Original Paper

The challenges of sustainable conservation and management of mangrove forests in Kenya

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Abstract. *There is a scarcity of contextual information on the current status and challenges facing the sustainable management of mangroves. Using a literature review, this study explores this problem in the case of Kenya's mangrove sites, with the aim of contributing to a better understanding of the strategies needed to promote their sustainable conservation and management. The results indicate that Kenya's mangrove forests span approximately 62,459.8 hectares, accounting for roughly 3.0% of the overall natural forest cover or less than 1.0% of the country's total land area. The majority of mangroves, constituting about 59%, are found in Lamu County. The country has nine species of mangroves, with* Rhizophora mucronata *and* Ceriops tagal *(Perr.) C.B. Rob. being the dominant species. Even though these resources provide many ecosystem goods and services, mangroves are still being threatened by human-induced changes. Fortunately, the government appears to be strongly committed to conserving these critical resources and has established a positive environment for restorative actions. The development of the National Mangrove Ecosystem Management Plan (2017-2027) and the recognition of private sector-led incentive-based Payment for Ecosystem Services initiatives such as the Mikoko Pamoja Project provide renewed impetus for improved management of mangroves. Even though more studies are required, the success of the Mikoko Pamoja project serves as an inspiring example to the world of how community involvement in innovative incentive-based approaches can contribute to the preservation and sustainable use of mangroves.*

1. Introduction

Mangrove forests are important strategic assets that provide many benefits for sustainable development (Lee et al., 2014). Mangroves offer diverse ecosystem services, including climate change mitigation, recreation, coastal protection, and food production (Spalding & Parrett, 2019; Hochard et al., 2019; Donato et al., 2011; Vo et al., 2012). Despite these benefits, only four countries account for over 40 percent of the total global mangrove area. Indonesia leads with 19 percent, followed by Brazil with 9 percent, Nigeria with 7 percent, and Mexico with 6 percent (FAO 2020). Jia (2023) estimates that in 2020, the global coverage of mangrove forests was 145,068 km2. Asia had the highest proportion of mangrove forests, accounting for 39.2 percent. Indonesia possessed the largest amount of mangrove forests at the country level, followed by Australia and Brazil.

However, with the changing global socio-economic development matrices occasioned by factors such as population growth, urbanization, and climate change, existing literature shows that mangrove forest resources are on a decline (Richards & Friess, 2016; Goldberg et al. 2020). Goldberg et al. (2020) conducted studies that indicate a global average annual area loss of 0.13 percent of mangroves between 2000 and 2016. According to the FAO 2020 report, the total area of mangroves worldwide decreased by 1.04 million hectares between 1990 and 2020. Over three decades, the loss rate more than halved, declining from 46,700 hectares per year in 1990-2000 to 36,300 hectares per year in 2000-2010 and further to 21,200 hectares per year in the most recent decade. The ongoing loss of mangroves has prompted a strong drive to promote global mangrove restoration efforts. Initiatives such as the UN Decade on Ecosystem Restoration (2021-2030) and the ongoing negotiations for the Post-2020 Global Biodiversity Framework (Waltham et al., 2020; Khuyen et al., 2021) demonstrate the determined efforts to address this issue. Conservation results from these initiatives have varied depending on context. Research conducted in Asia indicates contrasting conditions among mangrove forests in different regions. South Asian mangrove forests were found to be in a relatively better state due to a higher level of conservation efforts and larger individual patch sizes. On the other hand, mangrove forests in East and Southeast Asia were identified as facing significant threats. Notably, nearly 99 percent of the mangrove forest areas studied had a patch width exceeding 100 meters, suggesting that most mangrove forests effectively mitigate coastal wave energy and its associated impacts (Jia, 2023).

In Kenya, mangrove forests are valued for their ecological and socio-economic importance. Still, they remain under the constant threat of loss due to deforestation and degradation occasioned by various reasons. The decline of mangroves has detrimental effects on various aspects, such as fisheries, the stability of shorelines, and the long-term sustainability of resources. However, with the advent of the 2010 constitution, which introduced county governments and the growing human need for forest products, this paper argues that the limited scientific studies have compared the current status of mangroves in devolved units (counties) that should be urgently addressed. It is because there are only a few scattered studies on the conservation and management of mangrove forests based on isolated local-level case studies, especially at the forest stand level. In order to address this challenge and help to design win-win regional-level mangrove conservation strategies across various counties, this study seeks to explore and document the current challenges of sustainable conservation and management of mangrove forests in Kenya. Using a literature review, this study will first explore the global status of the conservation and management of mangrove forest, review Kenya's context for conservation of mangroves then apply the global lessons to Kenya's context to generate the study implications. To achieve these aims, the following analytical question will be asked; What lessons can we draw from the current state of conservation and management of mangrove forests in Kenya?

Kenya is an appropriate study site for the challenges of sustainable management of mangrove forests, given its rich diversity of mangrove forest ecosystems, diverse stakeholders, history of community-based natural resource management, environmental and socio-economic pressures, and growing interest in sustainable development and conservation. By studying the challenges and opportunities for enhancing the sustainable management of mangrove forests in Kenya, researchers and practitioners can develop innovative and context-specific strategies that can be applied to other parts of the world facing similar challenges.

