ECONOMIC AND ECOLOGICAL VALUATION OF MANGROVE FOREST AT MIDA CREEK IN KILIFI COUNTY, KENYA

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A Thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science (Plant Ecology) in the School of Pure and Applied Sciences of Kenyatta University

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university or for any other award.

Signed________________________________ Date ________________________________

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We confirm that the work reported in this thesis was carried out by the candidate under our supervision**.**

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DEDICATION

To my husband Kenneth and my children Christian and Eileen

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ABBREVIATIONS AND ACRONYMS

CBO	Community Based Organization
FAO	Food Agriculture Organization
GOK	Government of Kenya
Ha	Hectares
HAT	Highest Astronomical Tide
IBA	Important Bird Area
KFS	Kenya Forest Service
KWS	Kenya Wildlife Service
MEA	Millennium Ecosystem Assessment
MLWN	Mean Low Water Neap
NGOs	Non-governmental Organizations
TEEB	The Economics of Ecosystems and Biodiversity
TESSA	Toolkit for Ecosystem Service Site-based Assessment
UNEP	United Nations Environmental Program

DEFINATION OF TERMS

Current scenario: This is the present condition of the habitat at the time of data collection.

Inundation: Refers to flooding of an area.

Landward position: Refers to “towards land.’

Neap tide: A tide in which the difference between high and low tide is the least.

Plausible future scenario: Refers to where the habitat is converted (for example to agriculture), restored (for example mangrove forests replanted following deforestation) or in which resources are used differently (for example increased intensity of fishing).

Rapid Eye: This is the five-satellite constellation which produces imagery in five spectral bands and offers high resolution images at 5m resolution which is helpful in vegetation mapping.

Sea ward position: Refers to ‘towards the sea.’

Spring tide: A tide in which the difference between high and low tide is the greatest.

Tide: The periodic rise and fall of the waters in the ocean produced by the attraction of the moon and sun.

Tidal limits: The furthest point the water level reaches at a given tide.

Wind fetch: This is the unobstructed distance the wind travels over water in the same direction.

ABSTRACT

Mangroves are considered a highly productive blue forest providing services that are important to the community both locally and globally. Increasing human population and demand for natural resources is threatening the existence of these forests. The concept of ecosystem services and its valuation helps in educating and informing people of the benefits and cost of their decisions. There is need to provide a simplified approach to identify, assess and quantify ecosystem services. This study assessed the value of harvested goods and coastal protection services provided by mangroves of Mida Creek in the current and plausible future scenarios. The study adopted the methods described in the Toolkit for Ecosystem Services Site-based Assessment (TESSA). Data was collected using primary techniques (focus group discussions, key informant interviews, spatial methods, household interviews and field measurements), and secondary data (data on wind speed and coastal protection values). Descriptive statistics was used to summarize quantitative data. The coastal protection value of mangroves was extrapolated from secondary data. This study estimated the annual current value of harvested goods in Mida Creek to US$ 11.3 million (US$ 6,869.5ha^{-} yr.$^{-}$). The value was expected to increase to US$14.2 million in the conservation scenario but reduce to US$ 10.9 million in the business-as-usual scenario. The study also established that a wider mangrove bandwidth offers better protection against coastal hazards as opposed to a narrow bandwidth. The value of coastal protection in the current scenario was estimated to be US$ 5.1 Million per year. It is likely to increase to US$ 5.7 Million per year in the conservation scenario and was estimated to reduce to approximately US$ 5.0 million in the business as usual scenario. From, these results, raising awareness among stakeholders on the importance of sustainable use of the natural resources as demonstrated by the value of ecosystems services that would be lost or gained if the mangrove of the Mida Creek is altered is necessary. These findings also add to growing literature on ecosystem services valuation and the need to use site specific non modelling tools like TESSA.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Ecosystem services are the direct and indirect benefits that human beings enjoy from nature (Costanza *et al.*, 1997; TEEB foundation, 2010). The Millennium Ecosystem Assessment (MEA) has classified ecosystem services into the following classes: Provisioning, Regulating, Supporting and Cultural services. Provisioning services are the goods people obtain from the ecosystem. They include food, wood products including poles for wood, firewood, medicine and fishery resource (MEA, 2005; Anam and Thomas, 2017). Regulating services are the benefits obtained from the regulation of ecosystem processes. They include resilience, nutrient cycling, biological control, air quality regulation, maintenance of biodiversity for ecosystem function and resilience, climate regulation through sequestering of carbon and coastal protection (MEA, 2005; Bosire *et al.*, 2008; Donato *et al.*, 2011). Supporting services are those services that enable the ecosystem to provide other services. Examples include soil formation, photosynthesis, primary production, nutrient cycling, water cycling, breeding and nursery grounds for marine and pelagic species many of which have commercial values. Cultural services are the non-material benefits people obtain from visiting the natural habitats which are mainly recreation and aesthetic experiences (MEA, 2005; Walters *et al.*, 2008).

Mangrove forests occur in the tropics along ocean coastlines and forms productive and biologically rich ecosystem. The forest maintains a home and nourishing grounds for different marine and coastal organisms including the critically endangered species of

Eleutherodactylus caribe (Luther and Greenberg, 2009). The complex networks of mangrove roots help reduces the effect of wave action, erosion and protect coastal communities from extreme events caused by global changes like storms and tsunamis (UNEP, 2014a).

The sustainable provision of these ecosystem services is essential for human wellbeing (Hooper *et al.*, 2012). However, approximately 60% of the world's ecosystem services have either been degraded or unsustainably used (MEA, 2005). For example, studies predicted that a third of the major world fisheries diminished by 2003 and may continue to decline (Worm *et al.,* 2006; Clavel *et al.,* 2010). Mangrove cover has also declined by 30-50 % (Donato *et al.,* 2011) because of anthropogenic activities (Macintosh and Zisman 1997; Valiela *et al.,* 2001).

Knowledge of the linkage between ecosystem services and human wellbeing through valuation methods (both market and non-market) allows policy makers to integrate the ecosystem services into the decision-making process (Fisher *et al.*, 2008; Fisher *et al.*, 2010). It also makes it clear to decision makers of the importance of ecosystems to the society and what would happen if the ecosystems were lost (Ruckelshaus *et al.,* 2013; Laurans *et al.,* 2013). Valuation also contributes to sustainable use of natural resources which in turn leads to poverty alleviation and conservation of the natural resources (Owuor *et al.,* 2017).

This study aimed to evaluate the value of harvested goods (for example, fish, honey, firewood and poles) and coastal protection potential of mangroves in the Mida Creek using the Toolkit for Ecosystem Service Site-based Assessment (TESSA toolkit) developed by Peh *et al.* (2017).

1.2 Statement of the Problem

Increasing human population and an increasing demand for natural resources have led to continued degradation and loss of mangroves hence, loss of ecosystem services (Alemayehu, 2016). Limited studies along the Kenyan coast highlighting the value of ecosystem services hampers awareness creation and policy formulation processes aimed at protecting mangroves. Many studies have failed to value ecosystem services that would be lost or gained in the alternative plausible scenarios. This study is designed to evaluate the value of goods harvested from mangroves and to assess the coastal protection potential of mangroves in Mida Creek in the current state and the plausible alternative state using the Toolkit for Ecosystem Service Site based Assessment (TESSA) developed by Peh *et al.* (2017). This study will also help stakeholders to recognize the value of mangroves using a case study of Mida Creek, thus highlighting the consequences of destruction and degradation of natural habitats (Peh *et al.*, 2013).

1.3 Justification of the Study

Monetary and non-monetary assessment of ecosystem services is important in communicating the benefits of environmental conservation among stakeholders and extending the benefits of conservation beyond protected areas (Hauck *et al.*, 2013). It also identifies management strategies to enhance economic sustainability and human wellbeing (Peh *et al.,* 2013). Mida Creek provides important ecosystem services. The services include provisioning services (food, honey, construction poles and medicine), regulating services (regulation of climate, erosion control and coastal protection), supporting services (biodiversity, habitat) and cultural services (recreation, education and research, cultural shrines) (Owuor *et al.,* 2017). It is also an Important Bird Area (IBA) as it forms important passage and wintering areas for Palearctic migrant waders and home to several bird species some of which are threatened including the little yellow flycatcher (Bennun and Njoroge, 1999; Birdlife International, 2020).

With many competing uses of marine and coastal ecosystem, there is a need to formulate and implement policies that will inform effective management of natural resources to reduce continued degradation of these important ecosystems (Owuor *et al.,* 2017). This study adopted the TESSA toolkit because it emphasizes on the importance of comparing estimates for alternative states of a site. This enables decision makers to assess the net consequences of such a change, and hence the benefits of human well-being that may be lost through the change or gained through conservation (Peh *et al.,* 2017).

1.4 Research Questions

i. What are the current drivers of change that are likely to change the future state of mangroves in Mida Creek?

ii. What is the trend in Land Use Land Cover change at Mida Creek and how is this likely to change in future scenarios?

iii. What are the values of harvested goods and coastal protection services of the mangrove forest in the current state and in future scenarios?

iv. Does Mangrove forest in Mida Creek protect the coastal communities by dissipating waves and how would it change in the future states?

1.5 Hypotheses

i. The current drivers of change are not significantly likely to change the future states of the mangrove forest in Mida Creek.

ii. Land Use Land Cover has not significantly changed over the years.

iii. The value of harvested goods and coastal protection services provided by Mida Creek's mangrove forest does vary significantly between the current and future scenarios.

iv. The mangrove forest in Mida Creek does not significantly protect the local community from wave action.

1.6 Objectives

1.6.1 General Objective

The main objective of this study is to determine the value of harvested goods and coastal protection services by mangrove forest in the Mida Creek in the current state in comparison to future scenarios.

1.6.2 Specific Objectives

i. To determine the plausible alternative states of mangroves in Mida Creek given the current drivers of change.

ii. To determine the trends in Land Use Land Cover at Mida Creek.

iii. To assess the values of goods harvested and the coastal protection services provided by mangroves of Mida Creek in the current state and in future scenarios.

iv. To determine whether the mangrove forest protects the coast from wave action in the current state and future scenarios.

CHAPTER TWO

LITERATURE REVIEW

2.1 Global Distribution of Mangroves

Mangroves are tropical forest ecosystems growing on muddy soils in sheltered coastal saline to brackish environments (Quartel *et al.*, 2007). Mangroves are found along subtropical coastlines between 25^0 N and 25^0 S latitude (Kauffman and Donato, 2012). Temperature controls latitudinal distribution of mangroves with the richest community occurring where the water temperatures is higher than 24^0C in the warmest month (Hensel *et al.,* 2002; Agrawala *et al.*, 2003). Mangroves grow in 118 tropical and subtropical countries (Giri *et al.,* 2010); 73 species are recognized as true mangroves (Spalding *et al.*, 2010; UNEP, 2014a). True mangrove species only grow in intertidal zones, e.g *Bruguiera gymnorrhiza*, *Avicennia alba and Rhizophora mucronata* (Chaudhuri *et al*. 2015; Tomlinson, 2016). In 2000, the total coverage of mangrove was estimated to be 137,760km^2 with Asia having the largest coverage of 42%, followed by Africa at 20%, North and Central America 15%, Oceania 12%, and finally South America at 12% (Giri *et al.,* 2010).

2.2 Mangrove Forests in Kenya

Mangrove forest in the Kenyan coast covers about 61,271 ha representing about 3% of the total natural forest cover (GOK, 2017). Mangrove forests are found in tidal estuaries, creeks and protected bays along the entire coastline. The largest coverage occurs in Lamu

61% with Mombasa and Tana River counties having the least at 6% and 5% respectively (Abuodha and Kairo, 2001; GOK, 2017). Nine mangrove species are found in Kenya including *Avicennia marina, Bruguiera gymnorrhiza, Ceriops tagal*, *Rhizophora mucronata*, *Sonneratia alba, Xylocarpus granatum, Xylocarpus moluccensis, Heritiera littoralis* and *Lumnitzera racemosa* (Gang and Agatsiva, 1992; Kairo, 2001) with *Rhizophora Mucronata* and *Ceriops tagal* being the most abundant in all the plant formation (GOK, 2017).

2.3 Importance of Mangroves

Mangroves are important coastal ecosystems that provide numerous ecosystem services and critical ecological functions (Kauffman and Donato, 2012). They provide the local people with wood products including timber, poles, fish traps, firewood and charcoal (FAO, 2007; Hussain and Badola, 2010). In coastal regions dominated by sandy beaches where timber species are scarce, mangrove plants are often the only available source of fuelwood and timber for construction of houses in tropical developing countries (Walters *et al*, 2008).

Mangroves also provide fish, honey, crabs and medicine to the locals. Mangrove fish and shellfish supply the main source of protein for coastal communities hence provides an essential component of people’s basic needs (UNEP, 2014b). Mangroves form nursery and feeding grounds for commercial and artisanal fisheries, and are important habitats and feeding grounds for a range of benthic and pelagic marine animals and bird species (Saenger, 2002; FAO, 2007).

Mangroves forms natural barriers by dissipating wave energy, protecting the lives and properties of the coastal communities from storms, cyclones, flooding and erosion (Walters, 2003; Hong, 2006). Mangroves protect shorelines against erosion and stabilizes the shoreline by trapping sediments (Dahdouh-Geubas *et al.*, 2005; Allsopp *et al.*, 2009; Ellison, 2012) hence protecting the sea grass and coral reefs. Through stabilizing the shorelines, the forests minimize the impact of tsunamis and hurricanes (Giri *et al.*, 2010). Studies show that the presence of mangroves along different coastlines helped protect communities from the effects of hurricanes, typhoons, tsunamis and tidal wave surges (Dahdouh-Geubas *et al.*, 2005; Hirashi, 2008). Mangroves reduce the height and energy of wind and swell wave passing through them reducing their ability to erode and damage other infrastructure like sea wall (Spalding *et al.*, 2010).

