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RESEARCH PAPER

Nature-Based Solutions for Flood Management and Soil Stabilization in Mbale City, Uganda

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Abbreviations

DLG	District Local Government
EAs	Enumeration Areas
EPRC	Economic Policy Research Center
FGD	Focus Group Discussion
IRB	Internal Review Board
KII	Key Informant Interview
LC	Local Council
NBS	Nature-Based Solutions
NEMA	National Environment Management Authority
NGO	Non-Government Organization
OCHA	Office for the Coordination of Humanitarian Affairs
OECD	Organization for Economic Co-operation and Development
PPS	Probability Proportionate to Size
PSUs	Primary Sampling Units
SDG	Sustainable Development Goal
SES	Social Ecological Systems
UBOS	Uganda Bureau of Statistics
UN	United Nations
UNCST	Uganda National Council of Science and Technology
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change

Abstract

Urban flooding is an escalating climate-related challenge in rapidly growing cities like Mbale, Uganda. Nature-Based Solutions (NBS) offer sustainable approaches to flood management and soil stabilization; however, limited data exists on their implementation in this context. This study employed a concurrent triangulation of mixed-methods design involving 480 survey respondents, six focus group discussions, ten key informant interviews, and Photovoice exercises. Quantitative data were analyzed in Stata 17 and qualitative data in Dedoose through thematic analysis. Most respondents were male and within the productive age group. The majority reported high past and anticipated future flood impacts, coupled with high flood-risk perception but limited knowledge of NBS. Tree planting, afforestation, agroforestry, crop rotation, and mulching were the most common NBS practices. Acceptance of NBS was moderate and influenced by demographic, experiential, and perceptual factors. Barriers to implementation included poor waste management, encroachment, high costs, and weak institutional enforcement, whereas facilitators included community awareness, NGO support, recognition of riparian buffers, and demand for expert guidance. Overall, while communities are receptive to NBS, their effectiveness is constrained by socio-economic and governance challenges. Strengthening technical support, regulation, and community education could enhance scaling of sustainable, locally owned NBS interventions in Mbale City.

Key words: Nature-Based Solutions (NBS), Flood Risk Management, Soil stabilization,

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1. Introduction

Urban flooding is recognized as one of the most severe climate-related disasters confronting cities worldwide. As urban areas continue to experience unprecedented growth, with more than half of the global population currently living in cities, pressure on infrastructure is intensifying (UN, 2020). This rapid urbanization is accompanied by increased challenges, particularly in managing water resources, reducing flood risks, and maintaining soil stability (Bilgiç & Baba, 2023; Feng, Zhang, & Bourke, 2021; UN Habitat, 2022). As cities expand, natural landscapes are being replaced by impervious surfaces due to constructions, which significantly reduce the land's natural ability to absorb rainfall (Bilgiç & Baba, 2023; Feng et al., 2021). This transformation often leads to increased surface runoff, contributing to frequent urban flooding and soil degradation (Feng et al., 2021). The situation is further compounded by the effects of climate change, which has intensified hydrometeorological extremes and led to more frequent and severe flooding events across the globe (C. S. S. Ferreira, Potočki, Kapović-Solomun, & Kalantari, 2022).

In many low-and-middle countries, including Uganda, urban expansion has outpaced the development of critical infrastructure, leaving cities ill-prepared to cope with these challenges (UN Habitat, 2022). The lack of adequate stormwater management systems, combined with deforestation and unsustainable land use practices, has exacerbated flooding (IAP, 2022; UN Habitat, 2022). Uganda's cities, particularly those with complex topographies like Mbale, are increasingly vulnerable to these impacts. Mbale City, located in Eastern Uganda, faces recurrent floods, landslides and soil erosion due to its hilly terrain, combined with unplanned urban sprawl and deforestation (DLG, 2018; UNDP, 2013). The city's infrastructure has not kept pace with the accelerated rate of urban development (DLG, 2018; UNDP, 2013). As a result, heavy rain often overwhelm existing systems, leading to frequent flooding that damages homes, roads, and public infrastructure (DLG, 2018; UNDP, 2013). Notably, in July 2022, Mbale experienced catastrophic floods triggered by torrential rains that caused the Nabuyonga and Namatala rivers to overflow (OCHA, 2022). This disaster claimed the lives of at least 30 people and displaced over 5,600 residents (OCHA, 2022). The impacts are most severe in low-lying areas and informal settlements where the urban poor reside, exacerbating their vulnerability to waterborne diseases, displacement, and loss of livelihoods (DLG, 2018; OCHA, 2022; UNDP, 2013).

Urban flood risk management aims not only to improve the capacity of infrastructure to manage excessive floodwater but also to reduce population exposure and enhance the resilience of vulnerable communities (Prashar, Lakra, Shaw, & Kaur, 2023; Yereseme, Surendra, & Kuntoji, 2022; Zhou et al., 2024). Traditionally, flood management has relied on structural solutions such as drainage systems and flood barriers (C. S. S. Ferreira, Potočki, Kapović-Solomun, & Kalantari, 2021). However, these approaches have proven insufficient in addressing the evolving challenges posed by urbanization and climate change (C. S. S. Ferreira et al., 2021). They often require significant financial investments, are challenging to

maintain, and are less adaptable to increasingly unpredictable weather patterns (C. S. S. Ferreira et al., 2021). Recognizing these limitations, there has been a shift towards Nature-Based Solutions (NBS), which leverage natural processes to manage water flow, reduce flood risks, and stabilize soil (C. S. S. Ferreira et al., 2021; V. Ferreira, Barreira, Pinto, & Panagopoulos, 2022). NBS interventions, such as wetland restoration, afforestation, and terracing, offer a sustainable alternative to conventional grey infrastructure by promoting water retention, increasing infiltration, and reducing surface runoff (C. S. S. Ferreira et al., 2021). For instance, planting trees and restoring wetlands can enhance water infiltration, reduce surface runoff, and prevent soil erosion, thereby mitigating the impact of heavy rains (C. S. S. Ferreira et al., 2021).

While NBS holds great promise, their implementation must be carefully planned to avoid unintended consequences (C. S. S. Ferreira et al., 2021). For example, if not strategically located, interventions like rain gardens may inadvertently disrupt local habitats or displace amphibian species. Additionally, failing to involve local communities in the planning and execution of NBS projects can marginalize vulnerable populations, and reduce the social acceptance and long-term sustainability of these interventions (C. S. S. Ferreira et al., 2021; V. Ferreira et al., 2022). Despite the potential of NBS in mitigating flood risks, their adoption and scale up remains limited in Mbale city. Moreover, there is a lack of understanding of the NBS already in place, as well as the effectiveness of these interventions in addressing the city's flooding and soil erosion challenges. Additionally, community perceptions, knowledge, and acceptance of these solutions play a crucial role in their success but are not well understood. Without community buy-in and adequate support from local authorities, the sustainability of these interventions may be compromised. This study sought to fill the existing knowledge gap by exploring the current implementation of NBS in Mbale City, assessing community perceptions and acceptance, and exploring the barriers and facilitators to scaling up these interventions. The study can inform interventions targeted at ensuring the long-term sustainability of urban development and improving the quality of life for the residents of Mbale city and similar areas globally.

2. Literature Review

2.1 Nature-Based Solutions currently implemented for flood management and soil stabilization

Nature-Based Solutions for flood management and soil stabilization utilize natural processes to mitigate environmental challenges and offer sustainable alternatives to traditional engineering methods (C. S. S. Ferreira et al., 2021; V. Ferreira et al., 2022). This literature review examines NBS implementations globally, with a focus on regions outside Africa, within Africa, East Africa, and specifically Uganda.

Globally, several countries have adopted NBS to address flood risks and soil degradation: in the United Kingdom's Tenbury Wells, Worcestershire, frequent flooding led to reforestation efforts. Phil Sturgeon's charity, Protect Earth, acquired a 70-acre plot to plant 12,000 saplings. This rewilding approach aims to absorb rainfall, delay runoff, and reduce flood risks (Ben Cooke, 2025). In early 2025, beavers naturally constructed a series of dams in the Brdy Protected Landscape Area of Czech Republic which restored wetlands and provided ecological benefits such as improved water quality and enhanced biodiversity. This intervention saved the Czech government approximately $1.2 million and showcases the potential of leveraging natural processes for environmental restoration (Jason Bittel, 2025).

The "sponge city" initiative in China integrates green infrastructures like urban parks, wetlands, and permeable pavements to absorb and reuse rainwater to mitigate urban flooding. This approach has been pointed out to enhance water quality, reduce flood risks, and address urban heat island effects which reflect a comprehensive NBS strategy at the city planning level (Tessa Wong, 2021; World Future Council, 2016).

In Africa, nations have implemented various NBS to combat environmental challenges. For instance, in the Tigray region of Ethiopia, the May Zegzeg Integrated Catchment Management Project employed measures such as stone bunds, check dams, and exclosures (protected areas) to enhance water infiltration and reduce runoff. These interventions have led to decreased flood magnitudes and improved baseflow in rivers and illustrate the effectiveness of community-based NBS in semi-arid regions (Nyssen, Jacob, & Frankl, 2019; Nyssen et al., 2007).

In the East African region, the Tana River Basin in Kenya has seen the implementation of NBS like reforestation and wetland restoration to stabilize soil and manage floods. These efforts have improved water quality and provided sustainable livelihoods for local communities, which highlights the socio-economic benefits of NBS. Additionally, the Rugezi Wetlands restoration project in Rwanda focused on rehabilitating degraded wetlands to regulate water flow and prevent downstream flooding. The initiative led to increased biodiversity and improved livelihoods through sustainable agriculture and ecotourism, hence ecological and economic gains (Olivier Nsengimana,

2020). Around Uganda's Mount Elgon region, agroforestry practices have been promoted to stabilize soils and reduce landslide risks. Integrating trees into farming systems along the slopes and riverbanks can improve soil structure, enhance water retention, and provide additional income sources for farmers. This literature shows that Nature-Based Solutions offer versatile and sustainable approaches to flood management and soil stabilization across diverse regions. There's however a literature gap regarding the NBS being implemented in Mbale city, which is similarly prone to flooding and impacting people's housing and livelihoods.

2.2 Community knowledge, perceptions, and acceptance of Nature-Based Solutions in reducing flood risks and improving soil stability

Nature-Based Solutions have gained widespread recognition for their potential to mitigate flood risks and improve soil stability while providing co-benefits for ecosystems and local communities. However, the successful implementation and scaling of NBS depend not only on technical and ecological factors but also on community perceptions, knowledge, and acceptance of these solutions. Understanding how communities perceive, understand, and accept NBS is crucial for designing interventions that are both effective and sustainable. We therefore synthesize research on community perceptions, knowledge, and acceptance of NBS, focusing on flood management and soil stabilization.

2.2.1 Community knowledge and understanding of NBS

Despite the recognized value of NBS, there is a scarcity of quantitative studies that assess the extent of community knowledge about them. Research indicates that community knowledge of NBS is often limited. However, there is consensus that educating communities about the benefits and functions of NBS is crucial, since increased awareness leads to greater acceptance and participation in NBS projects (V. Ferreira et al., 2022). To this, a study by Quandt, Neufeldt, and McCabe (2017) in Isiolo County, Kenya, found that while agroforestry can enhance livelihood resilience to floods and droughts, its adoption is influenced by farmers' perceptions and understanding of its benefits. The study highlighted that increased awareness and education about agroforestry's role in reducing soil erosion and improving water retention can lead to greater acceptance and implementation of these practices (Quandt et al., 2017). Similarly, research indicates that agroforestry training programs in Uganda have positively influenced farmers' awareness and adoption of sustainable practices (The Center for Agroforestry, 2025). In Uganda, such evidence is limited and the gap in community knowledge could be a significant barrier to the adoption of NBS.