1.1 Sustainable conservation and management of mangrove forests

Mangroves refer to communities of shrubs and trees that are adapted to saline environments and thrive in intertidal zones found in tropical, subtropical, and certain temperate coastlines (Kathiresan & Bingham 2001). Mangroves play an important environmental and socio-economic function (Howard et al. 2019; Biwas & Biwas 2019; Salampessy et al. 2015). Mangrove ecosystems exemplify the production of a diverse array of forest products, both wood, and non-wood, which play a vital role in safeguarding coastal regions and coral reefs, and other

forms of biodiversity (FAO 2022; Alongi 2009; Mitsch & Gosselink 2007; Giesen et al. 2007; Duke et al. 2007; Kauffman & Donato 2012). The Millennium Ecosystem Assessment Report of 2005 classifies the benefits of mangroves into provisioning, regulating, supporting, and cultural services (Assessment 2005).

The sustainable forest management theoretical approach provides an overarching framework for the sustainable conservation of mangrove forests for future generations. The approach seeks to address deforestation, degradation, and fragmentation by promoting responsible forest management practices that ensure the long-term health and productivity of forests while providing economic and social benefits to local communities. Sustainable forest management involves a range of strategies, including forest certification, community-based forest management, and conservation and restoration initiatives. It is monitored through ecological, social, and economic criteria and indicators. Specific indicators used to measure sustainable forest management include: forest area, tree species diversity, community participation, income generation, and forest product prices.

Globally, mangroves cover approximately 14.8 million ha, with Asia having the largest area. Indonesia, Brazil, Nigeria, and Mexico account for over 40% of the total mangrove area. Between 1990 and 2020, the global mangrove area decreased by 1.04 million ha, with a decreasing rate of loss over the decades. In Africa and Oceania, the rate of loss also declined. South America experienced an increase in mangrove areas during 2010-2020, reversing the declining trend. Guyana played a significant role, reporting an annual increase of 19,500 ha, attributed to a restoration project and improved mapping. In North and Central America, there was a moderate increase of 10,500 ha during the same period. Forest area under mangroves exhibits regional and country-specific variations. In North and Central America, Cuba's reported gain of 12,000 ha per year contributed to the regional increase in 2010-2020, attributed to improved data collection and restoration programs. However, in Asia, the average annual rate of mangrove loss significantly increased, mainly driven by Indonesia's loss of 21,100 ha per year in the most recent decade. The FAO (2022) report states that Africa is home to approximately 20 percent of the world's mangroves. The distribution of mangroves in Africa consists of 74 percent along the west coast and 26 percent along the east coast. These mangroves are found in 19 countries on the west coast and 15 on the east coast of Africa. These losses and gains call for concerted efforts to design robust strategies for the sustainable management of mangrove resources.

Historically, the design and implementation of sustainable mangroves conservation strategies across the globe have been done to minimize loss and damage caused by natural disasters, legal requirements in various jurisdictions, and to sustain the range of economic benefits from mangrove restoration activities (Buckingham and Hanson 2015). As such, there is passive management through promoting natural regeneration which is based on inherent mangrove regenerative capabilities (Kamali & Hashim 2011; Martinuzzi et al., 2009). However, caution should be exercised. When disturbances occur, the regenerative abilities slowly degrade and/or disappear. The aboveground biomass of mangroves in the area needs a minimum of 25 years to recover and attain the same levels of biomass carbon observed in undisturbed mangrove forests (Sasmito et al., 2020b). The potential to enhance the functionality of coastal forests lies in the restoration of degraded mangroves, yet the aspect of preserving species diversity is frequently overlooked. Mangrove restoration aims at reversing biodiversity losses (Nellemann et al., 2009). However, the challenge with restorative efforts is connected with the selection of plant materials for human-induced restoration efforts in severely degraded mangrove sites tends to favor mono-species compositions based on their availability. The extent to which such restoration or rehabilitation endeavors can effectively enhance the recovery process of mangroves in terms of forest structure and functioning remains unknown (Branoff & Martinuzzi 2020). There are many considerations when undertaking mangrove restoration efforts, such as assessing the stability of the soil and the flooding patterns, determining the elevation of the site, evaluating the salinity of the soil and water, and understanding the input of freshwater to the site (Ngongolo et al. 2015).

Many challenges still impede the sustainable restoration of mangrove ecosystems. These factors involve the potential failure of restoration goals when relying solely on active mangrove planting without conducting a comprehensive assessment of the underlying causes of mangrove loss. Identifying and leveraging natural recovery opportunities is crucial, and determining how to facilitate and enhance them effectively (Fistrek & Bergman 2010). In some cases, the human dimension is ignored as an important consideration in mangrove restoration projects resulting in the failure of restoration efforts (Ellison 2000). Another obstacle is the constrained availability of sustainable funding, as the majority of mangrove restoration projects rely heavily on external funders for nearly all aspects of project activities. Furthermore, restoration programs are ongoing and necessitate a continuous and consistent supply of funds throughout various stages, including planning, project implementation, and post-management phases (Ngongolo et al. 2015). Other challenges include a lack of databases on the successes of

restoration projects. It is essential to keep the public informed about completed projects and the benefits they bring. News releases, media events, and public celebrations play a crucial role in ensuring awareness and understanding of the progress made in these projects (Klötzli & Grootjans 2001). Articles intended for public consumption can be crafted in a non-technical manner. Furthermore, mangrove restoration efforts can be hindered by pests and diseases. Young plants are susceptible to damage caused by barnacles and leaf-eating crabs from the sesarmid family. Additionally, certain caterpillars act as parasites on the fruits of the Rhizophora L., impeding seed germination (Ngongolo et al. 2015). Insufficient long-term monitoring and the socio-economic status of neighboring communities are contributing factors. The greater the poverty among individuals, the more they rely on natural resources, leading to significant degradation of mangrove resources. This widespread degradation, in turn, perpetuates a cycle of poverty, as poverty itself becomes a recurring cause of further degradation.

