

NATIONAL MANGROVE ECOSYSTEM RESTORATION GUIDELINES (2025)



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Approval Page

These National Ecological Mangrove ecosystems Restoration Guidelines are approved as a technical reference.

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Preface



Mangrove forests along the Kenyan coast cover approximately 61,271 ha. These were declared reserve forests by Proclamation No.44 of 30th April, 1932 and later by legal notice No. 174 of 20th May, 1964. A National Mangrove Ecosystem Management Plan (2017-2027) was developed to guide the management and implementation of various management programmes. Mangroves provide goods and services that are of economic, ecological and environmental values at local, national, and international levels.

Mangrove forests along Kenya's coast are facing severe over-exploitation and degradation. Unfortunately, the significance of mangrove resources to local communities is often overlooked in restoration management strategies. To address this issue, Kenya developed the Mangrove ecosystems Restoration Guidelines. In 2023, the Kenya Forest Service (KFS) established a task force comprising key agencies to coordinate the preparation and development of these guidelines. The process involved gathering county-specific information through expert consultations, retreats, workshops, and field visits. Additional details on mangrove restoration were sourced from the Regional Mangrove Restoration Guidelines for the Western Indian Ocean (WIO) region and through direct contacts with ongoing initiatives in other regions for comparative learning.

This national guidelines on mangrove ecosystems restoration are designed to engage various stakeholders involved in restoration activities, including local communities, civil society organisations, national agencies, and conservation practitioners. This document aims to streamline mangrove restoration activities in Kenya by providing best practice approaches that are applicable at both community and institutional levels. These include:



(i) Mangrove ecosystem attributes,



(ii) Challenges and solutions to identified barriers to mangrove restoration, and



(iii) A step-by-step approach to mangrove ecological restoration.

This guidelines are hosted by the Kenya Forest Service (KFS), which is responsible for overseeing their implementation, dissemination, and revisions. It is expected that mangrove practitioners in Kenya will adopt these guidelines for effective ecosystem management and conservation.

Foreword

Mangrove forests play a crucial role in maintaining coastline integrity and biodiversity and supporting livelihoods and human well-being. However, these invaluable habitats face numerous threats, emanating from deforestation, habitat conversions, and increased incidence of natural hazards. Climate change impacts mangrove forests due to rising sea levels, ocean acidification and sedimentation. Recognising the importance of mangrove restoration and conservation for nature and society is critical for sustainable coastal development. Therefore, the development of the National Mangrove ecosystems Restoration Guidelines (2025) is a significant milestone in these restoration efforts. This will support the Government's agenda of successfully growing the 15 billion tree seedlings to increase the Country tree cover to 30% by 2032.

These guidelines provide a comprehensive framework for the restoration of mangroves and provide practical guidance for communities, government agencies, conservation organisations, and all practitioners involved in restoring these vital ecosystems for current and future generations. This document offers a holistic approach to mangrove restoration that is tailored to the unique ecological and socio-economic context of Kenya. By incorporating best practices and community engagement strategies, these guidelines aim to: (i) Restore the health and resilience of Kenya's mangroves; (ii) Enhance coastal ecosystem services; (iii) Support mangrove fisheries and biodiversity; (iv) Secure coastal communities' livelihoods; and (v) Contribute to climate change mitigation and adaptation.

These guidelines underscore the importance of collaboration and partnership among mangrove stakeholders, highlighting the need for shared commitment and collective action. This will address the complex challenges facing mangrove ecosystems and achieve meaningful conservation outcomes. The Nature Conservancy (TNC), through a grant to KMFRI, and additional support from Federal Ministry of Economic Cooperation and Development Germany (BMZ) through World Wide Fund for Nature-Kenya (WWF-Kenya) and Wetlands International, facilitated the development of these guidelines. A national task force was constituted by KFS, with members drawn from KFS, KEFRI and KMFRI coordinated the development of these guidelines. The National Mangrove Management Committee (NMMC) and an expert working group (Annex 1) assisted the task force in developing these guidelines. The process involved a wide consultative framework with key stakeholders including non-state actors, the private sector and the local communities along the Kenyan coast.



Acknowledgements

The mangrove restoration guidelines taskforce expresses gratitude to all individuals and organisations who contributed to the development of the National Mangrove ecosystems Restoration Guidelines (2025). Special thanks go to the Chief Conservator of Forests Director, Kenya Forestry Research Institute (KEFRI), and Chief Executive Officer, Kenya Marine and Fisheries Research Institute (KMFRI) for nominating the taskforce that offered leadership and coordination throughout the process. We are particularly grateful to the members of the NMMC for their support.

Our sincere appreciation goes to the technical team comprising members from KFS, KEFRI, KMFRI, the National Environment Management Authority (NEMA), *Jumuiya ya Kaunti za Pwani* (JKP) Kenya Fisheries Service (KeFS), WWF-Kenya, and Wetlands International-East Africa. Their expertise and commitment were instrumental in the creation of these guidelines. We also thank the Community Forest Associations (CFAs), local leaders, and community members who provided invaluable insights and support during field visits and consultations.

Lastly, we acknowledge the financial and technical support provided by TNC, WWF-Kenya, Wetlands International, and other partners. Your contributions were vital to the success of this initiative. Thank you all for your dedication to the conservation and restoration of Kenya's mangrove ecosystems.



Executive Summary

The National Mangrove ecosystems Restoration Guidelines (2025) aim to enhance and streamline the restoration of mangrove ecosystems along Kenya's coast. Recognizing the critical role mangroves play for human communities, biodiversity, and climate regulation, these guidelines seek to address the severe threats from over-exploitation, habitat conversion, and climate change. They provide a comprehensive framework for effective restoration practices, coordinating efforts among local communities, civil society organisations, national agencies, and conservation practitioners to ensure effectiveness, alignment, and collaboration. Additionally, these guidelines serve as a resource to improve knowledge and best practices in mangrove ecosystems restoration, guiding forest managers and stakeholders in selecting appropriate restoration methods.

These guidelines outline a detailed restoration process that emphasises stakeholder involvement for sustainable management and community engagement. This process includes thorough biophysical and social assessments to evaluate current site conditions, developing plans with clear restoration objectives, and implementing tailored restoration activities. To ensure success and continuous improvement, there is need to establish a robust monitoring and evaluation framework. The guidelines also address common challenges, proposing solutions such as early community engagement, enhanced knowledge management, and fostering stakeholder collaboration. Through case studies of successful projects, the document provides practical references and highlights the importance of a holistic approach, integrating ecological, social, and economic aspects. Overseen by KFS, these guidelines are expected to enhance the resilience and sustainability of Kenya's mangrove ecosystems, contributing to coastal protection, biodiversity conservation, and community livelihoods.



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Acronyms and Abbreviation

BMUs	Beach Management Units
BMZ	Federal Ministry of Economic Cooperation and Development (Germany)
CFAs	Community Forest Associations
CMMC	County Mangrove Management Committee
EMR	Ecological Mangrove Restoration
FSM	Forest Station Manager
GIS	Geographic Information System
GoK	Government of Kenya
Ha	Hectares
IGAs	Income Generating Activities
JKP	<i>Jumuiya Ya Kaunti Za Pwani</i>
KEFRI	Kenya Forestry Research Institute
KeFS	Kenya Fisheries Service
KFS	Kenya Forest Service
KMFRI	Kenya Marine and Fisheries Research Institution
MDAs	Ministries, Departments and Agencies
MEA	Millennium Ecosystem Assessment
NbS	Nature-based Solutions
NEMA	National Environment Management Authority
NMMC	National Mangrove Management Committee
PBOs	Public Benefits Organizations
SLR	Sea Level Rise
sp.	Species

Glossary

Driver: An agent of change in the ecosystem, it could be human-induced or a natural factor. Drivers can result in negative or positive effects on mangroves, so it's important to understand them for planning how to protect mangroves.

Degradation: is the long-term reduction in overall supply of benefits from ecosystems, which includes wood and non-wood products, biodiversity and other ecosystem services.

Mangrove ecosystem degradation: refers to biotic or abiotic processes that result in the loss of productive potential of mangrove ecosystems. Degraded mangrove areas may take a long time to recover thus requiring human intervention.

Enrichment planting: The process by which one plants trees to increase the population density of existing tree species or increase tree species richness by adding tree species to a degraded forest.

Threat: This is something that can damage mangroves, like cutting down trees or pollution. Unlike drivers, threats usually have bad effects on mangroves. Conservation efforts focus on stopping threats to keep mangroves healthy and safe.

Rehabilitation: is a process of restoring or improving some aspects of an ecosystem, but not necessarily to restore fully all components.

Restoration: is the process of assisting in the recovery of ecosystems that have been degraded, damaged or destroyed, and focuses on establishing the ecological processes necessary to make ecosystems sustainable, resilient, and healthy under current and future conditions.