This research aimed to quantify the community knowledge/awareness of NBS in Mbale city, Uganda.

2.2.2 Community perceptions of NBS

A study assessing nature-based solutions to climate change mitigation and adaptation in urban areas reports that public and stakeholder perceptions of NBS play a crucial role in determining their implementation and success. The study notes that misperceptions exist that NBS are "soft solutions" compared to grey infrastructure (e.g., flood walls, drainage systems), which makes some communities skeptical about their effectiveness. Additionally, public perceptions of NBS are largely shaped by the visible and immediate benefits of these solutions. While NBS offer co-benefits such as biodiversity conservation, urban cooling, and recreational spaces, their adoption is sometimes hindered by perceived drawbacks such as maintenance concerns (e.g., overgrown vegetation, mosquitoes in wetlands), land-use conflicts especially in cities where space is limited and delayed impact, as NBS often take time to establish compared to grey infrastructure (V. Ferreira et al., 2022; Kabisch, Korn, Stadler, & Bonn, 2017) documented that community perceptions of NBS are influenced by cultural values, past experiences with natural disasters, and trust in authorities. The current study established the perceptions of community members in Mbale city towards NBS since these are not well documented.

2.2.3 Acceptance of NBS for flood risk reduction and soil stabilization

Literature on the level and extent of acceptance of NBS is limited, however, in a study that reviewed public acceptance of nature-based solutions, the authors identified several factors influencing public acceptance of NBS for disaster risk reduction, including risk perception, trust in implementing authorities, perceived benefits and trade-offs, and competing societal interests. Communities with a high risk-perception, especially those who have recently experienced severe flooding or other disasters, were reported to be more receptive to NBS, as they are more motivated to seek effective mitigation strategies. Conversely, communities with low risk-perception, often due to a lack of direct experience with disasters, may be less inclined to accept NBS, perceiving them as unnecessary or secondary to other infrastructure investments (Carl C Anderson et al., 2021). Additionally, public trust in government agencies, environmental organizations, and other implementing bodies played a critical role where high levels of trust in these institutions facilitated smoother implementation and community cooperation while low trust often stemming from past failures, corruption, or lack of transparency led to resistance and skepticism. Communities may question

whether NbS are being implemented in their best interests or merely as cost-cutting alternatives to traditional engineering solutions (Carl C Anderson et al., 2021).

Further, perceived benefits of NBS also influence community acceptance. Communities assess NBS based on their expected benefits and potential disadvantages compared to traditional "grey" infrastructure (e.g., concrete levees, flood walls). Some of the key benefits of NBS that were noted to influence public acceptance include: Environmental co-benefits, such as biodiversity conservation, improved water quality, and carbon sequestration, aesthetic and recreational value, as NBS can create green spaces that improve urban live ability, and the economic advantages, particularly for communities that depend on natural resources, such as improved fisheries and eco-tourism (Carl C Anderson et al., 2021).

Trade-offs, including land use conflicts, where NBS projects require repurposing land previously used for agriculture, housing, or industry etc., delays in effectiveness, as NBS often take time to establish and reach full functionality, and maintenance challenges, since some NBS require sustained community or governmental investment in conservation and upkeep can in unison or independently reduce acceptance (Carl C Anderson et al., 2021). Competing societal interests including socio-politically complex settings where multiple stakeholders have differing priorities, competition with infrastructure development, housing projects, or commercial land use, political dynamics and priorities, and community preferences inclined to traditional practices or preferences for engineered flood defenses may also influence acceptance of NBS (Carl C Anderson et al., 2021).

A chapter by C. S. S. Ferreira et al. (2021) generally agrees with the above findings that community acceptance of NBS is influenced by awareness of their benefits, cultural values, and perceived effectiveness compared to traditional infrastructure. Therefore, it was noted that building trust and demonstrating the efficacy of NbS through pilot projects and education can improve community perceptions and acceptance. There's however a need for research on the NBS being implemented in Mbale city given the unique nature of the city, low-income status and limited land availability for some of the necessary NBS.

2.3 Facilitators and barriers to the successful implementation of Nature-Based Solutions for flood management and soil conservation

Several barriers and facilitators influence the acceptance of NBS for flood risk reduction and soil stabilization. A key issue is the general unawareness of NBS as a viable alternative to traditional grey infrastructure, as well as a lack of understanding

of their long-term benefits. The lack of awareness and understanding cuts across stakeholders, including policymakers, urban planners, and local communities. Studies show that many communities and decision-makers are unfamiliar with NBS, their benefits, and how they compare with traditional grey infrastructure in managing climate-related disasters such as flooding, landslides, and heatwaves (Kabisch, Frantzeskaki, Pauleit, Naumann, Davis, Artmann, Haase, Knapp, Korn, Stadler, et al., 2016). City planners and engineers have been trained to rely on conventional grey infrastructure, such as drainage systems, flood walls, and engineered water treatment plants, rather than ecosystem-based approaches and often lack technical know-how. The technical knowledge required to design, implement, and monitor NBS is still developing, which makes it difficult for planners and engineers to integrate NBS into standard urban planning practices (Castelo, Amado, & Ferreira, 2023). Moreover, in developing countries, research on NBS is limited, and there are few case studies that provide empirical evidence on their effectiveness in different contexts.

The perceived uncertainty of NBS effectiveness in different contexts is also a significant barrier. Unlike grey infrastructure, which delivers immediate and visible results, NBS often take time to establish their full benefits (e.g., urban trees need time to grow; wetlands need years to stabilize hydrological cycles). This delayed impact discourages policymakers from investing in NBS, especially in fast-growing urban areas where quick solutions are prioritized but also may not be popular among the stakeholders who may in the meantime continue to suffer with disasters (Castelo et al., 2023). Literature also indicates that some policymakers and communities question whether NBS can withstand extreme climate events such as hurricanes or heavy flooding, given that long-term studies on their resilience are still emerging (Bowyer et al., 2024). Further, conventional infrastructure, such as stormwater drainage systems and flood walls, are often perceived as more predictable and controllable compared to NBS. Engineers and urban planners may be more comfortable with grey infrastructure, which has established design and maintenance standards, while NBS require context-specific designs and ecosystem management expertise Moreover, communities may mistrust NBS, viewing them as experimental or risky, particularly if there are no prior successful examples within their region (Carl C. Anderson & Renaud, 2021; V. Ferreira et al., 2022).

Another barrier is that in most countries, NBS are not yet integrated into national and local climate adaptation policies, which results in a lack of structured guidelines for their implementation (OECD, 2020). Available funding frameworks also often tend to favour large- scale engineered projects over ecosystem-based solutions, hence an imbalance in investment between NBS and traditional infrastructure (Kauark-Fontes, Marchetti, & Salbitano, 2023). For example, a case study conducted in European cities found that many municipalities acknowledged the importance of NBS but

reported knowledge gaps in terms of financing, long- term maintenance, and integration into spatial planning policies (Kabisch et al., 2016). Similar findings have been observed in sub-Saharan Africa, where NbS initiatives are often donor-driven rather than locally institutionalized (Wamsler et al., 2020).

Institutional and bureaucratic barriers have also been documented. Many cities have strict regulatory frameworks that prioritize grey infrastructure. The lack of flexibility in policies can delay or prevent NBS implementation. For instance, a study on urban NBS projects in the Netherlands found that even when municipalities recognized the value of NBS, their adoption was limited by institutional inertia and preferences for traditional infrastructure (Castelo et al., 2023). Additionally, city departments often work in sectoral silos, which makes cross- department collaboration difficult. Since NBS require coordination across environmental, water, and urban planning sectors, the lack of interdepartmental cooperation acts as a roadblock (Castelo et al., 2023).

The lack of community participation in the planning and implementation of NBS is a major challenge. When communities are not actively engaged, they may oppose or misunderstand NBS projects, which reduces their effectiveness and long-term sustainability. According to Kabisch, Frantzeskaki, Pauleit, Naumann, Davis, Artmann, Haase, Knapp, Korn, and Stadler (2016), many NBS projects are designed and implemented without sufficient input from local communities, which leads to a limited feeling of ownership, and in some cases, NBS interventions have been imposed on communities without addressing local concerns, hence resistance (Carl C. Anderson & Renaud, 2021). Other authors stress that successful implementation of NBS requires the involvement of local communities, policymakers, and other stakeholders from the planning stages through execution. Engaging stakeholders ensures that NBS projects are tailored to local needs and conditions, enhancing their effectiveness and sustainability (C. S. S. Ferreira et al., 2021). Similarly, Zhou et al. (2024) recommend fostering interdisciplinary collaborations, enhancing community participation, and developing supportive policies to overcome these barriers.

While several barriers hinder the acceptance and implementation of NBS for flood risk reduction and soil stabilization as discussed above, addressing these challenges presents clear opportunities for facilitating their successful adoption. Enhancing awareness and understanding of NBS, for example, among policymakers, urban planners, and local communities can shift perceptions and encourage investment in these solutions. Providing technical training and integrating NBS into national and local climate adaptation policies can overcome resistance from engineers and city planners who traditionally rely on grey infrastructure. Similarly, ensuring NBS are backed by structured guidelines and adequate funding mechanisms can help balance investment priorities between ecosystem-based solutions and conventional

engineered projects. Institutional reforms, such as fostering interdepartmental collaboration and breaking down sectoral silos, can create enabling governance structures for NBS. Moreover, increasing community involvement in decision-making processes from the outset can enhance local ownership and hence long-term sustainability. Ultimately, transforming the forementioned barriers into facilitators through targeted policy interventions, capacity building, and participatory approaches can accelerate the mainstreaming of NBS for resilient and adaptive urban planning.

3. Methodology

3.1 Study site

The study was conducted in Mbale City, a secondary city located in Eastern Uganda, at the foot of Mount Elgon, near the Kenya-Uganda border. It was elevated to city status in July 2020 as part of Uganda's national urbanization strategy (EPRC, 2021). Administratively, Mbale City comprises two divisions: Northern division and Industrial division and includes peri-urban areas previously part of Mbale District. As of the 2024 estimates, Mbale district had approximately 657,700 people, with Mbale City itself housing 358,700 residents, with projections indicating steady growth due to rural-urban migration (UBOS, 2024). The population is composed of both urban and peri-urban communities. Urban areas are more densely populated and characterized by informal settlements, particularly in flood-prone lowlands, while peri-urban zones face encroachment pressures and inadequate land-use planning.

Mbale has been severely affected by poor flood management, especially during heavy rainfall seasons. The city's topography includes sloped terrain draining into low-lying flood plains, which makes it highly vulnerable to surface runoff and flash floods. Poor solid waste disposal, silted drainage channels, and unregulated development along riverbanks exacerbate flood risks (MWE, 2022). Recent floods (e.g., in 2019 and 2022) resulted in displacement, damage to infrastructure, contamination of water sources, and loss of life. Currently, Mbale City is under the management of the Mbale City Council, operating under the Ministry of Local Government. Environmental and urban planning issues fall under the Physical Planning Department, supported by actors such as the National Environment Management Authority (NEMA) and the Ministry of Water and Environment.