On a continental scale, Naidoo (2023) identifies the key threats facing mangroves in the African context as anthropogenic factors such as harvesting, pollution, and conversion to aquaculture and agriculture, lack of considering stakeholder interests (social, economic, and ecological interests) in regional development strategies. Other challenges include; uncertain tenure, encroachment on land, elite control, inequitable distribution of benefits, limited understanding of biophysical conditions, lack of propagules and improper species site matching, pests and diseases (Friess et a. 2016; Jusoff & Taha 2008; Barnuevo & Asaeda 2018; Suman 2019; Kusmana 2014).

Despite the challenges in mangrove management, the growing recognition of the importance of mangroves has fostered the emergence of a new conservation approach. Cross-sectoral and multi-stakeholder participatory strategies have become central in mangrove management in many countries, including Brazil, Ghana, and Mexico have achieved successful co-management of mangroves. In certain countries like Vietnam, the Philippines, and Ecuador, the legal framework for forest tenures has shifted from state-based to community-based approaches (Rotich et al. 2016; Rotich et al. 2016). Other strategies include incentivizing mangrove preservation, promoting environmentally sustainable utilization in coastal communities, and enhancing public acceptance and community involvement in mangrove management. Other strategies include research and development, facilitating technology transfer, and utilizing information systems (Thu et al. 2019; Locatelli et al. 2014; Byran et al. 2020; Zaldívar-Jiménez et al. 2017; Aheto et al. 2016; Mangora 2011; Bosire et al. 2008). In addition, analyzing policy and institutional frameworks is vital to address these knowledge gaps,

including understanding and evaluating indigenous knowledge and traditional management systems for effective integration. Indonesia offers a compelling example of incentivizing mangrove conservation through the bio-right scheme. The approach involves establishing a funding mechanism for communities engaged in conservation and restoration activities to enhance economic benefits while promoting ecological preservation (van Eijk & Kumar 2009).

From the foregoing review, sustainable forest management is crucial for effective mangrove resource conservation. Global literature review reveals decreasing mangrove areas, with Asia being the most affected. The key challenges include limited funding, lack of restoration databases, pests, diseases, and limited socio-economic understanding of project sites. Successful approaches involve co-management and community-based management, supported by incentives, funding, research, policy revision, and indigenous knowledge. It will thus be interesting to explore Kenya's context for mangroves and suggest solutions for their sustainable management.

1.2 The context for forest management in Kenya

Trees and forests are important strategic national assets in Kenya because of their ecological and socio-economic value. Kenya's forest sector contributes to a livelihood base for over 82% of Kenya's households. Direct employment for over 750,000 Kenyans and indirect benefit to over 4 million citizens. About USD 365 million (3.5%) to GDP (KFS, 2014; MEF, 2018).

Whereas Kenya is a low forest cover country with less than the recommended minimum global standard of 10%, the rapidly expanding population and conversion of forest lands to agriculture were the major drivers of forest cover loss over the years. From 1990 to 2015, about 311,000 Ha of forest land was converted to other land uses (FAO 2015b). Weak governance, unsustainable exploitation, overreliance on forest products, forest fires, and increasing adverse effects of climate change have further exacerbated deforestation and degradation of forests in Kenya (FAO 2022a; FAO 2022b).

To cut back on reliance on domestic forest products in key economic sectors, Kenya has positioned itself as a trading nation at regional and global levels in forest products. Nevertheless, Kenya is committed to contributing to global climate change mitigation and adaptation through Nationally Determined Contribution (NDC) as part of UNFCCC in line with the Paris Climate Change Agreement requirements aimed at lowering her GHG emissions by 30% by 2030.

The Kenyan Constitution 2010 recognizes the need to increase the national tree cover to at least a minimum of 10% by the year 2030. This development aspiration is also in line with Kenya's commitment to restore 5.1 million hectares of forest and degraded landscapes, which formed part of the African Forest Landscape Restoration Initiative (AFRI100) target, and the NDC target of reducing greenhouse gasses emissions by 32% by 2030 relative to a business-as-usual scenario.

2. Materials and Methods

2.1. Study area

Kenya is a country located in East Africa, known for its diverse wildlife, scenic landscapes, and vibrant culture. Its population is approximately 50 million people, with over 40 ethnic groups, each with its unique language, customs, and traditions. Kenya's capital city is Nairobi, which serves as the country's economic and cultural hub. Kenya's geography is diverse, ranging from savannas, forests, mountain ranges, and coastal plains. It is home to some of the world's most famous wildlife reserves, including the Masai Mara National Reserve, known for the annual wildebeest migration, and Amboseli National Park, renowned for its large elephant herds. The country's coastline is dotted with pristine beaches, coral reefs, and marine parks, making it a popular destination for beach holidays and water sports enthusiasts. In terms of its economy, Kenya is one of the most developed countries in East Africa, with a GDP of approximately $100 billion (Macheru 2023).

