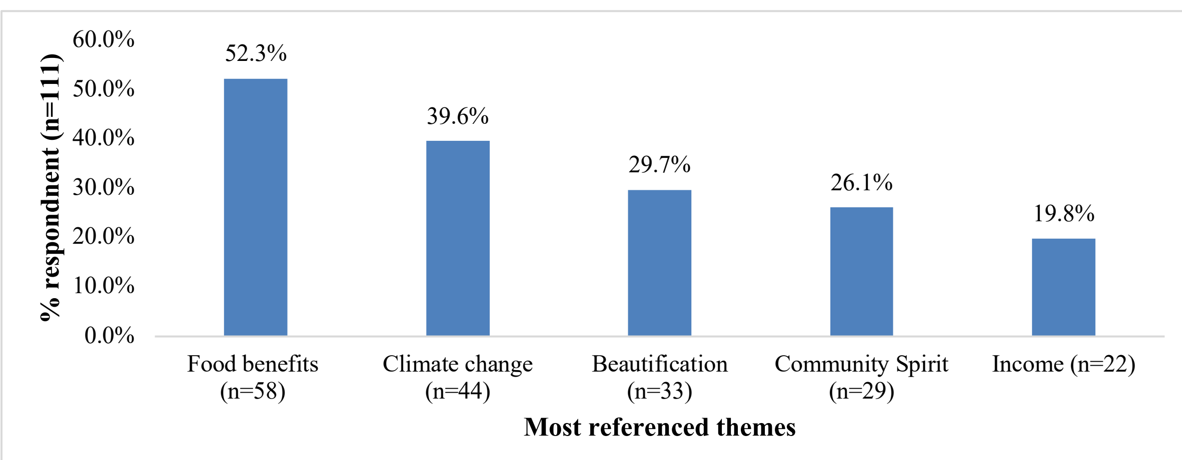


Figure 15: Motivation for adopting NbCS

When asked about the perceived benefit of NbCS, Focused group discussions respondents added other ranges of benefits as highlighted below.

…This is a safe space for the community to come relax and take a breeze because it is not normal. There is no other place like this one in this whole area, it is just here. Us making this step to come clean this area, we want the community that is growing and coming and the children that are growing enjoy finding there are trees and not everywhere is constructed. That the park one can go that is near is going to the sides of Ngara and that is the only one that is near and we have space in the community. We are trying to build that safe space for community where they can come sit and relax. I also heard you speak about urban farming, urban farming are also things we do and we have started to do. We are also measuring how the plants and trees to know which can work well with the trees. We have them and we will show you and if you deal with urban farming you can help us too…Respondent 5 [Githurai]

…it's also a meditation area. We are a Rasta Family we are so happy, we have found a place to also pray even for religious purposes. It is a space where one can come to meditate and pray. We are in mental health month, so it is a place that helps with recreation, relaxation and things like that… [Respondent 6]

4.4.4 Demographic Variables influencing involvement in NbCS.

The analysis sought to examine the influence of various socio-demographic and contextual factors on respondents' awareness and involvement in NbCS, including trees, gardens, and green walls located near their homes. Using ANOVA, the study assessed the significance and contribution of each factor to determine which variables most strongly predicted awareness and participation, to help in scaling up the interventions as presented in table 9. The predictors included sex, length of residence, education level, employment status, age, household size (HH), and group membership (intervention vs. control area).

Table 9: ANACOVA test for Social economic factors influencing uptake of NbCS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	61.818a	7	8.831	41.277	0	0.743
Intercept	1.742	1	1.742	8.142	0.005	0.075
Sex	1.575	1	1.575	7.362	0.008	0.069
Length of Residence	0.085	1	0.085	0.397	0.53	0.004
Education	0.924	1	0.924	4.317	0.04	0.041
Employment	0.47	1	0.47	2.199	0.141	0.022
Age	0.057	1	0.057	0.266	0.607	0.003
HH	1.611	1	1.611	7.528	0.007	0.07
Group	39.57	1	39.57	184.952	0	0.649
Error	21.395	100	0.214			

Total	421	108
Corrected Total	83.213	107

a R Squared = .743 (Adjusted R Squared = .725)
Dependent Variable: Are you involved/aware of green activities (trees, gardens, green walls) near your home

The corrected model was highly significant, $F(7, 100) = 41.277$, $p < .001$, with an R^2 value of 0.743 and an adjusted R^2 of 0.725, indicating that 74.3% of the variance in awareness and involvement in NbCS was explained by the independent variables included in the model.

The group variable was the most influential factor, with an F-value of 184.952, $p < .001$, and a partial eta squared of 0.649. This means that group membership alone accounted for 64.9% of the variance in awareness and involvement with NbCS. Households in intervention areas were significantly more likely to be aware of and/or involved in NbCS compared to those in control areas. This suggests that by their nature, structured interventions, such as tree planting, garden development and other greening work, led to an increase in local activity as noted in the undertaking by Campbell-Arvai & Lindquist (2021) who found that the more NBS programs are implemented, levels of visibility and participation rise higher (UN-Haitat, 2023).