3.2 Study population and eligibility criteria

The study population included residents who were recruited at household level to assess their knowledge, perceptions, and acceptance of NBS for flood mitigation. The secondary study population included community leaders, officials from the Mbale City Council, community-based organizations and non-governmental organizations who

have been directly or indirectly involved in flood management initiatives. The study included respondents aged 18 years and above who had resided in Mbale City for at least three years, to ensure that they have sufficient knowledge or experience related to the city and its climate-related challenges. Individuals who don't consent to participation were excluded.

3.3 Study design

This research utilized a convergent mixed-methods design, where quantitative and qualitative data were collected at the same time (concurrently), analyzed separately, and then merged during interpretation (Almeida, 2018). The findings from both approaches complemented each other to provide a well-grounded understanding of the research objectives. This design was particularly appropriate as it allowed for the validation of quantitative findings (Almeida, 2018).

3.4 Sample size

For the quantitative component of the study, the sample size was calculated using the Kish Leslie formulae for cross-sectional studies (Kish, 1965). Assuming a confidence level of 95%, a margin of error of 5%, and an estimated 50% prevalence of acceptance of NBS in the population, a minimum sample size of 384 respondents was obtained.

After accounting for non-response and a design effect of 1.5, a sample size of 636 was be obtained. However, a total of 480 respondents were reached during data collection. The reduction in achieved sample size was primarily due to field-related constraints, including non-response, participant unavailability, and inaccessibility of some sampled households in hard-to-reach flood-prone areas during data collection. Despite this shortfall, the final sample of 480 still provides sufficient statistical power to generate reliable estimates within acceptable precision limits and maintains representativeness across the targeted study clusters in Mbale City. For the qualitative component, purposive sampling was used to select the participants. A total of 10 Focus Group Discussions (FGDs) with 8-10 participants each, as well as 15 Key Informant Interviews (KIIs) with community leaders, government officials, and NGO representatives were conducted, at which point, thematic saturation was reached.

3.5 Sampling procedures

The survey used a household-based sampling frame. We first delineated target areas using administrative boundaries (parishes/zones) and recent flood-risk information from Mbale city council offices. We purposively select neighborhoods that have experienced recurrent flooding and soil erosion. Within each target area, we selected UBOS enumeration areas (EAs) as primary sampling units (PSUs) using probability proportional to size (PPS). For each sampled EA, trained research assistants with the

aid of local council leadership conducted a rapid door-to-door listing of all residential households, to produce an up-to-date roster (household IDs, head/name, contact, GPS point). This EA-level household list served as the sampling frame. Within each selected site, based on the list, a simple random sampling method was applied to select households for participation. Research assistants approached selected households with an introductory letter from the PI and LC1 leaders. Any adult (≥18 years) resident of the household who has lived in Mbale City for at least 36 months was eligible to participate. Only one respondent per household was selected to avoid duplication. The RAs explained the purpose of the study and invited eligible adults to participate.

Breakdown of the participant categories and numbers

Category	Method	Number of participants	Selection criteria	Rationale
Community residents (male adults, ≥31)	FGDs	4 groups (8-10 per group)	Residents of flood/erosion-prone areas, household heads	Capture adult male perspectives on NbS, community practices, and governance
Community residents (female adults, ≥31)	FGDs	4 groups (8-10 per group)	Women residing in affected areas	Capture women's experiences, coping strategies, and unique vulnerabilities
Youth (18–30 years, male & female)	FGDs	2 groups (8-10 per group)	Young residents in affected areas	Understand youth perspectives and role in NbS adoption
Key informants (local leaders, city officials, NGOs)	KIIs	10 individuals	Identified based on role in flood/soil management	Provide governance and institutional perspectives

3.6 Study variables

The primary outcome is the acceptance of NBS for flood management and soil stabilization. Acceptance was categorized as '1' for High acceptance and '0'for Low acceptance. Acceptance of NBS for flood management and soil stabilization was defined as "High" for those who achieved a 75% and above acceptance score from a set of questions while the rest were categorized as low acceptance. Independent variables include demographic characteristics (such as age, sex, education level), awareness of NBS and perceptions of their effectiveness, community norms and social pressures, among others.

3.7 Data collection methods and techniques

Recruitment and training of research assistants

The study engaged five research assistants to support data collection, including administration of the questionnaires, coordination of the Photovoice process, and facilitation of focus group discussions and key informant interviews. The minimum qualification to be considered was a bachelor's degree in environmental health, social sciences, or a related field. Prior experience in conducting surveys, qualitative research or community-based participatory methods (e.g., Photovoice, FGDs, key informant interviews) were prioritized. Fluency in both English and Lumasaba (Lugisu) was required for effective community engagement.

All selected RAs underwent intensive training for 2 days prior to data collection. The training was facilitated by the Principal Investigator and senior qualitative research experts. Topics included: Details of the study, ethical principles in human subjects' research (consent, confidentiality, voluntariness), techniques for moderating focus group discussions and conducting photo-elicitation interviews, Procedures for safe data storage, backup, and transfer, and risk management, including safe interactions in the field and safeguarding devices. A field pre-test (pilot) session was also conducted to practice the methods in a non-study site before formal data collection begins.

Tools

Structured interviews: A structured questionnaire was administered at household level using Kobo collect mobile application to minimize errors and streamline data entry. The questionnaire covered various aspects, including demographic factors such as age, gender, education level, and socio-economic status; knowledge of NBS, perceptions of their effectiveness, acceptance levels, and the willingness of residents to implement such practices.

FGDs: An FGD guide was used to facilitate discussions with community members from various strata (e.g., lowland, hillside, and peri-urban areas). The FGDs explored community perceptions of flood risks and NBS effectiveness, experiences with existing NBS projects in their neighborhoods, and barriers and facilitators to the acceptance and adoption of NBS.

KII: KII guides were used to obtain data on the facilitators and barriers to implementing NBS, the sustainability of current interventions, and recommendations for scaling up efforts in flood management and soil conservation. The interviews were conducted in areas convenient to the key informants, probably offices, homesteads or public spaces.

3.8 Data management and analysis

Data was downloaded in excel where it was cleaned and coded. Data was checked for normality and quality and then exported to Stata version 17 for further cleaning and analysis. Descriptive statistics such as frequencies, means, and percentages were used to summarize demographic characteristics, awareness levels, and perceptions of NBS among respondents. The mean score of acceptance of NBS was used to generate the binary outcome variable. It provided a balanced distribution of acceptance categories (54.1% vs. 45.9%), optimizing model stability and interpretability while maintaining alignment with the study's goal of assessing community-wide acceptance of NBS. Given that the outcome variable had a prevalence of 54.1%, we used a modified Poisson regression with robust standard errors to directly estimate relative risks rather than odds ratios, which can overstate associations when outcomes are common. Model adequacy was evaluated using Pearson's goodness-of-fit test (χ^2 = 44.8, df = 380, p = 1.00), indicating excellent fit. Multicollinearity diagnostics showed no significant issues (mean VIF = 2.17). The model demonstrated internal consistency and theoretical plausibility, which support the robustness of the findings.

For qualitative data, audio recordings from FGDs and KIIs were transcribed verbatim and analyzed using Dedoose software. A thematic analysis approach was used to identify, code, and categorize patterns in the data. The analysis followed an inductive process, where themes related to community perceptions, barriers, facilitators, and strategies for scaling up NBS were derived directly from the data. The photographs and accompanying narratives were analyzed thematically using Dedoose software. This analysis helped identify recurring themes related to the perceived impact of NBS and the barriers to their effectiveness.

3.9 Ethical considerations

The study protocol underwent ethical review and approval by the Makerere University School of Public Health Research and Ethics Committee (MakSPH-REC) to ensure compliance with ethical guidelines for research involving human subjects. The study adhered to stringent ethical standards to ensure the protection of participants and the integrity of the research process. Prior to data collection, the research team obtained written informed consent from all participants. The consent process was conducted in English and/or Lugisu, depending on participants' preference. Trained research assistants explained the purpose, procedures, potential risks, benefits, confidentiality, and voluntary nature of participation. Participants were given adequate time to ask questions before deciding whether to take part. For those who agreed, written or thumbprint consent was obtained before any interview or activity begins. Separate consent forms were used for the survey, key informant interviews, focus group discussions, and Photovoice, each describing the specific activity and

duration of participation. Participants received a copy of the consent form for their records. No participant was coerced or unduly influenced to participate, and individuals had the right to withdraw at any time without penalty or loss of benefits.

All data was anonymized, with participants assigned unique identification codes. The data was securely stored in password-protected files, accessible only to the research team. Interviewers were trained to handle discussions with empathy, and referral information for local support services will be provided when needed. The research team engaged with community leaders beforehand to ensure the study methods were culturally sensitive and did not disrupt local activities.

4. Results

4.1 Socio-demographic characteristics of the study respondents

Of the 481 respondents that took part in this study, 47% (n=228) had lived in Mbale for 12 or more years, 44.1% (n=212) were aged 35 years or older, 62.8% (n=302) were female while 47.4% (n=228) had attained secondary level education. More than half of the respondents (59.5%, n=286) were married, and a quarter (n=120) were farmers while 31% (n=149) owned small scale businesses as main occupations. The mean distance from the river to the residences was 135.6 (100.72) over 53% (n=256) living between 1-100 meters away from the rivers. Table 1.

Table 1: Socio-demographic characteristics of study respondents in Mbale City, Uganda

Variable	**Category**	**Frequency (n=481)**	**Percentage (%)**
Duration of stay in the area in years Mean (SD) = 15.3(12.04)	3-5	104	21.6
	6-8	72	15.0
	9-11	77	16.0
	12+	228	47.4
Age Mean (SD)=36.0(14.63)	18-24	116	24.1
	25-29	80	16.6
	30-34	73	15.2
	35+	212	44.1
Sex	Male	179	37.2
	Female	302	62.8
Education level	No formal education	26	5.4
	Primary	166	34.5
	Secondary	228	47.4
	Tertiary	28	7.9
	University	23	4.8
Religion	Anglican	105	21.8

	Catholic	99	20.6
	Moslem	179	37.2
	Pentecostal	86	17.9
	SDA	10	2.1
	Others	2	0.4
Marital status	Never married	117	24.3
	Married	286	59.5
	Separated/divorced	54	11.2
	Widowed	24	5.0
Main occupation	Farmer	120	25.0
	Small scale business owner	149	31.0
	Medium/large scale business owner	29	6.0
	Government employee	5	1.0
	Private sector employee	36	7.5
	Student	52	10.8
	Unemployed	90	18.7
Permanent address near a river	No	12	2.5
	Yes	469	97.5
Name of river	Nabuyonga	326	69.5
	Namatala	143	30.5
Distance of residence from river (m) Mean (SD)=135.6 (100.72)	1-100	256	53.2
	101-200	119	24.7
	201+	106	22.0
How many minutes does it take you to move to the river and back Mean (SD)=8.12(4.64)	1-4	102	21.2
	5-9	167	34.7
	10+	212	44.1

4.2 The past impact of floods to vulnerable communities in Mbale City

Over 94.2% (n=453) of the respondents expressed that flooding negatively affected the roads that they use, 70.3% (n=338) mentioned that flooding negatively affected their livelihood, 85.9% (n=413) reported that flooding has negatively affected their residence in the past, while 87.5% (n=421) mentioned that flooding has negatively affected other property of theirs in the past. Additionally, 85.2% (n=410) agreed that flooding negatively affected their survival/threatened their life and slightly more than 51.2% (n=194) reported that floods had ended the life of a dear one.
The majority 71.5% (n=344) of the respondents had a high past flooding impact score. Table 2.