2.4 Threats to Mangrove

Mangroves have continued to degrade at alarming rate; this is despite their importance being reported in different publications and media (Balmford *et al.*, 2002). Exploitation of mangroves for forestry uses such as timber, firewood and charcoal cause considerable loss if not well managed (Valiela *et al.*, 2001; Macintosh and Zisman 1997). However, the biggest threats are high population growth and development pressures experienced in coastal wetland ecosystems across the world (Hassan *et al.*, 2005).

High population pressures and the limited research highlighting the Total Economic Value of mangrove forest to policy and decision makers, and development agencies have led to the conversion of the mangrove forest for aquaculture, agriculture, salt ponds, and urban development (Gilbert and Jannsen, 1998). An example is the large-scale conversion of the mangrove forest to create land for aquaculture and tourism infrastructure which was witnessed in the period before 1980 in Asia, Caribbean and Latin America (FAO, 2007). Since 1978, agriculture, shrimp farming and urbanization have destroyed more than half of the mangrove area in Segara Anakan Lagoon, Indonesia (Ardli, 2007; Hinrichs *et al*.,2009).

Pollution from land to sea such as industrial affluent, human waste, and oil spills from oil tankers disrupt ecosystem processes and put further strains on the mangrove ecosystems (Valiela *et al.,* 2001). Mangrove loss is also attributed to failures in policy, management and enforcement (Bagarinao and Primavera, 2005).

Mangrove forest in Kenya faces several threats including population pressure, poverty, low levels of education, overexploitation, economic development, pollution and poor governance (Bagarinao and Primavera, 2005). Between 1985 and 2009, the country lost about 20% of its mangrove cover, translating to about 450ha of mangrove each year with the largest loss occurring in the urban centers (Kirui *et al.*, 2013; GOK, 2017). The continued degradation and loss of mangrove cover translates to the loss of the ecosystem services provided by the mangroves (Friess *et al.,* 2012).

2.5 Analysis of the Plausible Alternative States of the Mangrove Ecosystem

A plausible is a simplified description of how the future may develop, based on the best available current information and a coherent and internally consistent set of assumptions about key driving forces and relationships (CCI and BirdLife International, 2011). The TESSA toolkit is designed to provide a practical guide for conservation practitioners on how to identify which services may be significant at a site of interest, what data are needed to measure them, what methods or sources can be used to obtain the data and how to communicate the results (Peh *et al.*, 2017).

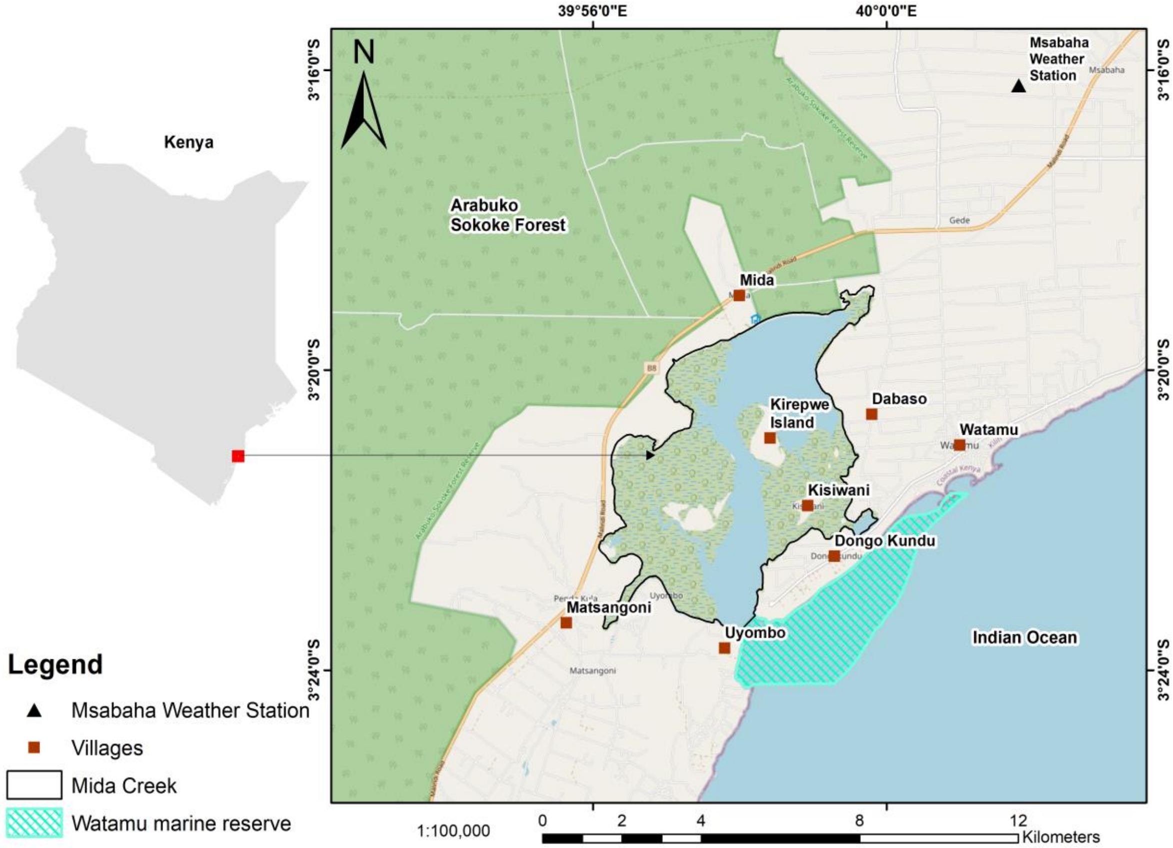
The toolkit emphasizes the importance of comparing estimates for alternative states of a site (for example, before and after conversion to agriculture). Identification of an alternative state allows for a comparative assessment that can make services provided by the site at its current state compared to alternative; where the ecosystem may have been converted, degraded, restored or where the resources are used differently (Peh *et al.*, 2017). This allows decision-makers to assess the net consequences of such a change, and hence the benefits for human well-being that may be lost through the change or gained by conservation.

Based on the drivers of change and their relative impact on the habitats and associated ecosystem services, projected future land cover / land use and ecosystem services change, stakeholders can be engaged to arrive at a realistic plausible state that is based on policies and process relevant to the site (Peh *et al.*, 2017). Studies by Muoria *et al*. (2015) in Yala swamp recommended that the land use and management policies and plan adopt a balance between development and conservation, to improve the socioeconomic wellbeing of the residents while protecting the diversity. Blaen *et al*. (2016) investigating the socio-economic benefits of ecosystem services provided by a former mineral extraction site, demonstrated that restoration for nature conservation can yield ecosystem services that benefit both local and global communities.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Site



Mida Creek is located in the Kilifi County, at the Kenyan Coast lying at 3^{0}22’0’S and 39^{0}58’0E and an altitude of 0-10m above the sea level (Figure 1).

Figure 1: Location of the Study Site (Mida Creek)

(Generated by Earth GIS Version 10.8)

The mangrove forest ecosystem is surrounded by human settlements living in seven villages: Dabaso, Kirepwe, Uyombo, Sita, Gede, Matsangoni, Dongo Kundu and Mida with approximately 4838 households (Kenya National Bureau of Statistics, 2010). The economic activities of most of the people living around Mida Creek are fishing, crop farming, business activities and tourism-related ventures (Owuor *et al*., 2019). The major drivers of change include overexploitation of some mangrove species, overfishing, residential and commercial development, conservation action, climate change, lack of management plans and pollution (Alemayehu, 2016; GOK, 2017).

The total mangrove cover in the Mida Creek is estimated at 1,746ha and is dominated by *Rhizophora- Ceriops* type forest (GOK, 2017). Seven mangrove species have been identified at Mida Creek including, *Avicennia marina, Bruguiera gymnorrhiza, Ceriops tagal*, *Rhizophora mucronata, Sonneratia alba*, *Xylocarpus granatum* and *Lumnitzera racemosa* (Gang and Agatsiva, 1992; Kairo, 2001).

Mida Creek is an important passage and wintering area for Palearctic migrant waders. The populations of *Charadrius leschenaultii*, *Charadrius mongolus* and *Dromas ardeola* at Mida Creek are internationally important (Birdlife International, 2020). Many other species use the site: up to 6,000 waders may be present at any one time (Birdlife International, 2020). It is also an important spawning grounds for many fish species for example, *Spratelloides delicatulus* and *Ambassis natalensis* (Gajdzik *et al*., 2014).

3.2 Methods and Materials

The study adopted the methods described in TESSA (*Peh et al*., 2017). This is because the toolkit is site specific and allows for comparison of estimates for alternative states of a site. The data was collected using primary data collection techniques (focus group discussions, key informant interviews, spatial methods, household interviews and field measurements), and secondary data (data on wind speed and coastal protection values).

3.2.1 Focus Group Discussions (FGDs) and Key Informant Interviews

A preliminary scooping appraisal form (Appendix I) adopted from The Toolkit for Ecosystem Service Site-based Assessment (TESSA) (Vol.2) by Peh *et al*., (2017) was used to conduct a participatory ecosystem service appraisal for Mida Creek in Dabaso ward. A total of thirty-nine participants (chosen using purposive sampling) representing community-based groups, forest and marine park management and academia from Pwani university were in attendance. The purpose for this exercise was to gather information on; status of mangroves, current drivers of change and their impact, formulate plausible future states based on the current drivers of change and compare the ecosystem services provided by the creek in the current and future states. Key informant interviews were used to obtain information on the hazards experienced in the study area using questionnaire on coastal protection (Appendix II). The key informant interview included older members of the community who have lived for a period of at least 50 years and have the knowledge of the hazards and changes that have taken place in the area.

3.2.1.1 Status of Mangrove

The participants were independently asked about their perception on the state of mangroves in Mida Creek in terms of degradation, using a Likert scale ranging from ‘heavily degraded’ to ‘excellent state. The socio-economic profile of each participant of the focus group discussion was also taken (Table 1). This was useful in assessing the influence that socio-economic variables had on the perceptions of the respondent regarding the status of mangroves.

3.2.1.2 Identifying Current Drivers of Change and their Impact

The thirty nine participants of the focus group discussion were randomly divided into three groups. Each of the group was provided with a list of possible drivers of change or threats relevant to the site. The groups added any other driver of change/threat that was not on the list provided. Group members discussed each threat and agreed on a score for timing, scope and impact of each of the drivers/threat on the creek. The scores were as follows:

Timing

1= Likely in long-term (beyond 10 years)

2= likely in the short term (10 years)

3= Happening now

Scope

0= little of area (<10%)

1= some of the area (10-49%)

2= most of the area (50-90%)

3= whole area (>90)

Impact

1 = low (1-10%)

2 = Moderate (10-30%)

3 = High (>30%)

For each driver of change, the timing, scope and impact scores were summed to give a total impact score. The mean impact score for the three groups was then calculated.

3.2.1.3 Formulating Plausible Future States based on the Current Threats

The group members discussed the threats identified in step 1 and the possibility of conservation and management interventions being implemented by various stakeholders in the creek to counter the threats identified in step 1. They also discussed the reality of continued overexploitation of the mangrove resources and other related services provided by mangroves.

3.2.1.4 Comparing the Importance of Ecosystem Services Provided by the Current and Future Alternative States

Each of the three groups was provided with a list of potential ecosystem services provided by the creek. They were requested to add any other that was not on the list. Each group deliberated on the list and scored the importance of each ecosystem service at the current and each plausible future scenario. Scores ranged from 0 (very low importance) to 5 (very high importance). Based on the scores from the three groups, the mean score of each ecosystem service identified was calculated.

3.2.2 Land Use Land Cover Changes

The study used Landsat imagery to assess the changes in the land use characteristics of the study area. For 1985, Landsat 5 Enhanced Thematic Mapper (ETM+) was used while in 2000, Landsat 7 (ETM+) was used. For 2015 and 2019, Landsat 8 was used. The images were on the Landsat path 166 and row 062 and at a resolution of 30m. Choosing criteria of the Landsat imagery ensured same seasonality of images, with a slight variation of the dates or months due to the challenges of high cloud presence in the coastal areas. The data was downloaded from the USGS (United States Geological Survey) earth explorer website and processed using remote sensing software; ArcMap 10.8.

3.2.3 Quantification on Harvested Goods

A detailed structured questionnaire (Appendix III) was used to collect data for estimating amount of harvested goods. The number of households around Mida Creek was estimated from the 2009 Kenyan Population and Housing Census. The total number of people in Mida Creek in 2009 was estimated to be 30,300 occupying 4838 households. The number of people per household was estimated to be 6.26 persons per household and a growth rate of 2.9% (Kenya National Bureau of Statistics, 2010). From these figures, the total population currently living around Mida Creek was then estimated to be 40,327 persons. This translated to 6442 household. The sample size was then obtained by the formula:

$$n_o = \frac{Z^2pq}{e^2}$$

Where; $n_{o\,=}$ is the sample size, e is the margin of error, p is the estimated proportion of the population which has the attribute in question, q is $1 - p$ and Z is the desired confidence level (Israel, 2013). The sample size was found to be 95 households at 95 percent confidence level and a margin of error of 10 percent. The number was then rounded off to a hundred for easier computations. Thus, heads of the families in a hundred households were sampled and interviewed. In cases where the household heads were absent, adults above eighteen years old were selected. The interviews were done in villages adjacent to Mida Creek including Uyombo, Dabaso, Dongo Kundu, Kirepwe Island and Mida.

Systematic sampling was used to select households. The main path, track or road in each village was used as sampling transects to standardize participant selection. The first household was then selected randomly, followed by selection of every fifth homestead along transects. The data collected included the type and quantity of harvested goods, the unit of measurement, whether the product is harvested for domestic consumption, price of the commodity per unit and production cost. Production cost comprised of annual costs of labor, tools and market costs.