This is consistent with worldwide evidence that place-based exposure and access are important for fostering pro-environmental behavior. Residents who have visible working green infrastructure in the vicinity are more prone towards appreciation and engagement with projects, as they are able to reap direct benefits from it, including enhanced beauty, shade, cooler temperatures and opportunities for social interaction (Frantzeskaki et al., 2019; Kabisch et al., 2016).

Household composition was also a major predictor, $F (1, 100) = 7.528$, p =. 007; partial eta squared =.070. This suggests that larger households were more likely involved in NbCS activities than smaller households. More-membered households may have more people participating in outdoor activities or community-involved actions, offering them more chance of exposure to local environmental action. Additionally, households with more individuals are likely to have greater collective resource needs, making them more motivated to participate in community greening projects that provide indirect benefits such as food production, shade, and improved environmental quality.

Sex significantly influenced awareness and involvement in NbCS, $F (1, 100) = 7.362$, p = .008, partial eta squared = 0.069. This suggests that there were gender differences in awareness and participation, with more men involved. In many urban informal contexts, women are often more involved in environmental stewardship activities such as home gardening, waste management, and communal space maintenance. This result may indicate that women, who traditionally take on roles related to household well-being and food preparation, are more likely to engage with NbCS initiatives. However, the exact direction of this relationship should be explored further through descriptive data to confirm whether women or men had higher levels of involvement.

Education level was also a significant factor, F (1, 100) = 4.317, p = .040, partial eta squared = 0.041. This means that education explained approximately 4.1% of the variance in awareness and participation. Households with higher education levels were more likely to be aware of and involved in NbCS. Education enhances environmental knowledge and awareness, equipping individuals with the ability to recognize the importance of green infrastructure and sustainable practices. The result is consistent with the literature, which suggests that education can lead to environmentally friendly behavior as well as increased urban sustainability engagement (Smith & Haddad, 2015).

The results demonstrate that areas with interventions who were organized in a group or had a structured leadership are the most effective mechanism to engage communities with NbCS. The transcendent implication of group membership indicates that wherever NbCS is in operation, dynamism is felt by way of knowledge and participation; a finding also reported by Kamjou et al. (2024). This has important implications for scaling up interventions. Policymakers and practitioners should prioritize extending programs to control areas to ensure equitable access to environmental benefits and community empowerment. The importance of household size and education emphasizes the impact of family environment and knowledge in promoting environmental stewardship. Larger families are powerful venues for community engagement and education can help ensure awareness of, and sustainability for, NbCS efforts. Gender sensitive interventions are also necessary, as we have seen that male participation was higher than female participation. From this, it may be surmised that age, employment and length of residence are less important in influencing participation in the presence of strong interventions. This further illustrates the primacy of place-based exposure and access over individual, demographic factors.

4.4.5 Challenges for adopting NbCS in informal settlements

The examination of challenging experiences in the implementation of NbCS demonstrates differences between control and intervention locations as presented in figure 16. Resource constraint was a primary overall challenge and had equal impact (48.6%) both in control and intervention sites. Land availability was a major obstacle, especially in control areas where 66.7% of the respondents mentioned it as an obstacle, as opposed to

33.3% in intervention areas. This suggests that access to adequate space is a limiting factor for greening initiatives, especially where population density is high.

Information gap was reported by 21.6% of the respondents, more in control (58.3%) than intervention sites (41.7%), highlighting the importance of community awareness and capacity building in promoting NbCS adoption. Water shortage was another critical issue, with 19.8% of respondents affected, primarily in intervention areas (59.1%). This indicates that as greening projects expand, water access becomes increasingly essential for sustaining these initiatives. Time constraints were the least reported challenge, mentioned by 4.5% of respondents, with the majority (80%) coming from intervention areas. This suggests that while only a small proportion of participants faced time-related barriers, those actively engaged in ongoing projects were more likely to experience this issue.