Over the past decade, Kenya has made significant political and economic reforms that have contributed to sustained economic growth, social development, and political stability. From 2015 to 2019, Kenya's economy achieved broad-based growth averaging 4.8% per year, significantly reducing poverty to 34.4% in 2019 (World Bank 2022). Kenya's economy is highly dependent on the natural resource base. With over 84% of its land area classified as arid and semi-arid, Kenya is so exposed and highly vulnerable to increasingly extreme weather conditions. An average drought results in a 20–30% food deficit, slash GDP growth by 3–5% and affects the livelihoods of over 80% of the population (ADB 2022). According to the Global Climate Change Risk Index (GCRI) of 2021, Kenya is ranked the 25th most affected country by extreme weather conditions and weather-related losses (ADB 2022). Youth unemployment and a high poverty rate are key challenges to Kenya's economic growth and development. The youth unemployment rate is 38.9%, with an estimated 800,000 young people

entering the labour market every year and over 8.9 million people in Kenya living below the poverty line (Statista 2022). With a population growth rate of 2.7%, the Kenyan population is projected to rise to 66.3 million by 2030. The increasing population presents a challenge to the sustainable utilization of forest resources and an opportunity for expanding farm forests. According to a study by GATSBY Charitable Fund in 2014, Kenya's national wood deficit was estimated at 12 million M3 in 2014 and is predicted to rise to as high as 34.4 million M3 by 2030. Against this background, the new Kenya Kwanza administration's bottom-up economic model has prioritized accelerating the achievement of 30% national tree cover by 2032 for increased employment opportunities, improved livelihoods, climate change reliance, and enhancing Kenya's economic growth within the context of Vision 2030 (Government of the Republic of Kenya, 2007).

Mangroves are found in Lamu, Kilifi, Mombasa, Tana River, and Kwale counties along the Kenyan coast. Table 1 shows the counties where mangroves are found in Kenya. Kilifi County is the most populous, while Lamu County is the least populous and has the highest tree cover. Mombasa County is a city county and has experienced increased infrastructural developments.

Parameter	**Lamu**	**Kilifi**	**Kwale**	**Tana River**	**Mombasa**
Area (Ha)	613,953.01	1,250,414.05	822,927.05	3,915,064.52	21,602.29
Population	143,920	1,453,787	866,820	315,943	939,370
Gross County Product (Kshs., MM) Year 2020	26,861	163,818	92,577	24,314	402,373
Forest Cover (%)	32.13	26.25	5.52	9.97	19.59
Tree Cover (%)	44.06	27.75	13.99	10.40	23.75

Table 1: Description of counties with mangroves in Kenya Source: Author from Multiple sources

2.2. Data Collection and Analysis

This study seeks to explore the challenges facing the sustainable conservation and management of mangrove resources in Kenya in order to draw lessons for sustainable forest management. To achieve on this aim, literature review through document content analysis was conducted to collect both qualitative and quantitative data on the variable under study. The process of document content

analysis entailed; identifying relevant documents, selecting a sample for analysis, developing coding schemes or categories to organize the data, and systematically analyzing the content of the documents to draw conclusions about the research question.

Document content analysis was the preferred research method for this study because it is less expensive than other research methods, such as surveys or experiments, since the data is readily available and does not require the researcher to collect new data. Unlike surveys or experiments, document analysis does not require direct contact with study participants, which can be useful when studying sensitive topics or when the researcher wants to avoid influencing the participants' behavior. Document content analysis is more objective than other research methods, as it relies on the content of the documents rather than the researcher's interpretation of the data. Lastly, this study explores historical data on forest cover and central bank rate of interest, and thus document content analysis was applicable to study the historical trends and patterns over time by providing a rich source of information (Cole 1988; Downe-Wamboldt 1992; Drisko & Maschi 2016).

Data on mangrove resource conservation and management status was sought from existing literature using desktop Google Scholar and supplemented with official records. During the desktop search, appropriate keywords related to the topic, such as "mangroves," "mangrove conservation and challenges," "mangrove management," "deforestation," or any other relevant terms, were chosen. In some cases, the use of advanced search techniques such as quotation marks (" ") to search for exact phrases or the minus sign (-) was used to exclude certain keywords. Notes were taken, and a track of the reference sources was noted. The information was later synthesized and used to develop insights or support arguments fronted in this research. The choice of Google engine was infomed by the need for improving study reliability and reproducibility.

Other secondary data were collected by reviewing the key documents and studies listed in Table 2. These documents provided context information and key results used in this study.

No.	Document/study consulted	Key information sought	Source
1.	Constitution of Kenya (2010)	Article 60 (1) (e) provides for sound conservation and protection of ecologically sensitive areas such as mangrove sites	Kenya law reporting website

No.	Document/study consulted	Key information sought	Source
2.	Forest Policy (2015)	Context information for forest management	Kenya Forest Service website
3.	Forest Conservation and Management Act (2016)	Institutions established to promote forest management	Kenya law reporting website
4.	Kenya Vision 2030 (2007)	Context information for forest management	Vision 2030 website
5.	Wildlife Conservation and Management Act, (2013)	Context information for marine resource management	Google Search
6.	Environmental Management and Coordination Act, (1999)	Context information for management of environmental resources	Google Search
7.	County Government Act (2012)	Role of counties in managing forests	Kenya law reporting website
8.	National Mangrove Ecosystem Management Plan (2017-2027)	Context information on the status of mangrove ecosystems in Kenya	Google Search
9.	Office Records	Context information on the status of mangrove ecosystems in Kenya	Kenya Forest Service
10.	Abuodha &Kairo (2001).	Human-induced disturbance of mangroves in Mombasa and Lamu counties caused by salt work, housing, and aquaculture	Google Scholar
11.	Doute et al. (1981)	Mangrove resource assessment using remote sensing	Google Scholar
12.	Kairo et al. (2001)	Overview of mangrove conservation in Eastern Africa	Google Scholar
13.	Kairo et al. (2008)	Structural development and productivity of planted mangroves in Gazi bay, Kwale County	Google Scholar
14.	Mwamuye et. al. (2021)	The multi-stakeholder approach has an overall improvement in the conservation and management of mangrove forests resources, more so with a functional coordination framework among stakeholders in Mida Creek, Kilifi County	Google Scholar
15.	Kirui et al. (2008)	Influence of species richness and environmental factors on survival of replanted mangroves in Gazi bay, Kilifi County	Google Scholar
16.	Olago et al. (2023)	Impacts of climate change on mangroves in Lamu County	Google Scholar