3.2.4 Data Collection for Wave Characteristics

The wind speed and wind direction data collected several times a day for a period of one year was obtained from Msabaha weather station. Msabaha weather station is approximately 10km from the study site which is within the recommended distance of 50km (Peh *et al*., 2017).

The tidal limits and percentage inundation of the site was estimated by randomly asking the local fishermen the most landward position of the water level as observed during the spring tide and neap tide (Mean High Water Spring; MHWS and Mean High Water Neap; MHWN respectively), the most landward position of the water level within an entire year (Highest Astronomical Tide; HAT), the most seaward position of the water level as observed during the Spring and neap tide (Mean Low Water Spring; MLWS and Mean Low Water Neap; MLWN respectively).

The frequency of the flooding of the site was determined by establishing whether the landward limit of the site lies between HAT and MLWS (Peh *et al*., 2017).

Landward limit in zone A (Figure 2) means that the site will only ever completely flood during meteorologically induced storm surges. Landward limit in zone B means that the site only floods completely during the highest spring tides of the year and any wave reduction service will be restricted to those times. Those occasions occur during less than 10 % of the year. Landward limit in zone C means that the site only floods during spring tides which occurs approximately 40% of the year. Landward limit in zone D means that the site is likely to be completely inundated on every tide and is estimated to occur approximately 50% of the year. Finally, landward limit in zone E indicates that the site is likely to be completely inundated on every tide and is sometimes not exposed between tides. A percentage figure of 80 should be used in this case (Figure 2) (Peh *et al*., 2017).

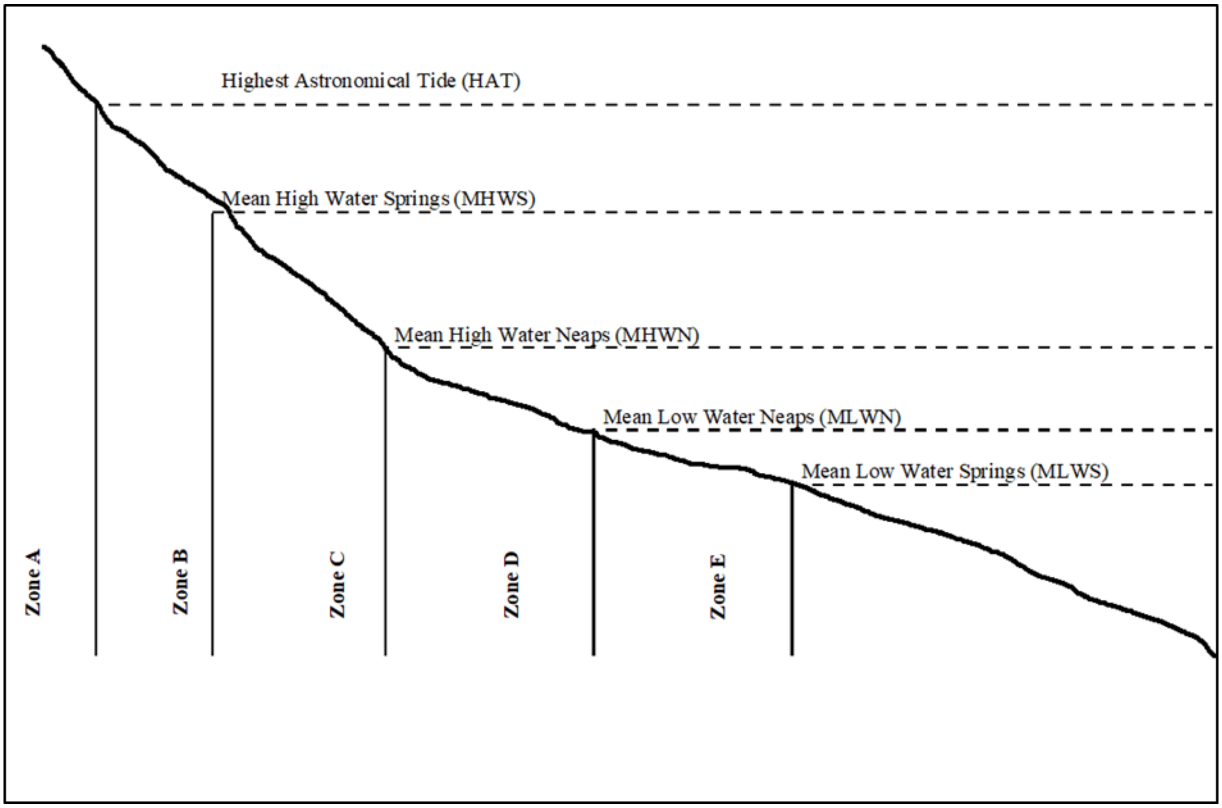


Figure 2: The Position of the Various Tidal Limits on the Cross-shore Profile Indicating the Location of Zones A to E

The water depth across the mangroves in the creek was obtained by first identifying two zones based on the levels of destructions using a GIS application; not degraded areas (Sudi Island) and degraded areas (Uyombo) were chosen. 100m transects was then used across each site to determine the water level by measuring the watermark left on the trees during the spring high tides. The trees that touch or those near the transect line were selected.

The value of coastal protection by mangroves in Mida Creek was estimated using secondary data from the study done by Marwa and Evan (2012). The mean value per hectare obtained from their study was multiplied by the land cover of mangrove in Mida creek in all the scenarios. Data from this study was used because it compiled data from

73 studies involving 352 observations for mangrove ecosystem services valuation done in 18 countries in Asia, America, Middle East and Africa (Marwa and Evan, 2012).

3.2.5 Data Analysis

3.2.5.1 Stakeholder's Perception on Deliberations

Measures of central tendency (mean) and percentages were computed to summarize the data on perception of the status of mangrove ecosystem in terms of degradation and socio-economic characteristics of participants in the focus group discussion. Ordinal logistic regression (Torres-Ryan, 2012) was used to assess those factors that influenced perception of degradation status of the mangrove. The dependent variable had four categories: Excellent state, good, somewhat degraded and heavily degraded. These were ordered in a Likert scale from "heavily degraded" to "excellent state" for ease of analysis. All five socio-economic characteristics of the respondents were tested for significance at 95% level, and only those that had 0.05 or less significance is reported in this study. Data on current drivers of change and those comparing the importance of the ecosystem services provided by the creek in the current and future states were also summarized into percentages.

3.2.5.2 Land Use Land Cover Changes

Supervised classification was conducted with the maximum likelihood algorithm (Otukei, 2010). A high-resolution imagery from RapidEye was used to run the accuracy assessment for the recent years (2015 and 2019), while Google Earth imagery was used in the accuracy assessment of the years 1985 and 2000. For accuracy assessment, 100 random points were selected for the mangrove classified areas while 25 sampling points were selected for the non-mangrove terrestrial areas (Miettine, 2012). The random points were then used to verify the classified land cover in comparison to RapidEye and Google Earth.

The rate of change of mangrove cover was then quantitatively estimated based on Peng *et al*. (2008) procedures; $K1 = \frac{Ub-Ua}{Ua} \times \frac{1}{T} \times 100\%$ where $K1$ is land use dynamic degree, U_a and U_b are the areas of the target land use at the beginning and end of the study period respectively and T is Study period. From the land use dynamic degree, the rate of mangrove cover change in fifteen years was estimated and therefore the mangrove cover area in the future scenarios were projected assuming that all factors remains constant. The fifteen years period was the time frame for the projected future scenario in this study.

3.2.5.3 Analysis of Harvested Goods

Data on harvested goods collected using questionnaires was summarized into percentages and mean. Since the total number of households was estimated to be 6442 and the sample size was 100 households, the total value of harvested goods was obtained by multiplying the values obtained from the 100 respondents by a figure 64.42. The value of harvested goods that would be gained or lost was obtained from extrapolation of the future states based on the changes in the land cover of mangroves.

3.2.5.4 Analysis of Wave Attenuation Service by Mangroves

The wind speed and direction data were used to produce a wind rose diagram using the lake view software. A wind rose shows the relative frequency with which winds of a particular direction occurs and the speed associated with them. Data from the wind speed was also used to obtain the wind fetch. The wind fetch was calculated using the wind fetch scripts developed by Finlayson and running on the ArcGIS 10.5 software (Finlayson, 2005).

The wave height being significant to this study was also calculated using the ArcGIS 10.5 software using several inputs. The pre-calculated wind fetch outputs were used alongside the wind data as inputs to the model. The wind data contained numeric values made up of the wind direction and the wind speed and the date of collection of the data. Bathymetric data downloaded from General Chart of oceans was also included in the model as this influences the wave height. The wind speed, 9.37m/s, incident to the site, together with their direction, 30 degrees, were used in the model to estimate the maximum wave height that reached Uyombo and Sudi Island. Consequent analysis was based on these model outputs and was visualized in a map.

Since the mangrove species in Mida Creek have aerial roots, the wave height reduction per meter was estimated using equation; Wave height reduction / meter = $0.0086\,d^2 - 0.0128\,d + 0.0076$, (Peh *et al*., 2017) where 'd' is water depth (Peh *et al*., 2017). The expected wave height reduction across the mangrove of the site was calculated using equation; $H_x = H_0.e^{(-r.x)}$. Where H_0 is the height of incoming waves (cm), H_x is the wave height (cm) after the wave has travelled x meters through the mangrove, and r is the wave height reduction per meter. Wave Attenuation Service Provision of the site was obtained by; (percentage inundation frequency) x (percentage frequency of onshore directed waves) x (percentage wave dissipation across the full width of the site as determined above for maximum wave heights from an onshore direction) / 10^6 (Peh *et al*, 2017).

3.2.5.5 Analysis of the Value of Coastal Protection of Mangroves

Economic valuation of coastal protection by mangroves was derived from studies done by Marwa and Evan (2012) on economic valuation of mangroves. From the results of their findings (Marwa and Evan, 2012), the value of coastal protection of mangroves in Mida Creek was estimated based on the current area of Mangroves and the estimated future areas in both the conservation and business as usual scenarios.

CHAPTER FOUR

RESULTS

4.1 Stakeholders' Perception on the Current and the Plausible Alternative States of Mangroves in Mida Creek

4.1.1 Social- Economic Profile of the Participants of the Focus Group Discussion

The socio-economic profile of participants of the focus group discussion is as shown in Table 1.

Table 1: Socio Economic Profile of the Participants of the Focus Group Discussion

Attribute	Description	Percentage	Mean
Age	20-70		38.75
Gender	Male	65%	
	Female	35%	
Level of Education	No formal education	19%	
	Primary Education	55%	
	Secondary Education	18%	
	Diploma	4%	
	Degree	3%	
	Postgraduate	1%	
Member of environmental group	Yes	75%	
	No	25%	
Source of income	Fishing	32%	
	Business	29%	
	Crop farming	25%	

The age of the respondents who participated in the focus group discussion ranged from 20 to 70 years with a mean age of 38.8 years (Standard Deviation [SD] 12.1). The value of the mean suggests that most of the participants were youthful. Over half the numbers of respondents (65%) were men while women were 35%. The respondents who had formal education were 81% while only 19% had no formal education. Regarding membership of environmental groups within Mida Creek, 75% were members of different environmental groups within the creek while 25% were non-members. Out of this 25%, 5% of the respondents were from the Kenya Wildlife Service, 5% of the respondents were from the Pwani University while 15% were local residences who were neither members of the environmental groups nor other groups mentioned above. The primary source of income for the respondents included fishing 32%, business activities 29%, and crop farming 25%.

4.1.2 Perception of the Participant of the Focus Group Discussion on the Status of Mangroves

The results on the status of the mangrove forest as summarized in (Figure 3) showed that 15.4%, 25.6%, 48.7%, and 10.3% of the respondents perceived that the mangroves were in an ‘excellent state’, in a ‘good state’, ‘somewhat degraded’ and ‘heavily degraded’ respectively.

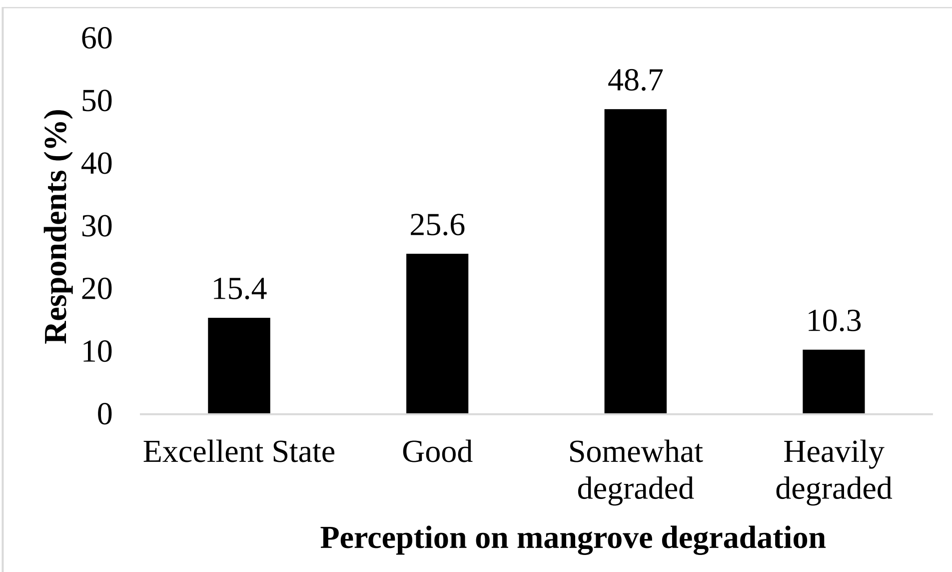


Figure 3: Percentage Response on the State of Mangrove Degradation

Five socio-economic variables were tested for their influence on the perception of the level of mangrove degradation. Results showed that only three of the five independent variables (age, member of an environmental group and gender) had *p* values less than 0.05 at 95% confidence level (Table 2). This implies that the age, being members of environmental group and gender had statistically significant results hence influenced the perception of the respondents.

