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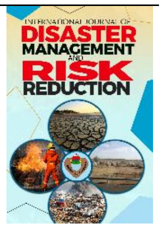

Ecosystem-Based Adaptation Approaches to Flood Management in Sub-Saharan Africa: A Review

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ABSTRACT

Rapid urbanization, climate change, and a growing population in urban cities have resulted in increased flooding incidences in Sub-Saharan Africa. Informal settlements that encroach on wetlands and floodplains restrict the space to store and convey flood waters. Further, an expansion of impermeable surfaces in urban areas restricts water flow and increases the frequency and magnitude of flooding. Ecosystem-based adaptation strategies (EBA) provide a potentially sustainable approach to managing flooding in sub-Saharan African countries. Studies have explored the use of EBA strategies in various African countries. Ecosystem-based adaptation strategies (EBA) are increasingly gaining traction as a sustainable way to mitigate climate change effects as they integrate ecosystem services and biodiversity into an overall strategy to enhance people's capacity to adapt to adverse climate change effects. This review examines the adoption, challenges, and opportunities of EBA strategies for flood management in Sub-Saharan Africa. EBA approaches not only reduce vulnerability to climate and non-climate risks but also provide environmental and societal benefits. Some specific approaches include replanting and restoring upland forests to reduce the risk of coastal erosion and landslides, restoring wetlands, adopting an integrated watershed management approach, incorporating green infrastructure, and community-based adaptation strategies that consider the local community context. Findings highlight the need for African countries to adopt participatory and multi-sectoral approaches to flood management that facilitates collaboration between the formal and informal sectors, the adoption of sustainable flood management practices, and coordination at different levels of decision-making. Strengthening these strategies would reduce the challenges associated with EBA implementation, and empower African countries to optimize the opportunities to mitigate flood risk.

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1. Introduction

Climate change has increased the severity and frequency of natural disasters globally. Extreme instances of disasters like tsunamis, droughts, and floods damage property, cause loss of lives, and affect economic activities (IPCC, 2022). Floods are among the most prevalent natural disasters in recent times (Samu & Kentel, 2018). Flooding refers to an overflow of a large volume of water exceeding the normal amount resulting from above normal precipitation, tides or when large volumes of water are released from storage. The losses resulting from flooding are compounded by the high urbanization rates in flood-prone areas, poor land usage practices, global warming, high population densities, and sub-optimal construction projects (Egbinola et al., 2017; Samu & Kentel, 2018). The design of structures to defend against flooding and urban planning significantly determines the damages caused by floods. Consequently, cities and urban areas are more likely to experience flooding events than rural areas, as economic activities are higher and population densities are higher in cities.

The severity and frequency of hydrological extremes like droughts and floods are expected to increase in the near future, as close to two-thirds of the world's population is projected to be residing in cities by 2030, with about 80% of this growth occurring in Asia and Africa (Kalantari et al., 2018). The challenges resulting from such changes are often exacerbated by the high

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population density and poor economy that may characterize cities in developing countries. In sub-Saharan Africa (SSA), the ineffectiveness or absence of flood management measures and inadequacy of basic infrastructure, services, and systems significantly contribute to high vulnerability to floods, especially in urban areas (Egbinola et al., 2017; Mguni et al., 2016; Ramiaramanana & Teller, 2021). Further, Sub-Saharan cities' inability to sufficiently accommodate their fast-growing population in proper conditions results in the construction of dangerous and unsuitable sites like floodplains. Also, deficient drainage systems mean that the population, particularly those residing in floodplains, is affected by floods.

Ecosystem-based adaptation strategies (EBA) are increasingly gaining traction as a sustainable way to mitigate climate change effects. EBA integrates ecosystem services and biodiversity into an overall strategy to enhance people's capacity to adapt to adverse climate change effects. It involves sustainable ecosystem conservation, management, and restoration to result in services that foster adaptation to climate change and climate variability (Ogundele & Ubaekwe, 2019). EBA approaches reduce vulnerability and promote resilience to non-climate and climate risks, as well as provide multiple environmental and societal benefits. Some specific approaches include replanting and restoring upland forests to reduce the risk of coastal erosion and landslides, restoring wetlands, adopting an integrated watershed management approach, incorporating green infrastructure, and community-based adaptation strategies that consider the local community context (Mguni et al., 2016).

This review aims to discuss EBA strategies for flood management in Sub-Saharan Africa, with a focus on the extent of adoption, challenges, and opportunities for enhancing EBA strategies for flood management. Although EBA strategies have been reviewed at country level (Debele et al., 2019; Munang et al., 2014; Nkwunonwo et al., 2023), the present review is comprehensively, at a regional scale, in terms of strategies in SSA. To achieve sustainable flood management in SSA, it is necessary to understand the current flood management approach, develop systems to cope with the challenges and introduce effective mitigation strategies. The information was sourced from online data bases such as Scopus, Web of Science, Google Scholar, Directory of Open Access Journals (DOAJ) and databases of organizations such as United Nations Office for Disaster Risk Reduction and the World Bank for peer reviewed articles, books, and grey literature. The search strategy was executed using Boolean operators "AND & OR" using string of words and phrases such as flood, flood management, flood mitigation, disasters, nature-based solutions, ecosystem-based adaptation and sub-Sahara Africa. The literature was screened using three stages: title, abstract and keywords and the full text.