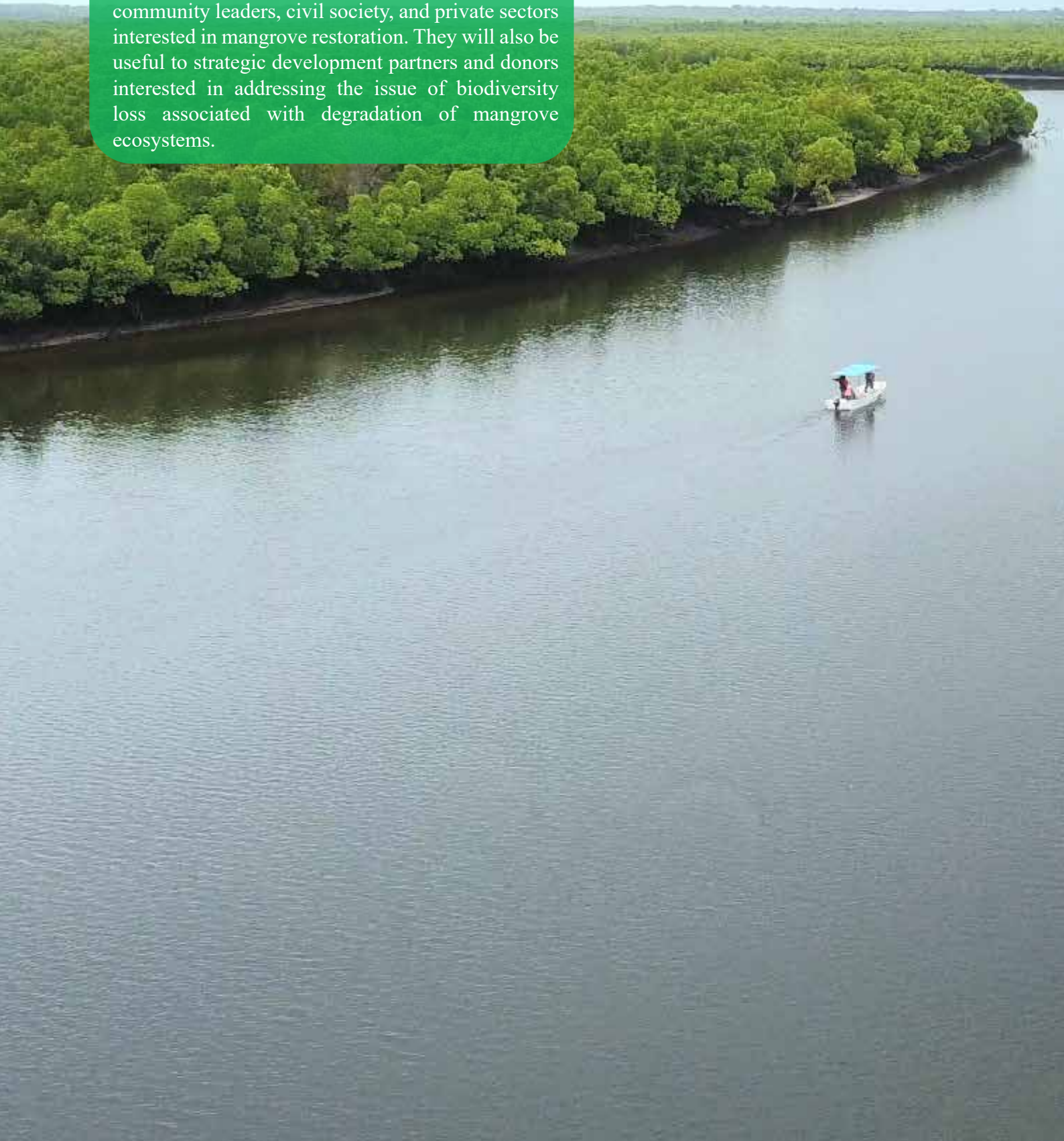
Forest formation: a descriptive term used to group stands of similar characteristics and species composition by which they may be differentiated from other groups. It may also mean cover type or forest type.

Restoration plan: A site-specific methodology/document that guides the steps to follow for the restoration of mangroves. It may also involve identifying appropriate restoration approaches/techniques, strategies, and costs of the restoration.



Target audience

These guidelines will benefit all stakeholders involved in mangrove restoration activities in Kenya. These guidelines are intended for various groups, including project managers, practitioners, foresters, community leaders, civil society, and private sectors interested in mangrove restoration. They will also be useful to strategic development partners and donors interested in addressing the issue of biodiversity loss associated with degradation of mangrove ecosystems.



1.0 BACKGROUND INFORMATION



1.0 BACKGROUND INFORMATION

1.1 Mangroves of Kenya

Mangrove forests are a common feature in creeks, protected bays, lagoons, and deltas of major rivers spread across the 600 km Kenyan coastline. According to the National Mangrove ecosystems Management Plan 2017-2027 (NMEMP), the area of mangroves in Kenya is given as 61,271 ha, representing approximately only 3.0% of the area under natural forests or less than 1% of the national land area (GoK, 2017). Approximately 61% (37,350 ha) of mangrove forests occur in Lamu County (Table 1).

Table 1: Mangrove areas in the five counties along the Kenyan coast

County	Mangrove area (ha)	Percentage representation (%)	Non-mangrove areas (water ways, salt pans, bare saline areas) (ha)
Lamu	37,350	61	61,836
Tana River	3,260	5	1,382
Kilifi	8,536	14	12,092
Mombasa	3,771	6	5,513
Kwale	8,354	14	7,205
Total	61,271	100	80,823

There are nine mangrove species found in Kenya with *Rhizophora mucronata* (Mkoko) and *Ceriops tagal* (Mkandaa) representing more than 80% of mangrove formations (GoK, 2017). The less occurring species *Heritiera littoralis* (Mkungu) and *Xylocarpus moluccensis* (Mkomafi dume) are restricted to inter-tidal areas toward the landward side. These guidelines use both specific and local names as referenced in the National Mangrove ecosystems Management Plan 2017-2027 (Table 2).

Table 2: Mangrove species identified in Kenya

Scientific Name	Local Name	Uses
<i>Avicennia marina</i> (Forsk.) Vierh.	Mchu/Mtu	Firewood, fencing, dug-out canoes
<i>Bruguiera gymnorrhiza</i> (L.) Lamk.	Muia/Msinzi	Poles, firewood
<i>Ceriops tagal</i> (Perr.) C.B. Robinson	Mkandaa	Poles, firewood
<i>Heritiera littoralis</i> Aiton.	Msikundazi	Poles, boat masts
<i>Lumnitzera racemosa</i> Willd.	Kikandaa	Firewood, ribs for boats
<i>Rhizophora mucronata</i> Lam.	Mkoko	Poles, firewood, charcoal
<i>Sonneratia alba</i> Sm.	Mlilana	Firewood, boat masts, floaters for fishing nets
<i>Xylocarpus granatum</i> K.D.Koenig	Mkomafi	Poles, firewood, carving
<i>Xylocarpus moluccensis</i> M.Roem.	Mkomafi dume	Firewood, fencing

1.2 Mangrove Forest Types

Mangroves may be classified into at least six forest types according to their growth form and structural characteristics (Table 3). Generally, mangrove trees in Kenya do not exceed 15m in height. However, in some cases they may attain a height of more than 30m, particularly at the creek edges and other areas containing recent sediment deposits (Ferguson, 1993).

Table 3: Mangrove Forest Types in Kenya

Mangrove forest type	Description
Fringing mangroves	Occurs mostly on the gentle coastline that is frequently inundated by tides.
Riverine mangroves	These are mangroves influenced by freshwater input and usually occur at the edge of major rivers draining into the oceans.
Basin mangroves	Have no direct link with the ocean; and are found at the back of both fringing and riverine mangroves.
Over-wash mangroves	These are dominated by intertidal isolated mangroves on the seaward side such as stands of <i>S. alba</i> .
Dwarf or stunted mangroves	Scrub forests are common in abnormal or equinoctial tidal reach, having tidal inundation of a few days per month.
Hammock mangroves	These are similar to basin mangroves but are formed over accumulated mangrove-derived peat.

Mangroves in Kenya would normally, but not always, display a horizontal distribution of species (or zonation) which is influenced by salinity tolerance, inundation regimes, and predation pressure, among other factors (Fig. 1). In a typical mangrove ecosystem, the seaward margin is normally occupied by *Sonneratia alba*. This is often followed by *Rhizophora mucronata*, then *Ceriops-Bruguiera* community and then *Avicennia marina* and/or *Xylocarpus sp.* to the landward side. *Lumnitzera racemosa* is normally found fringing the land-ward side. Except in the Tana River Delta where it forms a pure stand, a few individual trees of *Heritiera littoralis* are normally found on the landward edges. Often, un-vegetated sandflats are found interspersed, particularly towards the landward areas, within the vegetated areas. Such bare areas have extreme salinity and temperature conditions that reduce colonisation by plants. Annual herbs, especially *Sesuvium portulacastrum*, grow in these bare areas. Such areas are also inhabited by a variety of faunal species, especially some species of fiddler crabs. Knowledge of mangrove distribution across the intertidal area is important in designing restoration programmes for the degraded mangrove ecosystem.

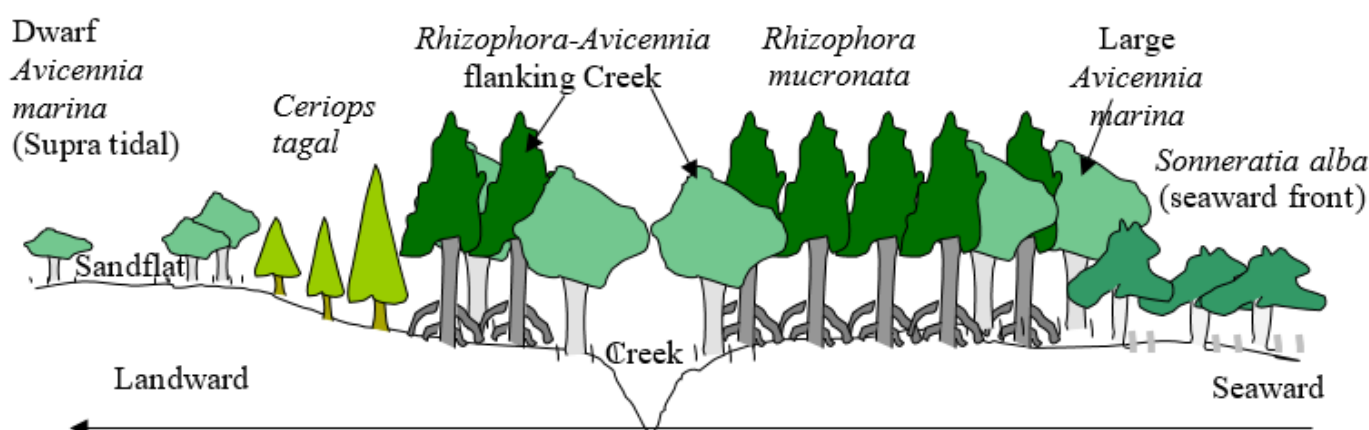


Figure 1. Mangrove zonation profile typical of the Kenyan mangrove forests depicting predominant vegetation formations (adapted from Lang'at, 2008).

