AFRICAN UNION
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Strengthening Conservation and Restoration of Blue Carbon Ecosystems for Community Benefits and Environmental Sustainability

Mapping and Identification of Degraded Mangrove Areas in Gazi Bay

KMFRI
Kenya Marine and Fisheries Research Institute

CONSERVING AQUATIC BIODIVERSITY
AFRICA BLUE ECONOMY STRATEGY

KENYA
Forest Service

Citation: AU-IBAR, 2023. Report on Mapping and Identification of Degraded Mangrove Areas in Gazi Bay. Nairobi, Kenya.

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Published by AU-IBAR, Nairobi, Kenya

Acknowledgements:
This report is a product of the project on 'Strengthening Conservation and Restoration of Blue Carbon Ecosystems for Community Benefits and Environmental Sustainability', also referred to as the 'Imarisha Project'. Special regards are accorded to the African Union – InterAfrican Bureau for Animal Resources (AU-IBAR) for funding the project.

We thank the Kenya Marine and Fisheries Research Institute (KMFRI) and Kenya Forest Service (KFS) for the technical and logistical support during the implementation of this activity leading to the culmination of this report. We also thank the Community Forest Association (CFA) members from Gazi, who participated in the Fieldwork activity.

Special thanks go to the Swedish International Development Cooperation Agency (SIDA) for the on-going cooperation and the team at AU-IBAR for the editorial work. This work was done with financial support by the Government of Sweden, through the Embassy of Sweden to the African Union.

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Synopsis

The African Union InterAfrican Bureau for Animal Resources (AU-IBAR) is collaborating with the Kenyan Marine Fisheries Research Institute (KMFRI) to support ongoing initiatives that promote aquatic biodiversity conservation and climate change mitigation efforts applying nature-based solutions. This is being rolled out under AU-IBAR's project on "Conservation of Aquatic Biodiversity in the Context of the Africa Blue Economy" funded by the Swedish International Development Cooperation Agency (SIDA). The project aims to enhance the policy environment, regulatory frameworks and institutional capacities of AU member states and Regional Economic Communities (RECs) to sustainably utilize and conserve aquatic biodiversity and ecosystems. The scope of the project includes actions to strengthen measures for mitigating the negative impacts of climate change on aquatic biodiversity and environment, which support economic activities and livelihoods of AU member states.

Subsequently, AU-IBAR is supporting KMFRI in implementation of the sub-project on "Strengthening Conservation and Restoration of Blue Carbon Ecosystems for Climate Change Mitigation and Adaptations", also referred to as the "Imarisha Project" in the Gazi Bay, designed to support restoration of the functionality of blue carbon ecosystems for community development and environmental sustainability. The Imarisha project aims to: 1) Establish ecological baselines and characterize degraded mangrove areas in Gazi Bay; 2) Educate, train and demonstrate community based ecological restoration of mangrove forests; 3) Establish community woodlots in schools and community land to provide alternative sources of wood and livelihood opportunities; and 4) Reduce pressure on mangrove resources through promotion of nature-based enterprises.

This report summarizes the preliminary project implementation activity of mapping which was conducted in the Imarisha project site to identify and characterize degraded mangrove areas for restoration.

1.0 Introduction

Mangrove forests within Kwale County cover approximately 8,354 ha of which 9% (715ha) are located within Gazi Bay (GoK, 2017). These forests offer a range of benefits and opportunities at both local as well as at national scale, improved livelihoods and provision of environmental goods and services such as habitat for fish, shoreline protection, and carbon sequestration. It is therefore critical that mangroves are protected and conserved so that they can continue providing the desired goods and services for the benefit of all. This management plan is aimed at providing the road map towards sustainable management of the mangrove ecosystem in Kenya and enhanced livelihood of communities dependent on mangrove resources.

Empirical studies on mangrove forest cover all over the globe continue to indicated decline on the spatial coverage over the recent past at a high rate ranging 1-2%/annum (FAO, 2005; UNEP, 2007, 2016; Kairo, *et al.,* 2008; Giri *et al.,* 2008, 2011, 2014; Kirui, *et al.,* 2012; Bosire, *et al.,* 2014, 2016; Hamilton, & Casey, 2016; Thomas *et al.,* 2017; Mungai et al., 2019; Kairo et al, 2021). Mangrove forest in Kenya are faced by both natural and anthropogenic threats which has resulted to loss of about 20% of the initial forest cover in 1980s (GoK, 2017). According to the national mangrove management plan the identified anthropogenic threats in Kenya are: over-exploitation of wood products, conversion of mangrove areas to other land uses, aquaculture, pollution and sedimentation, diversion and damming of rivers, and infrastructure & development. Additionally, the natural threats include extreme weather event 1997/98 El nino, pest infestation and desiccation. Over-extraction of mangrove poles for export has left the mangrove forest cover in poor condition in terms of quality (Bosire *et al.,* 2014). This has also left some areas risking extinction of species like *Xylocupus granatum* and *Heritiera Littoralis* in Kilifi and Kwale counties (Bosire *et al*., 2016). Oil pollution through spillage at Mombasa port caused a great negative effect on mangroves at Makupa creek whereby, there has been frequent re-oiling of the area from the sunken reservoir of oil (Kairo *et al.,* 2001; Bosire *et al*., 2016). Although the ranking of threats and benefits of mangroves small variation between coastal counties, Illegal harvesting ranks as the highest threat while construction poles rank highest in benefits of mangroves at country level (GoK, 2017).