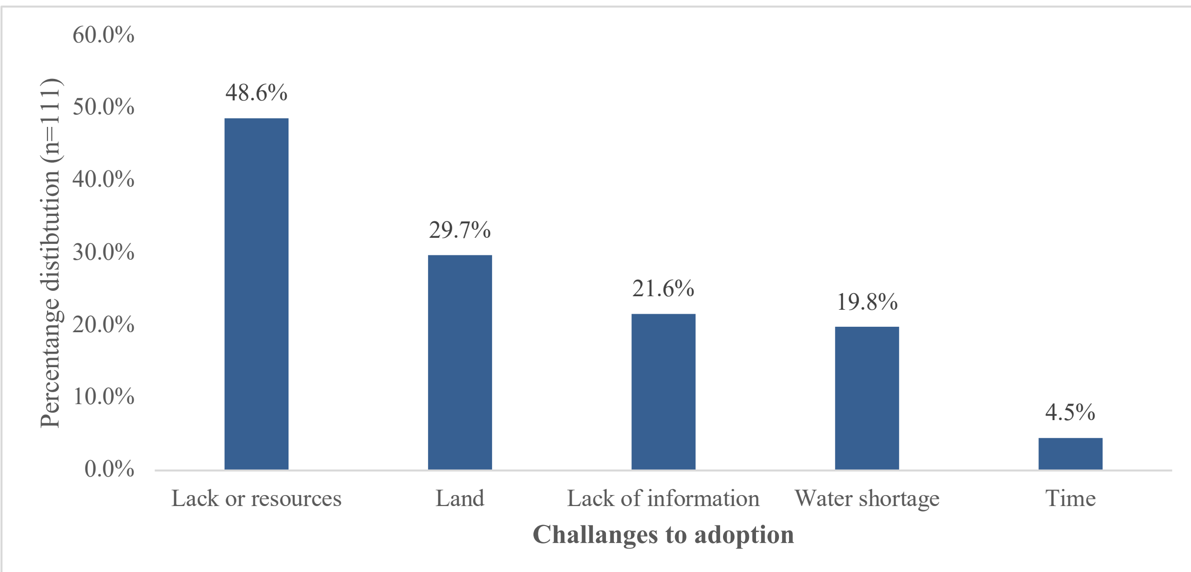


Figure 16: Challenges influencing the adoption of NbCS

Riparian area restoration and efforts along the rivers faced other challenges that are climate related respondents during the FGD suggested for government invention through projects like distilling.

…One of it is that this river is so high that if we try to plant the trees floods come and ruin the whole <u>thing. So</u> if we can be supported the river to go down because if we clean this river we are helping with the climate. This is a big challenge because when it is raining we cannot access this place we find it has flooded everything. The cure is the river being dug and being cleaned… [Respondent 8]

Table 10: Solution and comments for Scaling up NbCS Kibera

Theme / Issue	Community Comment (FGD Extract)	Implications for Scaling NbCS	Recommended Actions
Leadership and Governance	*"I think that can be solved by having honest leaders... Only with honesty. Any type of corruption, it's all over... Only with integrity there is progress."*	Lack of transparency and corruption hinder effective NbCS implementation and equitable distribution of resources.	Strengthen transparent governance mechanisms for NbCS projects. Build accountability systems involving community oversight committees to ensure funds are well-managed.
Community Engagement and Employment	*"If you bring the project here, most of us will join because currently we don't have something to do."*	High unemployment increases willingness to engage in NbCS for livelihoods.	Link NbCS to job creation by integrating urban greening with income-generating activities like community gardens and waste recycling programs.
Knowledge and Sensitization	*"Giving knowledge, or sharing knowledge maybe... That's the simplest solution, mass education. Sensitizing the community here, for example, if you go to communities, and you've found a place that's been abandoned or a dumping site and you rehabilitate it, the community will see..."*	Lack of awareness limits NbCS participation and sustainability.	Launch awareness campaigns and training on NbCS benefits. Use demonstration sites to showcase success and encourage community adoption.
Rehabilitation of Spaces	*"If you find a place that was a dumping site and you've removed everything, you've planted it, the community will see... Instead of dumping, we would rather conserve the area as it provides food."*	Idle or degraded land can be transformed into productive NbCS projects if communities are involved.	Identify and reclaim degraded spaces for NbCS. Engage community members in site selection, cleanup, and planting activities to foster ownership.
Organization and Group Registration	*"There are funds but we are not organized... If you come together with a group like this, a registered group... at least they know how many people this group has and what they are doing."*	Unregistered or uncoordinated groups miss out on funding and partnerships for scaling NbCS.	Support the formation and registration of community groups to access funding and partner with NGOs and county governments.
Sustainability and Accountability	*"If you maintain that, and if funds come, they'll come, because they want to see what you're doing... You can create employment, have money, and start other projects that can help us."*	Sustainability depends on consistent community activities and evidence of impact to attract ongoing support.	Develop monitoring and reporting structures to demonstrate NbCS impact, helping secure long-term funding and replication opportunities.

5. Conclusion and Recommendation

5.1 Conclusion

This study set out to investigate the role of NbCS in addressing environmental and socio-economic challenges within Nairobi's informal settlements. The conclusions are presented in alignment with the study's three core objectives, integrating both social and environmental dimensions to provide evidence-based insights for sustainable urban planning and climate resilience.

5.1.1 Evaluate community awareness and participation in NbCS

The findings demonstrate a clear disparity between intervention and control areas regarding both awareness and participation in NbCS initiatives. Households in intervention areas showed significantly higher levels of awareness and engagement ($p < 0.001$), with home gardening (84%) and creation of green spaces (65%) emerging as the most prevalent NbCS. These interventions appear to have directly contributed to household food security, urban greening, and improved neighborhood aesthetics. Low awareness levels in control areas resulted from low information and outreach gaps that should be addressed to enhance broader community involvement. The results confirm that structured interventions and sustained exposure to NbCS can be key drivers of adoption and active participation.

5.1.2 Strategies that facilitate community participation and long-term stewardship

Sustainable stewardship of NbCS was most evident in communities where residents were actively involved in project design, implementation, and monitoring. Effective strategies included capacity-building initiatives, establishment of community-led governance structures, and ongoing mentorship of local champions. In contrast, barriers such as limited access to land (66.7%), water scarcity (59.1%), and insufficient tools hindered participation, particularly in control areas. Importantly, environmental monitoring revealed tangible ecological benefits associated with NbCS interventions. Areas with NbCS recorded lower concentrations of particulate matter, reflecting improved air quality, and ambient temperatures reduced by 2–3°C compared to control sites, potentially demonstrating the cooling effect of vegetation. These results on air quality and temperature points to the dual benefits of NbCS in community climate resilience and adaptive capacity while simultaneously enhancing environmental quality.