No.	Document/study consulted	Key information sought	Source
17.	Kitava et al. (2021)	The study on integrating mobile phone communication technology in the management of mangrove forests in Lamu County found that mobile phones are affordable, convenient, and effective for reporting criminal activity and monitoring forest changes. The study recommended providing employees with internet-enabled phones to utilize social media applications.	Google Scholar
18.	Karanja & Saito (2018)	Environmental benefits of mangroves in Tana Delta, Tana River County	Google Scholar
19.	Hanshi (2017)	Dynamics of conflicts in Tana Delta Region. Lack of mutual understanding on how to share benefits from natural resources causes conflicts and degradation of mangrove resources.	Google Scholar

Table 2: Key documents consulted in Kenya

3. Results

3.1. The current state of conservation and management of mangroves

Kenya has about 61,271 ha of mangrove forests (Table 2). These resources are found in five coastal counties: Lamu, Kwale, Tana River, and Mombasa. Lamu County has the most extensive mangrove cover, spanning 37,350 hectares. It is followed by Kwale, Kilifi, Tana River, and Mombasa counties, in descending order (as shown in Table 3). It is important to note that estimates of mangrove areas may differ among sources due to variations in estimation methods, survey timing, classification criteria, and delineation of the mangrove ecosystem. Mombasa County exhibits the highest percentage of degraded mangrove areas. Figure 1 shows the distribution of mangroves along the Kenyan coastline.

County	County Total Area (Km^2)	Mangrove Area (Ha)	Degraded Area (%)
Lamu	6,273.1	37,350	38.6
Kilifi	12,246	8,536	40.0
Kwale	8,270	8,354	44.6
Tana River	35,376	3,260	36.2
Mombasa	294.7	3,771	49.1
Total	**62,459.8**	**61,271**	

Table 3: Extent and Distribution of Mangroves in Kenya Source: National Mangrove Ecosystem Plan (2017-2027)

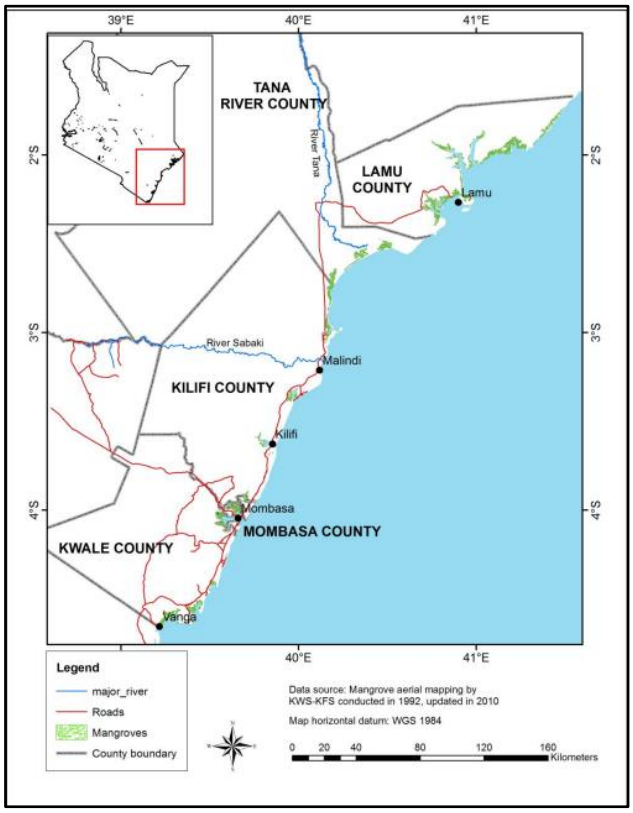

Figure 1: The Distribution of Mangrove forests in Kenya Source: National Mangrove Ecosystem Plan (2017-2027)

There are nine mangrove species in Kenya (Kairo et al. 2001). *Rhizophora mucronata Lam.* and *Ceriops tagal* (Perr.) C.B. Rob. are prevalent species found in nearly all mangrove formations, indicating their dominance. *Heritiera littoralis* and *Xylocarpus moluccensis* are rare species within the mangroves of Kenya. Moreover, the distribution of mangrove species in Kenya exhibits a horizontal pattern or zonation, primarily influenced by factors such as inundation levels, geomorphology, and salinity. Alongside mangrove trees, other plant species associated with the ecosystem include *Acrostichum aureum*, which commonly occupies degraded areas, *Sesuvium portulacastrum*, a fleshy herb often found in elevated sandy regions, and Salicornia spp., as well as various types of grass,

rushes, and sedges (National Mangrove Ecosystem Plan 2017-2027; Kairo et al. 2001).