1.1 Objectives of the Consultancy:

The aim of the consultancy is to conduct mapping and identification of degraded areas, with the goal of identifying areas for intervention within Gazi Bay along Kenya coast.

The specific tasks being:

i. To conduct mapping and identification of degraded areas for restoration of blue carbon ecosystems for climate change mitigation and adaptation.
ii. To produce a report on mapping activities conducted
iii. Any other tasks leading to effective, efficient and successful implementation of the activities

2.0 Methodology

2.1 Study site

The climate in Gazi Bay is typical of that of the Kenyan coast and is principally influenced by monsoon winds. The topographic gradient of the Gazi mangroves is fairly small, particularly to the north of the bay, resulting in a wide intertidal area typical for basin mangrove settings. As a result, the mangrove forests experience high tidal flushing rates, albeit with short residence times (3–4 hours), which are a function of wide shallow entrance, lack of topographic controls and the orientation of the bay with respect to dominant water circulation patterns. Total annual precipitation varies between 1000 mm and 1600 mm with a bimodal pattern of distribution. The long rains fall from April to August under the influence of the southeast monsoon winds, while the short rains fall between October and December under the influence of the northeast monsoon winds. It is normally hot and humid with an average annual air temperature of about 28°C with little seasonal variation. Air temperature in Gazi Bay varies between 24°C and 39°C. Relative humidity is about 95% due to the close proximity to the sea (UNEP, 2009; Bosire *et al.,* 2016).

The mangrove forest is not continuously under the direct influence of freshwater because the two rivers, Kidogoweni in the North and Mkurumudzi in the South draining into the bay are seasonal and dependent on the amount of rainfall inland. Groundwater seepage is also restricted to a few points. Sediment characteristics vary with respect to topographic gradient. The landward sites are characterized by hyper saline compact sediment substrates, whereas the seafront sediments consist mainly of loose sandy substratum owing to movement of sand by waves. Most sites in the intermediate regions are composed of deep muddy substrates rich in organic matter. However, is in most mangrove sediments, essential nutrients like nitrates and phosphates are limiting.

Gazi Bay mangrove community closely resembles other mangrove forests of Kenya in terms of species distribution and structure. There is a total of nine mangrove species in Gazi Bay. The dominant species are *Rhizophora mucronata* (Mkoko), *Ceriops tagal* (Mkadaa), *Avicennia marina* (Mchu) *Bruguiera gymnorrhiza* (Mkifi), *Sonneratia alba* (Mlilana); which contributes more than 80%

of the Gazi mangrove formation. Other species are Xylocarpus granatum (Mkomafi), Xylocarpus mollucensis (Mkomafi dume), Heritiera littoralis (Dryand ex H.Ait) and Lumnitzera racemosa (Kikandaa) (Kairo et al., 2008; Gok, 2017).