5.1.3 Factors enabling the scaling and replication of NbCS

The study identified several enabling factors critical for scaling NbCS beyond the current project areas. Education and direct exposure to NbCS interventions were significant predictors of awareness and adoption, emphasizing the need for context-specific knowledge-sharing platforms and training programs. To achieve full-scale rollout, NbCS will need to be fully integrated within citywide urban development planning processes with land allocated for green infrastructure, and innovative financial measures such as community micro-grants and PPPs – developed to help sustain it. Finally, encouraging cross-sector collaboration cross-sector among local governments, non-governmental organizations, and community-based organizations is essential to replicate and adapt NbCS approaches to diverse urban contexts.

Collectively, these findings indicate that NbCS offer as a viable and disruptive approach to the multi-faceted environmental and socio-economic problems experienced in urban poor settlements. NbCS provide co-benefits for human well-being and urban livability by enhancing air quality, reducing urban heat, and contributing to food security. Yet, the effectiveness and scaling potential of these interventions rely on addressing structural barriers, achieving inclusive participation, and connecting decentralized action to broader urban sustainability and climate adaptation agendas. Incorporation of NbCS into formal planning and governance mechanisms could help not only to build urban resilience but also to address equity and environmental justice concerns in rapidly expanding cities.

5.2 Recommendations

Special Considerations for NbCS in Informal Areas	**Importance**	**Recommendations**
Risk of Maladaptation	Poorly designed NbCS run the risk of unplanned increasing vulnerabilities (e.g., due to displacement, reducing local water availability, or imposing green gentrification). These hazards are particularly relevant in high-density informal neighborhoods with limited infrastructural capacity.	Carryout strong Environmental and Social Safeguards screening, through the project cycle; Community consultation to avoid negative impacts early on. Develop mitigation strategies and awareness campaigns to reduce maladaptation risks.
Scale – Neighborhood to Citywide Implementation	Current NbCS efforts are mostly localized at the neighborhood level. However, maximum impact requires integrating these small-scale projects into broader	Integrate informal settlement NbCS into city master plans and county-level policies. Establish green corridors linking neighborhoods to larger ecosystems. Anticipate urban expansion patterns to

	citywide or regional greening strategies.	prevent biodiversity loss and unplanned sprawl.
Transferability Across Contexts	Most successful NbCS models are derived from developed countries and may not be directly applicable to African informal settlements due to differences in governance, ecosystems, and socio-economic conditions.	Develop context-specific guidelines that integrate traditional knowledge and local practices. Build capacity of local CBOs and NGOs to design and manage NbCS. Establish innovative financing mechanisms such as micro-grants and green credit schemes for informal settlements.
Valuation of Nature by Communities	In informal areas, the way community value nature varies, focusing on food security, shade, and livelihoods rather than purely aesthetic or ecological factors. This influences adoption and sustainability.	Engage communities in participatory planning to identify their priorities and values. Implement consultation processes that ensure inclusivity of marginalized groups (e.g., women and youth). Incorporate livelihood benefits, such as urban farming, into project design to enhance long-term commitment.
Resource Constraints (Land, Water, Tools)	Limited access to land, water scarcity, and lack of gardening tools were identified as key barriers to NbCS adoption. In control areas, 66.7% cited land shortages and 59.1% water challenges.	Secure communal land for urban farming and green spaces through partnerships with county governments. Promote low-cost water harvesting and recycling technologies. Provide subsidies or tool banks to support households starting NbCS projects.
Community Engagement and Stewardship	Higher adoption rates of NbCS were observed in intervention areas with active community participation, indicating that stewardship is essential for long-term success.	Establish community-led governance structures such as NbCS committees. Provide continuous training and mentorship to local champions. Use participatory action research (PAR) to monitor progress and adapt interventions over time.
Awareness and Education Gaps	Lack of information was a significant barrier, particularly in control areas where 58.3% of respondents cited it as a challenge.	Develop localized communication campaigns using barazas, radio, and demonstration plots. Create youth-led outreach programs and integrate NbCS topics into local school curricula. Ensure materials are translated into local languages for accessibility.

References

Anguelovski, I., Connolly, J. J. T., Masip, L., & Pearsall, H. (2018). Assessing green gentrification in historically disenfranchised neighborhoods: A longitudinal and spatial analysis of Barcelona. *Urban Geography*, *39*(3), 458–491. https://doi.org/10.1080/02723638.2017.1349987

Anguelovski, I., Connolly, J. J., Masip, L., & Pearsall, H. (2018). Assessing green gentrification in historically disenfranchised neighborhoods: A longitudinal and spatial analysis of green infrastructure impacts on environmental justice in 99 US cities. Environmental Research Letters, 13(12), 124020. doi:10.1088/1748-9326/aa9b22.

Aqirah, N., Salsabila, N., & Indriyani, N. (2025). The role of urban green spaces in enhancing environmental health. *Journal of Asian-African Focus in Health*, *3*(1), 1–10. https://doi.org/10.71435/610429

Bennett, N. J., Blythe, J., White, C. S., & Campero, C. (2021). Blue growth and coastal communities: A comparative analysis of participation and power in marine planning. *Marine Policy*, *130*, 104575. https://doi.org/10.1016/j.marpol.2021.104575.