The objective of this review is to provide a comprehensive synthesized review EBA strategies for flood management in SSA. Firstly, flood occurrence in SSA cities is described followed by the extent of adoption of EBA strategies in flood management. Thirdly, challenges in adoption of EBA strategies are provided. Fourthly, the opportunities for adoption of EBA strategies in flood management is described. Finally, the conclusion and future perspectives is highlighted.

2. Flood Occurrence in Sub-Saharan

In SSA cities, flooding can occur multiple times in a month, particularly from rainfall overflowing from channels or failing to reach the channels. The rise in groundwater levels due to heavy rainfall can also cause flooding through the release of subsurface water (Douglas, 2017).

2.1. Types of Floods

African cities experience different types of flooding: pluvial flooding, which occurs when rainwater reaches the ground at a faster rate than it can flow downslope; groundwater flooding, which is when a rise in the subsurface water table causes flooding in ground-level rooms; and flooding caused by overflowing water channels and drains (Douglas, 2017; Douglas, 2018). Flooding can also occur from an increase in water volumes in major rivers and from seismic waves or storm surges that increase water volumes in seas and lakes. As Global Center on Adaptation (2021) highlights, 73% of the vulnerable populations reside in countries where a higher percentage of the poor are exposed to river flooding compared to the general population, particularly in Angola, Cameroon, the Democratic Republic of Congo, Nigeria, and Zambia.

While an estimated 1.47 billion people live in high flood-risk areas globally, Sub-Saharan Africa accounts for more than half of the world's impoverished population exposed to such dangers (Global Center on Adaptation, 2021). This reveals the disproportionate impact of flooding on impoverished communities within the region. Governmental agencies are mandated to take responsibility for population safety and disasters. By 2050, the number of people exposed to river flooding in Africa is projected to climb to 23.4 million, with a 57% increase in fatalities if global average temperatures rise by 1.5°C. Without additional flood protection, and considering the anticipated surge in economic value within flood-prone areas, the projected economic damage could reach US$266 billion annually by 2050 (Global Center on Adaptation, 2021). However, a common perception is that these authorities lack the capacity to avert all-natural disasters and protect the population from their consequences, especially in developing regions where disaster risk management involves multiple actors (Schaer et al., 2018).

2.2. Intensity of Floods

Most rainstorms in Sub-Saharan Africa are localized. In some cases, rainstorms can cover less than ten sq. km and are often characterized by a high intensity and a short duration, such as 90 mm of rainfall in 30 min (Richard & Okeke, 2023). The climate change profile in Africa is also highly variable. Rainfall records from various Sub-Saharan African countries indicate a high level of annual, monthly, and even daily variability (Richard & Okeke, 2023).

Localized thunderstorms can cause a heavy downpour that covers as little as 2.5 km^2. The intensity of floods in Sub-Saharan Africa has increased in recent decades (Aliyu et al., 2023). For example, the Indian Ocean cyclone in 2018 and 2019 significantly affected Zimbabwe and Mozambique, resulting in 299 fatalities and 602 deaths (Aliyu et al., 2023). It also destructed $1 billion worth of infrastructure. In 2012, 33 of the 36 Nigerian states were affected by floods, which displaced close to 2.1 million people, killed 363 people, and injured 18,200 people (Aliyu et al., 2023). In April 2022 in Ghana and Nigeria, there were at least eight reports of serious flooding events. The long rains that start in March 2020 in East Africa affected more than 13 million people. Kenya, for instance, experienced mudslides and overflowing rivers that displaced more than 40,000 people. Also, in an unprecedented occurrence in the past 120 years when flood records began being kept, the water levels in Lake Victoria reached the highest point, flooding homes and displacing people (Aliyu et al., 2023; Richard & Okeke, 2023).

2.3. Duration of floods

Flooding in Sub Saharan Africa occurs at irregular intervals and vary in terms of duration. Temporal changes in the duration of floods are particularly significant in central and western Africa. In the years before the 1960s, these regions experienced longer flood durations (Ekolu et al., 2022).

The floods were also more intense and frequent. Between the late 1960s to the 1990s, flooding events in Sub Saharan Africa became shorter and less frequent. Post the 1990s, flooding became more intense and more frequent once more. The duration of floods also depends on the type. For instance, fluvial floods are of a shorter duration since they occur when convection storms of a short duration fall over a small area. Also, regional climate variability affects the duration and magnitude of floods in Sub Saharan Africa (Bischiniotis et al., 2018).

2.4. Frequency of floods

The frequency of floods in Sub-Saharan Africa have increased in recent decades. This change is due to several interrelated factors, such as urbanization, environmental degradation, and climate change (Bischiniotis et al., 2018; Ekolu et al., 2022).

Rainfall patterns have become more intense and erratic, with an increase in the frequency of downpours that has caused more frequent occurrence of flash floods. The frequency of floods has also increased due to an increase in extreme weather events, such as tropical cyclones. For example, Cycle Idai that occurred in 2019, which caused significant damage in Malawi, Mozambique, and Zimbabwe (Bischiniotis et al., 2018) . Hydrological changes in recent years have also increased the frequency of flooding events. For example, water diversion and dam construction alter river basins, affecting water flow patterns and increasing flood frequency.