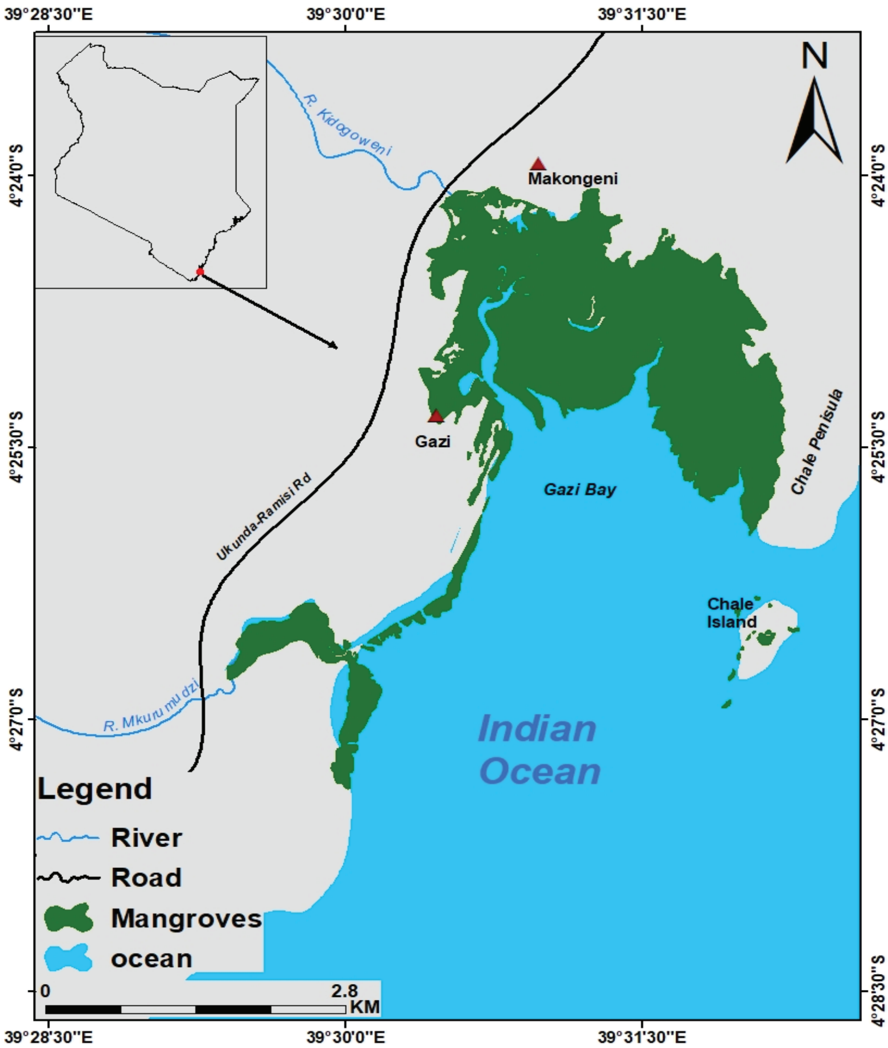

Figure 1: *Locational map showing distribution of mangroves within Gazi Bay*

Like in most parts of Kenya, mangrove in Gazi display horizontal distribution of species. *S.alba* forms the outermost zone towards the open water followed by pure or mixed stands of *R .mucronata* or mixed stands of *R .mucronata* and *B. gymnorhiza* and in turn these stands are followed by pure stands of *C. tagal* and *A. marina*. Along the creeks, *A. marina* usually replaces *S. alba* and these *A. marina* trees are much taller (12-18metres) than those on the elevated areas (2-3metres, shrub type). Gazi Bay Mangroves are distributed as shown in Figure 1.

2.2 Data Acquisition

The study utilized freely available remotely sensed data accessed from USGS Glovis website (http://glovis/usgs/gov). Landsat satellite images were acquired from global land survey data archive for spatial mangrove mapping. Due to the challenge of cloud cover in using the optical Landsat products, imageries were selected based on least cloud cover. Data included the medium spatial resolution Landsat imagery (30m) as detailed in (Table 1). The Google earth pro aided in validating, gaps identification and filling. The acquired multispectral Landsat imagery facilitated the discrimination into the individual land use signatures. The Ground Control Points (GCP) as well as validation points were collected during fieldwork exercise (Plate 1).

Plate 1: *Some of the photos taken during the field validation/ground truthing exercise*

Table 1: *Information of USGS data used in analysis and mapping of mangrove on both Kenyan and Tanzanian sides of the trans-boundary area.*

Sensor	Resolution (meters)	Raw and column	Epochs
Thematic Mapper	30	166/063	1986
Thematic Mapper	30	166/063	1991
Enhanced Thematic Mapper plus	30	166/063	2003
Observation Land Imager	30	166/063	2016
Observation Land Imager	30	166/063	2020/2021

2.3 Pre-processing of the acquired data

Geo-referencing of acquired spatial data (Landsat & Sentinel imagery, Ground Control Points (GCP)) to a common global geo-referencing system that is World Geodetic System (WGS) 1984 was performed. The data was then registered to the local area coordinate system of Universal Transverse Mercator (UTM) Zone 37S with first-degree polynomial adjustment using ArcGIS geo-referencing tools. Normalization process was performed on all imageries to eliminate variation brought about by solar angle and the Sun-Earth distance.

The normalization process entailed conversion of Digital Numbers (DN) to top of atmosphere reflectance in two steps: First, the DN was returned to values that can be compared between scenes. Secondly, the values obtained in step one were converted to account for difference in solar irradiance due to earth/sun geometry (orbital distance and tilt). The conversion was carried out in ArcMap using a raster calculator tool while the scene variables were sourced from metadata files acquired together with the imagery. To improve clarity and quality of the outputs, image enhancement was performed in the image analysis window in ArcMap.

Geometric correction was executed to improve the geo-location to a Root Mean Square (RMS) of 0.5 of pixels. The area of interest thus included mangrove cover and the adjacent land uses/ cover along the area of interest area. The corrected imageries were then subset and clipped out to include only areas within and adjacent to where mangroves are likely to occur. This process is imperative; as it improves overall image classification accuracy by reducing image spectral variations as well as the total number of land cover types

2.4 Data processing/Image classification

Different methods will be used at different stages of data processing. Mangrove coverage and forest conditions within the study area were interpreted by use of a hybrid unsupervised & supervised digital image classification technique. Unsupervised classification was done prior to fieldwork to retrieve different spectral classes for comparison of best result yielding method. These group grouped into broad informational classes after fieldwork and close expert knowledge examination. This helps in identifying regions of interest (ROI), collection of ground control points (GCPs) and delineation of training sites for supervised classifications. For actual analysis and processing stage, a Combined Mangrove Recognition Index (CMRI) technique used utilized in mapping mangrove extent. Data management and spatial analysis tools in ArcGIS were used in analyzing Hotspot areas of mangrove cover change. Below is a combined summary of the methodology applied in the study (Figure 2).