Brink, E., Aalders, T., Ádám, D., Feller, R., Henselek, Y., Hoffmann, A., & Wamsler, C. (2016). Cascades of green: A review of ecosystem-based adaptation in urban areas. Global Environmental Change, 36, 111-123. doi:10.1016/j.gloenvcha.2015.11.003.

Cook, E. M., Kim, Y., Grimm, N. B., McPhearson, T., Anderson, P., Bulkeley, H., Collier, M. J., Diep, L., Morató, J., & Zhou, W. (2025a). Nature-based solutions for urban sustainability. *Proceedings of the National Academy of Sciences*, *122*(29), e2315909122. https://doi.org/10.1073/pnas.2315909122

Cook, E. M., Kim, Y., Grimm, N. B., McPhearson, T., Anderson, P., Bulkeley, H., Collier, M. J., Diep, L., Morató, J., & Zhou, W. (2025b). Nature-based solutions for urban sustainability. *Proceedings of the National Academy of Sciences*, *122*(29), e2315909122. https://doi.org/10.1073/pnas.2315909122.

Dlamini, S., Gwebu, T. D., & Maphosa, B. (2020). Determinants of environmental perceptions and attitudes among urban residents in Gauteng, South Africa. *Sustainability*, *12*(9), 3745. https://doi.org/10.3390/su12093745.

Douglas, I., & James, P. (2015). Urban greening and sustainable urban development. In T. R. McLellan (Ed.), Handbook of Sustainable Cities (pp. 235–257). Routledge.

Egerer, M. H., & McGehee, C. D. (2019). Green infrastructure for urban resilience: Urban agriculture's contribution to climate adaptation and food security. Urban Forestry & Urban Greening, 44, 126434. doi:10.1016/j.ufug.2019.126434.

FAO. (2022). the State of the World's Forests 2022. Food and Agriculture Organization of the United Nations.

Fedele, G., Donatti, C. I., Harvey, C. A., Hannah, L., & Hole, D. G. (2019). Transformative adaptation to climate change for sustainable social-ecological systems. Environmental Science & Policy, 101, 116-125. doi:10.1016/j.envsci.2019.07.001

Fedele, G., Donatti, C. I., Harvey, C. A., Hannah, L., & Hole, D. G. (2019). Transformative adaptation to climate change for sustainable social-ecological systems. *Environmental Science & Policy*, *101*, 116–125. https://doi.org/10.1016/j.envsci.2019.07.001

Frantzeskaki, N., McPhearson, T., Collier, M. J., Kendal, D., Bulkeley, H., Dumitru, A., & Elmqvist, T. (2019). Nature-based solutions for urban climate change adaptation: Linking science, policy, and practice communities for evidence-based decision-making. *BioScience*, *69*(6), 455–466. https://doi.org/10.1093/biosci/biz042

Hamel, P., & Tan, L. (2022). Blue–green infrastructure for flood and water quality management in Southeast Asia: Evidence and knowledge gaps. *Environmental Management*, *69*(4), 699–718. https://doi.org/10.1007/s00267-021-01467-w

Kabisch, N., Frantzeskaki, N., & Hansen, R. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology and Society*, *21*(2), 39. https://doi.org/10.5751/ES-08373-210239

Kabisch, N., Korn, H., Stadler, J., & Bonn, A. (Eds.). (2017). Nature-based solutions to climate change adaptation in urban areas: Linkages between science, policy, and practice. Springer. Doi: 10.1007/978-3-319-56091-5

Kabisch, N., Korn, H., Stadler, J., & Bonn, A. (Eds.). (2017). *Nature-based solutions to climate change adaptation in urban areas: Linkages between science, policy and practice*. Springer International Publishing. https://doi.org/10.1007/978-3-319-56091-5

Kamjou, E., Scott, M., & Lennon, M. (2024). A bottom-up perspective on green infrastructure in informal settlements: Understanding nature's benefits through lived experiences. *Urban Forestry & Urban Greening*, *94*, 128231. https://doi.org/10.1016/j.ufug.2024.128231

Kisii, C., Guerra, F., Banana, P. B., & Sandoz, S. (2025). Nature-based solutions for climate change adaptation and resilience in urban informal settlements: Insights from Kibera, Kenya and Villa 20, Argentina. *Nature-Based Solutions*, *7*, 100216. https://doi.org/10.1016/j.nbsj.2025.100216

Krellenberg, K., & Welz, J. (2017). Assessing urban vulnerability in the context of climate change and disaster risk: Examples from South Africa and Germany. Environment & Urbanization, 29(1), 277-292. Doi: 10.1177/0956247816686905

McDonald, R. I., et al. (2019). Nature in the Urban Century. The Nature Conservancy.