Table 2: Past impacts of floods on respondents settled along the Namatala and Nabuyonga rivers in Mbale City, Uganda

Variable	Category	Frequency (n)	Percentage (%)
In the past, flooding negatively affected roads that I use.	No	28	5.8
	Yes	453	94.2
In the past, flooding has negatively affected my recreation in or around the river	No	143	29.7
	Yes	338	70.3
In the past, flooding negatively affected my livelihood	No	60	12.5
	Yes	421	87.5
In the past, flooding has negatively affected my residence	No	68	14
	Yes	413	85.9
In the past, flooding has negatively affected other personal property	No	60	12.5
	Yes	421	87.5
In the past, flooding negatively affected my survival/threatened my life	No	71	14.8
	Yes	410	85.2
In the past, floods have ended the life of a dear one	No	194	51.2
	Yes	185	48.8
Past flooding impact score among the respondents Mean (SD) = 5.49(1.73)	Low impact	137	28.5
	High impact	344	71.5

4.3 The anticipated future impacts of floods to vulnerable communities in Mbale City

The majority of the respondents, (96%, n=462) mentioned that in the future, flooding could negatively affect roads they use, 72.3% (n=348) agreed that flooding could negatively affect their recreation in or around the river in the future, 89% (n=428) mentioned that flooding could negatively affect their residence while 89.6% (n=431) expressed that flooding could negatively affect other personal property in the future. Over 85% (n=323) also expressed that flooding could negatively affect their survival/ threaten their life in the future and 82.5% (n=397) had a high anticipated future flood impact score. Table 3.

Table 3: Anticipated future impacts of floods among respondents settled along the Namatala and Nabuyonga rivers in Mbale City, Uganda

Variable	Category	Frequency (n=481)	Percentage (%)
In the future, flooding could negatively affect roads that I use.	No	19	3.9
	Yes	462	96.1
In the future, flooding could negatively affect my recreation in or around the river	No	133	27.7
	Yes	348	72.3
In the future, flooding could negatively affect my livelihood	No	34	7.1
	Yes	447	92.9

In the future, flooding could negatively affect my residence	No	53	11.0
	Yes	428	89.0
In the future, flooding could negatively affect other personal property	No	50	10.4
	Yes	431	89.6
In the future, flooding could negatively affect my survival/ threaten my life	No	56	14.8
	Yes	323	85.2
Future flooding impact score among respondents Mean (SD)=5.18(1.29)	Low anticipated impact	84	17.5
	High anticipated impact	397	82.5

4.4 Flood risk perceptions among the study respondents

More than half (52.4%, n=252) of the respondents either disagreed or strongly disagreed that they would easily be able to deal with any negative impacts on their daily life if a major flood occurred, 66.3% (n=319) agreed or strongly agreed that they would be more negatively affected than other residents who live in equally risky areas, and 58.4% agreed that floods with negative impacts occur frequently in the place where they live. Additionally, 61.5% (n=296) expressed that floods in their places of residence will be stronger and more frequent in the future, almost all either agreed or strongly agreed that the current risk of negative impacts from flooding must be reduced and 63.4% were categorized to have a high flood risk perception. Table 4.

Table 4: Flood risk perception of respondents settled along the Namatala and Nabuyonga rivers in Mbale City, Uganda

Variable	**Category**	**Frequency (n=481)**	**Percentage (%)**
If a major flood occurs, I will easily be able to deal with any negative impacts on my daily life.	Strongly agree	132	27.4
	Agree	85	17.8
	Neutral	12	2.5
	Disagree	154	32.0
	Strongly disagree	98	20.4
If a flood occurs, I will be more negatively affected than other residents who live in equally risky areas.	Strongly agree	143	29.7
	Agree	176	36.6
	Neutral	22	4.6
	Disagree	117	24.3
	Strongly disagree	23	4.8
Floods with negative impacts occur frequently in the place where I live.	Strongly agree	281	58.4
	Agree	136	28.3
	Neutral	13	2.7
	Disagree	40	8.3
	Strongly disagree	11	2.3
Floods in my place of residence will be stronger and more frequent in the future.	Strongly agree	296	61.5
	Agree	124	25.8
	Neutral	23	4.8

	Disagree	31	6.4
	Strongly disagree	7	1.5
The current risk of negative impacts from flooding must be reduced.	Strongly agree	313	65.1
	Agree	131	27.2
	Neutral	3	0.6
	Disagree	27	5.6
	Strongly disagree	7	1.5
Other residents of my village believe that the current risk of negative impacts from flooding must be reduced.	Strongly agree	339	70.5
	Agree	106	22.0
	Neutral	5	1.0
	Disagree	19	4.0
	Strongly disagree	12	2.5
Flood risk perceptions score	Low risk perception	176	36.6
	High risk perception	305	63.4

4.5 Knowledge of Nature-Based Solutions among study respondents in Mbale City.

The majority of respondents (87.1%, n=419) agreed to have knowledge of Nature-Based Solutions for flood management and soil stabilization. The most mentioned NBS included tree planting (99.5%, n=419), agroforestry (71.4, n=299) and mulching (40.8%, n=171). Over 84% (n=350) had been involved in activities that promote NBS, 72.1% (n=302) mentioned that they were currently involved in activities that promote nature-based solutions and 81.9% (n=394) mentioned that NBS can help reduce the risks of flooding and soil erosion in Mbale City. About 63% (n=302) somewhat well understood how NBS work for flood and soil management. Overall, less than a third of the respondents (29.4%, n=123) had a high knowledge score of NBS. Table 5.

Table 5: Knowledge of and involvement in Nature-Based Solutions among study respondents settled along the Namatala and Nabuyonga rivers in Mbale City, Uganda

Variable	**Category**	**Frequency (n)**	**Percentage (%)**
Knowledge of Nature-Based Solutions for flood management and soil stabilization	Yes	62	12.9
	No	419	87.1
Mention some examples of NBS?	Tree planting and afforestation	419	99.5
	Wetland restoration	62	14.8
	Agroforestry	299	71.4
	Riverbank stabilization	50	11.9
	Contour ploughing	93	22.2
	Mulching	171	40.8
	Permanent soil cover	93	22.2

	Rainwater harvesting	73	17.4
	Restoration of natural drainage channels	39	9.3
	Grassland restoration	31	7.4
	Forest buffer establishment	28	6.7
Ever been involved in activities that promote nature-based solutions?	No	69	16.5
	Yes	350	83.5
Currently involved in activities that promote nature-based solutions?	No	117	27.9
	Yes	302	72.1
NBS can help reduce the risks of flooding and soil erosion in Mbale City	No	66	13.7
	Yes	394	81.9
	Not sure	21	4.4
Extent of understanding how NBS work for flood and soil management?	Very well	109	22.7
	Somewhat well	302	62.8
	Not well	63	13.1
	Not at all	7	1.5
Knowledge score Mean (SD) = 13.91 (2.07)	Low knowledge	296	70.6
	High knowledge	123	29.4

4.6 Implementation of NBS for flood management and soil stabilization in Mbale City, Uganda

Nine NBS were being implemented by respondents along the Namatala and Nabuyonga rivers in Mbale City. The commonest NBS included tree plantings and afforestation (97.9%, n=410), agroforestry (43.9%, n=184), crop rotation (26%, n=109) and mulching (24.8%, n=104). More than three quarters of the respondents (76.1%, n=366) supported the implementation of NBS in their community through planting trees and vegetation (97.7%, n=469), protecting wetlands and rivers (70%, n=336), and participating in awareness campaigns (60.4%, n=293). About 35% (n=170) thought that the government is doing enough to promote NBS in Mbale City, and lack of awareness and knowledge (94%, n=452) and limited funding and resources (92.5%, n=445) were the major challenges in implementing NbS in Mbale City. Table 6.

Table 6: Implementation of Nature-Based Solutions for flood management and soil stabilization along the Namatala and Nabuyonga rivers in Mbale City, Uganda

Variable	**Category**	**Frequency (n)**	**Percentage (%)**
NBS being implemented in your neighborhood	Tree planting and afforestation	410	97.9
	Wetland restoration	37	8.8
	Agroforestry	184	43.9
	Riverbank stabilization	32	7.6

	Contour ploughing	84	20.1
	Mulching	104	24.8
	Permanent soil cover	85	20.3
	Crop rotation	109	26.0
	Intercropping	85	20.3
I support the implementation of NBS in my community	Strongly agree	366	76.1
	Agree	100	20.8
	Neutral	6	1.3
	Disagree	7	1.5
	Strongly disagree	2	0.4
If yes, in what ways would you be willing to participate? (Select all that apply)	Planting trees and vegetation	469	97.7
	Protecting wetlands and rivers	336	70.0
	Participating in awareness campaigns	290	60.4
	Reporting environmental violations	197	41.0
	Other	2	0.4
Think the government is doing enough to promote NBS in Mbale City?	No	293	60.9
	Yes	170	35.3
	Not sure	18	3.7
Ways to encourage you to support NbS implementation in your community	More awareness and education	455	94.6
	Government incentives (e.g., funding, seedlings)	434	90.2
	Community leadership involvement	284	59.0
	More visible success stories	117	24.3
The major challenges in implementing NbS in Mbale City	Lack of awareness and knowledge	452	94.0
	Limited funding and resources	445	92.5
	Government policies and regulations	256	53.2
	Resistance from communities	162	33.7

4.7 Community perceptions towards Nature-Based Solutions among respondents in Mbale City.

More than half of the study respondents (56.8%, n=273) perceive NBS to be equally effective when compared with traditional infrastructure and associate NBS with benefits such as reduced flood risk (88.4%, n=425), improved soil stability (84.4%, n=406), and improved air and water quality (59%, n=284). Some of the most mentioned concerns regarding NBS included requiring too much land (81.7%, n=393), taking too long to show results (81.1%, n= 390), high maintenance costs (55.5%, n=267), and performance in extreme weather conditions (37.8%, n=182). Table 7.