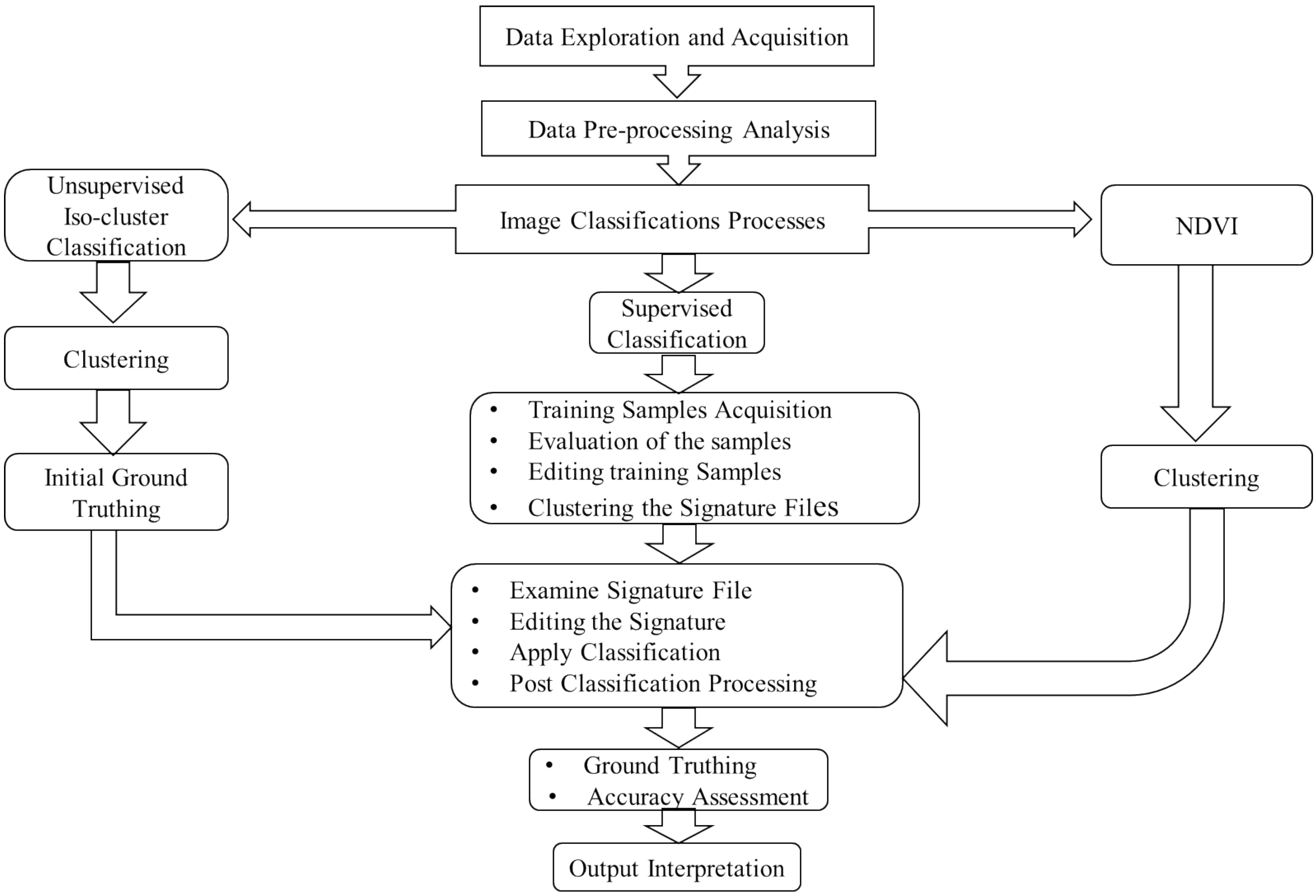

Figure 2: *A summary of methodology used for mangrove mapping*

3.0 Results

Gazi mangroves include the basin forest at Chale Island that boasts of the tallest *Bulguiera* trees in the country that are over 35m. Fringing forest with good participation of community in conservation and rehabilitation activities. The principal species are *Rhizophora mucronata*, *Ceriops tagal*, *Sonneratia alba* and *Avicennia marina*. Partly falls under Diani-Chale Marine reserve. Main driver of mangrove cover change is illegal harvesting and sedimentation.