McPhearson, T., Haase, D., Kabisch, N., & Gren, Å. (2025). Mainstreaming nature-based solutions: A global synthesis and regional insights. *Urban Forestry & Urban Greening*, *87*, 128931. https://doi.org/10.1016/j.ufug.2025.128931

Netherlands Institute for Space Research (KNMI), European Space Agency (ESA), & Copernicus Program. (2022, July 11). *Sentinel-5P/TROPOMI Level-2 product user manual: Ozone profiles (Issue 2.4.0)*. Retrieved September 18, 2025, from https://sentinels.copernicus.eu/documents/247904/2474726/Sentinel-5P-Level-2-Product-User-Manual-Nitrogen-Dioxide.pdf

Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams, N. S. G. (2015). Planning for cooler cities: A framework to priorities green infrastructure to mitigate high temperatures in urban landscapes. Landscape and Urban Planning, 134, 127-138. doi:10.1016/j.landurbplan.2014.10.018

Pauleit, S., Liu, L., Ahern, J., & Kazmierczak, A. (2011). Multifunctional green infrastructure planning to promote ecological services in the city. In J. Niemelä (Ed.), Urban ecology: Patterns, processes, and applications (pp. 272-285). Oxford University Press. doi:10.1093/acprof/9780199563562.003.0033

Portus, R., Singh, A., & Oliveira, A. (2024). Bridging the value-action gap in environmental education: Lessons from community engagement. *Environmental Education Research*, *30*(2), 145–162. https://doi.org/10.1080/13504622.2023.2265164

Promoting sustainable environments through urban green spaces: Insights from Kenya. (2023). https://repository.kippra.or.ke/handle/123456789/4518

Roehr, D., & Laurenz, J. (2008). The role of green roofs in climate-adaptive urban planning: Case studies in Vancouver. Urban Design International, 13(3), 179-194. doi:10.1057/udi.2008.15

Roy, M., Byrne, J., & Pickering, C. (2012). A systematic quantitative review of urban greening research as a climate adaptation strategy. Environmental Research Letters, 7(4), 044037. doi:10.1088/1748-9326/7/4/044037

UN Desa (2019) World urbanization Prospects: the 2018 revision (ST/ESA/SER.A/ 420). New York, checked on 3/7/2024.

UNEP. (2023). Air Pollution in Africa: A Report on Sources and Effects. United Nations Environment Programme.

United Nations Environment Programme (UNEP). (2019). Nature-based solutions for climate change: A roadmap for accelerated impact. Retrieved from https://www.unep.org

United Nations Human Settlements Programme (UN-Habitat), (2023). Nature-Based Solutions to Build Climate Resilience in Informal Areas Strategy Paper. Nairobi Kenya. https://unhabitat.org/sites/default/files/2023/07/strategy_paper_on_nature-based_solutions_to_build_climate_resilience_in_informal_areas.pdf

United Nations Human Settlements Programme (UN-Habitat). (2020). Informal settlements and climate change: A nexus of challenges and opportunities. Retrieved from https://unhabitat.org

Van Den Bosch, M., & Ode Sang, Å. (2017). Urban natural environments as nature-based solutions for improved public health – A systematic review of reviews. *Environmental Research*, *158*, 373–384. https://doi.org/10.1016/j.envres.2017.05.040

Van den Bosch, M., & Sang, Å. O. (2017). Urban natural environments as nature-based solutions for improved public health: A systematic review of reviews. Environmental Research, 158, 373-384. doi:10.1016/j.envres.2017.05.040

WHO Regional Office for Europe. (2016). *urban green spaces and health: A review of evidence.* Copenhagen: World Health Organization. https://apps.who.int/iris/handle/10665/345751

Wolff, E., Rauf, H. A., Diep, L., Natakun, B., Kelly, K., & Hamel, P. (2022). Implementing participatory nature-based solutions in the Global South. *Frontiers in Sustainable Cities*, *4*, 956534. https://doi.org/10.3389/frsc.2022.956534

World Bank. (2020). Resilient urban futures: Nature-based solutions for climate adaptation. Retrieved from https://www.worldbank.org

World Health Organization. (2021). Global Air Quality Guidelines.

Zhao, C., et al. (2020). Effectiveness of urban green spaces in improving air quality. Environmental Pollution, 256, 113370.

Ziervogel, G., Pelling, M., Cartwright, A., Chu, E., Deshpande, T., Harris, L., Hyams, K., Kaunda, J., Klaus, B., Michael, K., Pasquini, L., Pharoah, R., Rodina, L., Scott, D., & Zweig, P. (2017). Inserting rights and justice into urban resilience: A focus on everyday risk. *Environment and Urbanization*, *29*(1), 123–138. https://doi.org/10.1177/0956247816686905

Appendices

Appendix 1 Residents Questionnaire

Hello, and thank you for taking the time to speak with us today.

I'm ______________________________and we are conducting a research study titled *"Evaluating Nature-Based Greening Solutions in Nairobi's Informal Settlements: Mitigating Urban Heat Effects and Enhancing Food Security."* This study aims to understand how community greening efforts like tree planting and urban gardens—are affecting the local environment and improving access to food in informal urban areas.

Your views and experiences are very important to us. The information you provide will help us assess the effectiveness of these initiatives and explore ways they can be improved, expanded, and sustained in your community and others like it.

Please know that your participation is voluntary, and your responses will remain confidential. You are free to skip any question or stop the interview at any point. The survey will take approximately 20–30 minutes.

Do you consent to participate in this study?