3. The Extent of Adoption EBA Flood Management Strategies

EBA strategies include both structural and non-structural as described in the Table 1 and Table 2 below. The adoption of EBA strategies in African countries has improved over the years, as stakeholders have recognized the crucial role of ecosystems in addressing climate change and promotion. EBA strategies focus on using nature to adapt the environment to climate change. They also focus on the economic, social, and environmental aspects of climate change.

Sub-Saharan African countries have adopted EBA in various capacities to address not only flood management but also drought. For example, in In Togo, reservoir rehabilitation improved water access, boosted cereal and vegetable production, and built climate resilience. Implemented with NGOs, CSOs, and government, the project enhanced community awareness, trained specialists, and generated social benefits, including youth and women’s engagement in irrigation employment (Munang et al., 2014). In South Africa, it was noted that adoption of EBA strategies in an all-inclusive approach through the flood risk management cycle (mitigation, preparedness, response and recovery) and all levels is necessary (Busayo et al., 2022).

Communities in Zimbabwe have also adopted EBA strategies, which have been essential in combating the effects of climate change in the country. Community members use local ecological knowledge to conserve water and adapt to changing rainfall patterns, droughts, and extreme temperatures (Kupika et al., 2019). For instance, water harvesting techniques like digging wells are widely used to collect water during the rainy season and conserve it for use during the dry seasons. The stored water supports crop and vegetable irrigation, promoting food security. These efforts have also empowered the communities to utilize indigenous food sources and develop alternative ways of generating income.

Countries that are signatories to the United Nation’s Hyogo Framework, HFA, implement their projects within the framework, which prioritizes risk reduction and early warning systems (Schaer et al., 2018; Tiepolo, 2014). The framework has also brought different actors in water management together for a coordinated response, including governments, NGOs, experts, and international development agencies. In 2015, the UN replaced it with the Sendai Framework. The Sendai Framework for Disaster Risk Reduction 2015-2030 is a global agreement for United Nations member states, which was adopted in March 2015. Its primary aims were to reduce disaster risk and the associated loss of lives, health, livelihood, and cultural, social, economic, and physical assets. Nonetheless, providing sustainable solutions has remained a challenge, and a majority of the EBA initiatives occur at the individual and community levels. Whereas the Hyogo framework was established in the

Millennium Development Goals era, the Sendai framework is implemented in the sustainable development goals (SDG) era, which makes it more appropriate in the present disaster risk reduction discourse.

4. Challenges of EBA Adoption in Sub-Saharan Africa

The challenges affecting the adoption of EBA in Sub-Sahara Africa include; social challenges, knowledge gaps, planning inefficiency, limited evidence, integrated approach insufficiency, legal barriers, poor maintenance, and land ownership limitations among others (Fig. 1).

Fig. 1: Challenges of EBA Adoption in Sub-Saharan Africa (Authors' illustration).

The challenges associated with flood management in Sub-Saharan Africa predominantly relate to poor planning and systematic shortcomings. These limitations have constrained the adoption of EBA in sub-Saharan African countries, contributing to the limited implementation of the strategies.

The knowledge gaps in EBA design prevent practical implementation. Admittedly, multiple studies have discussed the role of EBA in managing natural hazards. Studies have also explored the importance of an inclusive and multi-stakeholder approach to EBA strategy implementation. However, the available knowledge on the topic is mainly academic, with limited knowledge of practical advantages and proof of functionality (Munroe, et al, 2012). The primary advantages of EBA over conventional flood management solutions are its cost-effectiveness, multi-functionality, climate resilience, and long-term adaptability and sustainability (Smith et al., 2020). However, the available evidence on EBA provides insufficient evidence to illustrate the linkage of EBA and the benefits it can have in Sub-Saharan African countries.

The limited evidence hinders more uptake of EBA. Knowledge gaps also exist in regard to the long-term advantages, performance, effectiveness, and co-benefits of EBA; this understanding is crucial to accelerating EBA adoption in vulnerable regions like Sub-Saharan African countries (Debele et al., 2019). Little is known about the efficiency of these strategies in urban areas and the primary constraints to practical application. For instance, integrating green infrastructure in urban areas can be beneficial to flood management (Zuniga-Teran et al., 2020).

However, such outcomes are context-specific and depend on factors like the soil's filtration rate. Most rainstorms in Sub-Saharan Africa are localized. The climate change profile in Africa is also highly variable. Rainfall records from various Sub-Saharan African countries indicate a high level of annual, monthly, and even daily variability (Richard & Okeke, 2023). Localized thunderstorms can cause a heavy downpour that covers as little as 2.5 sq. km. However, the available standards guiding the implementation of EBA adopt a one-size-fits-all approach, which is ineffective in managing the flood risk of such diverse profiles.

The knowledge gaps around EBA can be categorized differently. Firstly, there is a lack of information sharing and monitoring of existing EBA projects in the region. Secondly, there is a knowledge gap regarding the link between EBA and society, especially in terms of recognizing the best approach to transfer successful outcomes of EBA. Thirdly, there is a knowledge gap in project design and implementation elements like the optimal types of EBA (Debele et al., 2019). Due to these gaps, practitioners remain reluctant to consider EBA as a practical approach to mitigating climate change. In a study conducted in Ogun State, Nigeria, researchers established an EBA approach to flood risk management would require a unique perspective that encompasses various aspects (Nkwunonwo et al., 2023). Firstly, flood management policies in Sub-Saharan African countries must clearly illustrate flood characteristics, types, and attributions. Also, the policies must demonstrate the specific shortcomings of conventional flood mitigation approaches that are already existing. Further, it is essential that the policies emphasize and enhance the understanding of local ecosystems and the mechanisms through which natural resources can assist in mitigating and managing floods at different levels.