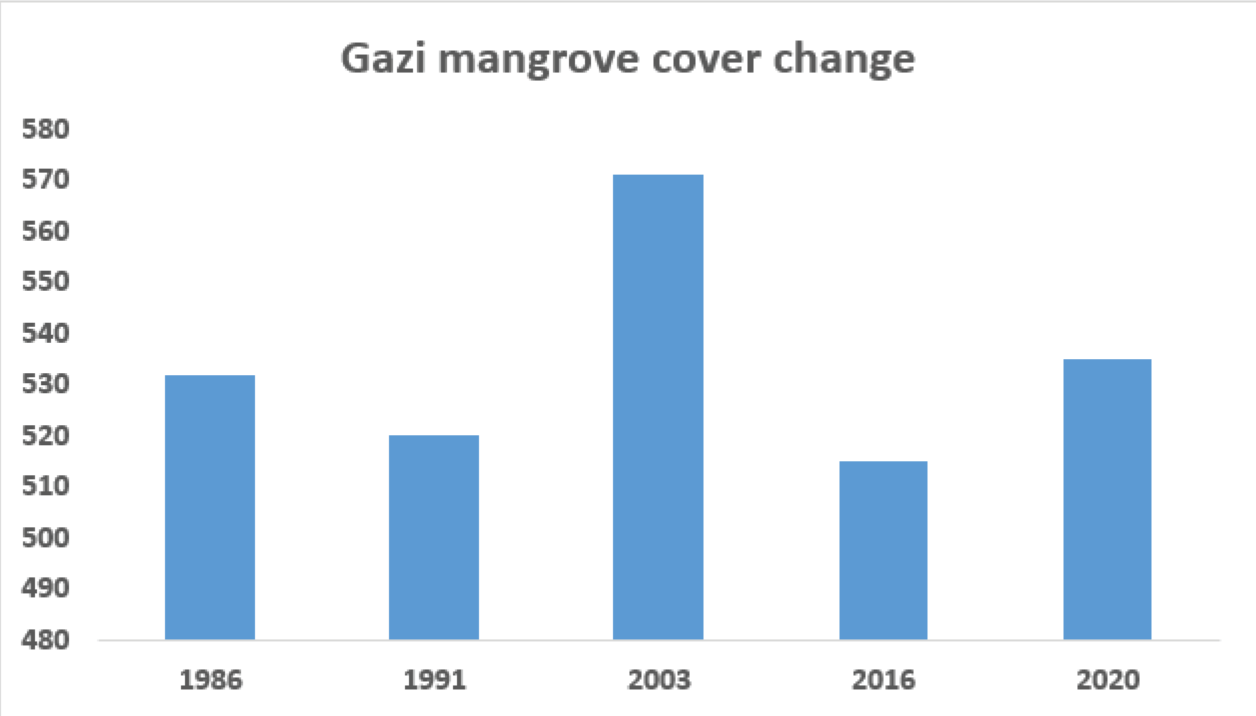

Figure 3*: Mangrove cover change over the study period (1986-2020)*

Overall, Gazi mangrove cover has declined by 1.3% (7ha) ha from 1986 to 2020; translating to a rate of 0.04%/yr. over the 34 year study period. The loss of mangroves cover was particularly higher between 2003 and 2016 (11%) at a rate of 0.8%/yr. as compared to the 1986-1991 period (2% at a rate of 0.5%/yr.). On the other hand, the highest increase in cover was observed over 1991-2003 period at a rate of 0.8%/yr. (Figure 3&4).

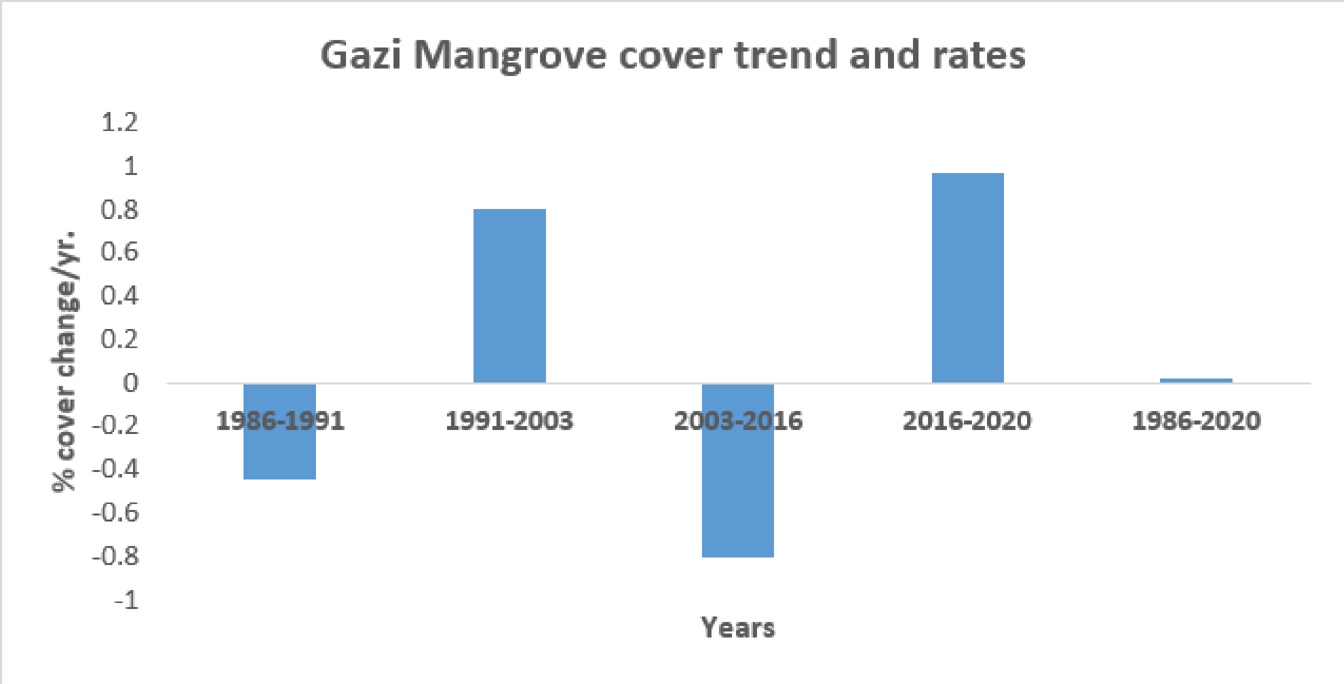

Figure 4: *Gazi mangrove cover change trends and the rates of change per annum*

The total area of mangroves in Gazi is estimated at 525ha. This forest has experienced both loss and gains in cover. This loss and degradation of mangroves in the site has been associated to over-harvesting of mangrove wood products, conversion of mangrove area to other land uses such as pond aquaculture; and the impacts of climate change (Bosire *et al.,* 2016; GoK, 2017).

Overall, rate of mangroves loss in Gazi during the 2003-2020 epoch has gradually been declining from 0.8%/yr. to 0.5%/yr. The reduced rate could be attributed to ban on domestic harvesting of mangroves, restoration effort at different sites within the study area as well as increased awareness of mangroves goods and services among the community (Bosire *et al.,* 2016, Mungai *et al*., 2019). In Gazi, the community participation in mangrove restoration has significantly contributed to rehabilitation, conservation and sustainable utilization of mangroves in the area (Kairo *et al.,* 2001; Bosire *et al.,* 2003, 2016). The decline in rate of loss of mangrove cover observed within Gazi Bay area in the post 2000 period agrees with other studies in the region and other parts of the world (Kirui *et al.,* 2013; Lang'at *et al.,* 2014; Lovelock *et al.,* 2015; Hamilton, & Casey, 2016, Mungai et al., 2019). From the analyses, the hotspot areas of mangrove cover change was observed within Makongeni, Chale main land and Island as well as along the mouth of Mkurumudzi River (Figure 5).