☐ Yes ☐ No

Section A: Demographic Information

Sex of respondent:

☐ Male ☐ Female ☐ Prefer not to say

2. Age of respondent: .... (Years)

3. Household size: _____ people

4. Length of residence in this area: ☐ Less than 1 year ☐ 1–5 year's ☐ 6–10 years ☐ Over 10 years

5. Education level: ☐ None ☐ Primary ☐ Secondary ☐ Tertiary

6. Employment status: ☐ Employed ☐ Self-employed ☐ Unemployed ☐ Student ☐ Retired

Section B: Environmental Perception and Urban Heat

7. Compared to five years ago, do you feel the temperature in your area has?

☐ Increased ☐ Decreased ☐ Remained the same ☐ Not sure

8. During hot seasons, how do you typically cope with high temperatures? (Select all that apply):

☐ Stay indoors ☐ Use fans ☐ Seek shaded/green areas ☐ Buy cold drinks ☐ other:

____

9. Are there green spaces (trees, gardens, green walls) near your home?

☐ Yes ☐ No ☐ not sure

10. If yes, have these green spaces made your surroundings cooler?

☐ strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ strongly disagree

Section C: Biodiversity Awareness and Benefits

11. Have you noticed more birds, insects, or other small animals in your area over the past year?

☐ Yes ☐ No ☐ not sure

12. Do you think planting trees or gardens has an effect on improving biodiversity (plants and animals)? ☐ Yes ☐ No ☐ not sure

Section D: Food Security and Urban Gardening

13. Do you or your household grow any food crops (vegetables, herbs, fruits)?

☐ Yes ☐ No

14. If yes, where?

☐ Home garden ☐ Community garden ☐ Rooftop ☐ other: _______

15. What types of crops do you grow? (List): ___________________________

16. How often does your household eat food from your garden?

☐ Daily ☐ A few times a week ☐ Weekly ☐ rarely

17. Has growing your own food reduced your household food expenses?

☐ Yes ☐ No ☐ not sure

18. Compared to before, how would you describe your household's food situation?

☐ much better ☐ slightly better ☐ No change ☐ worse

Section E: Community Participation in Greening Projects

19. Are you aware of any greening or environmental projects in your neighborhood?

☐ Yes ☐ No

20. If yes, have you or any household member participated in these activities?

☐ Yes ☐ No

21. What roles have you played or seen others play in these projects?

☐ Planting ☐ Watering/maintenance ☐ Planning/leadership ☐ Harvesting ☐ none

22. What motivates or would motivate you to join greening projects? (Tick all that apply)

☐ Food benefits ☐ Beautification ☐ Community spirit ☐ Climate change ☐ Income ☐ other: _________

23. What challenges discourage participation in green projects?

☐ Time ☐ Lack of information ☐ Land/space issues ☐ Water shortage ☐ Lack of support/resources

24. What suggestions do you have for improving or expanding such projects?

____

Section F: Final Reflections

25. In your opinion, how important are green spaces in solving climate and food problems in informal areas?

☐ Very important ☐ somewhat important ☐ Neutral ☐ Not important

26. Would you support future expansion of greening initiatives in your neighborhood? ☐ Yes ☐ No ☐ not sure

27. Any other comments or experiences you would like to share about climate, heat, or food issues? ____

Appendix II: Focus Group Discussion

Focus Group Discussion Guide for Participatory Action Research on Nature-Based Climate Solutions (NBCS) in Informal Settlements

Introduction

Welcome and thank you for joining this discussion. My name is ________________, and I will be guiding our conversation today. We are here to learn from your experiences with nature-based greening projects in your community. Our goal is to understand what works, what challenges you face, and how we can improve these projects for the benefit of everyone. Your input is essential in shaping future environmental projects in this area.

Before we get started, I would just like to remind you:

This discussion is voluntary, and you can choose not to answer any question or leave at any time.

Your responses will be kept confidential and will be used for research purposes only.

We encourage everyone to share their thoughts, as there are no right or wrong answers.

Any questions before we begin?

Section 1: Understanding Community Perspectives on NBCS

What do you think of current greening projects in the area? How have they affected your daily lives?

What benefits have you observed from these greening efforts (e.g., cooler environment, improved air quality, increased food availability)?

Have you noticed any changes in the local climate or environment since the projects began? If yes, can you share some examples?

In your opinion, how important are these projects for addressing climate change and improving your community's quality of life?

Section 2: Challenges and Barriers

What challenges have you faced in participating in these projects? (e.g., time, resources, awareness, land availability, security)

What barriers do you think prevent others in the community from getting involved?
Have there been any conflicts or misunderstandings related to these projects? How were they resolved?

How can these challenges be addressed to make the projects more successful and inclusive?

Section 3: Community Participation and Ownership

How involved are you in planning, decision-making, and maintaining these greening projects?

What motivates you to participate in these activities? What would encourage others to join?

How do you think these projects can be sustained over the long term? What role should the community play?

Are there ways in which the project leaders can better engage the community to ensure everyone feels included?

Section 4: Future Aspirations and Co-Creation

What are your hopes and aspirations for the future of these greening projects in your community?

If you had the opportunity to improve these projects, what changes would you make?

What types of support (e.g., training, funding, and tools) would help you participate more effectively?

How can these projects be expanded or replicated in other parts of the community or city?