Integration of practice, policy, and science is critical to achieving sustainable environmental conservation. However, the absence of such an integrated approach limits the successful adoption of EBA (Munroe, et al, 2012). Another challenge of EBA adoption is limited public awareness and capacity for maintenance. EBA strategies require regular maintenance to ensure that communities maximize the approach (Nkwunonwo et al., 2023). For example, the lack of proper management and monitoring of wetlands can cause them to become breeding grounds for mosquitoes. In tropical regions, this can increase malaria transmission.

The adoption of these strategies would also require changing the surrounding landscape elements, which is a complex process that hinders policy development and implementation in order to support EBA (Debele et al., 2019).

Table 1: Non-structural EBA Strategies.

EBA strategy	Description	Reference
Educating Citizens on Responsible Waste Disposal	Raising awareness about proper waste disposal to prevent drains from clogging and reducing flood risks	(Debele et al., 2019; Egbinola et al., 2017; Gajjar et al., 2021; Nkwunonwo et al., 2023)
Cleaning of Waterways and Removal of Invasive Species	Restoring natural river flow by removing waste and invasive species from waterways	(Egbinola et al., 2017; Gajjar et al., 2021; Kalantari et al., 2018; Mguni et al., 2016)
Demolition of Houses Built on Waterways	Removing illegal structures built on natural drainage paths to restore proper water flow and reduce flood risks	(Egbinola et al., 2017; Gajjar et al., 2021)
Vulnerability Mapping	Conducting detailed assessments of flood-prone areas to identify vulnerable populations and infrastructure	(Debele et al., 2019; Gajjar et al., 2021; Thorn et al., 2021; Zuniga-Teran et al., 2020)
Early Warning Systems	Implementing forecasting and early warning systems to alert communities about impending floods and minimize impacts	(Gajjar et al., 2021)
Inclusion of Local Knowledge in Flood Management	Utilizing local knowledge and organizations in flood risk management to ensure culturally appropriate and effective solutions	(Debele et al., 2019; Gajjar et al., 2021)
City-wide Climate-related Planning	Developing comprehensive climate protection plans at the municipal level to address and mitigate flood risks	(Mguni et al., 2014)
Community-responsive Adaptation	Supporting community-driven initiatives for flood adaptation, such as riverbank stabilization and drainage improvement	(Kupika et al., 2019; Long'or Lokidor et al., 2024; Mguni et al., 2014)
Eviction of Illegal Settlements from Riparian Areas	Removing unauthorized settlements from flood-prone areas to restore natural drainage and reduce flood risk (note: effectiveness varies)	(Kalantari et al., 2018; Mguni et al., 2014)
Afforestation	Planting trees on previously non-forested land to reduce surface runoff, stabilizes slopes, and contributes to flood control by increasing the land's capacity to absorb and retain water	Gajjar et al., 2021; Thorn et al., 2021)
Reforestation	Replanting trees in deforested or degraded areas to reduce runoff, prevent erosion, and mitigate flooding by increasing the land's water-holding capacity	(Ashley et al., 2015; Carter et al., 2017; Debele et al., 2019)
Incorporation of Green Infrastructure	Integrating green spaces and natural features into urban planning to improve water absorption and reduce surface runoff.	(Ashley et al., 2015; Carter et al., 2017; Debele et al., 2019)
Conservation Agriculture Practices	Sustainable farming techniques that protect soil and water resources such as minimum tillage, crop rotation, cover cropping, and maintaining organic soil cover	(Gajjar et al., 2021; Kalantari et al., 2018)
Protection and restoration of sand dunes, Kelp Beds and Wetlands	Sand dunes, Kelp beds and wetlands are vital coastal and aquatic ecosystems that play a crucial role in flood protection. Kelp beds dissipate wave energy, reducing coastal erosion and storm surge impacts. Wetlands act as natural sponges, absorbing and storing excess water during heavy rains, and releasing it slowly, thereby reducing the risk of flooding. Protecting these ecosystems maintains their flood mitigation benefits and supports biodiversity	(Carter et al., 2017; Gajjar et al., 2021; Kupika et al., 2019)

Table 2: Structural EBA Strategies.