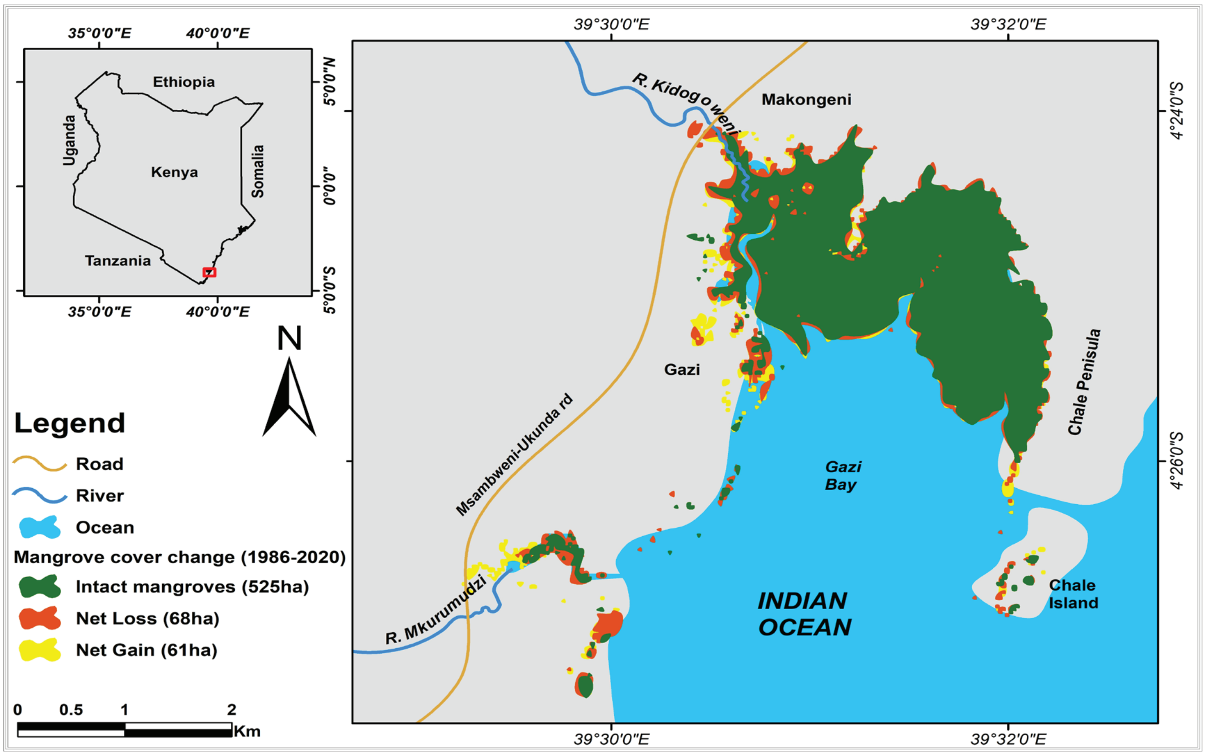

Figure 5: *Analysis results showing areas of both decrease and increase in mangrove forest cover over the study period (1986-2020)*

For effective resource management, a resource management plan is paramount which has not been the case. In Kenya for instance it was not until 2017 when the national mangrove management plan for the entire country's mangrove ecosystem was developed (GoK, 2017). This is expected to provide guidance in utilization patterns and in overall improve management and conservation of this critical ecosystem in the country.

Although the pattern of degradation can largely be attributed to anthropogenic causes, natural causes have also contributed to the observed changes. Climate related events including increased sea level rise, extended drought periods, flooding and shoreline change have contributed to loss and degradation of mangroves within Gazi Bay (Kitheka *et al.,* 2002; Bosire *et al.,* 2014) and specifically Kwale County (Dahdouh-Guebas *et al.,* 2004; Bosire *et al.,* 2006; Wells *et al.,* 2007). Observed shoreline change in 2003-2016 has resulted to loss of mangroves along the TBCA through increased sedimentation of the forest (Mungai et al., 2019). Similar observations were made at Gazi Bay whereby increased sedimentation led to loss and degradation of mangroves.

Loss and degradation of mangroves was disproportionately higher closer to human settlements at the mouth of Mkurumudzi, along the shoreline, on the landward side of Makongeni and Chale. FAO (2005), the WIO region have been estimated to loose more than 50% of the current mangrove forest cover that has largely been attributed to anthropogenic causes. Areas with high human settlement in the region adjacent to mangrove areas has not only recorded continous decline but the rate of loss are also high.

According to UNEP, (2009) the root causes to the observed drivers of mangrove loss within the region being the value attached to mangrove as extractable resource hence overexploitation of mangroves. Secondly, is the multiple use potential of mangrove environments that brings about catchment degradation and land use change for muliculture and other uses that has occurred within the bay.

Possible Intervention Areas/Sites

From the result analysis and the field validation, the team was able to identify and come up with the possible intervension sites within Gazi Bay Mangrove area, where if both resources and time allows actions shpuld be taken as follows.

Figure 6: *Intervention area 1 impacted by construction of saltpands*

At the site(close to Wanga wa Manyani), the forest was observed to be moderately degraded as per the KMFRI degradation levels and the driver of degradation identified as anthropogenic precisely (saltpands construction). The recommendation for the site was first establishment of Avicenia Marina mangrove nursery at the site that on maturity would be used for enrichment planting at the that site.