1.3 Mangrove Biodiversity



Mangrove forests have a comparatively low species diversity compared to their terrestrial counterparts. There are only nine species of mangroves found in Kenya (Table 2). Other mangrove-associated plant species, including *Hibiscus tiliaceus*, *Pemphis acidula*, *Suaeda maritima*, *Sesuvium portulacastrum*, and *Salicornia* sp. that occur mostly on the landward edge of the intertidal system (Fig. 2) (Ferguson, 1993). The terrestrial flora commonly occurring on branches of mangrove trees mainly comprise lichen and mistletoes.

Mangroves provide habitats, breeding grounds, nurseries and food which support a large variety of fauna ranging from birds, fishes, reptiles, amphibians, mammals, micro-organisms, and aquatic as well as terrestrial invertebrates. These organisms inhabit the mangroves' specialised roots (pneumatophores), soil, trunks, and canopies. The widely ramified mangrove roots provide perfect anchorage for sponges, algae and mussels, while prawns, crabs and fish use the open area between the roots for shelter, spawning, and food sources. Crabs are among the most abundant and diverse groups of invertebrates inhabiting mangroves (Fig. 2). These crabs create burrows, oxygenate sediments, enhance groundwater penetration, and provide habitats for other invertebrates like molluscs and worms.

The rooting system establishes a complex structure that shields juvenile fish and some organisms in the water column from predators while offering solid substrate for the attachment of algae, as well as sessile and mobile invertebrates (e.g. oysters, mussels, sponges, and gastropods). The roots also protect soils from erosion, stabilising a habitat that is exposed to continuous tidal movements. The diversity of benthic (micro/macro-organisms) communities, including molluscs, polychaetes, and other invertebrates, is supported by the organic-rich substrate found within the mangrove ecosystem. The substrate contributes significantly to the overall biodiversity of the mangrove habitat.

Organic matter present in mangrove sediments originates within the mangrove ecosystems as well as transported by tides and riverine input from other habitats. Above the water, reptiles, amphibians, birds and insects use the trunks and canopy's wide network of branches. Many animal species such as monkeys, crocodiles, and hippopotamuses, use the dense forest system as shelter and food sources. With the ongoing loss of the mangrove ecosystems, many associated animal and plant species are at risk of habitat loss and possibly extinction within the affected areas.



Figure 2. Some plants and fauna found in mangrove ecosystems: top left; *Suaeda* sp. (*Msabuni bara*), top right; *Salicornia* sp., bottom left; Malachite kingfisher (*Alcedo cristata*), bottom middle; a crocodile, and bottom right; fiddler crab (*Uca* sp.)

1.4 Mangrove Ecosystem Services

Mangrove forests provide goods and services that are of ecological, environmental, and economic value to the people. Some of the important goods and services provided by mangroves in Kenya are listed below (Fig. 3) based on the comprehensive systems of classification of ecosystem services, Common International Classification of Ecosystem Services (CICES) and Millennium Ecosystem Assessment (MEA, 2005). The total estimated value of services from mangrove ecosystems in Kenya is approximately US\$ 85 million annually (Erftemeijer et al 2022).

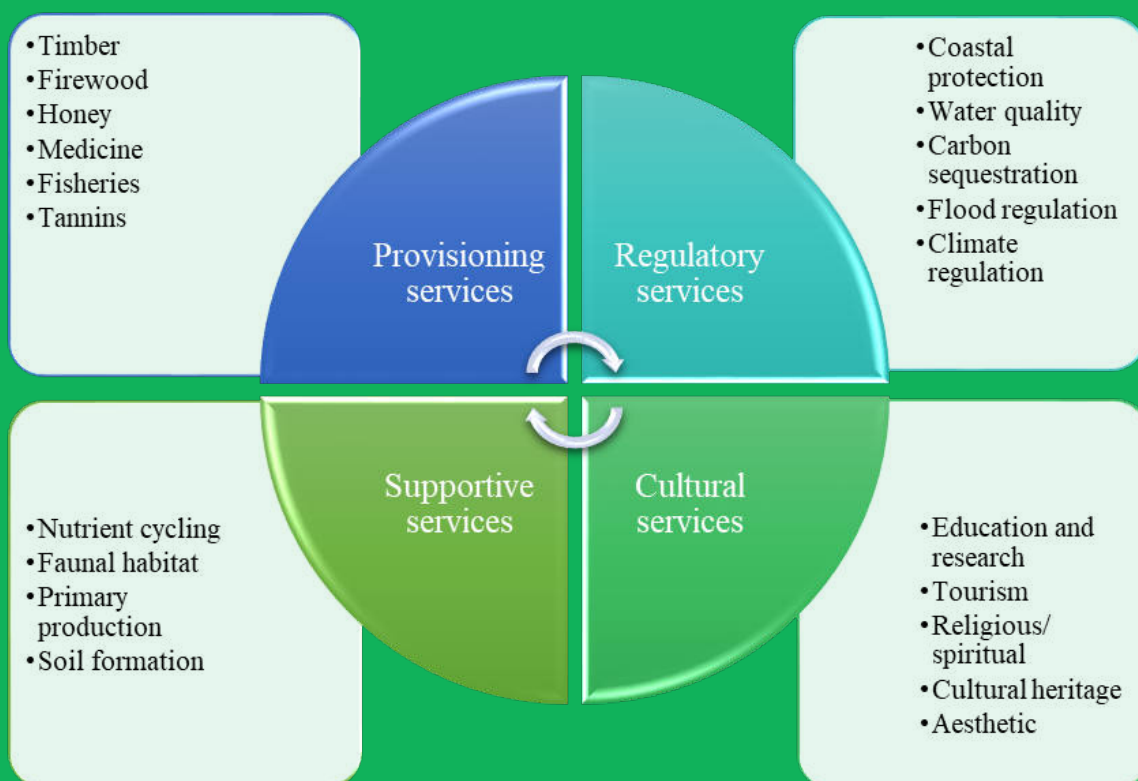


Figure 3. Mangrove goods and services; total estimated economic value is US\$ 85 million/year

1.5 Connectivity with other Habitats

Mangrove ecosystems are dynamic and intricate coastal habitats that are characterised by a myriad of interlinked processes and components such as water purification, sediment trapping and nutrient cycling. Understanding the linkages between these ecosystems is crucial for comprehending their function, resilience, and response to environmental changes. Mangroves are located at the interface between land and sea which contributes to their rich biodiversity, as well as making them vital for protection and livelihood support of coastal communities.

The complexity and heterogeneity of the vegetation structure maintain ecosystem functions and facilitate the colonisation of diverse faunal communities. The faunal community in turn influences the mangrove structure and functioning through burrowing and grazing, particularly the macro-benthic species. There are essential links between mangrove trophic levels such as detritus and consumers that can often be used as bio-indicators of ecosystem health. Despite the wide array of mangrove co-benefits, the depletion of this resource or unfavourable changes in management policy pose significant social and economic threats to resource-dependent communities.

2.0 SITUATIONAL ANALYSIS OF MANGROVE ECOSYSTEM IN KENYA



2.0 SITUATIONAL ANALYSIS OF MANGROVE ECOSYSTEM IN KENYA

2.1 Status, Conditions, and Trends

Mangroves were declared government reserve forests by the Proclamation No. 44 of 30th April 1932, and later by Legal Notice No. 174 of 20th May 1964. Under this “Gazette Notification for Mangrove Forests in Kenya” all land between high water and low water marks (ordinary spring tides) are described as mangrove areas (GoK, 2017). They have played a long and important role in the history of human activity on the East African coast. Records indicate that along with slaves and ivory, mangrove poles made up a major regional trade by the 9th Century. Mangrove exploitation for building poles forms a subsistence livelihood for local people along the coast, with Lamu County exhibiting the highest dependence. For many years, house construction in Arab countries was dependent on mangrove poles brought by dhows (traditional Arab boats) from the East African coast (GoK, 2017).

Over the years, mangrove ecosystems in Kenya have been subjected to degradation stemming from human-induced and natural drivers (GoK, 2017; Hamza et al., 2020). This degradation is most evident in declining mangrove canopy cover. At least 40% of existing mangrove forests in Kenya are perceived to be in degraded conditions resulting in impaired ecosystem functionality. Though the available information on mangrove degradation shows discrepancies due to methodological differences, these estimates show a consistent decline in mangrove cover (FAO 2007; Kirui et al., 2013; Eftermeijer et al., 2022).

Despite the decrease in the rate of mangrove cover loss in recent years, some areas still experience high degradation levels (Table 4), with peri-urban mangroves in Mombasa County being the most affected (Kirui et al., 2013; Bosire et al., 2014). Major drivers of mangrove cover change in Kenya include over-exploitation of wood products, conversion of mangrove areas to other land uses, pollution, and climate change (Kitheka et al., 2002). Over-reliance by coastal communities associated with increased population, poverty and inequality, inadequate financial resources, economic drivers and poor governance, are equally linked to the loss and degradation of mangroves in Kenya (Fig. 4). A decline in mangrove extent, ecosystem health and functionality have direct impacts on fisheries, resource sustainability, and coastal stability.