Soft Structural (Nature-based) EBA Strategies		Reference
EBA strategy	**Description**	
Planting Vegetation on Slopes	Establishing vegetation on slopes to prevent soil erosion and improve natural water absorption	(Debele et al., 2019; Gajjar et al., 2021; Kalantari et al., 2018)
Urban Agriculture Along Urban Rivers	Encouraging small-scale farming along urban rivers to utilize natural water flow and reduce flood risks	(Ashley et al., 2015; Gajjar et al., 2021)
Rehabilitation of Mangroves	Restoring mangrove ecosystems to act as natural barriers against coastal flooding and enhance biodiversity	(Debele et al., 2019; Gajjar et al., 2021; Kalantari et al., 2018)
Source to the Sea Project	Maintaining natural catchment infrastructure to store water and protect against flooding	(Gajjar et al., 2021)
Hard Structural (Grey) EBA Strategies		
Building Culverts and Stormwater Drains	Constructing infrastructure to manage and direct excess rainwater and reduce flood risks	(Debele et al., 2019; Egbinola et al., 2017; Gajjar et al., 2021)
Low-cost Household Level Structural Measures	Implementing affordable flood resilience measures at the household level, such as raising foundations and improving drainage	(Egbinola et al., 2017; Gajjar et al., 2021; Munang et al., 2013)
Sea Walls	Constructing barriers along coastlines to protect against sea level rise and coastal flooding	(Gajjar et al., 2021)
Gravel Platforms Under Residential Dwellings	Elevating homes on gravel platforms to reduce exposure to floodwaters	(Egbinola et al., 2017; Gajjar et al., 2021; Mguni et al., 2014; Mguni et al., 2016; Ogundele & Ubaekwe, 2019)
Installation of Flush Toilets and Water Traps	Improving sanitation infrastructure to mitigate the health impacts of flooding	(Gajjar et al., 2021)
Installation of Groynes	Building structures in rivers and streams to redirect water flow and prevent erosion and flooding	(Gajjar et al., 2021)
Retention Ponds	Artificial or natural water bodies designed to collect and hold runoff water	(Debele et al., 2019; Gajjar et al., 2021)
Detention Basins	Dry basins or reservoirs that temporarily store runoff water during and after storm events. They control flooding by delaying the release of stormwater to downstream areas	(Debele et al., 2019; Gajjar et al., 2021)
Green Roofs	Rooftops covered with vegetation and soil or a growing medium to absorb rainwater, provide insulation, reduce the urban heat island effect, and improve air quality	(Egbinola et al., 2017; Gajjar et al., 2021; Munang et al., 2013)
Conservation Terraces	Earth embankments constructed across slopes to reduce soil erosion and surface runoff.	(Debele et al., 2019; Gajjar et al., 2021)
Rainwater Harvesting Practices	Collecting and storing rainwater from rooftops, land surfaces, or rock catchments to reduce surface runoff and mitigates flooding	(Debele et al., 2019; Gajjar et al., 2021)

Poor maintenance approaches are also another shortcoming of EBA adoption, particularly in peri-urban regions. Poor maintenance is mainly due to a lack of clarity on the single stakeholder that is responsible for managing the projects, which can create confusion and lack of accountability (Schaer et al., 2018). Besides, regular maintenance of the existing conventional flood management systems is a challenge, essentially because of unkempt vegetation, obstruction, and unregulated dumping of solid waste. Low-income communities in most Sub-Saharan cities lack access to effective and reliable solid waste management services, which makes them prone to flooding. Due to ineffective waste management, plant growth, and garbage clog drains, resulting in higher susceptibility to floods, even with low rainfall (Richard and Okeke, 2023). Consequently, some countries may be apprehensive about adopting EBA as they are likely to increase the pressure on the available drainage system.

In informal settlements and refugee camps, special constraints and land ownership limitations determine the type of EBA solutions that can be adopted. For example, in Kibera, Kenya, the land is owned by the government (Gajjar et al., 2021). Semi-permanent house owners rent them to residents, who then determine the activities that can be conducted around the slums, constraining the adoption of EBA at the individual and household levels. The adoption of EBA at small-scale capacities like informal settlements and refugee camps requires negotiating the special constraints, stakeholder interests, and local maintenance requirements. EBA adoption along coastlines is also limited due to a lack of extensive information regarding the efficiency of EBA strategies in different climatic conditions (Debele et al., 2019). It is vital to contrast the convention system with EBA strategies for specific areas to promote a better understanding of its effectiveness and capability of adoption.

Some of the challenges that limit the effective adoption of current flood mitigation approaches are likely to carry over to the adoption of EBA strategies due to systematic shortcomings. For example, incomplete infrastructural developments are a significant challenge in flood management projects in Africa in their study, Peden et al. (2023) revealed that interoperability is a contributing factor to poor coordination in governments. Respondents in the study stated that state departments that overlap with respect to mandates, responsibilities, and service delivery fail to work together in providing a coordinated flood response.

Another challenge of adopting EBA strategies in Sub-Saharan African countries relates to institutional and legal barriers. Municipalities in African countries are reluctant to adopt EBA strategies due to perceptions of low return on investments and high capital (Thorn et al., 2021). Reluctance to adopt also relates to perceptions of relative ease and historical preference. Cost-benefit analyses conducted often fail to recognize that EBA provides several ecosystem services, potentially due to a lack of adequate knowledge of the extensive benefits of EBA.

Governments also work within the limits of inefficient planning and legislation inherited from previous regimes, which struggle to remain at par with rapid urbanization. Urbanization increases the built-up surface area in a region and the concretization of surfaces (Richard and Okeke, 2023). For example, in South Africa, a significant portion of the population occupies the flood plain in the Soweto area near Alexander and Port Elizabeth. Poorly planned urbanization is a considerable contributor to flooding in Sub-Saharan countries. The absence of good corporate governance structures and poor land use management are characteristic of many Sub-Saharan cities. Land ownership and regularization legislation may hinder community and individual incentives to implement EBA strategies at small scales and make it challenging to monitor and maintain EBA projects, such as happened in Kumasi, Ghana (Thorn et al., 2021). Even in the presence of supporting policies and regulations, residents often feel that there is limited public participation and social inclusion in EBA-related decision-making processes (Thorn et al., 2021). Hence, policy implementation and enforcement become challenging.