Table 7: Community perceptions towards Nature-Based Solutions among respondents settled along the Namatala and Nabuyonga rivers in Mbale City, Uganda

Variable	Category	Frequency (n)	Percentage (%)
Effectiveness of NBS compared to traditional infrastructure (e.g., drainage systems, concrete flood barriers)	More effective	113	23.5
	Equally effective	273	56.8
	Less effective	79	16.4
	Not sure	16	3.3
Benefits do you associate with NBS (Select all that apply)	Reduce flood risks	425	88.4
	Improve soil stability	406	84.4
	Improve air and water quality	284	59.0
	Increase biodiversity	79	16.4
	Provide recreational spaces	84	17.5
	Reduce temperature (heat mitigation)	122	25.4
	I don't see any benefits	20	4.2
Concerns do you have about NBS? (Select all that apply)	Requires too much land	393	81.7
	Takes too long to show results	390	81.1
	High maintenance costs	267	55.5
	May not work in extreme weather conditions	182	37.8
	Not well promoted by the government	140	29.1
	No concerns	12	2.5
Suitable entity to be responsible for implementing NBS?	Government	451	93.8
	Local communities	362	75.3
	NGOs	148	30.8
	Private sector	104	21.6
	All the above	100	20.8

4.8 Acceptance of Nature-Based Solutions among respondents in Mbale City.

About 67% of respondents, (n=324) strongly agreed that it is good that NBS are being implemented, about half, (n=243) disagreed that other measures (technical measures) be used instead of NBS and (58.6%, n=282) preferred that other technical measures be used in addition to NBS. Slightly more than half of the respondents (55.7%, n=268) strongly agreed that people responsible for implementing the measures know what they are doing, 68.8% (n=330) strongly agreed that they believed the people implementing the measures are doing so in the best interest of the community while 53.6% (n=203) strongly agreed to feeling responsible for water protection for lake users. About 52% (n=252) strongly agreed that they need more evidence that natural measures will reduce risk of flooding, and 58.2% (n=280) strongly agreed that when

heavy rainfall events occur in the future, NBS measures will reduce the chance of flooding. Overall, 54.1% (n=260) had a high NBS acceptance score. Table 8.

Table 8: Acceptance of Nature-Based Solutions among respondents settled along the Namatala and Nabuyonga rivers in Mbale City, Uganda

Variable	Category	Frequency (n)	Percentage (%)
It is good that these measures are being implemented.	Strongly agree	324	67.4
	Agree	129	26.8
	Neutral	12	2.5
	Disagree	12	2.5
	Strongly disagree	4	0.8
I would prefer that other measures (technical measures) be used instead of these.	Strongly agree	75	15.6
	Agree	86	17.9
	Neutral	25	5.2
	Disagree	243	50.5
	Strongly disagree	52	10.8
I would prefer that other technical measures be used in addition to these.	Strongly agree	282	58.6
	Agree	147	30.6
	Neutral	8	1.7
	Disagree	32	6.6
	Strongly disagree	12	2.5
I believe the people responsible for implementing the measures know what they are doing.	Strongly agree	268	55.7
	Agree	146	30.4
	Neutral	35	7.3
	Disagree	26	5.4
	Strongly disagree	6	1.3
I believe the people implementing the measures are doing so in the best interest of the community.	Strongly agree	330	68.6
	Agree	121	25.2
	Neutral	10	2.1
	Disagree	16	3.3
	Strongly disagree	4	0.8
I feel that measures are being imposed on me.	Strongly agree	115	23.9
	Agree	131	27.2
	Neutral	39	8.1
	Disagree	139	28.9
	Strongly disagree	57	11.9
I believe resources would be better used for other community concerns.	Strongly agree	95	19.8
	Agree	67	13.9
	Neutral	9	1.9
	Disagree	109	22.7
	Strongly disagree	201	41.8
I would prefer to engage with more important community issues than flooding in Mbale	Strongly agree	79	16.4
	Agree	62	12.9
	Neutral	5	1.0

	Disagree	126	26.2
	Strongly disagree	209	43.5
I feel responsible for water protection for lake users.	Strongly agree	203	53.6
	Agree	153	40.4
	Neutral	10	2.6
	Disagree	10	2.6
	Strongly disagree	3	0.8
Too much responsibility has been placed on me to support the measures.	Strongly agree	127	26.4
	Agree	116	24.1
	Neutral	45	9.4
	Disagree	143	29.7
	Strongly disagree	50	10.4
I need more evidence that natural measures will reduce the risk of flooding.	Strongly agree	252	52.4
	Agree	139	28.9
	Neutral	26	5.4
	Disagree	49	10.2
	Strongly disagree	15	3.1
I believe that when heavy rainfall events occur in the future, these measures will reduce the chance of flooding.	Strongly agree	280	58.2
	Agree	160	33.3
	Neutral	23	4.8
	Disagree	16	3.3
	Strongly disagree	2	0.4
I believe there is nothing we can do to reduce risks posed by flooding in Mbale city.	Strongly agree	66	13.7
	Agree	79	16.4
	Neutral	6	1.3
	Disagree	140	29.1
	Strongly disagree	190	39.5
I believe the financial cost of these measures is too great.	Strongly agree	118	24.5
	Agree	74	15.4
	Neutral	24	5.0
	Disagree	125	26.0
	Strongly disagree	140	29.1
NBS acceptance score Mean (SD) = 53.12 (7.73)	Low acceptance	221	45.9
	High acceptance	260	54.1

4.9 Factors associated with Acceptance of Nature-Based Solutions among respondents in Mbale City

At bivariate analysis, duration of stay, age, sex, religion, marital status, main occupation, river near residence, past flooding impact, future flooding impact, and flood risk perception were significantly associated with acceptance of Nature-Based Solutions (NBS). However, after controlling for potential confounders in the multivariable Poisson regression model, age, sex, religion, main occupation, river near residence, past flooding impact, future flooding impact, and flood risk perception

remained statistically significant. Respondents aged 35 years and above (APR = 0.84, 95% CI: 0.76–0.93, p = 0.001) had a 16% lower prevalence of NBS acceptance compared to those aged 18–24 years. Female respondents (APR = 1.08, 95% CI: 1.01–1.14, p = 0.014) had a higher prevalence of acceptance compared to their male counterparts. Regarding religion, Catholics (APR = 0.89, 95% CI: 0.82–0.97, p = 0.007) were less likely to express high acceptance compared to Anglicans.

In terms of occupation, business owners (APR = 0.89, 95% CI: 0.83–0.97, p = 0.004) had a lower prevalence of NBS acceptance relative to farmers. Respondents residing along the Nabuyonga river (APR = 0.94, 95% CI: 0.88–0.99, p = 0.049) were less likely to express high acceptance compared to those along the Namatala river. Moreover, respondents who had experienced high past flooding impacts (APR = 1.11, 95% CI: 1.03–1.19, p = 0.004) and those anticipating high future flood impacts (APR = 1.21, 95% CI: 1.11–1.34, p < 0.001) were significantly more likely to report high acceptance of NBS. Similarly, respondents with high flood-risk perceptions (APR = 1.08, 95% CI: 1.01–1.15, p = 0.023) showed a higher likelihood of accepting NBS interventions compared to those with low-risk perception. Table 9.

Table 9: Factors associated with acceptance of Nature-Based among residents settled along the Namatala and Nabuyonga rivers in Mbale City, Uganda.

Variable	Acceptance	CPR at 95% CI	APR at 95% CI	P-values
	High acceptance 260 (54.1)			
Duration of stay in the area in years				
3-5	67 (25.7)	1	1	
6-8	29 (11.2)	0.85 (0.77-0.94) *	0.98 (0.89-1.08)	
9-11	39 (15.0)	0.92 (0.83-1.01)	1.05 (0.96-1.14)	
12+	125 (48.1)	0.94 (0.88-1.01)	1.05 (0.97-1.13)	
Age				
18-24	76 (29.2)	1	1	
25-29	60 (23.1)	1.06 (0.98-1.14)	1.01 (0.92-1.10)	
30-34	43 (16.5)	0.96 (0.88-1.05)	0.96 (0.87-1.06)	
35+	81 (31.2)	0.84 (0.78-0.90) *	0.84 (0.76-0.93) *	P=0.001
Sex				
Male	86 (33.1)	1	1	
Female	174 (66.9)	1.06 (1.00-1.13) *	1.08 (1.01-1.14) *	P=0.014
Education level				
No formal education	11 (4.2)	1	1	
Primary	89 (34.2)	1.08 (0.94-1.24)	1.04 (0.91-1.19)	
Secondary	120 (46.2)	1.07 (0.93-1.23)	1.07 (0.93-1.23)	
Tertiary	25 (9.6)	1.17 (0.99-1.37)	1.03 (0.88-1.22)	
University	15 (5.8)	1.16 (0.97-1.39)	1.17 (0.97-1.41)	
Religion				

Anglican	57 (21.9)	1	1	
Catholic	39 (15.0)	0.90 (0.82-0.99) *	0.89 (0.82-0.97) *	P=0.007
Moslem	111 (42.7)	1.05 (0.97-1.13)	0.99 (0.92-1.08)	
Pentecostal	46 (17.7)	0.99 (0.91-1.09)	0.94 (0.86-1.03)	
SDA	7 (2.7)	1.03 (0.85-1.24)	1.03 (0.88-1.21)	
Marital status				
Never married	81 (31.2)	1		
Married	138 (53.1)	0.88 (0.82-0.93) *	0.94 (0.87-1.02)	
Separated/divorced	25 (9.6)	0.86 (0.78-0.96) *	0.92 (0.82-1.04)	
Widowed	16 (6.2)	0.98 (0.87-1.11)	1.06 (0.91-1.23)	
Main occupation				
Farmer	71 (27.7)	1	1	
Business owner	67 (27.3)	0.87 (0.81-0.94) *	0.89 (0.83-0.97) *	P=0.004
Employee	28 (10.8)	1.05 (0.95-1.16)	1.02 (0.91-1.14)	
Student	35 (13.5)	1.05 (0.92-1.09)	0.88 (0.78-1.00)	
Unemployed	54 (20.8)	1.00 (0.92-1.09)	0.95 (0.87-1.03)	
River near residence				
Namatala	93 (37.2)	1	1	
Nabuyonga	157 (62.8)	0.90 (0.85-0.95) *	0.94 (0.88-0.99)	P=0.049
Distance of residence from river (m)				
1-100	152 (58.5)	1	1	
101-200	61 (23.5)	0.95(0.88-1.02)	1.01 (0.94-1.08)	
201+	47 (18.1)		0.93 (0.86-1.01)	
Minutes it takes you to move to the river and back				
1-4	62 (23.9)	1	1	
5-9	88 (33.9)	0.95 (0.88-1.03)	0.99 (0.92-1.06)	
10+	110 (42.3)	0.94 (0.88-1.02)	1.02 (0.95-1.10)	
Past flooding impact score among the respondents				
Low impact score	49 (18.9)	1	1	
High impact score	211 (81.2)	1.19 (1.11-1.27) *	1.11 (1.03-1.19)	P=0.004
Future flooding impact score among respondents				
Low impact score	13 (5.0)	1	1	
High impact score	247 (95.0)	1.40 (1.31-1.51) *	1.21 (1.11-1.34)	P=0.000
Flood risk perceptions				
Low risk perception	68 (26.2)	1	1	
High risk perception	192 (73.9)	1.18 (1.11-1.25) *	1.08 (1.01-1.15)	P=0.023
NBS Knowledge				
Low knowledge	166 (68.6)	1	1	
High knowledge	76 (31.4)	1.04 (0.97-1.11)	1.03 (0.97-1.10)	

4.10 The facilitators and barriers to the successful implementation of Nature-Based Solutions in Mbale City.

4.10.1 Barriers to NBS

Despite increasing awareness of the importance of Nature-Based Solutions in addressing flood risks and soil degradation, their successful implementation in Mbale City remains constrained by multiple structural, environmental, and perceptual barriers. Community members and key informants highlighted that while many appreciate the value of NBS, their sustainability and effectiveness are hindered by the issues listed below.