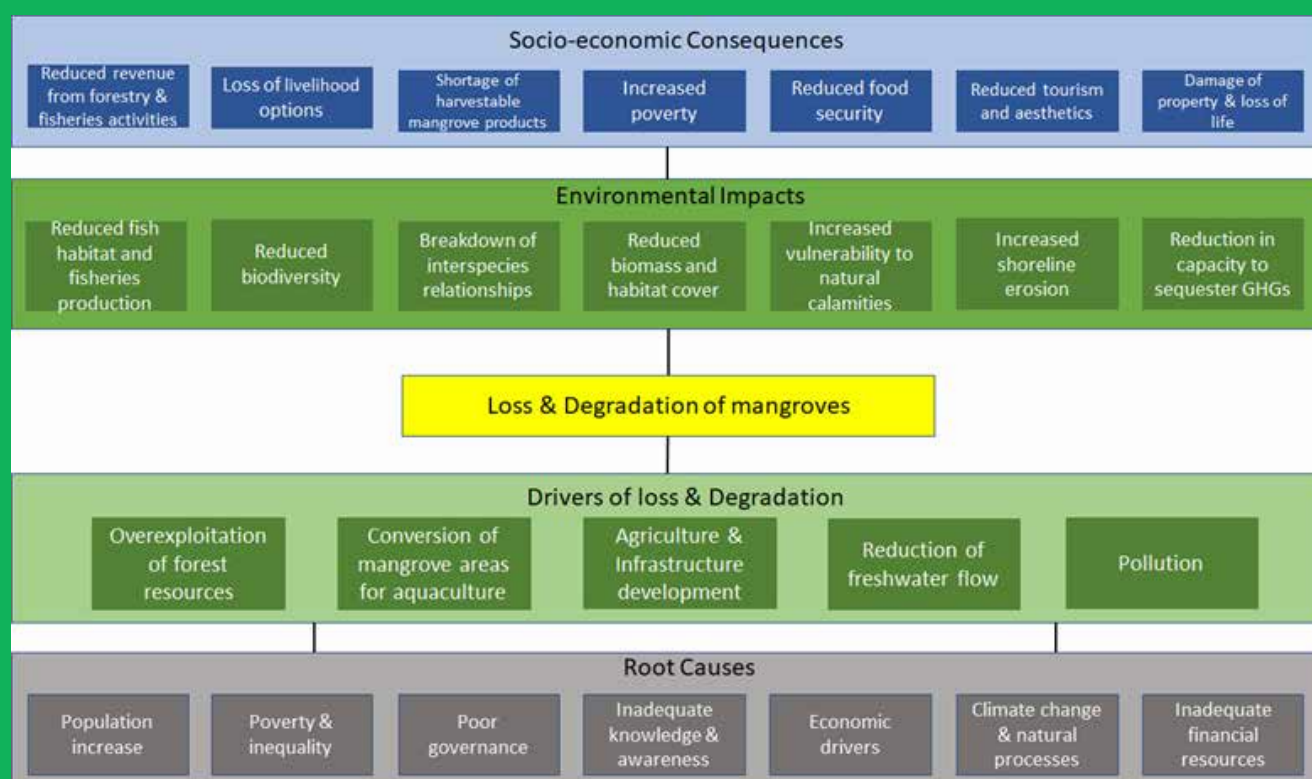


Figure 4. Root-cause analysis of mangrove loss and degradation in Kenya

Table 4: Levels and drivers of degradation and decline of mangrove ecosystems in Kenya

County	Degraded area (ha)	Main Threats	Agents/Drivers	Degradation levels and trends	Hotspots Areas
Lamu	14,407	Illegal cutting, die-back	Livestock, sedimentation, coastal development, pests and diseases, encroachment, windthrow, pollution	Moderate	Tchundwa, Bwajumwali, Siyu, Pate, Mtangawanda, Bori, Kizingitini, Nda, Njia ya ndovu, Kililana, matondoni, Mkunumbi, Mwabore and Rubu
Tana River	1,180	Illegal cutting, fire	Sedimentation, siltation flooding, erosion, encroachment, livestock, pests and diseases, climate change	Moderate to severe	Delta dunes, Kalota, Katsan-gani, Bujra, Bandarini, Funana, Mgombani, Mabandani, Haja, Adung'onda, Mulikani, Kakoneni, Mtotana channel, Kitiwani.
Kilifi	3,422	Illegal cutting, forest encroachment, conversion, die-back	Sedimentation, siltation, erosion, sewage pollution, brine seepage/disposal from salt works, conversion to other land uses (salt pans)	Moderate to severe	Mtwapa and Ngomeni
Mombasa	1,850	Illegal activities	Sedimentation siltation, oil and sewage pollution, encroachment	Moderate to severe	Tudor, Makupa
Kwale	3,725	Illegal activities	Damming of rivers, coastal development, sedimentation, siltation, erosion, flooding, wave energy	Low to moderate	Mwache, Ramisi and Gazi bay

2.2 SWOT Analysis of Mangrove Restoration Efforts

Declining mangrove cover and increasing public awareness have sparked interest in the conservation, rehabilitation, and sustainable management of this resource in Kenya. This increased awareness of the value of and threats facing mangroves led to the development of the National Mangrove Ecosystem Management Plan (2017-2027). The plan aims to foster sustainable resource management, as well as stakeholder engagement and collaboration by highlighting approaches that enhance ecosystem integrity. Aspects of co-management, equitable use, access and tenure for the communities living adjacent to mangrove forests are addressed in the management plan which compliments the Forest Conservation and Management Act, (Cap. 385) and other environmental policies in Kenya. These policies provide an enabling environment for the effective management of mangrove forests and stakeholder groups involved in mangrove conservation activities.

To assess the impact of mangrove restoration efforts an assessment of the strengths, weaknesses, opportunities, and threats (SWOT) was conducted. The success of restoration efforts in Kenya can be summarised based on issues surrounding governance, regulation of human activities, resource mobilisation and incentivising conservation efforts (Table 5).

S *Strengths* culminate from a combination of a supportive environment, engaged stakeholders, and access to knowledge and data creating a foundation for successful mangrove restoration.

W *Weaknesses* arise from the inability to overcome knowledge gaps and management challenges influencing the decision-making process, securing resources, and achievement of long-term success for mangrove restoration initiatives.

O *Opportunities* such as incentivising conservation efforts coupled with emerging market opportunities, and supportive policies create a positive environment for mangrove restoration initiatives, promoting both environmental benefits and sustainable socio-economic development.

T *Threats* which often act synergistically can exacerbate each other whereby climate change can impact the incidence of pests and diseases in mangrove areas.



Table 5: SWOT Analysis of Mangrove Restoration in Kenya.

Strengths	Weaknesses
● Goodwill from local communities and policy makers towards addressing mangrove degradation and restoration initiatives ● Supportive national and international policies and legal instruments on ecosystem management and restoration ● Existing technical capacity in multi-disciplinary research and restoration potential assessments ● Technological capacity in remote sensing and geographical information systems supporting mapping of degraded sites and real-time monitoring of restored sitesImproved mangrove management at both national and county levels ● Willingness of stakeholders to participate in mangrove restoration initiatives ● Improved understanding of the role of mangroves in climate change mitigation and adaptation ● Data on degraded mangrove sites is availableVibrant Community Forest Associations with high interest in restoration efforts	● Inadequate knowledge management that influences accurate decision-making in mangrove restoration efforts ● Inadequate information dissemination on best practices for mangrove ecological restoration ● High dependency on mangrove wood resources ● Low investment in mangrove-based nature-based enterprises such as carbon financing ● Limited standardised reporting templates for mangrove restoration projects ● Inadequate monitoring and evaluation of previously undertaken restoration efforts ● Inadequate inventory data for mangrove management ● Weak linkages between research and ongoing restoration efforts ● Weak enforcement in regulating entry into mangrove forests resulting into degradation ● Inadequate stakeholder engagement hindering restoration initiatives ● Conflicting and overlapping institutional mandates



Opportunities	Threats
● High interest and funding opportunities for mangrove restoration projects ● Nature-based solutions and enterprises for mangrove conservation ● Job creation and livelihood improvement ● Emergence of green, blue and circular economies to incentivize stakeholders on mangrove restoration initiatives ● Emerging of payment for Ecosystem services, including carbon financing ● Existence of a regional framework for sustainable forest management such as The UN Decade of Ecosystem Restoration ● Availability of research and education opportunities ● Public-private partnership frameworks on mangrove restoration initiatives	● Vulnerability of mangroves to climate change (flooding, sea level rise, saltwater intrusion) and other natural calamities including pests and diseases ● Encroachment and conversion of mangrove areas to other land uses ● Increased shoreline changes ● High demand for forest goods and services driving mangrove forest degradation ● Coastal development ● Land-based inappropriate land use practices and human activities ● Low level of awareness amongst stakeholders



3.0 ECOLOGICAL RESTORATION OF MANGROVE ECOSYSTEMS



3.0 ECOLOGICAL RESTORATION OF MANGROVE ECOSYSTEMS

3.1 Overview

Restoration is the process of assisting in the recovery of ecosystems that have been degraded, damaged or destroyed, and focuses on establishing the ecological processes necessary to make ecosystems sustainable, resilient, and healthy under current and future conditions while improving human well-being. It, therefore, broadly involves the act of returning a degraded mangrove ecosystem close to its original condition in terms of its structure and functionality. It aims to achieve the ecosystem's natural processes and dynamics through re-establishing species biodiversity, habitat quality, and ecological functions. As opposed to rehabilitation, restoration is challenging to accomplish because it works towards improving the conditions and functionality of a degraded ecosystem without necessarily looking to recreate its original state. Mangrove forests can regenerate if their natural prerequisites are met, including an undisturbed tidal regime and unhindered availability of seedlings. Assisted mangrove restoration is recommended when an ecosystem undergoes significant changes that prevent self-recovery. Ecological mangrove restoration has the potential to increase the mangrove resource base, conservation of biodiversity, coastal protection and stability, and create employment for local populations (UNEP, 2014).