Other species found in the mangrove ecosystem include *Vigna marina*, *Juncus* sp., and Athrocnemum sp., which are present in the higher shore areas devoid of vegetation. Various epiphytes, such as ferns, orchids, lichens, and mistletoe, can be found on the mangrove trees. Seagrasses and epiphytic algae are found in patches on the submerged mangrove floor, creeks, and sub-tidal areas adjacent to the mangroves. These plants play a crucial role in stabilizing sediment, providing habitats for sessile organisms, and serving as a source of food and shelter for numerous marine species. The county-specific species formations and their respective percentage cover per formation in Kenya are outlined in Table 4. Tana River County exhibits the largest single species formation, accounting for 87% of *Avicenia* sp.

County	Main species formation	% cover
Lamu	*Rhizophora sp. mix*	23.2
Kilifi	*Avicenia sp.*	31.8
Kwale	*Ceriops sp. mix*	40.0
Tana River	*Avicenia sp.*	87.0
Mombasa	*Ceriops-Rhizophora sp.*	45.9

Table 4: Mangrove Formations Source: Multiple sources

Mangroves support a rich fauna diversity thanks to abundant food resources and various microhabitats such as soil surface, tidal pools, tree roots, trunks, and canopies (Kairo et al., 2008). It includes a range of phyla in Kenya, from protozoa to mammals, with prominent groups being molluscs, crustaceans, fish, and birds (National Mangrove Ecosystem Plan 2017-2027). Crustaceans, particularly crab families like Grapsidae, Ocypodidae, Portunidae, Xanthidae, and Gecarcinidae, play a significant role among the epifauna in Kenya's mangroves. Migratory birds, including wading birds, shorebirds, diving birds, birds of prey, and arboreal birds, visit the mangrove forests during winter. (National Mangrove Ecosystem Plan 2017-2027)

3.2. Stakeholders involved in mangrove management

To promote sustainable management practices, the mangrove forest areas in Kenya were designated as government reserve forests through the Proclamation

No. 44 of 30th April 1932 and later reinforced by Legal Notice No. 174 of 20th May 1964. The "Gazette Notification for Mangrove Forests in Kenya" classifies the land between high water and low water marks (ordinary spring tides) as mangrove areas. The responsibility for the management of mangroves lies with the Kenya Forest Service, either independently or in collaboration with the Kenya Wildlife Service (KWS), when they are located within Marine Protected Areas (MPAs).

3.3. Key challenges and threats

Mangroves in Kenya provide essential services but face threats from human and natural factors. The country has experienced significant loss and degradation, particularly in peri-urban areas like Mombasa. The development of infrastructure, such as the Lamu port, poses potential environmental risks to mangroves. (Karanja & Saito 2018; Hanshi 2017). In particular, for Mombasa, which is a city county, the Mombasa Port Area Road Development Project (MPARD) poses a threat to valuable mangrove ecosystems. To mitigate this, a compensatory planting of 64 ha of mangroves is proposed. Table 5 highlights the county-specific benefits and threats to the sustainable management of mangrove resources in Kenya.

County	Benefits	Threats and Challenges
Lamu	Construction poles, fuelwood, fish production, coastal protection, beekeeping	Illegal harvesting of wood products, pollution from oil spills, overexploitation, coastal infrastructure development, and sedimentation (Abuodha &Kairo 2001).
Kilifi	Fuelwood, construction poles, fish production, shoreline protection (Karanja & Saito 2018), tourism	Illegal harvesting, climate change, soil erosion, encroachment, pollution
Kwale	Fish production, construction poles, firewood, air purification, shoreline protection	Illegal harvesting, conversion to rice farms, climate change, destructive fishing methods, strong ocean winds
Tana River	Construction poles, fishing, fuelwood, medicinal, tourism	Illegal cutting, climate change-induced flooding, sea level rise, sedimentation, encroachment, dams upstream
Mombasa	Construction poles, Fish production, fuelwood, coastal protection against erosion (Karanja & Saito 2018), climate change mitigation (Karanja & Saito 2018)	Illegal harvesting/ uncontrolled cutting for domestic use, pollution from oil waste, sedimentation, encroachment, and climate change (Abuodha &Kairo 2001).

Table 5: Mangrove utilization trends, challenges, and threats (Source: Multiple sources)

3.4 Improving the management of mangrove resources

County analyses provide good information that could be used to improve the management of mangroves in Kenya. The National Mangrove Ecosystem Plan highlights the need for improved community engagement, institutional capacity, awareness, and enforcement of regulations. Collaborative efforts between KFS, local communities, CFAs, PFMPs, and FMAs are crucial for effective mangrove conservation. (Abuodha & Kairo 2001; Mwamuye et al., 2021). Table 6 shows the suggested ways of improving the sustainable management of mangrove resources in the country.

County	Actions for improving management of mangroves
Lamu	Enforce licensing regulations to prevent over-harvesting, initiate reforestation programs for degraded areas, empower adjacent communities to form CFAs, and implement harvesting plans for sustainable mangrove management in Lamu. (Mwamuye et. al. 2021).
Kilifi	rehabilitating degraded mangrove areas in collaboration with communities and stakeholders, enforcing laws through surveillance and patrols, conducting regular monitoring, promoting sustainable farming practices, using spatial planning to designate development areas without encroaching on mangroves, and empowering communities through the formation and strengthening of Community Forest Associations (CFAs) for effective mangrove management.
Kwale	Promoting community involvement in managing mangrove areas, establishing a seed bank on Sii Island, restoring degraded mangroves, enforcing legislation against agricultural encroachment, building local capacity for sustainable mangrove forest management, promoting payment for ecosystem services (PES) schemes, and researching the connectivity of transboundary mangroves at Vanga. (Mwamuye et. al. 2021).
Tana River	Initiative tree-based livelihood options on lands situated outside mangrove sites and promote programmes that help in the adaptation of climate change effects.
Mombasa	The empowerment of Community Forest Associations (CFA) for mangrove conservation through training, study tours, and financing for implementing the Participatory Forest Management Plan (PFMP) (Mwamuye et al. 2021).