Table 2: Results from an Ordered Logit on the Perception of the Degradation Status of the Mangrove Forest

Variables	Odds ratio	Standard error	Z	P>|z|	[95% Conf.	Interval]
Age	1.194	0.060	3.53	0.000	1.082	1.317
Member of environmental group						
Yes	0.202	0.190	-1.70	0.089	0.032	1.278
Gender						
Male	4.651	3.556	2.01	0.044	1.039	20.811
cut1	3.203	1.771			-0.269	6.675
cut2	5.40	1.956			1.564	9.230
cut3	10.74	2.856			5.143	16.34
Number of observations	39					
Log Likelihood	-31.89					
LR chi-square (3)	31.45					
Prob > chi-square	0					
Pseudo-R2	0.3302					

For older respondents, the odds of reporting that the state of the mangrove is heavily degraded are 1.19 times higher than that of younger respondents. This implies that the older respondents are likely to report that the mangrove is heavily degraded in comparison to the younger respondents.

For respondents who are members of environmental group, the odds of reporting that the state of the mangrove is in “excellent state” is 0.202 times that of members who are not members of environmental groups. This implies that most of members of environmental groups report that mangrove is in excellent shape.

For male respondents, the odds of reporting that the state of the mangrove is heavily degraded are 4.65 times that of female respondents. Most male respondents therefore perceived the mangrove forest as heavily degraded as compared to their female counterparts.

4.1.3 Current Drivers of Change to Mida Creek and their Impact

According to the respondents, the most important drivers of change in the creek include overfishing and harvesting of other aquatic resources, agriculture and aquaculture, climate change and severe weather, residential and commercial development and conservation actions as shown in Figure 4.

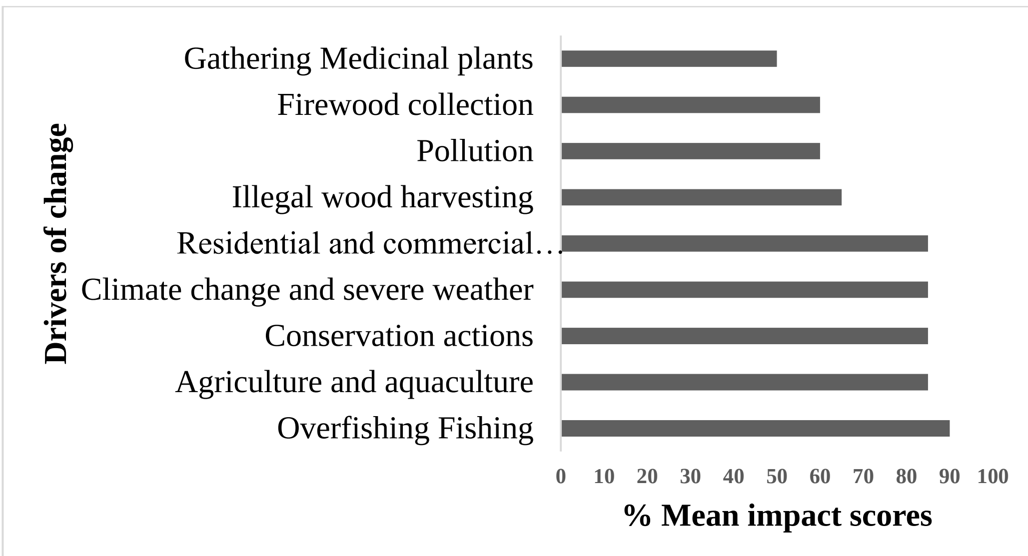


Figure 4: Drivers of change in Mida Creek According to Stakeholders' Perception

Impact scores are derived from a combination of their estimated timing, scope and severity (Peh *et al*., 2017).

Overfishing and use of the smaller mesh size negatively impact on the species numbers and composition. Overfishing can alter the ecological balance of food chains and mangrove fishing communities. Use of smaller mesh size enables capture of juvenile fish hence there may be a danger of recruitment failure due to diminishing stock. Some fishermen also dig around the roots of mangrove to obtain fishing baits and therefore negatively impacting on the mangrove ecosystem.

Agriculture and aquaculture (crab farming) were also reported as major threats to the mangrove ecosystem. The respondents reported that lack of limit on the boundaries of the farmlands around the creek and poor agricultural practices have led to siltation hence affecting the corals reefs nearby. Siltation smothers the roots causing oxygen shortage and possible death of the trees. The surface runoff fertilizers from the nearby farms may result in elevated nutrient concentrations leading to eutrophication and decline in primary productivity. The increase in toxic algal blooms may cause death of benthic fauna, threat to human life and may have negative aesthetical impacts limiting recreational activities.

Many conservation organizations, including government departments and agencies (e.g., KWS and KFS), NGOs and CBOs (e.g., The Mida Creek Conservation Community), have been implementing conservation activities at the site. Such activities include: Community environmental education and awareness, law and policy, sustainable management of natural resources, mangrove afforestation and beach clean ups. The CBOs have also initiated income generating activities like bee keeping, crab farming and ecotourism programs. The ban on logging by the Kenyan government in the year 2018 has also led to reduction on the number of mangrove trees being cut as people have to get licenses. The participants of the meeting believed that these conservation efforts will lead to restoration of the mangrove ecosystem and hence restoration of the ecosystem services that may have reduced in value. This will positively impact on the mangrove ecosystem.

The respondents noted that the area has experienced severe impact of changes in weather patterns including increasingly high temperatures leading to high salinity hence the quality of water is lowered. During the 2004 tsunami, mangroves died along the channels that were created and has not regenerated.

Residential and commercial developments lead to loss of biodiversity and a reduction in the aesthetic value of mangroves. Worse still, pollutants that accompany development can damage individual trees or whole tracts of mangroves. Pollution resulted from discharge from the hotels and surface runoff into the waters which may in turn affect biodiversity. Another source of pollution is oil spills from motorized ocean transport resulting from local transport, fishing and tourist excursions.

Illegal wood harvesting, firewood collection and gathering medicinal plants lead to a reduction in breeding sites for fish and hence a reduction in the potential of the ecosystem to provide important ecosystem services.

4.1.4 Formulating Plausible Future States based on the Current Threats

Based on the current drivers of change in Mida Creek, the respondents unanimously agreed on two possible future scenarios. **Scenario 1;** a future in which development is carried out in a sustainable way meaning that environmental safeguards are in place i.e., conservation scenario and **Scenario 2;** a future in which the current threats are not mitigated hence a business as usual scenario.

4.1.5 The Importance of Ecosystem Services in the Current and in Plausible Future Scenarios

The participants in the focus group discussion concluded that the Mida Creek was important in the provision of the following ecosystem services; Global climate regulation, local climate regulation, water quality regulation, erosion control, coastal protection, building poles, honey, fish, tourism and firewood as shown in Figure 5.

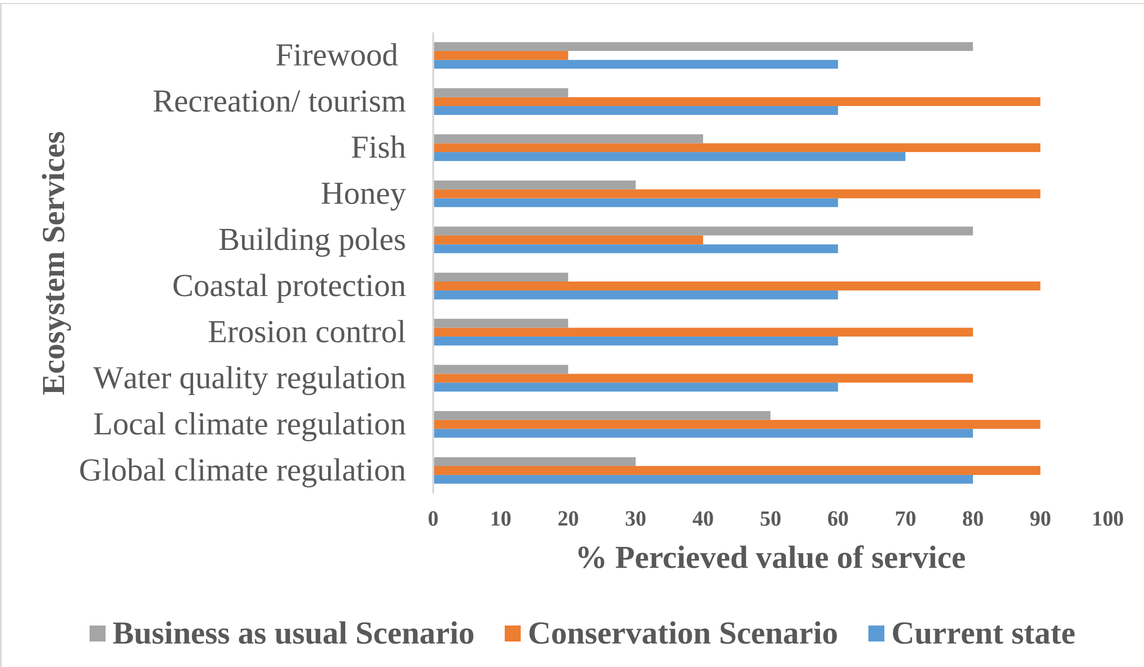


Figure 5: Comparative Ecosystem Service Provision under the Current State and Future Scenarios

The respondents believed that in the future scenario 1 (conservation scenario; where environmental safeguards are put in place and development is carried out in a sustainable manner), the value of most of these services including global climate regulation, harvested goods (fish and honey), water quality regulation, coastal protection, recreation and tourism will increase. Additionally, harvesting of building poles and firewood would decrease in the conservation scenario. The respondents agreed that if the current threats are not mitigated in the case of business as usual scenario, the value of all the ecosystem services will decrease except that of building poles and firewood.

4.2 Land Use Land Cover Changes

The land use changes for the 34 years period were quantified to show changes in land use and the area covered by the mangrove. The land cover for mangrove in the years 1985, 2000, 2015 and 2019 were estimated to be 1704 ha (Figure 6), 1654 ha (Figure 7), 1601 ha (Figure 8) and 1642 ha (Figure 9) respectively.

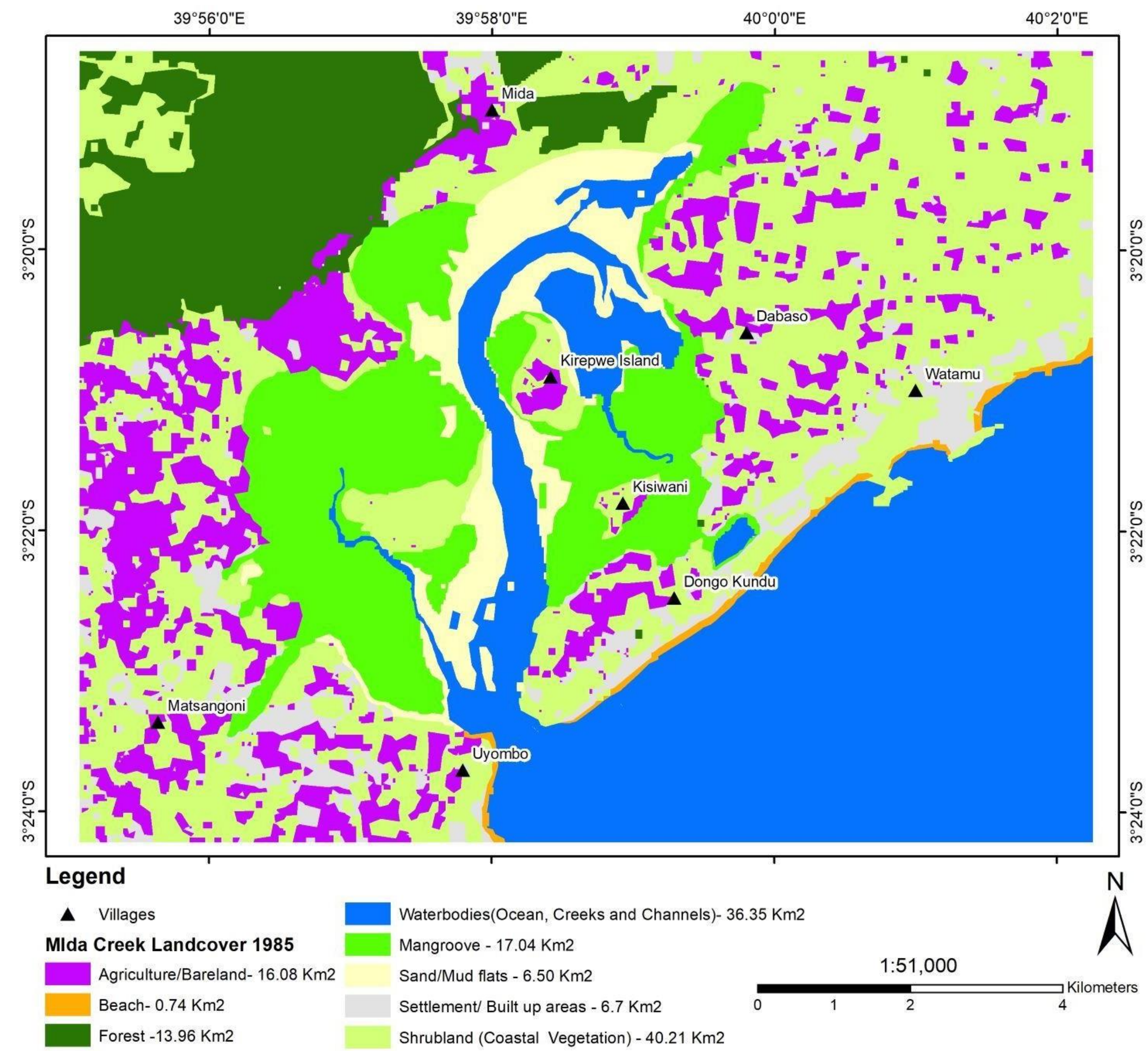


Figure 6: Map showing Mangrove Cover in Mida Creek in 1985

(Generated by Earth GIS Version 10.8)