3.2 Rationale for the National Mangrove Ecosystems Restoration Guidelines

The rationale for the National Mangrove Ecosystems Restoration Guidelines encompasses several key aspects that justify the need for a structured approach to restoring these critical ecosystems. These guidelines are a consolidation of science and evidence-based knowledge and information and best practices for ecological mangrove restoration in Kenya, regionally as well as globally. The purpose of these guidelines is to provide information and build the capacity of individuals, communities, the private sector, development partners, forest managers and other stakeholders on the concept of ecological mangrove restoration. These guidelines have been designed to provide descriptions of approaches and also activities that help mangrove restoration implementers understand and undertake successful ecological mangrove restoration. It is designed to be a practical guideline that allows restoration practitioners to develop an appropriate design and work plan for successful mangrove restoration projects.

3.3 Purpose of the Guidelines

Mangrove restoration projects in Kenya involve a diverse array of stakeholders with different backgrounds and agendas. However, successful collaboration and alignment of objectives are crucial for project success. Past failures have been attributed to factors such as insufficient community involvement, inadequate governance structures, and a disconnect between the goals of external agents and local stakeholders. The focus of these National Mangrove Ecosystems Restoration Guidelines (2025) is to bring practitioners through the major steps of mangrove restoration initiatives. These guidelines have been designed to provide descriptions of approaches and activities that help readers understand key concepts and build important skills. They are designed to be practical so as to engage users and other key stakeholders in undertaking restoration activities, with supporting reference materials. The guidelines give instructions on collecting qualitative and quantitative data. During the assessment phase users will better understand mangrove restoration challenges to enable them develop an appropriate design and work plan for successful mangrove restoration. 27 The guidelines also provide a framework for navigating the complexities of mangrove restoration projects by emphasising several considerations.

3.4 Objectives

The National Mangrove Ecosystem Restoration Guidelines (2025) have several key objectives:

- i. To coordinate restoration efforts by establishing a formal framework. This will foster better alignment and collaboration among stakeholders involved in mangrove restoration initiatives.
- ii. To enhance understanding and knowledge of mangrove ecosystems restoration practices among restoration project managers and other interested parties.
- iii. To serve as a resource to guide the selection of appropriate restoration approaches for different degraded sites. For restoration initiatives that involve planting of mangroves, these guidelines seek to determine the optimal number of seedlings or propagules to be planted per hectare, the planting density in a particular degraded site depending on the level of degradation, mangrove species to be planted, among other factors.
- iv. To offer insights into best practices for producing high-quality mangrove seedlings in nurseries. This will contribute to the overall effectiveness and success of mangrove restoration endeavours.

The desired outcomes include higher success rates for restoration initiatives/activities, increased resilience and biodiversity in restored mangrove ecosystems, improved coastal protection, and ecosystem services provided by mangrove habitats. When compared to scenarios without any restoration actions, it is expected that there will be a significant increase in mangrove coverage and biodiversity, improved health and resilience of ecosystems, and greater socioeconomic benefits for local communities that depend on mangrove ecosystems.

In terms of timeline, the short-term goals involve immediate improvements in stakeholder engagement, project coordination, and knowledge sharing. The medium-term objectives focus on tangible progress in restoration efforts and noticeable increases in mangrove coverage and biodiversity. The long-term aspirations include the sustainable management and conservation of restored mangrove ecosystems, leading to lasting benefits for both ecosystems and communities.

Timeline of Goals



3.5 Step-by-step Procedure for Mangrove Restoration

3.5.1 Overview

In considering the restoration of mangrove areas: potential rehabilitation sites must be identified. Once this is done, determine the stress factors and level – What was/is the agent of degradation/damage? How severe is the damage? Is it going on? If so, how can it be addressed? In identifying potential rehabilitation sites and determining the stress factors, it is ideal to take into consideration the golden rules of a successful re-forestation project (Lewis et al., 2009; Di Sacco et al., 2021; KEW and BGCI, 2021), summarised in Fig 5.

Box 1: Golden Rules of Ecological Restoration of Mangroves

This box outlines a detailed process for restoring a degraded mangrove site:

1. **Understand Mangrove Autoecology:** Begin by thoroughly understanding both the autecology (the relationship of individual species to their environment) and the community ecology of mangrove species. Record noticeable shifts in species composition as a result of degradation.
2. **Understand Hydrologic Regimes:** Identify and understand the appropriate hydrological conditions necessary for mangrove survival and growth. Follow the natural zonation of mangroves to correctly identify tidal regimes.
3. **Assess Factors Hampering Succession:** Evaluate the factors that hinder natural succession and regeneration of mangroves both natural and anthropogenic. Identify the level of impact and corrective measures to be undertaken.
4. **Survey Community Needs:** Conduct surveys to understand the needs, traditions, perceptions, and alternatives of subsistence users. Indigenous knowledge should supplement scientific knowledge. This helps ensure that restoration efforts are sustainable and beneficial to local communities.
5. **Select Appropriate Restoration Sites:** Choose restoration sites based on the information gathered in steps 1-4, ensuring the selected areas have the potential for successful restoration. Define the type of restoration to be undertaken; Assisted Natural Regeneration (Protection, Hydrological) or Planting.
6. **Restore Hydrology and Remove Barriers:** Implement measures (breaking dykes and or creating channels) to restore natural hydrological conditions.
7. **Select Appropriate Species for Planting:** Identify and select the suitable mangrove species, populations, and individuals for planting, considering the specific conditions of the restoration site.
8. **Mangrove Planting:** Proceed with the planting of mangroves in areas where natural regeneration is insufficient. Use recommended spacing and densities.
9. **Assessment of Success and Functionality:** Monitor and evaluate the restoration site to assess the success and functionality of the mangrove ecosystem. This includes:
 - **Assessing Vegetation Development and Floristic Succession:** Monitor the growth and development of mangrove vegetation and the succession of plant species.
 - **Faunistic Recruitment:** Evaluate the recruitment and presence of animal species in the restored site.
 - **Environmental Factors and Processes:** Monitor changes in environmental conditions and processes that impact the restoration site.
 - **Monitoring Potential for Sustainable Utilization:** Assess if the restored site can support sustainable use.
10. **Recommendations for Site Management:** Based on the assessment outcomes, provide recommendations to improve site management and ensure long-term success of the restoration project.

If assisted natural regeneration or planting fails at any step, the process involves reassessment and taking corrective actions to address the issues identified. This iterative process ensures that restoration efforts are continuously improved and adapted to achieve successful outcomes.

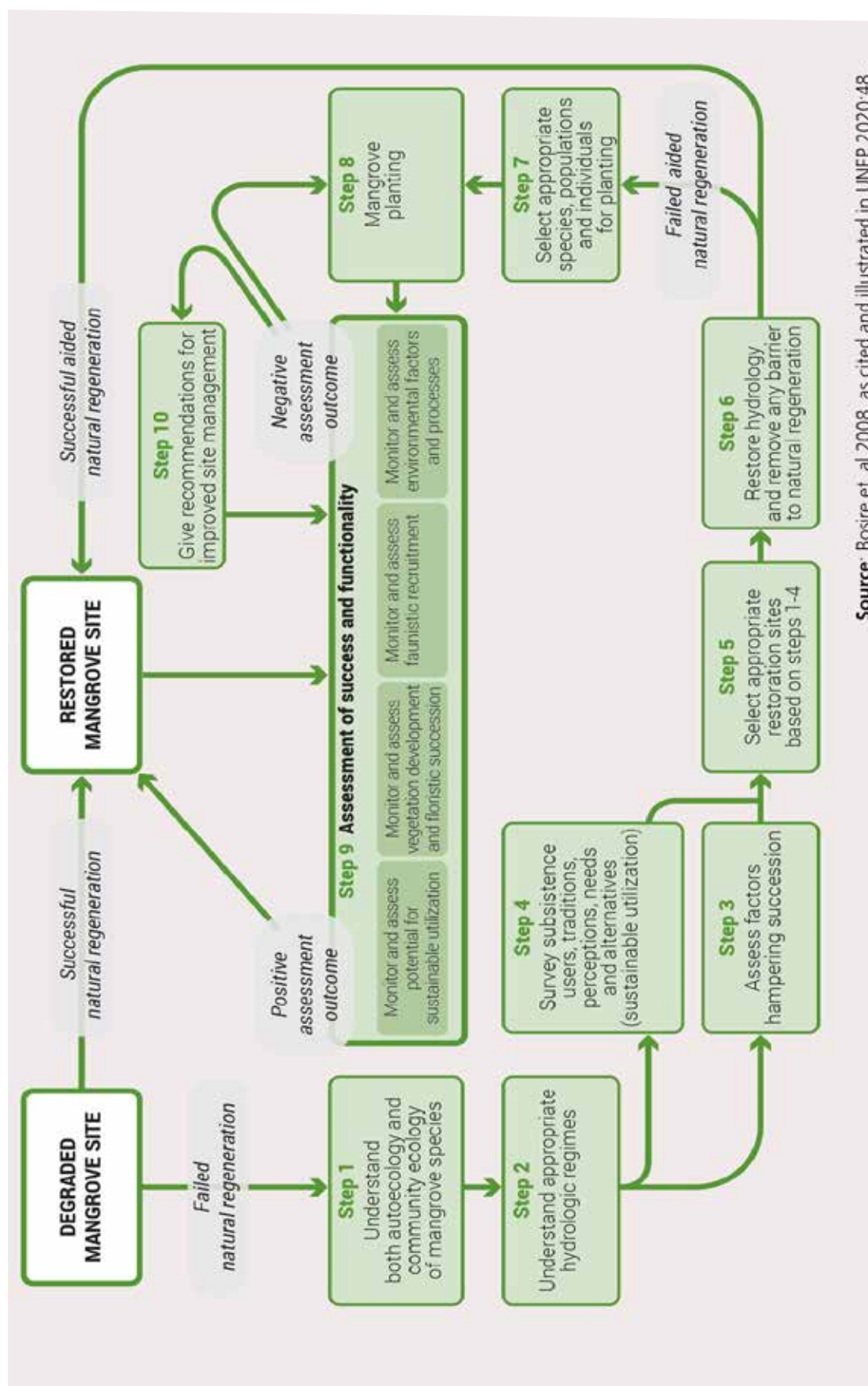


Figure 5. Step-by-step procedures for mangrove restoration (Lewis 2005; UNEP 2020)

3.5.2 Stakeholder Analysis and Engagement

To effectively restore mangroves, it is crucial for practitioners to first identify and engage with stakeholders of the designated restoration site. This process involves identifying the relevant actors and assessing their level of influence and interests. Stakeholders may include government (national government ministries, departments and agencies (MDAs), and county governments), private entities (individuals, companies, and NGOs), and communities. Successful mangrove restoration requires collaborative efforts from a diverse group of stakeholders. Each stakeholder adds valuable perspectives, resources, and expertise to the table. By actively involving and mobilising these stakeholders, restoration practitioners can effectively strive towards long-term conservation and sustainable management of mangrove ecosystems.