Tree survival & perceived efficacy of NBS

The survival and perceived effectiveness of tree-based interventions emerged as a major barrier to the success of NBS in Mbale City. Participants explained that planted trees are often swept away during heavy floods, undermining confidence in their long-term value. Others emphasized that while bamboo and similar vegetation help stabilize soils, they cannot alone mitigate flooding caused by excessive water volumes, narrow river channels, and steep mountain runoff. Misconceptions further compound the challenge, as some residents view tree planting merely as beautification rather than a flood control measure. Participants were quoted saying:

"We have planted trees along the river but when it floods, the water sweeps away those trees…" (Participant 7, Male FGD, Mbale City)

"Bamboo would have helped us with soil stabilization… But it was not going to stop the flooding of the water. The flooding is due to increased water volumes and narrow water passage downstream, as well as the fact that the water comes from the mountain at a terrible speed." (KII, City Leadership, Mbale City)

"Some people view the planting of trees as a way of beautifying the environment and [we] shall continue suffering with the floods… the trees will not reduce the water volumes." (KII, City Leadership, Mbale City)

Waste dumping and poor sanitation

Improper waste disposal and inadequate sanitation infrastructure present significant barriers to the effective implementation of Nature-Based Solutions in Mbale City. Continuous dumping of solid and liquid waste into rivers- often done secretly at night- leads to clogging of water channels and frequent flooding. Additionally, untreated sewage from upstream communities flows directly into tributaries, degrading water quality, and destabilizing restored ecosystems. These practices not only undermine the ecological benefits of NBS but also reinforce public health risks. Participants were quoted saying:

"People dump a lot of solid and liquid waste in the river. We have tried to prevent them from dumping waste there, but we are not always there to implement, and people still find

a way to do it… Some people bring the waste at night." (KII, Local council member, Mbale City)

"*The tributary brings all sorts of waste including plastics and these clog the river and cut off the flow… when the water comes at a high force, it ends up flooding.*" (Participant 11, Women FGD, Mbale City)

"*People upstream do not have septic tanks… toilets directly to that tributary… through pipes, the sewage joins the flowing water into the river.*" (Participant 4, Male FGD, Mbale City)

Encroachment and poor urban planning

Encroachment and weak urban planning were identified as major barriers to the success of Nature-Based Solutions in Mbale City. Participants noted that many households have constructed homes dangerously close to riverbanks, leaving little or no buffer zones for vegetation or flood control interventions. This unregulated settlement not only increases vulnerability to floods but also limits available space for implementing tree planting, bamboo establishment, and other riparian stabilization measures. The absence of clear enforcement of setback guidelines and weak coordination between urban planning authorities and environmental agencies exacerbates the problem.

"People construct houses very close to the river as you can see, instead of trees. We need to have a determined distance between the river and the residences." (Participant 5, Women FGD, Mbale City)

The land along the river is owned by individuals, and they can use it as they see fit. With the increasing population and migration into the city, the locals sell off some of the land and structures are put up close to the river. Also, people grow crops very close to the river. (Participant 3, Male FGD, Mbale City)

Infrastructure and governance failures

Infrastructure and governance failures were highlighted as key constraints to the successful implementation of Nature-Based Solutions in Mbale City. Participants pointed out that poorly designed and maintained infrastructure, particularly narrow bridges and blocked drainage systems, exacerbates flooding by restricting water flow and forcing it back into residential areas. Uncontrolled developments along the lower sections of the river further obstruct natural water channels and worsen flood impacts. Additionally, weak enforcement of building regulations and institutional fragmentation undermine effective environmental governance. Local leaders expressed frustration that technical officers at the city level approve construction

projects in high-risk zones without consulting community structures, which leaves them powerless to intervene. These governance lapses not only erode public trust but also limit the effectiveness of NBS interventions.

"The bridges were also narrow… the water hits it and flows back." (KII, Local leadership, Mbale City)

The lower end of the river has been clogged with so many developments… it has flooded and caused a lot of havoc. (KII, City leadership, Mbale City)

"There is a technical officer at the city level who approves people to put up these buildings and for us we don't have power to stop them once they come with such documentation." (KII, Local council member, Mbale City)

Ineffectiveness or limited sustainability of NBS interventions

Limited sustainability and perceived ineffectiveness of existing Nature-Based Solutions emerged as notable barriers to their wider adoption in Mbale City. Participants explained that tree planting initiatives along riverbanks often fail because floodwaters uproot young trees and erode the underlying soil, diminishing their stabilizing function. Others expressed skepticism about the ability of NBS alone, such as bamboo planting, to meaningfully reduce flood volumes, viewing such measures as more aesthetic than preventive. This skepticism is compounded by the absence of follow-up maintenance and technical guidance, which reduces long-term effectiveness. These perceptions undermine community confidence and willingness to invest in or maintain NBS interventions.

"We have planted trees along the river but when it floods, the water sweeps away those trees because the soil is softened below and swept away." (Participant 7, Women FGD, Mbale City)

"Bamboo would have helped us with soil stabilization… But it was not going to stop the flooding of the water." (KII, Local council member, Mbale City)

"Some people may view the planting of trees as beautifying the environment and continue suffering with floods… the trees will not reduce the water volumes." (KII, Local council member, Mbale City)

Cost and stewardship gaps

Cost and stewardship gaps were consistently identified as barriers limiting the successful and sustained implementation of Nature-Based Solutions in Mbale City. Participants noted that many interventions, such as tree planting, riverbank stabilization, and other ecological restoration activities, require financial input beyond

the means of local residents. The high cost of materials, seedlings, and maintenance discourages participation, especially in low-income communities frequently affected by floods. Furthermore, uncertainty around responsibility for the long-term care of planted trees or maintained riverbanks undermines continuity once external actors withdraw. The absence of clear stewardship structures or incentive mechanisms for community ownership further weakens sustainability, as a key informant was quoted saying:

"Construction is too expensive and cannot be done by the local people… but also who will be responsible for the provision, planting and taking care of the trees? Are we going to be asked to buy the trees if we need to plant more?" (KII, Local council member, Mbale City)

Lack of early warning systems

The absence of an early warning system was identified as a major institutional and technical barrier to effective flood preparedness and the implementation of Nature-Based Solutions in Mbale City. Participants explained that floods often occur suddenly, particularly at night, leaving residents with no time to respond or protect lives and property. The lack of reliable communication mechanisms or coordinated emergency response structures exacerbates the loss of life and destruction of homes, while also undermining trust in broader resilience initiatives such as NBS. Without timely information on rainfall intensity or river water levels, communities remain reactive rather than proactive, limiting opportunities to integrate NBS into early action strategies.

"We don't have any warning systems in place. The floods always catch people by surprise, sometimes at night when everyone is asleep. By the time the water comes, it's too late to save anything. People die, houses collapse, property is washed away, and there's no structured way of coping or getting help afterward." (Participant 1, Youth FGD, Mbale City)

4.10.2 Facilitators of NBS

Facilitators of Nature-Based Solutions in Mbale City were identified across institutional, social, and ecological dimensions, reflecting both community-driven initiatives and supportive external efforts. Participants emphasized that successful NBS implementation thrives where there is active collaboration between local authorities, community members, and development partners. Strong social cohesion, community awareness of flood risks, and existing environmental stewardship traditions have also encouraged participation in activities such as tree planting and riverbank restoration. In addition, the involvement of non-governmental organizations and technical experts could enhance local capacity and motivation. Collectively, these factors highlight that enabling governance structures, external partnerships, and

community ownership play a pivotal role in advancing sustainable NBS interventions for flood management and soil stabilization in Mbale City.

Existing community awareness and willingness

Existing community awareness and willingness emerged as strong facilitators of Nature-Based Solutions implementation in Mbale City. Participants noted that many residents already recognize the importance of environmental restoration and are motivated to participate in activities such as tree planting and riverbank protection. However, the sustainability of these efforts depends on structured organization and local authority support. The expressed desire for committees to oversee NBS initiatives-backed by local councils-demonstrates a readiness for collective action when proper coordination and accountability mechanisms are in place. This indicates that communities are not resistant to change but rather seek institutional guidance and legitimacy to sustain environmental interventions.

"We need a committee to oversee the planting and management of the trees, but it shouldn't stop there. That committee should be supported by the local councils so that it has real authority. When local leaders are involved, people will take the work seriously, and the trees will be protected. Without such follow-up, people plant today and cut them down tomorrow." (Participant 2, Male FGD, Mbale City)

Recognition of riparian buffers/afforestation

Recognition of riparian buffers and afforestation emerged as a key facilitator of Nature-Based Solutions in Mbale City, reflecting both community understanding and willingness to support regulatory and ecological interventions. Participants demonstrated awareness of the importance of maintaining buffer zones between rivers and settlements, noting that enforcing standard setback distances could reduce flood damage and create space for protective vegetation such as bamboo and indigenous trees. This recognition signals a shift toward more sustainable land-use practices and a readiness to embrace long-term ecological planning. The appreciation for bamboo's role in soil stabilization also indicates local knowledge of species that are both ecologically effective and locally adaptable.

"We need a standard distance between the river and where people build their houses, so that we leave enough space that can be covered with trees, bamboo, and other protective measures. Right now, everyone builds as they wish, even close to the water, and that's why the floods cause so much damage. If the government and local leaders could mark and enforce this buffer zone, it would really help to control the flooding."
(Participant 9, Male FGD, Mbale City)

Bamboo would have helped us with soil stabilization because it grows fast and holds the soil firmly along the riverbanks. If we can plant it and protect those areas, it would prevent the soil from washing away whenever it rains." (Participant 3, Youth FGD, Mbale City)

External and NGO support

External and NGO support emerged as an important facilitator for Nature-Based Solutions (NBS) implementation in Mbale City, as reflected in community discussions. Participants emphasized that while there is local willingness to adopt tree planting, financial limitations hinder these efforts. The high cost of seedlings and limited access to technical guidance have made it difficult for communities to act independently. External actors such as Oxfam were cited as having initiated bamboo planting projects, though uptake was constrained by perceptions that bamboo lacks direct economic value. These insights point to both the potential and challenges of external engagement-where material and technical support from NGOs and government agencies can empower local participation, but sustainability requires alignment with community priorities and livelihood interests.

"We want to plant trees, but they are expensive, and most of us can't afford to buy them on our own. The government or city authorities should support us by providing tree seedlings and showing us which types are best for controlling floods. If they gave us the right trees and some training, people would be more willing to plant and take care of them." (Participant 6, Male FGD, Mbale City)

"There was a program by Oxfam where they wanted to plant bamboo along the river, but people were not excited about it. People say that bamboo grows so fast and so much, covers a lot of space and yet has no economic value. So, it didn't go far. When you walk around the river you can see some scattered ones." (KII, Local council member, Mbale City)

Desire for expert guidance

Community participants in Mbale City expressed a strong desire for expert guidance in addressing persistent flooding and ensuring the sustainability of Nature-Based Solutions. Despite their local efforts, such as planting trees, clearing debris, and constructing barriers, many residents acknowledged that these interventions have produced limited results due to inadequate technical knowledge and lack of coordinated planning. Participants emphasized the need for technocrats and environmental experts to study the area and develop evidence-based, long-term solutions tailored to local hydrological and ecological realities. This sentiment reflects an awareness that community initiatives, while valuable, require integration with scientific expertise to achieve effectiveness and durability.