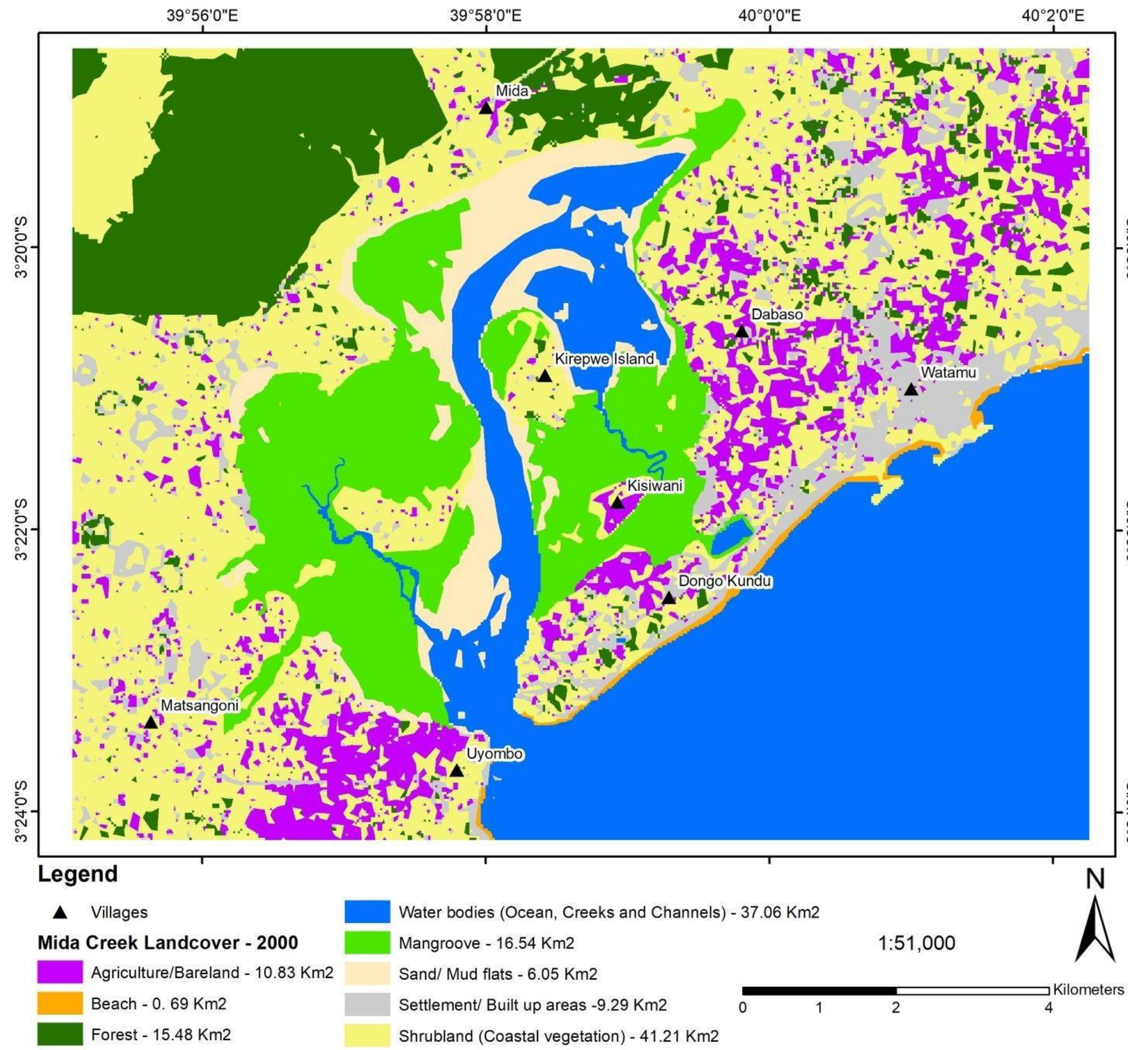


Figure 7: Map showing Mangrove Cover in Mida Creek in 2000

(Generated by Earth GIS Version 10.8)

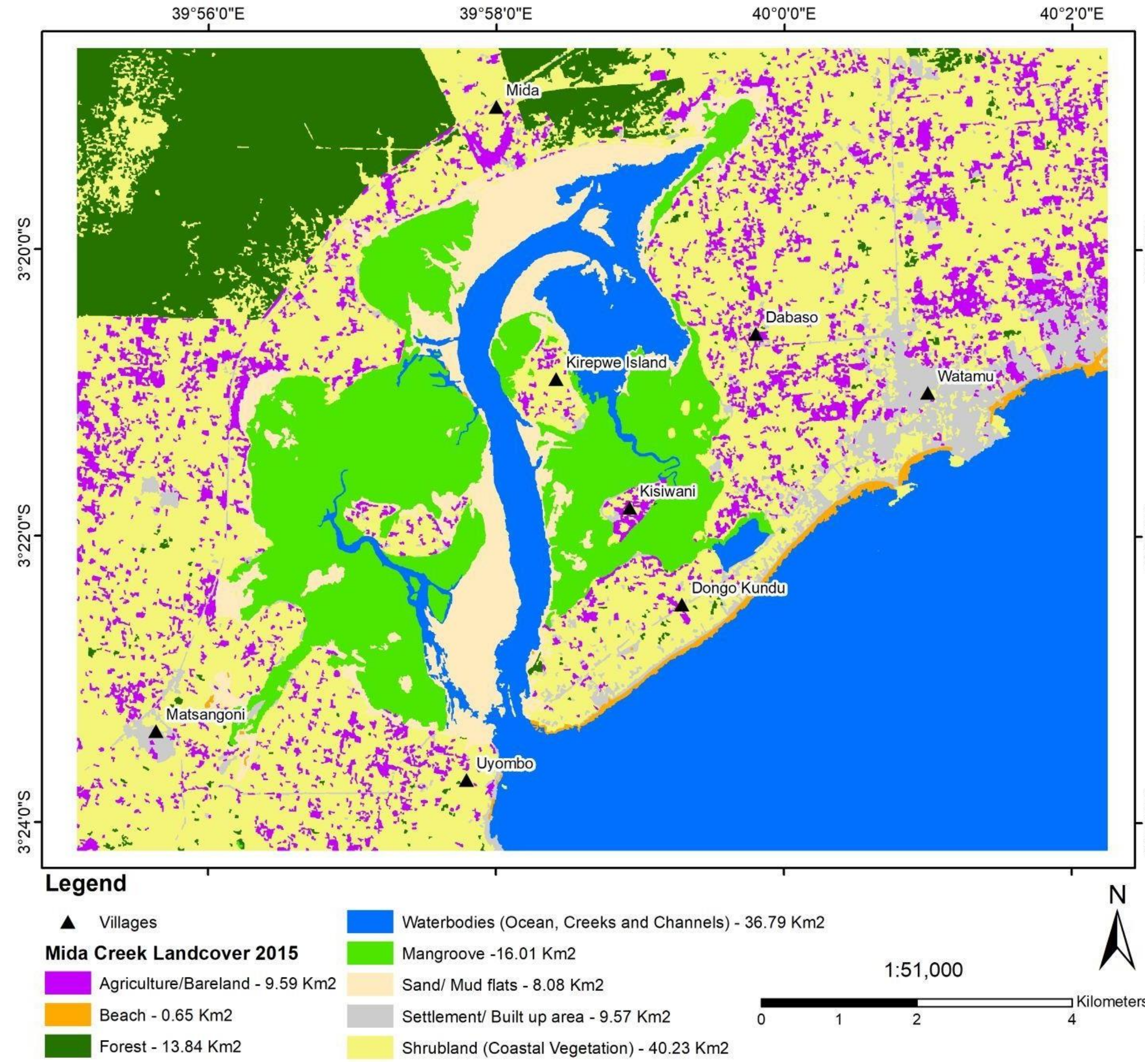


Figure 8: Map showing Mangrove Cover in Mida Creek in 2015

(Generated by Earth GIS Version 10.8)

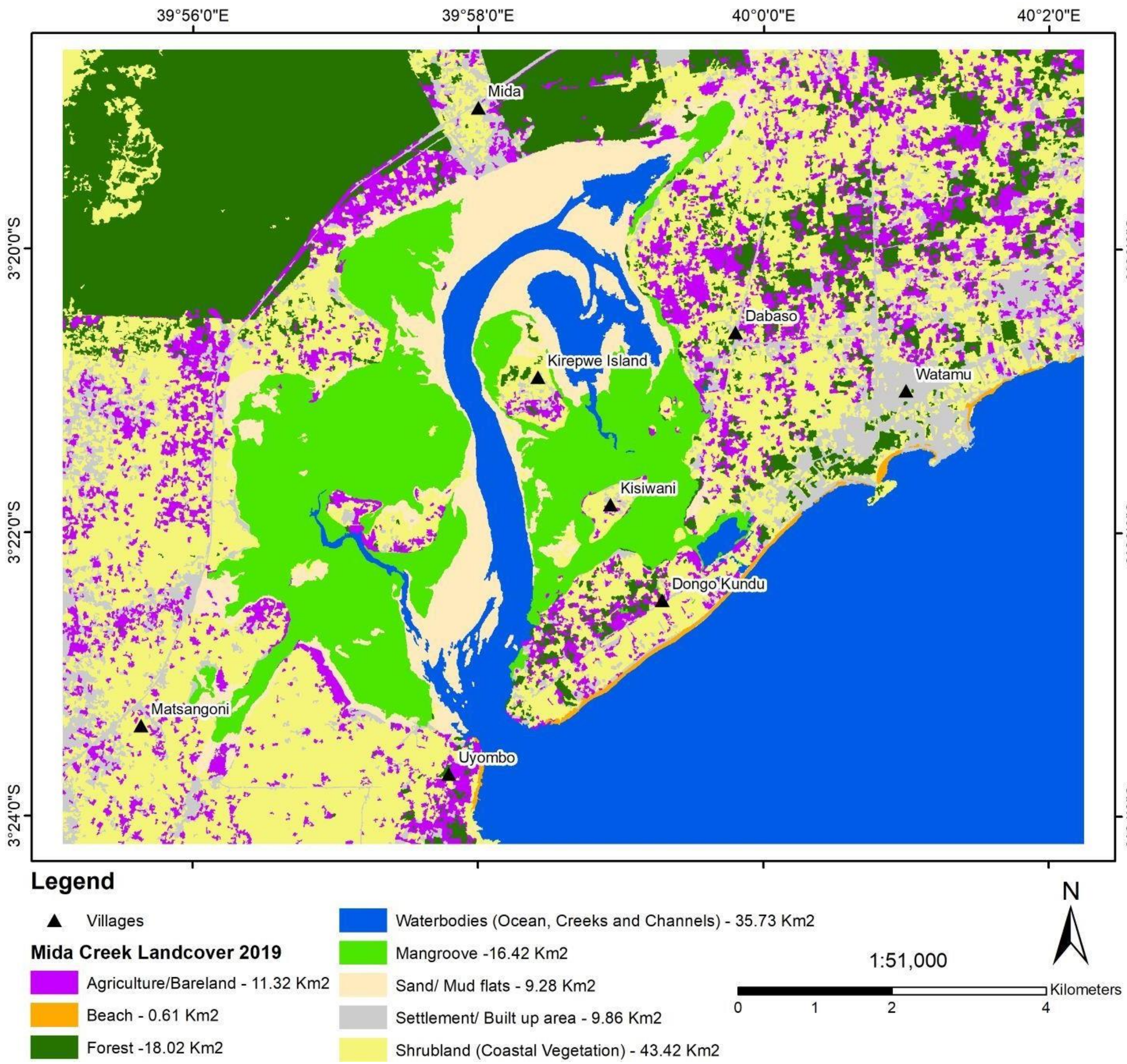


Figure 9: Map showing Mangrove Cover in Mida Creek in 2019

(Generated by Earth GIS Version 10.8)

The degree of change dynamic of mangrove cover between the periods of 1985 – 2000 was calculated to be -0.2 % while that of the periods between the years 2000 – 2015 was calculated to be -0.22%. The average change dynamic for a period of 15 years (a period when the mangrove cover was found to be decreasing) was therefore estimated to be -0.21%.

It was then estimated that if the business as usual scenario continues to take place and no measures are put in place to curb degradation, the mangrove cover area in 2034 would decrease to 1590.3 ha as shown in Figure 10.

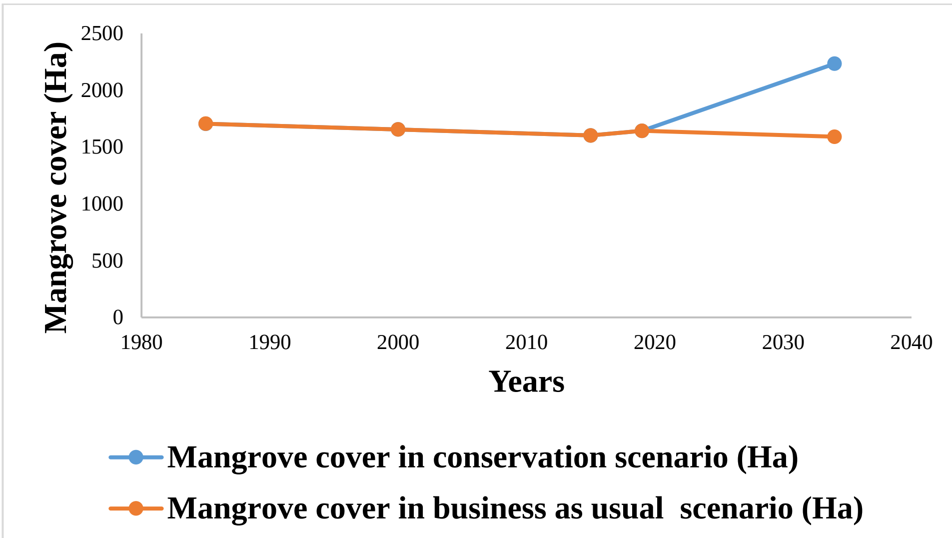


Figure 10: Mangrove Cover changes for the Previous Years and for the Projected Future Scenarios

The degree of change dynamic between the periods of 2015-2019 when there was an increase in the coverage of mangrove was estimated to be 0.64%. The degree of change in fifteen years if all factors remain constant and the conservation efforts continue to take place was then found to be 2.4%. The mangrove cover area in Mida Creek in 2034 in the conservation scenario was then projected to be 2233.2 ha.