Social challenges related to governance also constrain the implementation of flood management strategies, including EBA approaches. For example, in Nigeria, town planning officials have been heavily compromised, creating an environment where governmental agencies, NGOs, companies, and residents alter building designs without following the due approval process (Oladokun & Proverbs, 2016). Alterations that are potentially flood-inducing, such as borrow pits, dump sites, water dredging, sand filling, and trenches, occur in the absence of adequate environmental impact analyses. The use of pre-design studies like geotechnical studies to determine an area's suitability is an uncommon practice. This absence of proper urban development planning has significantly distorted ecological systems and resulted in the abuse of many flood plains in Africa (Douglas, 2018; Oladokun & Proverbs, 2016). These situations make it challenging to implement and maintain EBA projects.

Furthermore, in most Sub-Saharan cities, the focus of flood mitigation strategies has been on structural measures. Most governments focus on awarding contracts to oversee the construction of culverts, bridges, embankments, canals, and flood defenses (Oladokun & Proverbs, 2016). Such measures are often taken in the absence of adequate consideration for more sustainable approaches like EBA. A common limitation of this approach is that it is often handled by foreign contractors with a limited understanding of the local context. Consequently, the strategies become implemented without knowledge transfer to indigenous experts. Such reliance on the historical approach to doing things significantly limits the adoption of EBA in Sub-Saharan African countries.

While NGOs and, sometimes, governmental agencies organize and implement awareness programs like training sessions and seminars on sustainable flood management, these programs are often irregular due to weak implementation strategies (Perera et al., 2020). Inadequate drills and preparation programs to prepare communities for disaster awareness and response hinder coordination efforts. Also, there is inadequate participation of at-risk community members in decision-making processes. Sub-Saharan African countries are also characterized by a lack of integration of traditional knowledge in flood mitigation systems, which is critical in enhancing compliance with flood warning directives (Perera et al., 2020). Also, the failure to include vulnerable groups like marginalized ethnic groups can make these communities feel disempowered, reducing their interest in flood mitigation and resulting in lower response rates to warming systems. A coordinated response to flood management is undoubtedly necessary in the African context, particularly in cities, as these are the most prone to flooding.

Effective flood mitigation at the various levels requires governmental support and interoperability with other agencies (Peden et al., 2023). For instance, in a study conducted in South Africa, respondents stated that practical training was a significant challenge to taking individual flood mitigation measures (Peden et al., 2023). The government has de-prioritized flood mitigation at the individual level, resulting in a lack of coordination and communication from local governments in flood-prone areas. In Senegal, the challenge of flood management is exacerbated by competition among the parties involved in responding to floods. The country has several international aid agencies, donors, and funds, all of which have engendered a complex flood management process (Schaer et al., 2018). The different actors implement several diverse programs and projects for disaster relief, flood risk reduction, and climate adaptation.

Bilateral and multilateral agencies in Senegal have implemented various analyses of the needs, causes, impacts, and costs of floods over the years. Most of these projects have focused on identifying gaps in the existing flood management policies and recommending remedies (Schaer et al., 2018). However, most of these programs' objectives revolve around proposing new interventions. As such, they do not go into detail in examining the underlying issues and challenges facing the flood management interventions that prevent them from effectively addressing the flood risk in the country.

5. Opportunities for EBA Adoption in Sub-Saharan Africa

The opportunities for adoption of EBA in Sub-Sahara Africa include, among others, the need to shift from reactive to proactive flood management approach, sustainable urban water management, promotion of food security, improve health outcomes, and improve community resilience to floods (**Fig. 2**).

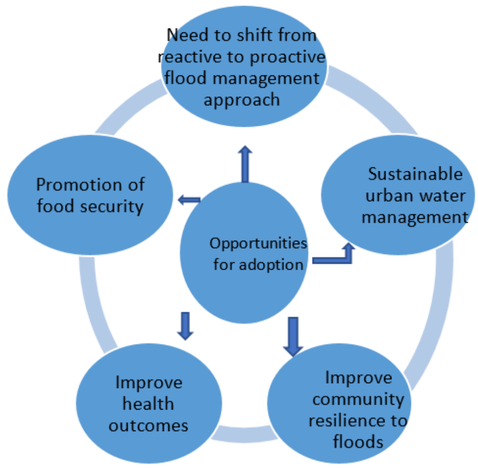

Fig. 2: Opportunities of EBA Adoption in Sub-Saharan Africa (Authors' illustration).

Sub-Saharan Africa has an opportunity to shift its approach from flood protection and reactive management measures to a flood risk management paradigm. This paradigm requires a synergetic and integrated approach that combines structural and non-structural approaches implemented by diverse actors in a participatory and polycentral manner (Wagner et al., 2021). Further, this approach recognizes that eliminating flood risk entirely is impossible; it advocates for strategies that cater to the residual risk that persists despite the implementation of risk-reducing measures or in case of failure. Flood risk management is also more thorough and broader as it addresses more comprehensive risk dimensions, including economic damage of floods, health effects, livelihood, effect on cultural heritage, and poverty.