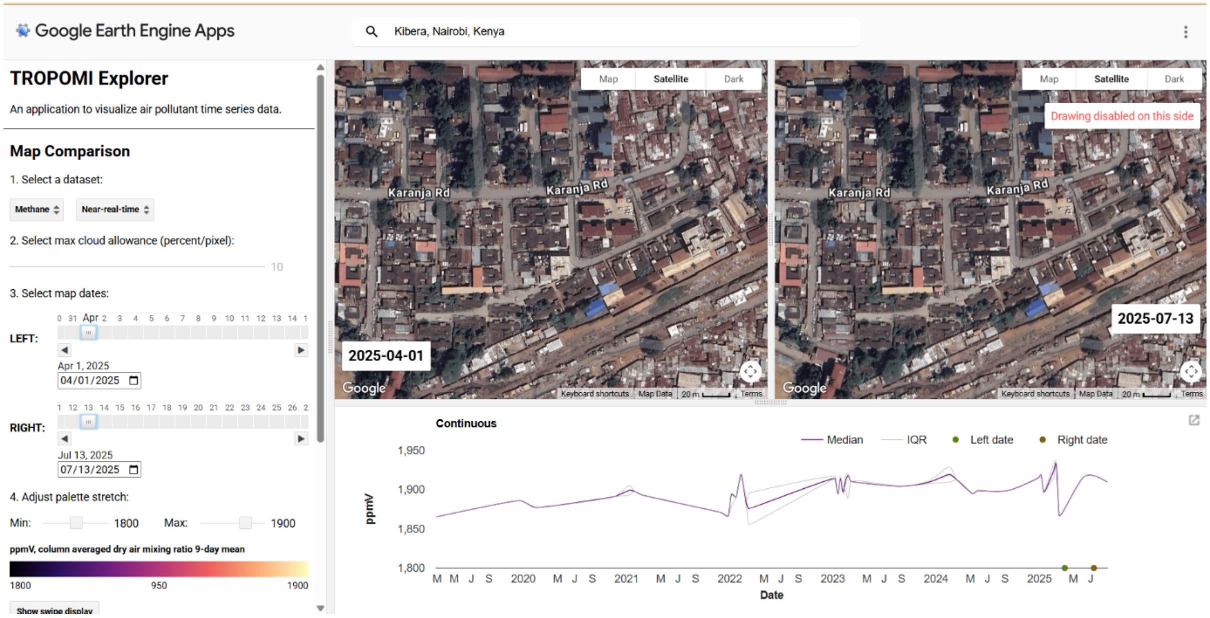
Section 5: Closing Reflections

Is there anything else you would like to share about your experiences or ideas for making these projects better?

How would you like to stay involved as this research continues?

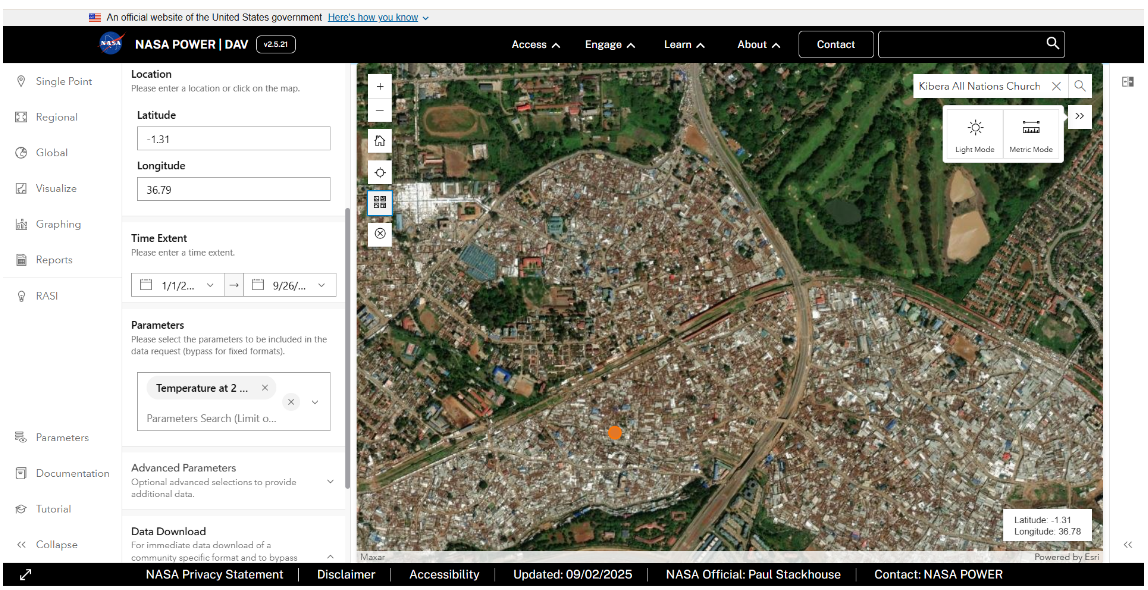
Thank you all for sharing your thoughts and experiences. Your insights are valuable in helping us understand how to make these projects more effective and sustainable. We appreciate your time and contributions.

Appendix III: Troponin Air Quality Assessment Platform



Link https://www.tropomi.eu/documents-and-information

Appendix IV: Daily Temperature Assessment Platform



Link https://power.larc.nasa.gov/data-access-viewer/

List of Figures

List of Tables