4.3 Harvested Goods from Mangrove Forest in the Current State

4.3.1 Types, Quantities and Values of Harvested Goods in Mida Creek in the Current State

The respondents interviewed mainly harvested fish, honey, firewood and poles. Other goods like oysters, crabs and medicinal plants were harvested by very few respondents (1%) hence excluded from further analysis. It was found that most households harvested two or three goods from the mangroves. The results of the value of harvested goods are as summarized in Table 3.

Table 3: Types, Quantities and Values of Harvested Goods in the Current Scenario (2019)

Attributes	**Description**				
Types of goods		**Fish**	**Honey**	**Firewood**	**Poles**
No. Harvesting	N	54	25	35	24
Annual Quantity harvested	Total	98614.8	4516	19296	7680
	Min	154.8	80	24.12	200
	Max	4320	432	1800	500
	Mean	1746.2	180.64	551.3	320
	SD	934.23	89.96	590.84	113.29
Unit price (US$)	Mean	2.31	9.09	1.03	0.97
	SD	0.19	0.924	0.43	0
Annual cost of production (US$)	Mean	1724.55	501.26	134.93	31.14
	SD	181.9	225.76	20.03	7.46
Annual Gross value (US$)	Mean	4,033.72	1,642.00	565.7	310.62
	SD	1984.21	822.93	228.43	100.8
Annual Net value (US$)	Mean	2,309.17	1,140.74	430.77	279.48
	SD	1,860.22	683.02	129.03	107.65
	Total	8,032,863.00	1,843,535.49	971,257.12	432,098.44
	per ha	4,892.12	1,122.74	591.51	263.15

1 United State Dollar (US $) =103.02 Kenya Shillings

4.3.1.1 Fish

Fish was the most valuable good harvested from the creek with an annual net value of US$ 4892.12 per ha per year. Results as summarized in Table 3 shows that 54% of the households harvested fish. This was with an assumption that the mangroves play a role in the fish caught from the creek by providing breeding sites for the fish. The annual total amount of fish harvested by the respondent was found to be 98,614.8kg with a mean of 1746.2 kg.

Out of the total fish caught, 20.5% was used for domestic consumption while the rest was sold. The mean market price of fish per kg as quoted by the respondents was estimated to be US$ 2.31 per kg. The difference in price was due to the type of fish caught. The different types of fish included red snapper, butterfly fish, gort fish and grouper rabbit fish.

The cost of harvesting included the annual cost of buying a canoe, fishing nets, labor, fishing lines and baits. The cost of buying a canoe ranged from US$ 242.67 to US$582.41 and the canoe was expected to last for a period of at least three years. Hence the annual cost of buying a canoe was estimated to be US$ 137.52. The average annual cost of fishing net was US$ 72.8 (range US$ 48.53 to US$ 97.07). If two people work in a canoe at a cost of US$ 5.82 per day and they are working at an average of 5 days in a week, the mean annual cost of labor per respondent was estimated to be US$1514.23. The mean annual cost of harvesting of fish per respondents was estimated to be US$. 1724.55.

The mean annual net value of fish was therefore estimated to be US $2,309.17 per respondent. The total net value for the 100 respondents was therefore estimated to be US$ 124,695.18 per annum. From the estimated total number of household (6442) around Mida Creek and the land coverage of mangroves in 2019 (1642 ha), the annual current net value of fish for the whole population was therefore estimated to be US$ 8,032,863.00 or US$ 4,892.12 per hectare per year.

4.3.1.2 Honey

Twenty five percent of the households' harvested honey as summarized in Table 3. The mean annual quantity of honey harvested per year was found to be 180.64kg. The total annual quantity harvested by the respondents was estimated to be 4516Kg. Nine percent of the honey produced was domestically consumed while the remainder was sold. The respondents who harvested the highest amount of honey had more beehives; 12 as compared to those who harvested the least amount of honey; 4 beehives. The beehives used were artificial hives (mostly Langstroth hive and a few Kenya Top Bar Hive) and were placed within the mangrove forest.

The mean market price of honey per kg was estimated to be US$. 9.09. The cost of production included the annual cost of hives, the bee suit, and annual cost of labor. The annual cost of equipment that lasted more than a year was obtained by dividing the buying price by the number of years the equipment is expected to last. The cost of production varied mainly due to the number of hives present per household; minimum number of hives 4 and maximum number of hives 12. This meant that the initial cost of buying the hives and the cost of maintaining each hive varied from one household to another based on the number of hives present in each household.

The annual mean gross value of honey per respondent was estimated to be US$ 1,642 while the annual mean net value of honey was estimated to be US $1140.75 per respondent. The total net value for 100 respondents was estimated to be US$ 28,617.44 per annum.

The wide range of the value of honey was mainly due to the number of hives per household and the amount of honey harvest per hive. This amount ranged from between 13kg to 45Kg per hive per harvest. This study also established that honey was harvested approximately thrice a year. The reason in difference in the quantity of honey harvested per hive was not established. The current net annual value of honey for the whole population was therefore estimated to be US$ 1,843,535.49 or US$ 1,122.74 per hectare per year.

4.3.1.3 Firewood

Thirty five percent of the respondents harvested a total of 19,296 bundles of firewood annually with a mean annual quantity of 551.30 bundles. Most of the firewood collected, 71.41% was used for domestic consumption while the excess was sold. The annual cost of harvesting firewood included annual cost of the tools used (axe and machete) and labor. The price of a bundle of firewood was estimated from the 28.59% of the respondents who sold firewood. The annual gross value of firewood per respondent was therefore estimated to be US$ 565.70 while the annual net value of firewood per respondent was estimated to be US$ 430.77 or US$ 15,076.95 for 100 respondents. The current net value for the whole population was therefore estimated to be US$ 971,257.12 or US$ 591.51 per hectare per year.

4.3.1.4 Poles

Table 3 shows that 24% of the respondents harvested poles. The poles are mainly harvested when there was a need to construct a house. *Rhizophora mucronata*, *Ceriops tagal*, and *Bruguiera gymnorrhiza* are the major sources of wood. The mean annual quantity of poles harvested per respondent was estimated to be 320 pieces with each piece estimated to be worth US$ 0.97. The annual mean gross value of poles was estimated at US$ 310.62. The mean annual cost of harvesting poles was estimated to be US$ 31.14 and it included annual labor paid and the cost of buying a machete. The mean annual net value of poles per respondent was estimated to be US $279.48 or US $ 6707.52 for 100 respondents. Therefore, the annual net value of poles for the whole population was estimated to be US$ 432,098.44 or US$ 263.15 per hectare per year.

4.4 Value of Harvested Goods in the Future Scenarios

From the projected mangrove cover in 2034, it was estimated that in the business as usual scenario, the mangrove cover would decrease by 3.6% while in the conservation scenario, the cover would increase by 36.0%. Assuming that all factors remain constant, it was projected that the value of fish and honey will be increased by the same percentage (36%) in the conservation scenario and decrease by the same percentage (3.6%) in the business as usual scenario. The values of harvested goods in the future scenarios have been summarized in Table 4.

Table 4: Annual Net Value of Harvested Goods in the Future Scenarios

Attribute	Net Value in the current state (2019) (US$)	Net value in Business as Usual Scenario (2034) (US$)	Net value in Conservation Scenario (2034) (US$)

Fish	8,032,863	7,743,680	10,924,694
Honey	1,843,535	1,777,168	2,507,208
Firewood	971,257	1,006,222	621,605
Poles	432,098	447,654	276,543
Total	11,279,754	10,974,725	14,330,050

In the business as usual scenario, the value of fish and honey were projected to decrease since the habitat would have undergone degradation. The value of firewood and poles were projected to increase in the business as usual scenario as cutting of the trees would continue. This would make more poles and firewood available for residence. The overall value of harvested goods in the business as usual scenario was expected to decrease from US$. 11.3 million to US$. 11.0 million annually.

In the conservation scenario, the net value of fish and honey were expected to increase because of the conservation measures in place, hence more breeding sites available for fish. Conservation scenario would also lead to lower harvests of firewood and poles due to the conservation measures instituted in this scenario. The overall net value of harvested goods therefore was projected to increase to US $.14.3 million per annum in the conservation scenario.

4.5 Coastal Protection Value in the Current and Future Scenarios

4.5.1 Key Informants Perception on Coastal Hazards

The interviews from the key informant revealed that 100% of them were aware of coastal hazards which included erosion, waves and occasional storm surges. The shoreline is exposed to erosion especially during the high tides and strong winds. The major area affected by erosion as reported by the key informants was the Uyombo where there was the highest degradation of mangroves. Some of the land around Uyombo has been lost to the sea and part of the land infrastructure is likely to be lost.

The key informants noted that the areas with the highest degradation of mangroves experienced greater erosion and hence concluded that mangrove ecosystem plays a role in reducing the impacts of coastal hazards. They also reported that greater erosion is experienced when there are strong winds especially between September to May as the waves exacts a lot of force and therefore transport particles from one point to another. The key informants reported that there are periodic storm surges and most of them could remember the major increase in water levels observed in 2004 when a tsunami hit the Indian Ocean leaving three people dead along the Kenyan coast.

4.5.2 Tidal Limits and Percentage Inundation Frequency

The tidal limits for both Uyombo and Sudi Island (mean high water spring, mean high water neap, mean low water neap, and mean low water spring) were obtained by interviewing the local fishermen. From interaction with the fishermen, the landward limit of the site both in Uyombo and Sudi Island was found to lie in zone C (Figure 2). This means that the sites only floods during spring tides and hence the percentage inundation is 40%. This means that complete flooding of the site occurs approximately 40% of the year.

4.5.3 Wind Rose, Fetch Distance and Incoming Wave Height

The wind rose shows the wind speed and direction at Mida Creek during the period of January 2018-December 2018 as summarized in Figure 11.

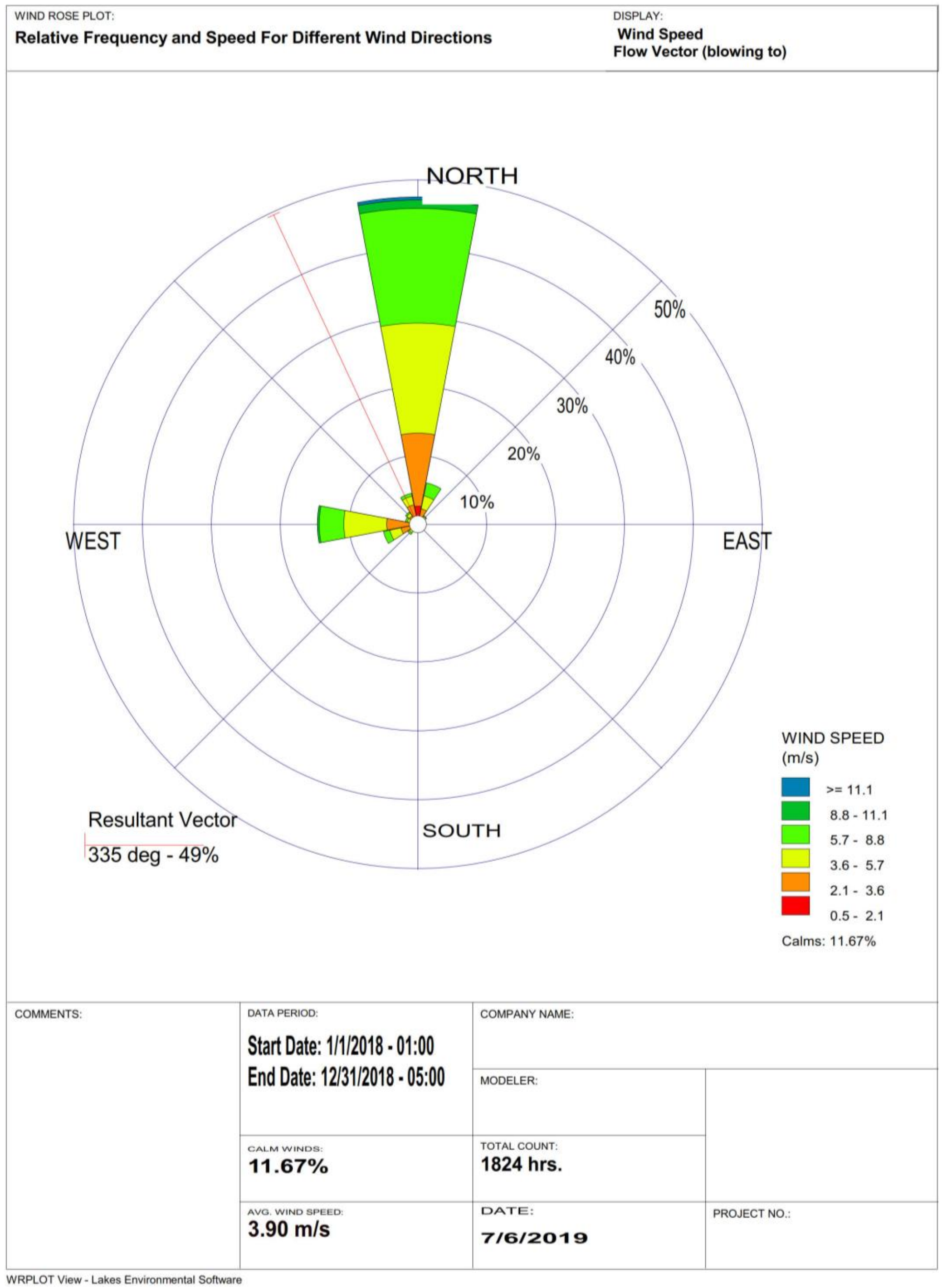


Figure 11: Wind Rose Diagram showing Wind Speed and Wind Direction in Mida Creek from 1st January 2018 to 31st December 2018

Approximately 48% of the wind blew from the south direction most of which had a speed of 3.60-5.70 m/s at a frequency of about 29.9% and a speed 5.70-8.80m/s at a frequency of about 24.3%. The wind also blew from the south with a speed of 8.80-11.10 m/s at a frequency of 1.5%. The highest wind speed encountered in the area blew at a speed of above 11.10m/s but it occurred approximately 0.7% of the time. The frequency at which the wind was calm was found to be 11.67%.