Table 6: Strategies for improving the conservation of mangroves Source: Multiple sources

The blue economy's emphasis on conservation has led to effective adopt-a-forest partnerships, transforming mangrove conservation with promising outcomes. For instance, the ongoing *Mikoko Pamoja* project, an innovative carbon credit, and PES scheme in Gazi Bay, Kilifi County, has shown that a local mangrove conservation scheme can have positive, sustainable development impacts by way

of protecting threatened ecosystems and improving the livelihoods of local community members. Gazi Bay, Kenya's residents lost 20% of their mangrove forests in 2010. They partnered with Plan Vivo and ACES to launch a conservation project. The project now protects 117 ha of mangroves with full-time guards and involves community members in regular reforestation efforts. The *Mikoko Pamoja* project generates income for Gazi and Makongeni communities by selling carbon credits from avoided CO_2 emissions. Payments from the sale of credits funded a project manager, guards, and community initiatives like purchasing books and installing clean water pumps at schools. The success of the *Mikoko Pamoja* project is attributed to the active involvement and support of Gazi and Makongeni residents. Transparent plans were agreed upon, addressing land use and revenue generation. Negative impacts were mitigated by planting pine trees as alternative building materials for the community.

4. Discussion

Mangrove forests in Kenya span an area of approximately 62,459.8 hectares, accounting for roughly 3.0% of the overall natural forest cover or less than 1.0% of the country's total land area (Table 3). The majority of mangroves, constituting about 59%, are found in Lamu County. Within Kenya, nine distinct species of mangroves exist, with Rhizophora mucronata Lam. and Ceriops tagal (Perr.) C.B. Rob. being the dominant species (National Mangrove Ecosystem Plan 2017-2027; Kairo et al. 2001).

Results also show that these critical ecosystems are still confronted with severe threats stemming from deforestation and degradation. The fundamental causes of mangrove loss and transformations are escalating population growth, deficient governance, inadequate appreciation of the true value of mangrove ecosystems, substantial poverty levels, absence of alternative livelihood options, and inadequate management guidelines. At the county level, there are unique challenges and threats, such as sedimentation, overexploitation, destructive fishing methods, pollution, changes in land use, and encroachment (Table 5). These threats appear to be causing repercussions on fisheries, shoreline stability, and the long-term sustainability of mangrove resources.

Nevertheless, there is a growing recognition of the ecological and socio-economic value of mangrove forests and the opportunities for local and national economic progress. The rich flora and fauna resources associated with mangroves provide essential ecosystem services needed for human well-being (Table 5). Reviewed literature has also agreed with these findings and has

highlighted the provisioning, regulating, supporting, and cultural benefits of mangrove resources (Howard et al. 2019; Biwas & Biwas 2019; Salampessy et al. 2015; National Mangrove Ecosystem Management Plan 2017-2027; Mwamuye et al. 2021). Therefore, it is imperative to safeguard and preserve them. Kenya appears to be committed to this course in view of the established favorable policy and legal environment for sustainable conservation and management of mangrove resources. From Table 2, the Constitution of Kenya, 2010 provides for the need to conserve ecologically sensitive areas in the country, amongst them mangrove sites. Other policy documents such as the Vision 2030, the Forest Conservation and Management Act, 2016, the Wildlife Conservation and Management Act, 2013, and the Environmental Management and Coordination Act, 1999 contain provisions that promote the sustainable management of mangrove resources.

However, the most overt indication of the government's commitment to the sustainable conservation of mangrove resources is the development of the objective-led National Mangrove Ecosystem Management Plan (2017-2027). The plan encompasses six distinct programs addressing various aspects of mangrove conservation and management in Kenya. These programs include forest conservation and utilization, fisheries development and management, community engagement, tourism development, research and education, and human resources and operations. Each program outlines specific measures and actions to be taken for the rehabilitation, conservation, and sustainable management of mangrove ecosystems throughout the country. The responsibility for implementing this plan lies primarily with the Kenya Forest Service (KFS). However, other important stakeholders, such as the Kenya Wildlife Service, the State Department of Fisheries, research institutions, academia, and community forest associations, will also play significant roles. To ensure effective coordination and collaboration among these entities, a National Mangrove Advisory Committee will be specially constituted, facilitating collective decision-making and sharing expertise and resources. By implementing the plan, Kenya aims to address the challenges faced by mangrove ecosystems and pave the way for their long-term conservation and sustainable use. The involvement of multiple key actors and the establishment of a dedicated advisory committee signifies the commitment to collaborative efforts and a multi-faceted approach toward preserving and managing mangroves.