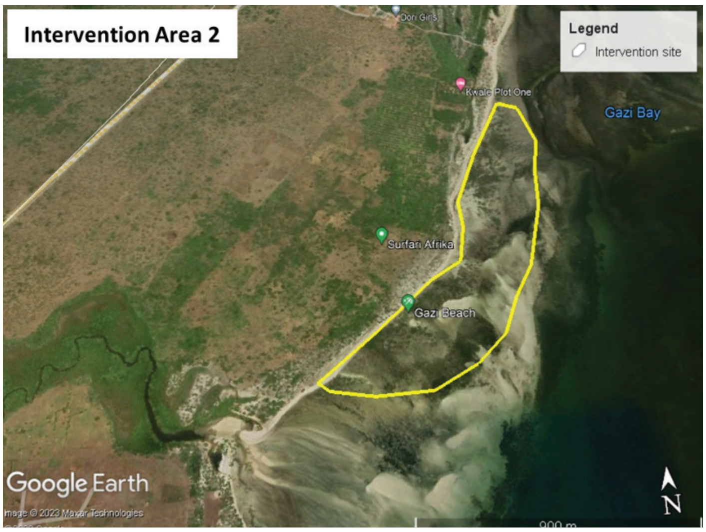

Figure 7: *Intervention area 2 impacted by Clear felling of mangrove wood for Lime production*

At the site (Mukurumudzi shoreline), the forest was observed to be critically degraded as per the KMFRI degradation levels and the driver of degradation identified as anthropogenic (clear cutting for lime production) as well as natural factors currently (Sedimentation and strong waves). The recommendation for the site experimental restoration with Rhizophora Mucronata, Sonneratia alba and Avicennia marina to find out the best method that could be replicated in restoring the critically degraded mangrove area.

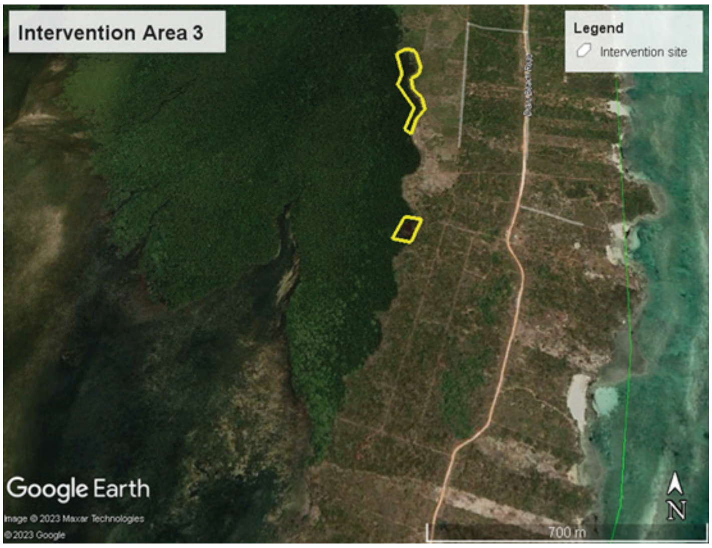

Figure 8: *Intervention Area 3 impacted by selective and clear felling of mangrove for wood products*

At the site(Between Makongeni and Chale), the forest was observed to be both moderately as well as critically degraded as per the KMFRI degradation levels and the driver of degradation identified as anthropogenic (selective and clear felling of mangrove for wood products). The recommendation for the site was enrichment planting of Rhizophora Mucronata at the site that was moderately degraded and direct planting of Rhizophora Mucronata at the clear fell area/site.

Figure 9*: Intervention area 4 impacted by increased accretion of sediments within mangrove site*

At the site(Between the Old and the New Landing site), the forest was observed to be critically degraded as per the KMFRI degradation levels and the driver of degradation identified as Natural (Increased sedimentation). The recommendation for the site was addresing the driver of change through processes like hydrological restoration depending on the availability of resources and time.

4.0 Conclusion

From the image analysis it is evident that the Gazi mangroves are not pristine as loss and degradation was observed over the study period. It is also of importance to note that although a decline in rate of mangrove loss was observed within the bay, without management interventions, removal of mangrove wood products is likely to increase. Secondly, the land use/cover adjacent to mangrove forests of Gazi Bay have influenced the changes occurring on mangrove cover both directly and indirectly. The results of this study will be used to strengthen capacity of the institutions mandated to manage mangroves within the County, as well as proving baselines and trends for improved management of mangroves in the area.

5.0 Recommendations

Based on the findings of the study the researcher recommends an integrated approach which combines sustainable agricultural practices upstream and mangrove conservation ensure sustainable management and utilization of mangrove resources that will help achieve ecosystem integrity along within Gazi Bay. Precisely, this study recommends the following:

Restoration of critically degraded (identified hotspots area of mangrove cover loss) areas should be initiated by KFS and other stakeholders in collaboration with the forest adjacent communities.

To overcome negative impacts on mangrove ecosystem within the bay arising from adjacent land use practices and change, the researcher recommends harmonization of the different adjacent land uses as a paramount decision. To start with a buffer against coastal erosion from up-stream activities should be established in the most affected areas to act as protective zone of mangroves of Gazi Bay.