3.5.3 Restoration Potential Assessment of Degraded Areas

To determine the restoration potential of a degraded site, it is very crucial to conduct a site assessment, which will assist in characterising the types and levels of degradation and thereby facilitate the design of an appropriate restoration plan for the selected site. A degraded mangrove site includes changes in abiotic (physical) factors such as soil conditions (e.g. soil texture, salinity), topography (slope) and inundation (tidal flooding regimes) and biotic factors such as vegetation and fauna (animals) species composition and structure.

Changes in abiotic factors normally result in adverse (unfavourable) conditions that may inhibit mangrove recruitment or lead to changes in species composition and structure. Changes in biotic attributes may lead to reduced functionality of the mangrove ecosystems. For example, shifts in species composition and changes in forest structure may lead to reduced sources of mangrove wood. Therefore, site assessment is very important for determining the restoration potential which involves describing its biophysical attributes and the associated sociological aspects (Table 6).

Table 6: Assessment of restoration potential in a degraded mangrove area

Biophysical assessment	Sociological assessment
- Assess sediment characteristics (e.g. salinity, pH, soil moisture, and texture) - Assess the topographic and hydrological regimes (e.g. inundation levels/zones, wave energy, freshwater input, etc.) - Assess vegetation attributes in the area (forest structure, species composition, etc.) - vegetation in the adjacent area can provide a clue of what a healthy forest in the area would be like - Assess any natural regeneration occurring in the area or the adjacent sites	- Assess site history including, site conditions and levels of degradation that have occurred in the site - Drivers of degradation, and trends (whether the drivers are still exerting pressure on mangrove ecosystems integrity, etc.) - Resource utilisation and/or land-use changes - Other human activities e.g illegal cutting, encroachment, pollution

3.5.4 Designing a Restoration Plan

In the planning phase of any mangrove restoration project, it's crucial to follow a structured approach to ensure the project's success and sustainability. Here are the steps involved:

Step 1: Problem Realisation: Identify the cause of degradation in the project site and define whether it is natural or anthropogenic (Table 7). Take note of the potential restoration approach in each case. For 1, 2, and 3, Restore the hydrological regime by either opening blocked channels or digging new ones to allow the inflow of seawater into the mangrove area. Finally, monitor the site for eventual natural regeneration, and if otherwise plant using desired species. For 5 to 8, Conduct education, awareness and sensitisation as well as enforcement of laws specific to the various threats after sensitisation.



Table 7: Common potential causes of degradation in mangrove ecosystems and the recommended appropriate respective restoration approach

Potential causes of degradation	Recommended specific restoration approach
1. Sedimentation	If the source of the course is still active, work on mechanisms to limit further sedimentation e.g. build barriers to restrain loose sediment
2. Blocked channels	Clear existing channels of debris to allow inundation of affected mangrove area
3. Increased salinity due to the diversion of freshwater flow	Improve hydrology and by extension, salinity balance will be attained. Encourage free flow of water in rivers
4. Prolonged flooding	Improve site drainage to get rid of excess water and monitor for eventual natural regeneration potential
5. Over-harvesting	Enforce laws that enhance protection; provide alternatives to mangrove wood
6. Pollution (oil/waste)	Depending on the form of pollutant this may have varied responses - Oil; bioremediation to mop up the oil - Other forms of waste including plastics; collection before planting where planting is necessary
7. Grazing	Fence off the area. (physical or social) Educate the community on alternatives for grazing livestock
8. Land-based drivers (poor agricultural practices)	Establish a buffer zone with appropriate tree species to reduce soil erosion





Step 2: Defining the Purpose of Restoration: Define the objectives and goals of the mangrove restoration project, by anchoring the achievement to the following objectives: enhancement of natural regeneration; biodiversity and ecological restoration; sustained yield of both wood and non-wood forest products; coastal protection, erosion control and channels stabilisation; support to fisheries resilience and enhancement; establishment of new mangrove locations and adapting to climate change; coastal landscaping and ecotourism; social enrichment; and, legislative compliance.

Step 3: Understanding Governance: Identify the relevant laws, policies, regulations, and institutional frameworks governing mangrove management and restoration at local, national, and international levels; assess the roles, responsibilities and institutional arrangements of MDAs, NGOs, community groups, and other stakeholders in decision making that will influence the planning and implementation of the restoration project; and, identify the resources that might be needed and identify potential sources of support.

Step 4: Stakeholder Analysis: Identify key stakeholders locally and regionally; develop strategies for engaging and collaborating with stakeholders throughout the project lifecycle to ensure their meaningful participation, ownership, and support; and, uphold the rule of law through enforcement and compliance.

Step 5: Local Community Engagement Engage local communities living in and around mangrove areas from the onset of the restoration planning process; facilitate participatory approaches, such as community meetings, workshops, focus group discussions, and participatory mapping exercises, to involve community members in decision-making, planning, and implementation; build awareness and capacity among community members about the ecological importance of mangroves, the benefits of restoration, and sustainable mangrove management practices; foster partnerships and collaborative relationships with community-based organisations, local leaders, and traditional leaders to leverage local knowledge, resources, and social networks for successful mangrove restoration.

Step 6: Implement Communication Strategy: Utilize communication tools for stakeholder education and awareness such as Information Education and Communication materials, documentaries, posters, brochures, exhibitions, social media, radio among others.

By following these steps, the planning phase of a mangrove restoration project can lay a solid foundation for effective and inclusive decision-making, stakeholder engagement, and project implementation, leading to positive outcomes for both mangrove ecosystems and coastal communities.

3.5.5 Implementation of the restoration plan

Approaches of mangrove restoration

Mangrove restoration involves two main approaches (aided/assisted natural regeneration and planting of mangroves) with each method tailored to the specific needs of each site and the species of mangroves involved. In most cases, mangrove restoration projects can effectively rehabilitate degraded areas and promote the recovery of these vital coastal ecosystems by employing a combination of these methods.

A. Assisted Natural Regeneration

This approach depends on naturally occurring mangrove propagules (or seeds) to restock degraded sites. It involves regeneration from direct, freely falling and dispersed mangrove propagules. In doing so, important biological and physical factors that determine success for natural regeneration including forest conditions, tides and soil stability are corrected to enhance the regeneration process. Where natural regeneration is an option to restore a degraded mangrove area, and availability of propagules and seeds is ensured, restoration planning should first examine and validate the potential existence of primary stressors such as blocked tidal inundation that might prevent natural succession from occurring and remove those stressors to enhance natural recovery.

a). Protection

The Constitution of Kenya (2010) advocates for environmental management, protection and conservation by involving the public. Under the National Mangrove Ecosystem Management Plan (2017-2027), the following are proposed activities to enhance the protection of mangroves:

- Support routine policing patrols by respective government agencies (KFS and KWS).
- Promoting community policing by recruiting and training community scouts for joint patrols.
- Beaconing of mangrove areas.
- Fencing of mangrove sites under certain threats e.g. livestock browsing.
- Community awareness forums to embrace social fencing.

b). Hydrological restoration

Hydrological restoration aims to re-establish the original conditions of ecosystems, particularly focusing on tidal regimes (Turner and Lewis 1996; Kamali and Hashim 2011). This process is essential for mangroves, as their survival depends on appropriate hydrology and hydrodynamics, which influence salinity, sediment supply, propagule dispersal, and flooding duration. Disruptions in tidal flow can cause imbalances, leading to significant shifts in the ecosystem's physical and chemical makeup. Understanding these dynamics helps in creating suitable conditions for mangrove recruitment and restoration.

Various methods are employed to restore natural water flow. The fish-bone canal design (Fig 6) directs water into potential restoration sites while dyke-breaking (Fig 7) is used for areas with fish ponds or salt pans. Opening blocked channels, which may be obstructed by soil or debris, allows for tidal flushing and propagule movement. These techniques facilitate the re-establishment of natural tidal patterns, crucial for the successful rooting and growth of mangroves.

However, these methods must be applied appropriately to avoid unintended consequences, such as converting sand flats into mangrove sites, which can alter habitat functions and affect biodiversity (Fig 8). Therefore, it is critical to understand the history and specific conditions of a site before initiating hydrological restoration to ensure its effectiveness and ecological balance.