Approximately 14.5% of the wind also blew from the east direction most of which were between the speed of 3.6 – 5.70 m/s and the least frequency being wind speed 2.1m/s to 3.6m/s. From the wind rose results, it can be estimated that the percentage frequency of the onshore directed waves in both Uyombo and Sudi Island was 48%.

The width of the mangrove, highest wind fetch and highest incoming wave height in Uyombo as shown in Figures 12 and 13 was estimated to be 41.27 meters, 4302 meters and 6.82 meters respectively. The width of mangroves, the highest wind fetch and the highest incoming wave height in Sudi Island as shown in Figures 14 and 15 was found to be 442.92 meters, 3058 meters and 9.37 meters respectively.

Figure 12: Map showing Wind Fetch in Uyombo

(Developed by ArcGIS 10.5 software)

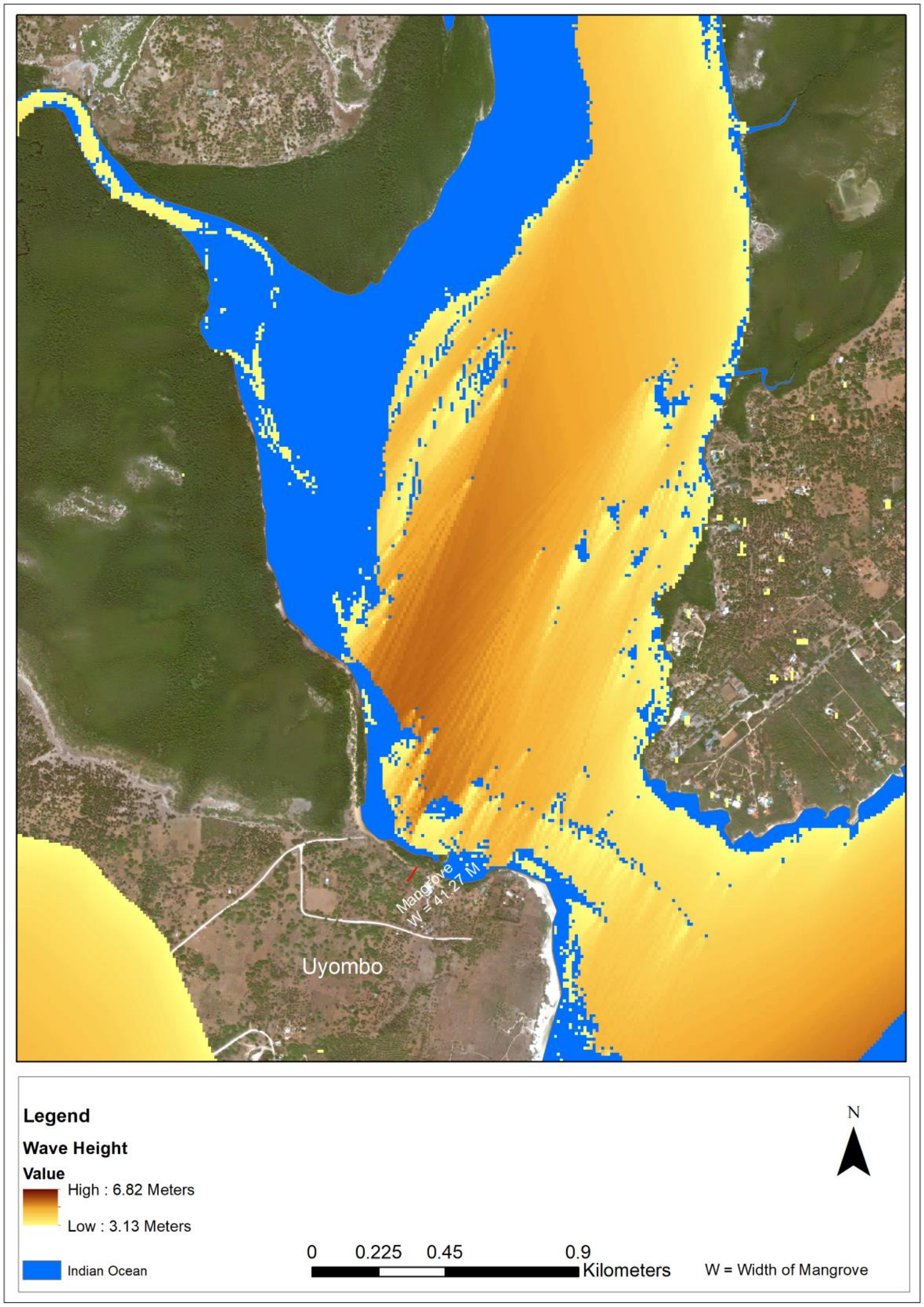


Figure 13: Map showing Wave Height in Uyombo

(Developed by ArcGIS 10.5 software)

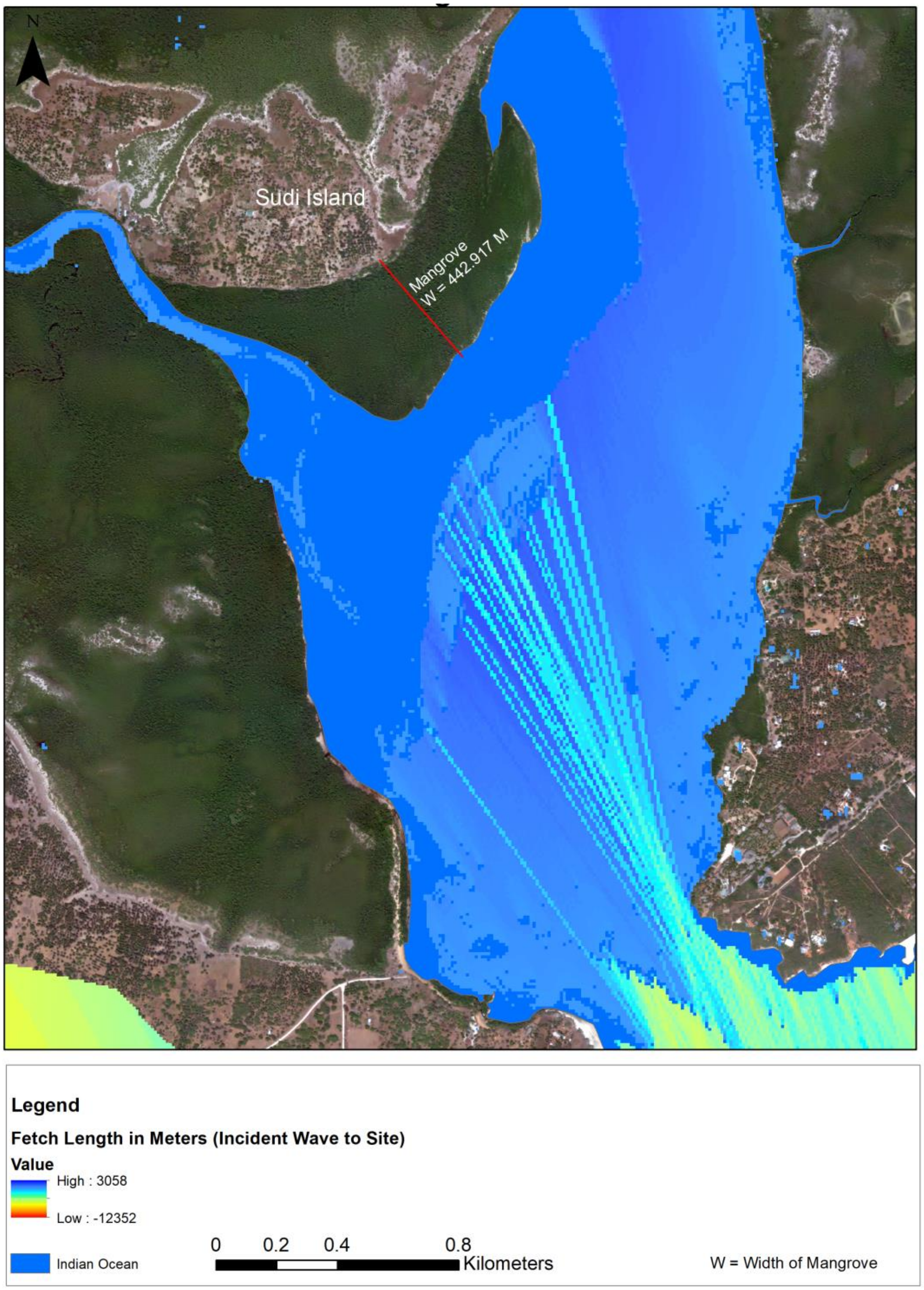


Figure 14: Map showing Wind Fetch in Sudi Island

(Developed by ArcGIS 10.5 software)

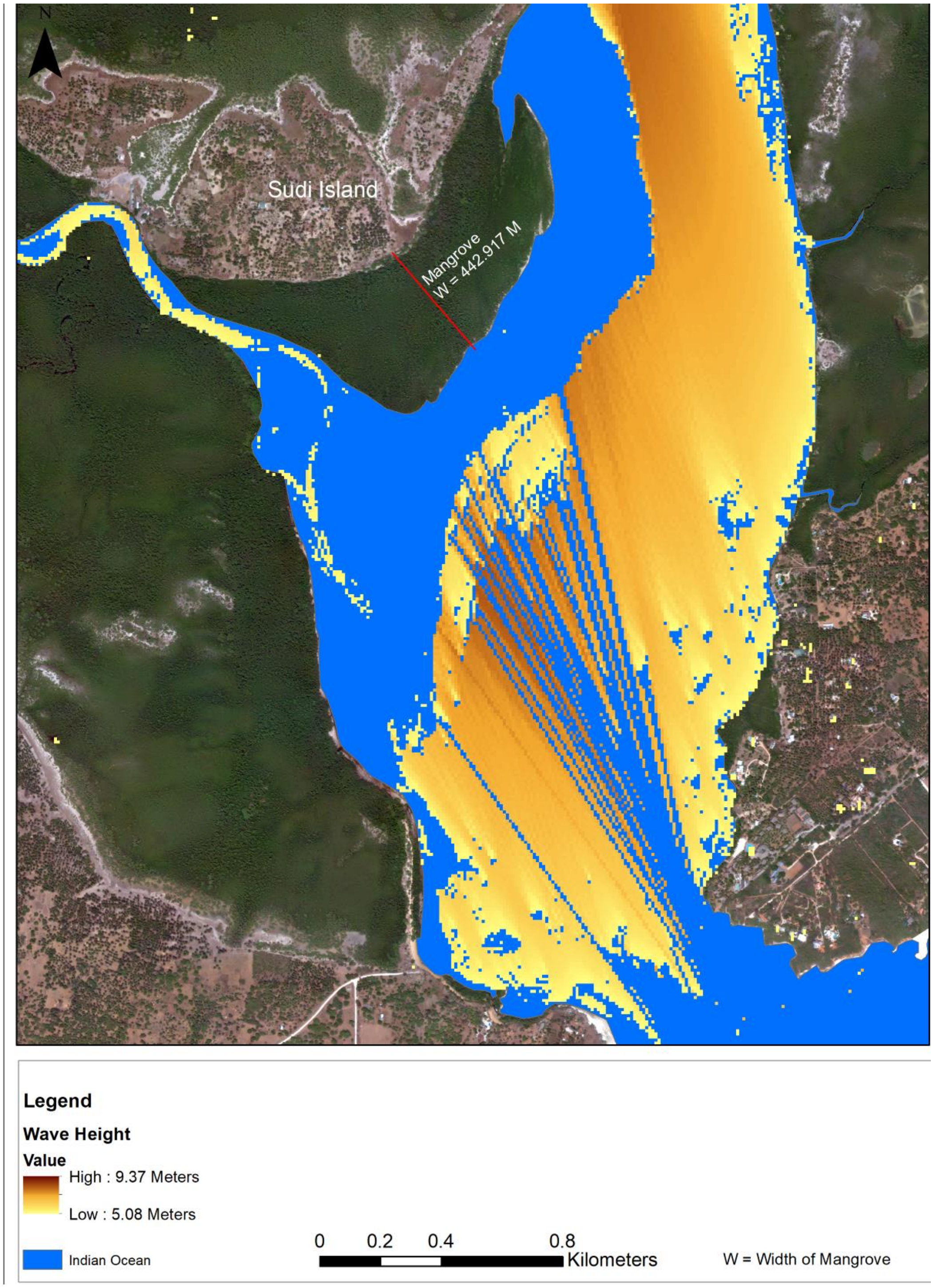


Figure 15: Map showing Wave Height in Sudi Island

(Developed by ArcGIS 10.5 software)

4.5.4 Estimating Percentage Reduction of Waves through the Mangroves

The average water depth measured in Uyombo was 0.927 meters (SD = 0.2814) while that of Sudi Island was found to be 0.939 meters (SD = 0.2688). The highest water depth measured in Uyombo and Sudi Island was 1.48 meters and 1.41 meters respectively (Figure 16).