EBA provides opportunities to effectively and sustainably manage water, particularly in urban areas, such opportunities stem from the ability to develop multipurpose features to store water temporarily or change the water flow to regions of low impact (Ashley et al., 2015). However, in Sub-Saharan Africa, EBA designs are yet to be implemented extensively. Implementing EBA approaches at any scale can potentially enhance water reuse, reduce flood risk, and improve community resilience and food security, among other beneficial possibilities, since the approach boosts water quality, quantity for use, and biodiversity.

One opportunity associated with EBA is that it can potentially promote food security and enhance water reuse. Various populations in Africa experience water scarcity and stress due to climatic changes (Douglas, 2018; Long'or Lokidor et al., 2024). EBA can potentially increase water supply, providing a solution to water scarcity in some communities. EBA strategies can achieve water retention below or above the surface (Munang et al., 2014). For example, creating awareness and empowering communities to harvest rainwater during rainy seasons can save the cost of acquiring water during the drought season and alleviate the water supply challenges during this season.

Strategies like tree planting and sack farming, which are possible in regions with low water accessibility or arable land constraints, can boost food security, reduce floods, and achieve carbon sequestration (Smith et al., 2020). Such strategies have multiple benefits as they contribute to the Sustainable development goal agenda by reducing poverty and hunger, promoting food security, and reducing the effects of climate change. Storing collected runoff using strategies like constructed wetlands also supports rain-fed agriculture, which is beneficial in various countries, such as Rwanda, where more than 90% of the agriculture is rain-fed (Smith et al., 2020). Further, this strategy is useful in areas that lack adequate drainage systems, such as refugee camps and informal settlements.

Implementing EBA strategies is also an opportunity to reduce standing water, which can impact water-borne diseases by enhancing environmental and human health. Another opportunity associated with EBA is developing community resilience. Effective implementation of EBA demands a multi-sectoral and holistic approach to mitigate social challenges and realize their full impact (Thorn et al., 2021). To this end, implementing EBA requires collaboration and engagement with the public, practitioners, scientists, private sectors, and indigenous community members. These individuals will allow the development of diverse knowledge that will improve the planning and implementation processes. A participatory approach that prioritizes stakeholder inclusion is more likely to be successful (Smith et al., 2020). Such an approach also prevents the application of negative intervention methods that would affect local communities and indigenous people, as well as fosters knowledge sharing regarding local environments. It provides the space for experimental and local interests, values, knowledge, and ideas.

EBA can also be effectively integrated into informal settlements and communities, which characterize most urban areas in Sub-Saharan African cities. For instance, in Kenya, integrating green infrastructure into the available traditional food management strategies in Kibera slums has increased small-scale ownership of green infrastructure (Thorn et al., 2021). In Dar es Salaam, detention ponds have been successfully used to address run-off (Mguni et al., 2014). These projects promote community resilience to flood management challenges and provide better ways of managing urban runoff, which can also boost community cohesion. Another opportunity lies in using preventative flood risk management. This approach is rarely used in Sub-Saharan Africa as it is time and cost-intensive. Nonetheless, risk management is an important aspect of sustainable flood management. It involves collaborating with communities to develop and update risk maps (Tiepolo, 2014). While risk was initially considered as a product of vulnerability and hazard, its definition has expanded to consider more factors, including preparedness, adaptation, and capacity. Flood risk assessment requires identifying flood-prone areas, which can be done by observing and mapping flooded areas. The preventative approach to risk assessment involves the use of hydrological models to identify risk-prone areas (Tiepolo, 2014). However, given the high number of informal settlements in Sub-Saharan Africa, this method of risk assessment is likely to result in imprecise measures. Informal settlements make modeling challenging as they undergo constant changes like blockages of the canal drainage networks and construction.

In implementing EBA strategies, awareness creation among the younger generation and capacity building on measures like rainwater harvesting, alongside the provision of the required infrastructure, will be beneficial in managing flood risk and enhancing the day-to-day lives of community members (Oladokun & Proverbs, 2016). Additionally, a flood risk management approach would also consider measures to address practices that increase flood risk, including agricultural practices that degrade the soil. Soil degradation, not only from agricultural practices but also from flood flows, is a concerning issue in Sub-Saharan Africa. For instance, high levels of soil degradation in Ethiopia, caused by overgrazing, overcultivation, deforestation, and population increase, have considerably reduced crop yields and increased flood risk (Lumbroso, 2020). In such a case, a participatory watershed management approach would enhance water retention and increase vegetation cover, thereby reducing flooding. To this end, an important aspect of flood management is community education and sensitization on practices that increase flood risk.