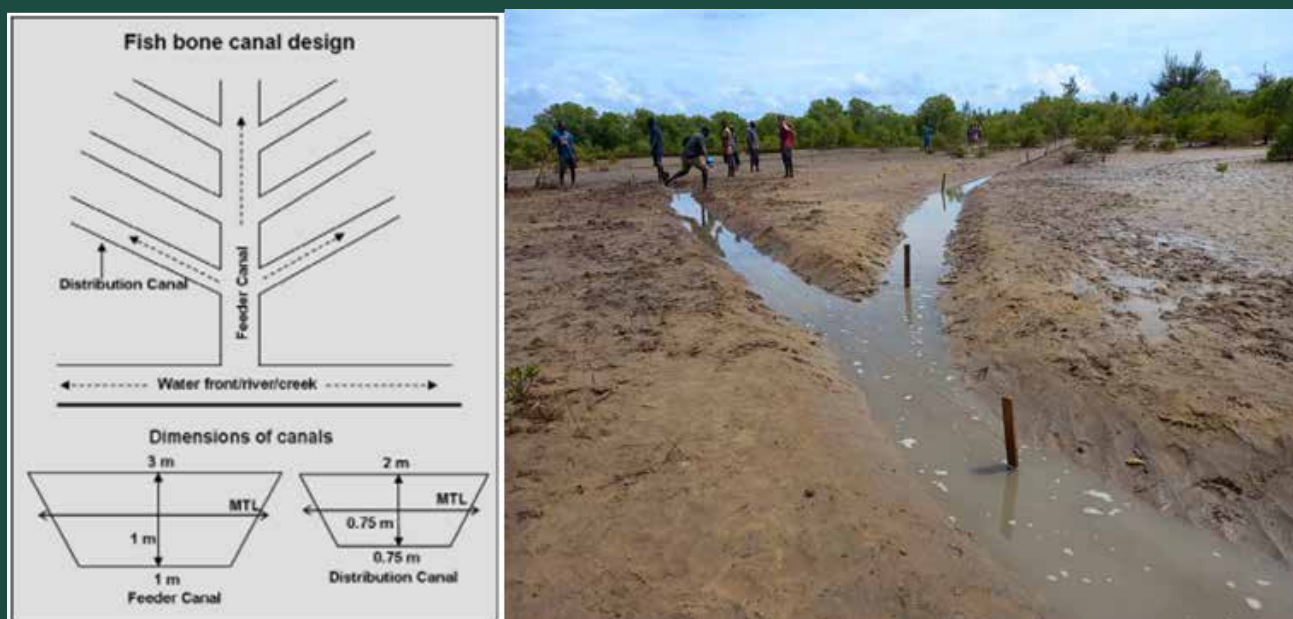


Figure 6 & 7: Fish-bone canal design being employed at Jimbo, in Vanga Kenya for hydrological restoration within abandoned salt pans (design adapted from Lewis and Brown, 2014)

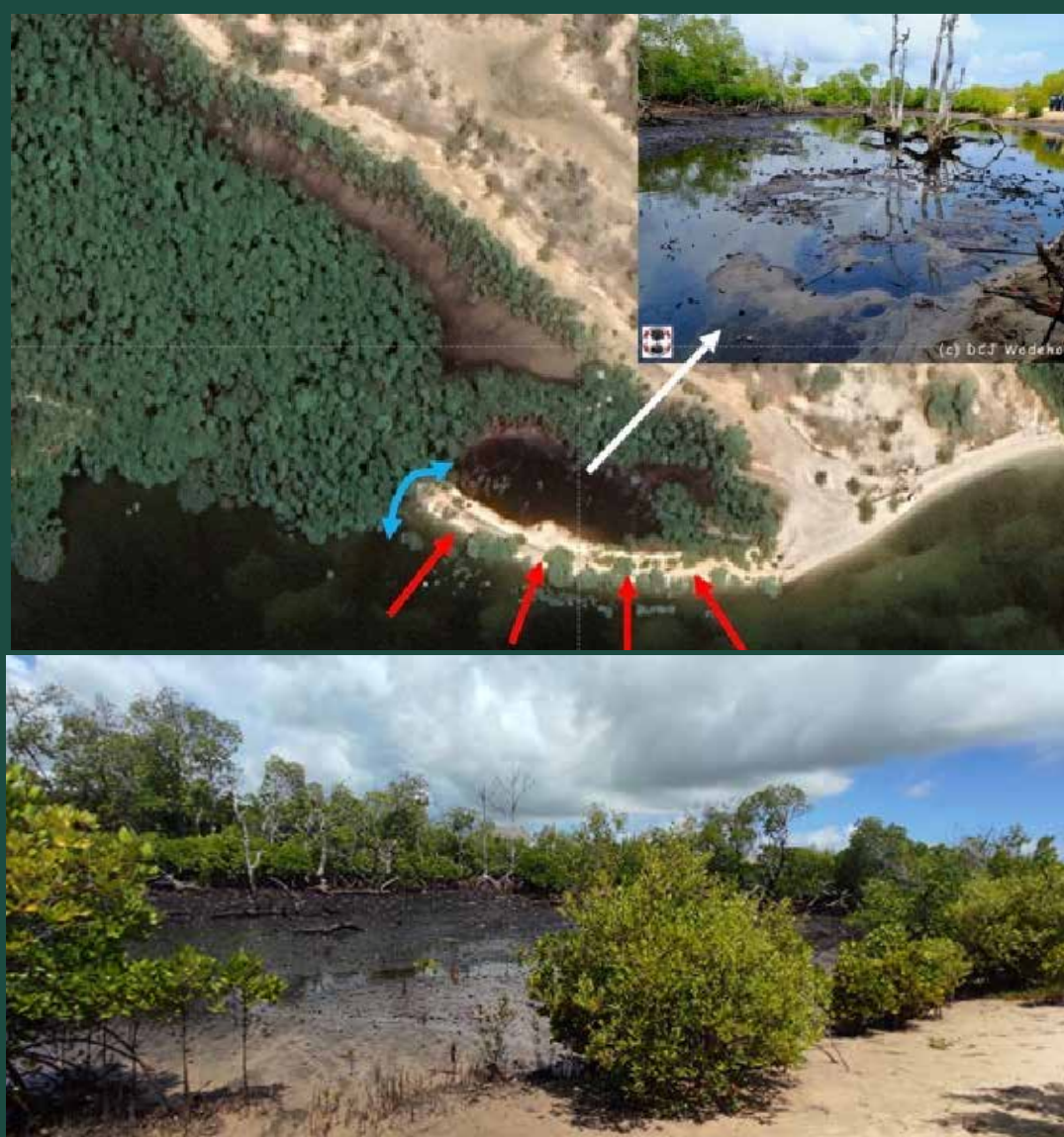


Figure 8: Transformation of the degraded Kitangani, Lamu Community-based Ecological Mangrove Restoration (CBEMR) Demo Site before and after the clearing of a blocked channel caused by sedimentation

c. Addressing other drivers/stressors (e.g. landscape approach, pollution control, provision of alternative livelihoods, education & awareness)

Solutions and work needed might be predominantly addressing social, rather than biophysical barriers to natural regeneration. Supporting livelihood activities enhances the local community's buy-in and sustainability of mangrove restoration initiatives. Integrating restoration activities with Income-Generating Activities (IGAs) in surrounding communities reduces human overdependence and subsequent pressure on mangrove ecosystems and their resources. Beekeeping, aquaculture (fish farming and crab fattening), mangrove eco-tourism, carbon financing, and the use of energy-efficient stoves should be promoted where appropriate to relieve pressures and safeguard mangroves.

B. Planting of Mangroves

Mangroves can naturally regenerate successfully including the colonisation of newly created mudflats. Where natural regeneration has failed or is insufficient, then planting can be done; through the use of propagules or seedlings. However, planting should be done as a last resort.



a) Planting Densities

The question of how many propagules or seedlings are appropriate to be planted per unit area ought to be clearly understood as it is defined by various factors. These include site conditions, selected species, and restoration project goals. Planting densities range from 500 to 2,500 seedlings per hectare, although some projects choose higher densities for specific areas. FAO (1994) recommends densities of 10,000 propagules/ha for direct planting and 2,500 individuals/ha for seedlings but with the assumption that the degraded area under consideration has no existing remnant trees.

In high-energy areas, planting at higher densities can improve survival rates and speed up recovery. On the other hand, lower planting densities may be more suitable for areas with favourable soil conditions or where natural regeneration is encouraged. To determine the most appropriate planting density for each restoration

site, it is crucial to carry out site assessments and seek advice from experts. Factors such as species diversity, site characteristics, and project objectives should all be considered. Site accessibility and available resources should also be taken into account when deciding on planting densities. Ultimately, the goal is to achieve a balanced approach that maximises the survival of seedlings, encourages natural regeneration, and contributes to the long-term health and resilience of the restored mangrove ecosystem. Table 8 outlines some recommended planting densities based on the objective of planting.

Table 8: Recommended planting densities based on purpose of planting

Purpose of planting	Spacing	Density	Species recommended
Rapid stabilisation of soils/ Erosion control	1 to 1.5m apart	6667 to 10000 seedlings per hectare High density	<i>Rhizophora mucronata</i>
Moderate erosion control/ Sustainable growth	1.5 to 2m apart	2500 to 4444 seedlings per hectare Moderate density	<i>Rhizophora mucronata</i> or <i>Avicennia marina</i>
Long-term ecological restoration/ minimal intervention/ promoting natural regeneration	2 to 3m apart	1111 to 2500 seedlings per hectare	Mixed species Depending on the zonation being restored

Adaptive Management and Monitoring Survival and Growth: Regular monitoring of seedling survival, growth rates, and health is crucial. Stakeholders are cautioned to adjust densities by replanting in areas with high mortality or thinning out where overcrowding occurs.

Consider Natural Regeneration: In areas with existing seed banks or nearby mature mangrove stands, natural regeneration can complement planting efforts. Planting densities can be adjusted based on the extent of natural recruitment.

Site-Specific Adjustments: Be prepared to modify planting densities based on site-specific observations and adaptive management practices. Factors such as herbivory pressure, hydrological changes, and community involvement can influence planting success.

In summary, while these guidelines provide a starting point, the optimal planting density for mangrove restoration should be tailored to the specific conditions and goals of the restoration site. Regular monitoring and adaptive management are essential to ensure the long-term success of the restoration efforts.

a) Mangrove planting methods

Planting may be done in open areas or as enrichment planting which aims to increase the density of trees to an optimum level in an existing forest.

i. Direct planting

Direct planting involves using propagules and is desirable where the site to be restored is not extremely degraded and as such the ecosystem has still retained its hydrology and physio-chemical conditions. The only factor that may hinder natural regeneration is lack of/limited supply of naturally dispersed propagules. Due to its simplistic nature, this method is preferred by many restoration practitioners though sometimes it may result in massive failure if misused.