References

1. ***Bosire, J. O., Dahdouh-Guebas, F., Kairo, J. G., & Koedam, N. (2003).*** Colonization of non-planted mangrove species into restored mangrove stands in Gazi Bay, Kenya. *Aquatic Botany*, 76(4), 267-279.
2. ***Bosire, J. O., Dahdouh-Guebas, F., Kairo, J. G., Wartel, S., Kazungu, J., & Koedam, N. (2006).*** Success rates of recruited tree species and their contribution to the structural development of reforested mangrove stands. *Marine Ecology Progress Series*, *325*, 85-91.
3. ***Bosire, J. O., Kaino, J. J., Olagoke, A. O., Mwihaki, L. M., Ogendi, G. M., Kairo, J. G., & Macharia, D. (2014).*** Mangroves in peril: unprecedented degradation rates of peri-urban mangroves in Kenya. *Biogeosciences*, 11(10), 2623-2634.
4. ***Bosire, J., Mangora, M., Bandeira, S., Rajkaran, A., Ratsimbazafy, R., Appadoo, C., & Kairo, J. (2016).*** *Mangroves of the Western Indian Ocean: status and management.* WIOMSA, Zanzibar Town.
5. ***County Government of Kwale, (2013).*** *First County Integrated Development Plan.* County Government of Kwale.
6. ***Dahdouh-Guebas, F., De Bondt, R., Abeysinghe, P. D., Kairo, J. G., Cannicci, S., Triest, L., & Koedam, N. (2004).*** Comparative study of the disjunct zonation pattern of the grey mangrove Avicennia marina (Forsk.) Vierh. in Gazi Bay (Kenya). *Bulletin of Marine Science*, *74*(2), 237-252.
7. ***Dahdouh-Guebas, F., Hettiarachchi, S., Seen, D. L., Batelaan, O., Sooriyarachchi, S., Jayatissa, L. P., & Koedam, N. (2005).*** Transitions in ancient inland freshwater resource management in Sri Lanka affect biota and human populations in and around coastal lagoons. *Current Biology*, *15*(6), 579-586.
8. ***Dahdouh-Guebas, F., Mathenge, C., Kairo, J.G., & Koedam, N., (2000).*** Utilization of mangrove wood products around Mida Creek (Kenya) amongst subsistence and commercial. *Marine and Freshwater Research,* 53, 255-310
9. ***Dan, T. T., Chen, C. F., Chiang, S. H., & Ogawa, S. (2016).*** Mapping and change analysis in mangrove forest by using Landsat imagery. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *3*, 109.
10. ***Duke, N.C., Meynecke, J., Dittmann, S., Ellison, A., Anger, K.U., Berger, U., Cannicci, S., (2007).*** A world without mangroves. *Science* 317: 41-42.
11. ***FAO, (1994).*** *Mangrove forest management guidelines* (Vol. 117), 319 pp. Rome.
12. ***FAO, (2005).*** *Status and trends in mangrove area extend worldwide.* Working paper No. 64. Forest Resource Division. FAO, Rome. 64(4), 367-379
13. ***FAO, (2007).*** The World's Mangroves 1980-2005. *FAO Forestry Paper*, No. 153. Rome.
14. ***FAO, (2015).*** Global forest resources assessment 2015. Kenya County Report.

15. ***Hamilton, S. E., & Casey, D. (2016).*** Creation of a high spatio-temporal resolution global database of continuous mangrove forest cover for the 21st century (CGMFC-21). *Global Ecology and Biogeography*, *25*(6), 729-738.

16. ***Kairo J.G., Kivyatu B. and Koedam N. (2002).*** Application of Remote Sensing and GIS in the management of mangrove forests within and adjacent to Kiunga marine protected area, Lamu, Kenya. *Environment, Development and Sustainability* 4: 153–166.

17. ***Kairo, J. G., Dahdouh-Guebas, F Bosire, J and Koedam, N (2001).*** Restoration and management of mangrove systems — a lesson for and from the East African region. *South African Journal of Botany*, 67: 383–389.

18. ***Kairo, J. G., Lang'at, J. K., Dahdouh-Guebas, F., Bosire, J., & Karachi, M. (2008).*** Structural development and productivity of replanted mangrove plantations in Kenya. *Forest ecology and management*, 255(7), 2670-2677.

19. ***Kirui, K.B., Kairo, J.G., Bosire, J., Viergever, K.M., Rudra, S., Huxham M. and Briers, R.A. (2012).*** Mapping of mangrove forestland cover change along the Kenya coastline using Landsat imagery. *Ocean & Coastal Management* 6(4), 26-54.

20. ***Kitheka U.J., Ongwenyi S.G., Mavuti M.K. (2002).*** Dynamics of suspended sediment exchange and transport in a degraded mangrove creek in Kenya. *Ambio*31: 580-587.

21. ***Lang'at, J. K. S., Kairo, J. G., Mencuccini, M., Bouillon, S., Skov, M. W., Waldron, S., & Huxham, M. (2014).*** Rapid losses of surface elevation following tree girdling and cutting in tropical mangroves. *PLoS One*, *9*(9), e107868.

22. ***Polidoro, B.A., Carpenter, K.E., Collins, L., Duke, N.C., Ellison, A.M., Ellison, J.C., Farnsworth, E.J., Fernando, E.S., Kathiresan, K., Koedam, N.E., Livingstone, S.R., Miyagi, T., Moore, G.E., Nam, V.N., Ong, J.E., Primavera, J.H., Salmo, S.G., Sanciangco, J.C., Sukardjo, S., Wang, Y., and Yong, J.W.H. (2010).*** The Loss of Species: Mangrove Extinction Risk and Geographic Areas of Global Concern. *PLoS ONE* 5, 1 – 10.

23. ***Richards, D. R., & Friess, D.A. (2016).*** Rates and drivers of mangrove deforestation in Southeast Asia, 2000–2012. In *Proceedings of the National Academy of Sciences USA*, *113*, 344–349.

24. ***UNEP, (2009).*** *Transboundary Diagnostic Analysis of Land-based Sources and Activities Affecting the Western Indian Ocean Coastal and Marine environment*. UNEP, Nairobi, Kenya, 378, 3-355 pp

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