Urban water management in the modern day requires more considerations, including visual amenities, runoff quality, ecological protection, and other water uses. Consequently, sustainable water systems provided by EBA provide an opportunity for the long-term sustainability of drainage system design, as they can complement or provide a better alternative to conventional systems (Zhou, 2014). One EBA approach to consider in urban areas is sustainable urban water drainage systems, SUDS. SUDS include diverse drainage techniques and approaches that are designed to mimic the natural hydrological cycle of the environment. The system has three overarching aims. The first aim is to reduce the quantity and velocity of runoff by controlling it at the source; the second aim is to improve stormwater quality by treating collected surface water before discharging it into a water body or onto the land; the third aim is to maintain an area's biodiversity and amenity (Mguni et al., 2016). SUDS uses four hydrological processes to achieve its aims. These include temporary storage of the collected stormwater, infiltration of the water into the soil, evaporating it into the air, and conveying and treating the water. SUDS approaches can be classified into three categories depending on their routing process and impact on the water runoff (Zhou, 2014). The first category includes source control measures that detain and attenuate water runoff, such as impervious pavements, local infiltration, and green infrastructure. These measures contribute to flood management by enhancing the management of flood risk. For instance, green infrastructure changes the surface area of landscapes, affecting runoff volume emanating from extreme rainfall (Carter et al., 2018).

The green infrastructural cover reduces rainwater flow and serves other functions like infiltration, rainwater interception, and storage, all of which reduce flood risk. Green infrastructure is different from conventional pipe-based infrastructure. They consist of incorporating green or 'soft' elements in infrastructural design, such as swales, rain gardens, and green roofs (Mguni et al., 2016). These elements depend on natural processes such as evapotranspiration, infiltration, conveyance, detention, and retention of stormwater. Stormwater management is a vital component of flood management. Green infrastructure provides an interconnected drainage network that complements the built environment with green spaces. Pervious pavements, on the other hand, enhance water quality and reduce peak flow after extreme rainfall.

The second group includes on-site control measures, which reduce and prevent flood hazard impacts on the susceptible recipients, such as modifying the topography and protecting individuals' assets (Zhou, 2014). The third category includes downstream measures addressing the drainage system's conveyance capacity. In a paper examining the potential of implementing SUDS for flood management in Tanzania, the authors established that the region has a separate sewer system that is advantageous for SUDS implementation (Mguni et al., 2014). Further, they noted that, as with other African countries, local and community-level efforts exist. Community groups at the local level make it easier to implement SUDS experimentally at the niche level to examine its effectiveness. These experiments can be implemented as part of the programs to upgrade infrastructure on water and sanitation (Mguni et al., 2014). Other than governmental support, SUDS projects would require support from NGOs, as they have a better ability to link knowledge with resources and institutional capacity building necessary to generate momentum to transition towards SUDS. However, as the authors also noted, coordinated support from the region's authorities and support services like garbage waste disposal are essential to the success of SUDS projects using a bottom-up approach (Mguni et al., 2016).

Another characteristic of the African context is the availability of soft institutional infrastructure, which relates to informal relationships and networks among organizations and between academics and practitioners, which can facilitate a coordinated approach to SUDS implementation. Also, some governance decisions and agreements can occur on the basis of these personal networks in the planning and implementation fraternity, making the process easier. Moreover, these networks are potentially crucial in diffusing the power of formal institutions, making it easier to implement strategies at the community level (Mguni et al., 2016). The associations between academic fraternity and practitioners can also be beneficial in generating discourse regarding the transition to SUDS. These associations may make it easier to approach the decision-making and implementation processes of SUDS at larger scales in Sub-Saharan cities. Strong informal networks could also cultivate the conditions to champion the transition to sustainable flood management.

Despite the necessity of collaborative action between governments and other players in flood management, governments should be careful not to offload their public responsibilities to these other actors. National, regional, and local adaptation and flood mitigation efforts should occur at the appropriate scale in collaboration with community members. Given that flooding affects other aspects of urban life, like water suppliers, transport, and food security, more integrated regional and national resilience planning efforts are necessary to effectively manage flood risk in Sub-Saharan Africa. In implementing EBA strategies, awareness creation among the younger generation and capacity building on measures like rainwater harvesting, alongside the provision of the required infrastructure, will be beneficial in managing flood risk and enhancing the day-to-day lives of community members (Lumbroso, 2020). Additionally, a flood risk management approach would also consider measures to address practices that increase flood risk, including agricultural practices that degrade the soil. Soil degradation, not only from agricultural practices but also from flood flows, is a concerning issue in Sub-Saharan Africa. For instance, high levels of soil degradation in Ethiopia, caused by overgrazing, overcultivation, deforestation, and population increase, have considerably reduced crop yields and increased flood risk (Lumbroso, 2020). In such a case, a participatory watershed management approach would enhance water retention and increase vegetation cover, thereby reducing flooding. To this end, an important aspect of flood management is community education and sensitization on practices that increase flood risk in Sub-Saharan Africa.

6. Conclusion

This study presents a review of EBA strategies in Sub-Saharan African countries, including the extent of adoption, challenges, and opportunities. Rapid urbanization in African cities has significantly contributed to increased flood risk and community vulnerability. Flood management has mainly focused on evacuating individuals and building water flow structures. However, these efforts have not been sustainable. EBA strategies would be more beneficial in flood management and boosting community resilience to climate change. Collaboration among the actors and integration of indigenous knowledge and the informal sector in decision-making processes is essential in facilitating a coordinated approach to risk management. African countries have an opportunity to explore climate adaptation approaches that align with the natural hydrological cycle. Sustainable solutions demand a multifaceted approach that addresses other systematic issues like corruption at the governance level to ensure their effectiveness. EBA strategies in flood management should be institutionalized through policy and legal frameworks relevant to climate change mitigation and adaptation.

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