Direct planting of propagules is done for mangroves belonging to the Rhizophoraceae family (*Rhizophora*, *Ceriops*, and *Bruguiera sp.*). These species produce large and pointed propagules that can be planted directly into the mud. Experience has shown that mature propagules picked from mother trees or those recently fallen have a higher survival rate than transplanting seedlings. This is because the latter leads to disturbance of root-balls when removing and transporting them. Further, transplanting seedlings is three times more expensive than the use of propagules.

ii. Use of seedlings

This involves the use of seedlings raised in nurseries for a restoration project. It is an essential part of reforestation programs because it can produce healthy planting stocks and subsequently high survival when out-planted. The seedlings can also be raised to larger sizes in a nursery to withstand inhospitable conditions of denuded or degraded and open coastal environments (Sinohin & Bacongus, 2000). Mangrove nurseries are essential where natural regeneration is unreliable due to: unfavourable soil conditions; the absence of nearby seeding trees; and, seeding patterns failing to coincide with the optimal planting period. Seedling production should be informed by a restoration plan, which will inform the type and number of seedlings required per specific site.

	
<i>Planting mangroves in seafront areas;</i>	<i>Planting of mangroves in sand flats;</i>
	
<i>Planting of <i>R.mucronata</i> in <i>A.marina</i> dominant zone (poor species site matching);</i>	<i>Planting mangrove in straight lines;</i>

Box 3: Common practices that should be avoided in restoration of mangroves

Embarking on planting without site assessment to determine appropriate intervention

Planting of mangroves in mudflats and sandflat

Planting of seedlings/propagules along water channels

Raising mangrove seedlings without a restoration plan

Planting some species out of their natural zonation

Planting mangroves in seafront areas

Planting propagules too shallow or deep into the sediment (appropriate depth is 6 inches)

Failure to eliminate site stressors before thinking of restoration



4.0 MONITORING AND EVALUATION



4.0 MONITORING AND EVALUATION

4.1 Monitoring and Evaluation of the Implemented Site Restoration Plan

Monitoring is important in any restoration process plan, there ought to be a robust monitoring and evaluation framework to track the progress of mangrove restoration sites at the ecosystem level. The monitoring and evaluation framework ought to enable timely progress, monitoring of restoration sites capturing results and learning and taking timely corrective actions as needed. Indicators that shall be continuously and periodically tracked, best practices, innovations, cases and unique experiences ought to be documented for subsequent learning and sharing. All the restored sites should be geo-tagged for ease of reference and follow-up. Research and innovation for emerging best practices on restoration also requires to be adopted.

4.2 Steps in Site Monitoring

1. Collect sufficient baseline data before any restoration work begins. This includes conducting surveys to gather baseline data on existing vegetation, soil conditions, hydrology, and biodiversity before restoration. .
2. Establish the monitoring objectives for each site such as biodiversity conservation, soil and water quality, hydrological conditions, carbon sequestration, human (social) impact, or sedimentation.
3. Develop a monitoring plan, outlining the method to be used in the particular site, and inform of the frequency of data collection. In the case of sampling, identify the best sampling techniques and resources required.
4. Select the verifiable indicators (Section 4.3 as per objective).
5. Follow the monitoring plan, especially on the frequency of data collection.
6. After data collection, analyse the data to answer the monitoring objective.
7. Interpret the data in relation to the monitoring objective established in Step 2.
8. Inform the findings of the stakeholders involved and for use in management decisions.
9. Revise and ensure the long-term sustainability objective is streamlined with Step 1.
10. Always ensure the local community is involved in each step to own the process and should be trained on how to monitor.

4.3 Indicators to be Measured

The table below shows verifiable indicators that will be used in the monitoring of nurseries and restoration sites through various approaches.

Table 9: Indicators used in monitoring restoration of mangrove ecosystems

Verifiable indicators (Aided/assisted natural regeneration)	Unit	Methodology	Responsible	Timeline
1. Assisted Regeneration				
a. Protection				
Mangrove area fenced	Ha	Social and/or physical fence*	Forest station manager (FSM), CFA	Continuous
Community Scouts deployed for patrols	No.	Community patrol	CFA & Rangers	Continuous
Area of degraded mangrove areas mapped	Ha	GIS mapping and ground truthing	GIS team, CFA, partners	Baseline Bi-annual
Community scouts trained on patrol methodology	No.	Training	CFA, partners, and KFS	Baseline Bi-annual
Area of land under natural regeneration being protected	Ha	GIS mapping Ground truthing	CFA, partners, and KFS	Baseline Bi-annual
Routine policing patrols by respective government agencies (KFS and KWS)	No.	Patrols	KFS KWS	Continuous
Survival rate after protection	Percentage	Survival and growth performance	CFA, Partners and KFS	Baseline Bi-annual
b. Hydrological restoration				
Hydrological restoration activities undertaken for each site	No.	Site assessment, return of hydrological conditions, regeneration, survival and performance	CFA, partners, and KFS	Baseline, bi-annual
Area under hydrological restoration	Ha	GIS mapping	GIS team, CFA and partners	Baseline
c. Addressing other drivers/stressors				
Education and awareness created	No.	Capacity building	CFA, partners, and KFS	Continuous
Income generating activities	No.	Capacity building Facilitation	CFA, partners, and KFS	Continuous

2. Planting				
a. Direct planting				
Propagules planted	No.	Survival and growth performance	CFA, partners, and KFS	Baseline Bi-annual
Area of land restored/ re-habilitated	Ha	GIS mapping Ground truthing	CFA, partners, and KFS	Baseline Bi-annual
Species planted	No.	Species site matching	CFA, partners, and KFS	Baseline Bi-annual
Survival rate	Percentage	Survival and growth performance	CFA, partners, and KFS	Baseline Bi-annual
Community participation	No.	Awareness creation	CFA, partners, and KFS	Continuous
b. Use of seedlings raised in nurseries				
Mangrove seedlings planted	No.	Species site matching Survival and growth performance	CFA, partners, and KFS	Baseline Bi-annual
Seedlings propagated	No.	Seedling assessment	CFA, partners, and KFS	Continuous
Area under restoration/ rehabilitated	Ha	GIS mapping Ground truthing	CFA, partners, and KFS	Baseline Bi-annual
Survival rate	Percentage	Survival and growth performance	CFA, partners, and KFS	Baseline Bi-annual
Community participation	No.	Awareness creation	CFA, partners, and KFS	Continuous

*Social fence refers to a short-term avoidance behaviour by individuals that leads to a long-term loss to the entire group

4.4 Assessment Reporting Framework

Monitoring and evaluation of mangroves restored are reported to the forester, who subsequently reports to the County Mangrove Management Committee (CMMC). The CMMC then submits a quarterly report to the NMMC. The information shall be utilised for decision-making in mangrove management.

Tools and Resources

- **Datasheet:** For recording indicators/parameters of the restoration site.
- **GPS devices:** For accurate location tracking and geo-referencing.
- **Drones:** For aerial surveys and mapping.
- **Cameras:** For taking time series images of the restoration site.
- **Salinometer:** For measuring salinity in cases where restoration involves improvement of hydrology.
- **Calliper/diameter tape:** For measuring stem diameter.
- **Graduated pole/linear tape:** For measuring height.
- **Timer (Simple flow meter):** For measuring the rate of flow of water through artificially created/improved channels.
- **Software:** For data management and analysis (e.g. GIS software, statistical analysis tools).
- **Questionnaires:** For assessing community/stakeholder perception.

5.0 References



5.0 References

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Annexes



Annexes

Annex 1: Types and levels of degradation in mangrove ecosystems (adopted from GoK, 2017; Zockler et al., 2021)

Type of degradation	Level of degradation	Indicators	Drivers/Root causes/Threats	Consequences/Impacts
Deforestation	High	Absence or sparse trees, Light to floor > 75% Stumps (still visible if recent degradation), Logs and debris,	Over-exploitation, illegal cutting/clear-felling Extreme events, wind throw	Could trigger adverse changes in site conditions, Low or no recolonization, Erosion and exposure of peat soils
	Moderate	Light to floor 25-75%, low tree density, numerous gaps, stumps	Over-exploitation, illegal cutting	Shortage of harvestable wood products, Changes in forest structure and species composition may have sufficient seeding trees to trigger natural regeneration
	Low	Light to floor < 25%, moderate to high tree density, few gaps, stumps, cut stems/branches	Low levels of illegal cutting, selective cutting	Low impact, natural regeneration occurring

Dieback	High	Mass tree mortality with several standing dead trees, dead wood and debris on the ground Light to floor >75%,	Natural events e.g. El Nino, high levels of sedimentation, siltation, prolonged flooding, pollution (e.g., oil spills, etc), sea level rise, change of environmental factors (e.g., increased salinity), shoreline change	May trigger adverse changes in site conditions, low or no recolonisation
	Moderate	Moderate dieback, standing dead trees, gaps, dead lying wood/debris, Light to floor 25-75%	Sedimentation/ siltation, flooding, pollution (e.g., sewerage), pests and diseases, changes in sediment conditions (e.g., increased salinity), disturbance from human activities	Natural regeneration may occur depending on the drivers of change.
	Low	Few trees experiencing dieback, with few dead branches Light to floor < 25%	Pests and diseases, lightning strikes, wind throw, sedimentation	Low impact, natural regeneration occurring
Erosion	High	Mostly occurring in fringing forests. Fallen trees with exposed roots, bank erosion and exposure of the underlying substrate	High wave energy, coastal erosion	Exposure to sediment may trigger peat collapse and enhanced carbon emissions. Regeneration may be inhibited. Source of sediment causing siltation in other sites
	Moderate	Moderate exposure to sediments and roots, fallen trees	Coastal erosion, including along channels, moderate wave energy	May progress to severe degradation, natural regeneration may be impeded by erosion
	Low	Few areas experiencing erosion	Intermittent coastal erosion incidences	Low impact, but may progress to a higher level of degradation if erosion persists