The multi-stakeholder approach outlined in the National Mangrove Ecosystem Management Plan (2017-2027) has also been highly lauded as a feasible approach to combating the loss of mangrove forest resources in recent studies conducted

in the coast region of Kenya (Abuodha &Kairo 2001; Hanshi (2017); Karanja & Saito (2018); Mwamuye et al. 2021; Olago et al. (2023); Table 6). Reviewed global literature on other countries' cases, such as the Philippines, Vietnam, Ecuador, Brazil, Ghana, and Mexico, also encourages this approach to the sustainable management of mangrove resources (Rotich et al. 2016; Mangora 2011; Bosire et al. 2008). Other strategies include establishing seedbanks, legislating against encroachment, establishing proper benefit-sharing mechanisms, enforcing regulations to prevent overharvesting of mangroves, promoting payment for ecosystem services (PES) schemes, and researching the connectivity of transboundary mangroves at Vanga and other coastal regions (Table 6; Mwamuye et al. 2021).

However, in the author's opinion, the promotion of an incentives approach such as PES schemes, an economical approach where individuals or organizations receive financial incentives in exchange for implementing practices that protect and enhance ecosystem services, would yield a greater conservation impact. PES promotes the idea that those who benefit from ecosystem services provided by mangroves should financially support their conservation and restoration. There are already indications that the country could be moving in the PES direction because of the benefits of ongoing PES projects. A successful mangrove conservation project, the *Mikoko Pamoja* project in Gazi Bay, Kilifi County, espouses the aspirations of Kenya to be a hub of best practices in sustainable mangrove conservation and management. This project demonstrates the positive impacts of a local mangrove conservation scheme through carbon credits and PES. The project has protected 117 hectares of mangroves, engaged local communities, and generated income for community development. Project reviews indicate that the success of the *Mikoko Pamoja* project is attributed to the active involvement and support of Gazi and Makongeni residents, besides the implementation of mutually agreed upon transparent plans that addressed land use and revenue generation. There was also a comprehensive analysis of the socio-economic conditions of community stakeholders, which elicited the anticipated negative impacts of conserving the mangroves, which was then mitigated by planting pine trees on land parcels outside the mangrove sites for alternative building materials for the community, thereby easing pressure on mangroves. The provision of incentives is increasingly being practiced across the globe to promote the conservation of mangrove resources. Indonesia's Bio-right scheme exemplifies this assertion (van Eijk & Kumar 2009). However, caution should be exercised because most incentive programs require partnerships and cooperation among the institutions at the site level to support product marketing

from up to downstream (Thu et al. 2019; Locatelli et al. 2014; Byran et al. 2020; Zaldívar-Jiménez et al. 2017; Aheto et al. 2016).

The highlighted conservation actions and impacts from *Mikoko Pamoja* Project and similar initiatives could immensely contribute directly to the achievement of Kenya's commitments to achieving the Constitutional target of maintaining a national tree cover of at least 10% by the year 2030 and global commitments such as the Global climate change mitigation and adaptation under the Paris Climate change Agreement aimed at lowering GHG emissions by 32% by 2030 and commitments to Kenya's quest to restore 5.1 million hectares of forest and degraded landscapes which formed part of the African Forest Landscape Restoration Initiative (AFRI100) target and NDC target of reducing greenhouse gasses emission by 32% by 2030 relative to a business-as-usual scenario.

In summary, from the foregoing discussion, mangroves are critical national assets. However, changes in Kenya's socio-economic conditions occasioned by unsustainable harvest, climate change, and infrastructural development negatively impact this critical resource. In order to improve the management of mangrove resources, there is a need for enhanced community engagement, institutional capacity, awareness, and enforcement of regulations. Collaborative efforts between the Kenya Forest Service (KFS), local communities, Community Forest Associations (CFAs), Protected Forest Management Plans (PFMPs), and Forest Management Agreements (FMAs) are crucial. Specific strategies for each county include enforcing regulations, initiating reforestation programs, rehabilitating degraded areas, empowering communities, promoting sustainable farming practices, conducting regular monitoring, and implementing payment for ecosystem services (PES) schemes.

5. Conclusion and Recommendations

Mangrove resources are critical national assets that promote Kenya's socio-economic development and environmental stability. Despite the threats posed by changes in socio-economic conditions that negatively impact the resource, the sustainable conservation and management of mangrove resources require that all management actions be geared towards enhancing the ecological, social and economic values derived from these resources.

Kenya has demonstrated an unwavering commitment to protecting and restoring the remaining mangrove resources by establishing a conducive legal and policy environment for restoration actions. It is thus the opinion of the authors that these conservation efforts should be supported by all stakeholders in order to

ensure the sustainable conservation of mangrove resources. Even though challenges are still many based on the country-specific findings, several plausible strategies have been carried out for the management of the mangrove ecosystem in Kenya. These strategies include the development of the National Mangrove Ecosystem Management Plan (2017-2027) as an objective-led instrument for giving effect to collaborative management of mangrove resources, enhancing the enforcement of laws, establishment of seedbanks and promoting community livelihoods through PES schemes such as the *Mikoko Pamoja* Project. Nevertheless, there is a need for increased multidisciplinary collaboration in research and concrete initiatives focused on mangrove management. This is particularly crucial in tackling challenges related to climate change, equitable sharing of benefits, mangrove degradation, microbial diversity, pollution, and socio-economic concerns. In a nutshell, to safeguard mangrove habitats, conservation efforts include establishing protected areas, promoting sustainable resource use, engaging local communities, reforestation, pollution control, climate change adaptation, research, collaboration, policy support, and responsible tourism management. By implementing these desirable practices, Kenya can work towards the conservation and sustainable management of mangrove ecosystems, preserving their vital ecological roles and supporting the livelihoods of millions of people who depend on these valuable coastal habitats. However, one potential research limitation is that the study's reliance on the Google engine may affect the generalizability.

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