"We as the locals have tried our different strategies but have failed. I think we need experts to come and support us with this challenge." (Participant 1, Male FGD, Mbale City)

"We have tried… but have failed. I think we need experts to come and support us. We need technocrats to… come up with evidence-based solutions." (Participant 5, Women FGD, Mbale City)

4.10.3 Context-specific strategies for enhancing the implementation and scaling of Nature-Based Solutions in Mbale City, Uganda.

Riparian buffer enforcement and regulation

Community perspectives in Mbale City underscore riparian buffer enforcement and regulation as a crucial component of effective flood management. Participants consistently expressed concern over uncontrolled construction and cultivation along riverbanks, which they linked to increased flood frequency and severity. The absence of enforceable regulations or visible demarcations has led to widespread encroachment, eroding the natural buffer zones that once absorbed excess runoff. Respondents emphasized that the establishment of a standard, legally enforced setback distance would allow for reforestation, bamboo planting, and agroforestry practices capable of stabilizing soils and mitigating flood impacts. This call reflects an understanding that ecological integrity and human safety depend on planning discipline.

"We need a standard distance between the river and where people are allowed to build or cultivate, so that we leave enough space for strategies like tree planting, agroforestry, and other protective measures. Without clear rules, everyone does what they want, and that's why the floods keep getting worse. The authorities should mark and enforce those buffer zones." (KII, City Leadership, Mbale City)

Formation of community environment committees

Participants emphasized the importance of forming community environment committees as a cornerstone for sustaining Nature-Based Solutions implementation in Mbale City. They argued that while many tree-planting and riverbank restoration efforts had been initiated, the absence of structured follow-up mechanisms led to neglect and eventual failure of interventions. Establishing community-based committees composed of environmental focal people and supported by local councils was seen as a practical strategy for ensuring continued oversight, ownership, and accountability. These committees could play vital roles in monitoring planted trees, preventing encroachment, mobilizing community participation, and coordinating with technical officers for training and resource access.

"We need a committee to oversee the planting and management of the trees, especially along the riverbanks, and it should include environment focal persons from the community. These people can work together with the local councils to monitor and protect the trees. When such structures are active and supported, people respect them, and the work continues even after the project ends." (KII, Local council member, Mbale City)

Provision of tree seedlings and materials

Participants emphasized that the provision of tree seedlings and related materials is critical to enabling widespread community participation in Nature-Based Solutions (NBS) initiatives. Many residents expressed willingness to plant and maintain trees but cited financial barriers as a key constraint, noting that seedlings are often too costly or unavailable locally. They highlighted the need for government and city authorities to distribute free or subsidized seedlings, along with technical guidance on appropriate species selection and maintenance practices. Access to planting tools, manure, and watering equipment was also seen as essential for sustaining newly planted vegetation, particularly during dry seasons. The call for material support highlights the economic realities faced by vulnerable urban communities and suggests that even modest resource inputs could unlock significant grassroots engagement.

"We really want to plant trees, but they are expensive, and most of us cannot afford to buy them. The government or city authorities should support us by providing free seedlings or at least making them cheaper. If they gave us the right species and helped us understand how to care for them, we would gladly plant and maintain the trees. We know trees can reduce floods and soil erosion, but without support, it becomes difficult."
(Participant 2, Male FGD, Mbale City)

Solid waste management and enforcement

Improper solid waste management and weak enforcement emerged as a key barrier to the success of Nature-Based Solutions (NBS) in Mbale City. Participants highlighted persistent waste dumping along riverbanks, often done covertly at night or by individuals from other parts of the city, leading to severe blockage of water channels. This accumulation of waste exacerbates flooding by obstructing river flow and reducing infiltration capacity. Despite community awareness of the issue, limited monitoring capacity and lack of strict penalties have undermined efforts to curb the practice. The situation reflects broader governance challenges in urban environmental management, where enforcement gaps allow harmful behaviors to persist.

"Some people bring the waste at night and dump it near the riverbanks where no one can see them. Others even come from as far as town just to dispose of their garbage here. By morning, the whole place is littered, and when it rains, all that waste is carried straight into

the river. It blocks the water channels and makes flooding even worse. We try to tell people to stop, but without strict monitoring and penalties, they keep doing it." (KII, Local council member, Mbale City)

Integrating NBS with grey infrastructure

Integrating Nature-Based Solutions (NBS) with grey infrastructure was identified as a critical approach to enhancing flood resilience in Mbale City. Participants noted that poorly designed bridges, culverts, and drainage systems often exacerbate flooding by obstructing water flow during heavy rains. Narrow bridge openings and inadequate culverts cause backflow and overflow, leading to destruction of roads, homes, and vegetation along riverbanks. While NBS such as tree planting, bamboo stabilization, and riparian buffers can reduce runoff and soil erosion, participants stressed that these measures alone are insufficient without corresponding improvements in physical infrastructure. A combined approach, where green interventions complement properly engineered drainage and transport systems, was seen as essential for long-term flood management.

"The bridges should be widened because they also contribute to flooding. When the water level rises, the narrow bridges block the flow, causing the river to overflow onto the roads and nearby homes. If the bridges were properly designed with wider openings and stronger culverts, the water could pass freely without causing destruction. It's not just the rain - it's poor infrastructure that worsens the flooding." (KII, City Leadership, Mbale City)

Expert-led hydrological and environmental studies

Participants emphasized the critical need for expert-led hydrological and environmental studies to guide the design and implementation of sustainable flood management solutions in Mbale City. They expressed concern that many interventions introduced in the past were not informed by scientific assessments of local conditions such as river flow dynamics, soil composition, or drainage patterns, leading to poorly adapted measures that failed to withstand seasonal floods. Respondents called for the involvement of trained hydrologists, environmental engineers, and ecologists to conduct localized studies and generate evidence-based recommendations tailored to the city's unique terrain and urban structure. Expert engagement, they noted, would not only improve the technical quality and durability of Nature-Based Solutions (NBS) but also build community trust in implemented projects.

"We need technocrats to come on the ground and develop evidence-based solutions that fit our reality. Too often, people come with ideas that look good on paper but do not work here. We need experts who can study our situation - the soil, the river flow, the drainage

systems - and then guide us with proper designs and plans. That way, what is implemented will be sustainable and not just temporary fixes." (Participant7, Male FGD, Mbale City)

Community education and risk communication

Participants consistently underscored the importance of community education and risk communication as a foundation for effective and sustainable adoption of Nature-Based Solutions in Mbale City. Many community members still perceive practices like tree planting, bamboo cultivation, and grass cover as merely aesthetic rather than functional measures for flood control and soil stabilization. These misunderstanding limits their participation and long-term commitment to maintaining such initiatives. Respondents emphasized the need for regular sensitization and environmental education programs that clearly explain how NBS work. Illustrating, for example, how vegetation slows surface runoff, stabilizes riverbanks, and reduces erosion. They also called for simplified and participatory communication methods such as community dialogues, radio talk shows, and local demonstrations in flood-prone areas.

"Some people still think that planting trees is just for beautifying the environment, not for controlling floods. We need to be taught how these things work - how trees, grass, and bamboo help stop erosion and slow down water. If people understood the science behind it, they would take it more seriously. There should be community sensitization and regular education programs so that everyone knows that these actions are not just about beauty but about protecting our lives and property." (Participant 8, Women FGD, Mbale City)

Upstream interventions and channel management

Participants identified upstream interventions and river channel management as essential for addressing the root causes of flooding in Mbale City. They emphasized that much of the flooding experienced downstream results from unmanaged water flow originating in the upper catchment areas. The absence of effective drainage or diversion systems upstream causes water to accumulate rapidly and rush downstream with destructive force. Community members proposed constructing controlled water channels, diversion trenches, and checking dams in the upper sections of the river to slow and redirect runoff before it reaches densely populated areas. Additionally, they noted that river widening and routine desilting are crucial to prevent blockages and overflow caused by sediment and debris accumulation. Participants stressed that combining these engineering interventions with vegetative measures, such as tree planting and bamboo reinforcement along riverbanks, would significantly improve the city's overall flood resilience.

"We could construct proper channels or diversion trenches along the river upstream to help control the water flow before it reaches the lower sections. This would reduce the volume

and pressure of the water that comes down here during heavy rain. If possible, the river itself should also be widened and desilted regularly, because when it becomes narrow and filled with debris, it cannot hold much water and easily overflows into people's homes. With proper river engineering combined with tree planting, we can greatly reduce flooding." (Participant 4, Youth FGD, Mbale City)

5. Discussion

This study examined the past and anticipated impacts of flooding, community flood risk perceptions, existing Nature-Based Solutions interventions, and the social and contextual factors influencing their implementation and acceptance in Mbale City. The findings indicate that several NBS practices are currently being applied, with the most common ones including tree planting and afforestation, agroforestry, crop rotation, and mulching. Communities generally perceive NBS as effective, recognizing their role in reducing flood risks, enhancing soil stability, and improving environmental quality. However, knowledge and understanding of NBS remain uneven across groups, reflecting the need for more targeted awareness and capacity-building initiatives. Furthermore, socio-demographic, experiential, and perceptual factors, such as age, gender, religion, occupation, and prior exposure to flood impacts, play an important role in shaping community acceptance of NBS. Individuals with greater flood experiences and those perceiving higher future risks tend to be more open to adopting nature-based interventions, whereas certain livelihood groups and residents in specific locations display more skepticism. These patterns highlight the complex social dimensions of NBS implementation and show the importance of integrating local experiences, perceptions, and socio-economic contexts into program design.

The findings reflect both a heightened awareness of flood risk and an uneven understanding of Nature-Based Solutions (NBS) among communities in Mbale City. The high proportion of respondents who reported severe past flood impacts and who anticipate greater future flood risks could be attributed to the recurrent flooding and salient hazard in the city. This awareness aligns with the increasing frequency and intensity of floods documented in eastern Uganda, where deforestation, unregulated construction, and encroachment on floodplains have amplified vulnerability (NEMA, 2022; Opedes, Mücher, Baartman, Nedala, & Mugagga, 2022). The strong flood risk perception observed suggests that these experiences have translated into widespread recognition of flood threats. According to studies such as Bubeck, Botzen, and Aerts (2012) and Kellens, Terpstra, and De Maeyer (2013), individuals who have directly experienced disasters tend to develop heightened risk perception and a stronger motivation to support preventive measures. In the context of Mbale, this perception provides a social foundation for promoting ecosystem-based flood control strategies, since people already understand the magnitude of the hazard.

Despite this, only a minority of respondents demonstrated high knowledge of NBS. This knowledge gap may stem from limited community involvement in the design or implementation of such measures and the technical framing often used by environmental agencies. Similar disparities have been reported in other developing-country contexts, where NBS awareness is restricted to expert or institutional circles rather than being mainstreamed into community adaptation planning (Kabisch, Frantzeskaki, Pauleit, Naumann, Davis, Artmann, Haase, Knapp, Korn, Stadler, et al., 2016; Nesshöver et al., 2017). Limited exposure to training or demonstration sites can hinder people's ability to link practices such as tree planting, mulching, or agroforestry with the broader NBS concept. As a result, even when individuals participate in these activities, they may not perceive them as integrated solutions for flood mitigation and soil stabilization.

Nevertheless, the community's general perception of NBS effectiveness indicates openness to innovation and experiential trust in their benefits. Practices like afforestation, agroforestry, crop rotation, and mulching are well-established locally and align with indigenous conservation knowledge that emphasizes soil fertility and water retention. Evidence from East Africa and other tropical regions confirms that these interventions enhance infiltration, reduce runoff, and stabilize riverbanks (FAO, 2020; Opedes et al., 2022). The positive community outlook therefore represents a promising entry point for scaling up NBS. However, to ensure sustainability and inclusiveness, future programs should prioritize participatory education, demonstration projects, and co-production of knowledge that bridges scientific and traditional approaches. Building community ownership through awareness campaigns and local training could transform existing ad-hoc conservation activities into cohesive, city-wide NBS systems that enhance flood resilience and soil stability.

Diving into the factors associated with acceptance of NBS, older respondents (aged 35 years and above) were less likely to report high acceptance of Nature-Based Solutions compared to younger individuals. This finding could be attributed to the tendency of older individuals to prefer conventional or familiar coping mechanisms over innovative approaches such as NBS, which may be perceived as experimental or uncertain. Younger respondents, on the other hand, are often more adaptable and receptive to new ideas, particularly those aligned with environmental sustainability and community innovation. Empirical evidence supports this pattern: a study by Wachinger, Renn, Begg, and Kuhlicke (2012) and further corroborated by Fuchs et al. (2017) found that younger populations demonstrate greater openness to adopting new flood-mitigation strategies due to their higher risk awareness and willingness to engage in adaptive learning. This implies that NBS awareness campaigns in Mbale City should be tailored to address generational differences by simplifying technical

information and providing tangible demonstrations to older residents to enhance trust and acceptance.

The higher likelihood of NBS acceptance among female respondents reflects women's greater perceived vulnerability to floods and environmental shocks, often linked to their caregiving and household management roles. Women frequently experience direct consequences of flood events, such as food insecurity, water contamination, and displacement, and therefore have a stronger motivation to support preventive strategies. Similar gendered patterns have been documented in Uganda and elsewhere in sub-Saharan Africa, where women demonstrate higher environmental risk perception and proactive adaptation behavior (Awiti, 2022; Bomuhangi, Nabanoga, Namaalwa, Jacobson, & Gombya-Ssembajjwe, 2016; Mersha & Van Laerhoven, 2016). This highlights the need to strengthen women's engagement in NBS initiatives, positioning them as key actors in community-led planning and implementation, which could enhance the sustainability and inclusivity of flood management programs in Mbale City.

The observed lower acceptance of NBS among Catholic respondents relative to Anglicans may relate to differing social networks, religious teachings, or historical engagement of faith-based organizations in environmental activities. In some settings, Anglican dioceses in Uganda have been more involved in ecological stewardship programs, such as tree planting and watershed restoration, under the Church of Uganda's climate resilience agenda (Bbosa, 2025; Esau Kimanje, 2024). Studies by Karimi, Liobikienė, and Alitavakoli (2022) emphasize that religious worldviews and institutional engagement significantly shape environmental attitudes and community action. Similar findings have been reported by other scholars (Gifford & Nilsson Hed, 2014; Mucunguzi, Musiime, & Ogola, 2022; Njeru & Nzengya, 2022). This finding suggests that partnerships with diverse religious institutions could enhance NBS advocacy, leveraging moral authority and community trust to promote stewardship messages across faith groups in Mbale City.

Occupation also influenced NBS acceptance, with business owners showing lower acceptance compared to farmers. Farmers, whose livelihoods depend directly on land and ecosystem health, are more likely to recognize the benefits of interventions such as tree planting, riverbank stabilization, and agroforestry in preventing soil erosion and maintaining fertility. Business owners, by contrast, may perceive NBS as less immediately relevant or as competing with urban development priorities. Comparable findings by (Zhang, Huang, Zhang, Nie, & Jia, 2024) and (Saddaf, Sultana, & Anjum, 2024) indicate that occupational relevance strongly predicts willingness to adopt green infrastructure and conservation measures. For flood management in Mbale City, communication strategies should therefore frame NBS in economic terms, such as

reduced property damage, improved market accessibility, and urban beautification, to appeal to the priorities of business communities and other stakeholders.

Respondents living along the Nabuyonga river were less likely to report high acceptance of NBS than those along the Namatala river. This variation could stem from contextual differences in flood experience, prior interventions, or community trust in environmental programs. In some cases, repeated exposure to poorly maintained flood-control projects may breed skepticism about the efficacy of new measures. Additionally, Nabuyonga river has previously caused more devastating floods characterized by damage to property, loss of lives and displacement compared with Namatala river (Farida & Maswanku, 2022). According to studies by Thaler and Levin-Keitel (2016) and Bradford et al. (2012), localized perceptions of risk and institutional credibility significantly shape community willingness to engage in ecosystem-based flood management. The implication for Mbale is that NBS implementation should adopt a river-specific approach, rebuilding trust along Nabuyonga through participatory planning and visible short-term results, while consolidating positive experiences along Namatala.

Experience with past floods was a strong motivator of NBS acceptance. Respondents who reported higher past flood impacts were significantly more likely to support NBS, likely due to increased risk awareness and recognition of the limitations of existing coping measures. The relationship between direct disaster experience and adaptive behavior is well established; studies by Bubeck et al. (2012) and Botzen, Kunreuther, Czajkowski, and de Moel (2019) highlight that personal loss experiences reinforce the perceived necessity of preventive actions. For Mbale City, this suggests that communities with severe flood histories represent critical entry points for NBS demonstration projects, where lived experience can catalyze collective action and peer-to-peer diffusion of innovations.

Similarly, respondents anticipating greater future flood impacts expressed higher acceptance of NBS. This may reflect heightened perceived vulnerability and a proactive stance toward adaptive strategies. According to Van Valkengoed and Steg (2019) and Kellens et al. (2013), future-oriented risk appraisal is one of the most consistent predictors of adaptive intentions, including willingness to invest in or support natural flood-mitigation options. This finding emphasizes the value of integrating climate risk communication, such as participatory mapping and scenario planning, into NBS promotion efforts to reinforce perceived relevance and urgency.

Finally, respondents with higher flood-risk perceptions were more likely to report high NBS acceptance. Perception of risk plays a central role in shaping behavioral responses to environmental hazards, as established in the Protection Motivation

Theory and confirmed in flood adaptation research across Europe and Asia (Grothmann & Reusswig, 2006; Shah, Ajiang, Khan, Alotaibi, & Tariq, 2022). Individuals who recognize floods as both probable and severe are more motivated to endorse preventive and ecosystem-based solutions. For flood management in Mbale City, enhancing community understanding of hydrological risks, through local data visualization, early warning systems, and participatory education, could significantly improve support for NBS implementation.

The findings reveal that while communities in Mbale City recognize the potential of NBS in addressing flood management and soil stabilization, a range of structural, socio-economic, and institutional barriers hinder their successful implementation. First and foremost, tree survival and perceived efficacy of NBS remain critical challenges, as frequent floods wash away young trees and bamboo shoots, which diminishes public confidence in their effectiveness. This aligns with global findings that NBS face ecological fragility when applied without complementary structural interventions (Raymond et al., 2017). The perception that tree planting is merely aesthetic rather than functional also highlights limited environmental literacy, which weakens long-term stewardship. Additionally, waste dumping and poor sanitation further compromise the ecological function of NBS. Persistent disposal of solid waste and untreated sewage into rivers undermines restoration efforts by clogging channels and contaminating soils. This mirrors findings by Douglas et al. (2008), who observed that poor solid waste management exacerbates urban flooding across African cities. Similarly, encroachment and weak urban planning emerged as major barriers, with settlements expanding into riparian zones due to rapid population growth and lax enforcement of zoning regulations. Such land-use conflicts have been noted in comparable settings like Kampala and Nairobi, where urban expansion undermines green infrastructure effectiveness (Kabisch, Frantzeskaki, Pauleit, Naumann, Davis, Artmann, Haase, Knapp, Korn, Stadler, et al., 2016).

Governance and infrastructure failures also weaken NBS performance. Participants highlighted narrow bridges and blocked drainage systems that redirect floodwater into homes, reflecting how inadequate grey infrastructure can negate ecosystem-based interventions. This echoes findings by Thaler and Levin-Keitel (2016), who argue that NBS must be embedded within broader urban planning frameworks. Furthermore, high implementation costs and unclear stewardship structures discourage community participation. Financial constraints, limited access to materials, and ambiguity about post-project maintenance responsibilities hinder sustainability, a challenge similarly noted by Carl C Anderson et al. (2021)and Castelo et al. (2023) in local adaptation initiatives in Europe.

Despite the above challenges, the study identified several facilitators supporting NBS implementation. Community awareness and willingness emerged as a strong enabler, with residents demonstrating readiness to engage in environmental restoration when backed by local authorities and structured coordination. This aligns with evidence that community-driven stewardship enhances ownership and project longevity (Munang et al., 2013). The recognition of riparian buffers and afforestation further illustrates growing ecological understanding, as participants articulated the importance of standard buffer zones and vegetation in mitigating flood impacts. External and NGO support was also recognized as pivotal. Interventions by organizations such as Oxfam illustrate how technical and financial assistance can catalyze NBS uptake, though sustainability depends on alignment with local livelihoods. This reinforces findings by Frantzeskaki (2019), who emphasize multi-stakeholder collaboration as key to NBS success. Additionally, participants expressed a strong desire for expert guidance, acknowledging the need for hydrological studies and technical planning to tailor interventions to local river dynamics.

The study further highlights several actionable strategies for improving NBS performance in Mbale City. Strengthening riparian buffer enforcement and regulation through clear zoning and visible demarcation can curb encroachment and safeguard ecological corridors. The formation of community environment committees offers a sustainable governance mechanism for monitoring, tree maintenance, and local mobilization, which reflect a participatory governance model akin to community forest user groups (CFUGs) documented by Ostrom (2010). Additionally, the provision of tree seedlings and planting materials through public-private partnerships could overcome financial barriers and increase participation. Integrating NBS with grey infrastructure, particularly through improved bridge and drainage design, will ensure systemic flood resilience. Lastly, the promotion of community education and risk communication, supported by expert-led hydrological and environmental studies, can build environmental literacy and reinforce community trust. The integration of upstream interventions, such as desilting and water diversion channels, further aligns with watershed management approaches shown to reduce downstream flooding (Carl C. Anderson & Renaud, 2021; Plüschke-Altof et al., 2025).

6. Conclusions

The study found that Mbale City has adopted several Nature-Based Solutions (NBS) for flood management and soil stabilization, including tree planting, afforestation, agroforestry, crop rotation, and mulching. While these practices are recognized by communities for their role in reducing flood risks, enhancing soil stability, and improving environmental quality, their implementation remains uneven and

constrained by multiple challenges. The majority of residents have experienced severe past and anticipated future flood impacts and perceive high flood risk, yet few possess strong knowledge or technical understanding of NBS. Acceptance of NBS was influenced by socio-demographic and contextual factors such as age, sex, religion, occupation, and river of residence, as well as past and expected flood impacts. Qualitative findings revealed that barriers such as poor waste management, riverbank encroachment, inadequate planning, weak enforcement, high costs, and the absence of early warning systems continue to limit the success of NBS. However, the study also identified important facilitators including community awareness and willingness, NGO and government support, recognition of riparian buffers, and demand for expert guidance. Together, these findings indicate that communities are ready to embrace NBS if supported through technical assistance, coordinated governance, and sustained investment in education and enforcement mechanisms.

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