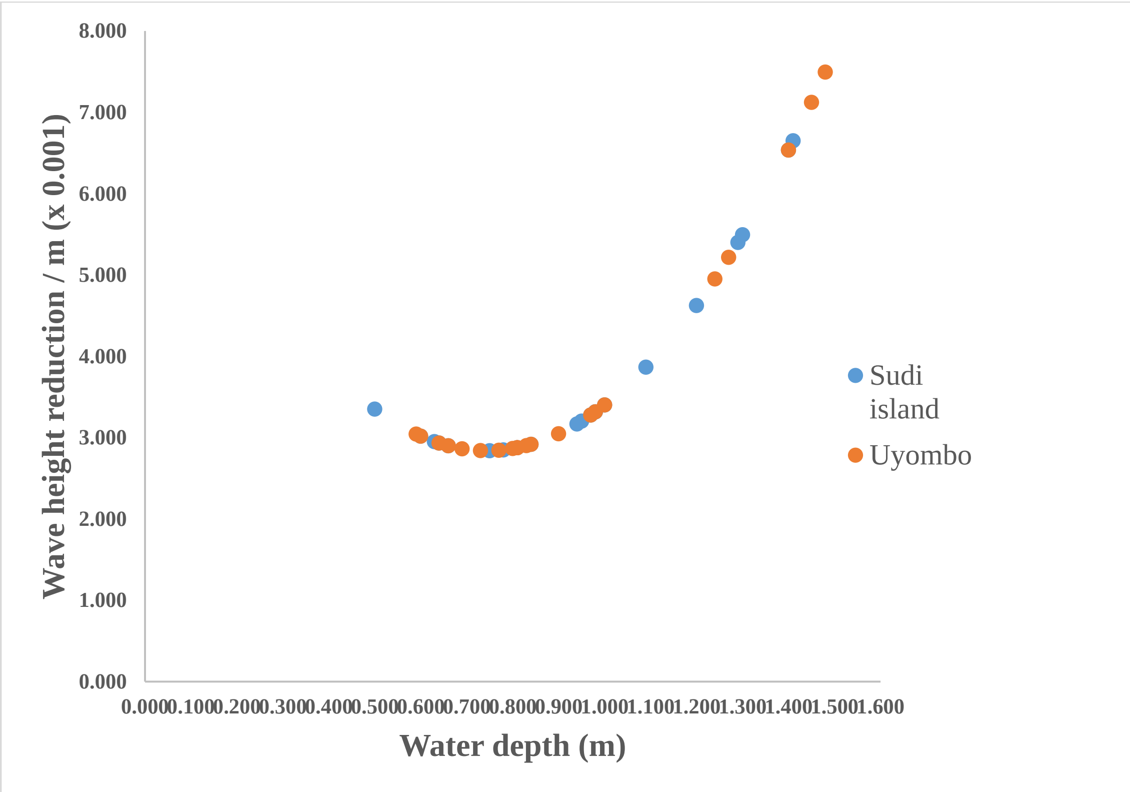


Figure 16: A Graph of Wave Height Reduction per Meter (x 10^{-3}) against Water Depth (m)

The wave height reduction per meter increased with the increase in water depth but at shallower water depth, the wave height reduction per meter increased slightly. The highest wave height reduction per meter in both Uyombo and Sudi Island was found to be 7.49 x 10^{-3} per meter and 6.65 x 10^{-3} per meter respectively which corresponded to the highest water depth (1.48m and 1.41m respectively). The average wave height reduction per meter in Uyombo and Sudi Island was found to be 3.124 x 10^{-3} per meter (SD = 1.523) and 3.164 x 10^{-3} per meter (SD = 1.223) respectively.

The wave height after the wave has travelled across the mangrove was found to be 6.04 meters and 2.31 meters in Uyombo and Sudi Island respectively. The percentage wave reduction through the mangroves in Uyombo and Sudi Island was then found to be 12.09% and 75.35% respectively. Wave Attenuation Service Provision (WASP) in Uyombo was estimated to be 0.023 while that of Sudi Island was estimated to be 0.14. From the above results, it can be concluded that the WASP in Sudi Island was approximately 6 times more than that of Uyombo.

4.5.5 Value of Coastal Protection by Mangroves in the Current and Future Scenario

Marwa and Evan (2012) estimated that the mean value of coastal protection by mangrove was US$ 3,116 per hectare per year, (Range US$ 10.45-8,044). From these results, the value of mangroves in coastal protection in the current state (Mangrove area 1642 ha) was estimated to be US$ 5,116,472, in the business as usual scenario (mangrove area 1590 ha) would be US$ 4,955,374.8 and finally in the conservation scenario (mangrove area 2233 ha) the value of coastal protection would be US$ 5,653,203.0.

CHAPTER FIVE

DISCUSSIONS, CONCLUSION AND RECOMMENDATIONS

5.1 Discussions

5.1.1 Stakeholders' Perception on the Current and the Plausible Alternative States of Mangroves in Mida Creek

With respect to the state of mangrove degradation, older respondents are more likely to consider the mangroves to be degraded, as they have witnessed more changes in the mangroves over the years than the younger responders. Members belonging to various environmental groups participate in several conservation projects taking place in the area, which might change their perception of the mangrove condition. Through these projects, they attend programs such as community environmental education and awareness, mangrove afforestation and ecotourism.

Mida Creek is a major tourists' attraction in the coast and supports many locals who are dependent on income from tourism and the natural resources in it. This ecosystem needs special protection because failure in management can affect it can be negatively. The area is currently under a lot of pressure emanating from increasing population growth and overdependence of the natural resources from the mangroves. The respondents in the focus group discussion identified various drivers of change including overfishing, agriculture, conservation action, climate change, residential and commercial development, illegal wood harvesting and pollution.

Farnsworth and Ellison (1997) and Gilman *et al*. (2006) show that mangroves are vulnerable to anthropogenic activities and climate change. Mangrove ecosystems have also been converted into farmlands, hotels and aquaculture (Duke *et al*., 2007; Dahdouh-Guebas *et al*., 2005). The loss of mangroves is also as a result of climate change for example, rise or fall of sea level (Field, 1995; Lovelock and Ellison 2007) changing patterns rainfall intensity and shoreline erosion (Blasco *et al*., 1996). Alongi, (2002) and Duke *et al*., (2007) have also shown that natural phenomenon has a lesser threat to mangrove ecosystems than anthropogenic activities. Mwakumanya, (2016) on pollution of Mtwapa Creek in Kilifi reported that there was an increase in the level of the NO^{-3} nutrients during the wet season suggesting that the pollutants are discharged into the creek by surface runoff from the source points. These studies confirm the deliberations of participants in the focus group discussion on the threats to mangrove forests.

This study established that Mida Creek has several conservation groups whose main mandate is to conserve the mangrove which is in agreement with the studies done by GOK, (2017) which reported that Mida Creek is among the two mangrove areas that have active conservation groups in Kilifi County.

5.1.2 Change in Mangrove Cover

The spatial analysis found that the area coverage of mangrove decreased from the years 1985 to 2015 by about 103 hectares and then increased from the year 2015 to 2019 by 41 hectares. Mangrove coverage areas have reduced in the earlier years mainly due to conversion to different land uses. Between the years 1969 to 2010, there was emergence of urban centers, expansion of settlements, increase in private holiday houses and hotels (Alemayehu, 2016).

Kirui *et al*. (2013) also found out that the highest loss of mangroves in Kenya occurred between the periods 1992 and 2000 in which mangroves in Kilifi where Mida Creek is found experienced the highest loss of approximately 76%. The lowest rate of loss was witnessed between the periods 2000 to 2010 which coincided with the presidential ban on harvesting mangroves for domestic markets (Kirui *et al*., 2013).

The slight variation in the results of the mangrove cover areas in this study to those of other studies for example Alemayehu, (2016) may be attributed to the tidal variation during the capture of satellite imagery. Findings of Xia *et al*. (2018) shows that only the high stand mangroves will be captured by the satellite imagery during the high tide while the low stand mangroves will be submerged.

5.1.3 Value of Harvested Goods in the Current State and Future Scenarios

Locals harvest several products from the mangrove which are of great economic value. According to this study, fish was the most valuable good harvested from the creek. Murkherjee *et al*. (2014) on valuation of ecosystem services established that fisheries were the highest ranked in terms of provisional services.

Consultation with the local fishermen indicated that fishing is done both in the creek and the open seas. The Annual net value of fish was found to be US$ 8 million (US$ 4,892 per hectare per year). This value is within the range of the value of fish in similar ecosystems. A review on the role of mangroves in fisheries enhancement by Hutchison *et al.* (2014) found that the mean value of fish in similar wetland as this study was US$ 3114.8 per hectare per year. The slight difference in the value might be due to the time difference between the periods of study.

The cost of production varied from one fisherman to the other due to the types of fishing vessels used. The respondents who used canoes and nets for fishing had a higher cost of production and a larger catch as compared to those who used fishing lines and baits hence more proceeds from fishing. The value of fish was expected to increase in the conservation scenario due to increased area for breeding and feeding grounds of the fish. And the value is expected to decrease in the business as usual scenario due to the continued destruction of the breeding and feeding grounds of the fish.

This study found out that honey harvesting was the second most valuable harvested good at US$ 1.8 Million (US$ 1123 $ha^{-1}y^{-1}$). This value is higher than that reported by UNEP (2011) in Gazi bay, Kenya which recorded a value of US$ 14.7$ha^{-1}y^{-1}$. There is a potential increase in the value of honey in the conservation scenario since there would be controlled cutting of the mangroves hence proper breeding and feeding grounds for the bees.

Bee keeping does not compete with other land uses including forestry, cattle and other livestock rearing, and agriculture (Field *et al*., 2018). Additionally, bees provide an important ecosystem service via pollination, directly contributing to enhanced food security and increased yields of crops (Klein *et al*., 2007). It is also a conservation friendly activity and requires minimum labor and financial inputs (Field *et al*., 2018). Bee keeping can provide local communities with reasonable incomes as demonstrated in this study. The yield from hives increases as the distance to forest increases ICIPE (2009) implying that if local communities are encouraged to engage in the exercise, they will support forest conservation. There is therefore a need for stakeholders invest in apiculture capacity building value addition and marketing.

Production of firewood and building poles are expected to increase in the business as usual scenario as the human population around the creek increases. However, this increase is temporary as the land cover of mangroves continues to decline. The value of firewood was higher than that of poles because the frequency of harvesting the firewood was more than that of the poles. This is because residents only harvest the poles when there was a need to construct a house. The number of respondents harvesting firewood was also higher than those harvesting poles.

The total value of both firewood and poles was estimated to be US$ 855 $ha^{-1}y^{-1}$ which is within the range reported by Spalding *et al*. (2010) as global range of timber and wood fuel as US$ 10 - 1093 $ha^{-1}y^{-1}$. The value of poles and firewood obtained in this study might not be very accurate since some respondents were not willing to give details on wood harvesting for fear of being arrested owing to the ban on harvesting of mangroves by the Kenyan government. The value of both poles and firewood in the conservation scenario is expected to decrease since there would be controlled cutting of mangroves.

The total overall value of harvested goods was expected to increase in the conservation scenario since the mangrove cover is expected to increase. Field *et al*. (2018) reported an increase in the value of harvested goods in a scenario where conservation and development coexist as opposed to a scenario where commercial development was allowed. Additionally, Muoria *et al*. (2015) projected a decline in the amount of harvested goods from Yala swamp if development continues as opposed to a scenario where there is a balance between development and conservation.

5.1.4 Wave Attenuation Service Provision

To determine the wave attenuation service provision, two sites within Mida Creek were selected (Uyombo and Sudi Island) based on their level of degradation. The width of mangroves in Uyombo was 41.27 meters hence considered degraded while the width of mangrove in Sudi Island was 442.92 meters. Based on their location in respect to wind direction, the significant wave height in Uyombo was 6.87 meters high while that of Sudi Island receives waves 9.37 meters high. ASCLME, (2012) reported that the significant wave height during the southeast monsoon (May- October) in Kenyan coastal waters is 8m.

This study demonstrated that the wave height reduction per meter was highest in highest water depth. Huge wave reduction occurs mainly at a height of over 0.6 m, at which mangrove leaves spread thickly and it is suspected that the periodic wave motion is transformed to turbulences or eddies through the interaction with intertwining leaves (Mazda *et al*., 2006). This means that the dependence of the reduction rate on the wave height is due to the energy dissipation caused by the thick leaves or canopy (Erick *et al*., 2012). At shallower ends; 0.59m in Uyombo and 0.5m in Sudi Island, the wave reduction per meter increased slightly to 3.042×10^{-3} and 3.350×10^{-3} per meter respectively. This may be due to the presence of prop roots and pneumatophores that offer resistance to water flow at shallower depths leading to greater wave reduction at these depths (Mclvor *et al*., 2012).

This study revealed that a higher percentage of wave height reduction per meter occurs over a wider mangrove bandwidth. Spalding *et al*. (2014) reports that as the wave enter the mangrove forest, they lose energy as they pass through the tangled above-ground roots and branches and the height is greatly reduced by between 13% and 66% over 100 meters of mangrove. Bao (2011) also revealed that the mean wave height reduction over the first 40meters of the forest was 21% and over the next 40 meters was 17%, with a total reduction of 35% of the first 80 meters.

Both Uyombo and Sudi Island had a wave attenuation service provision of less than one. A WASP of 1 indicates maximum service provision (Peh *et al*., 2017) but this is, not achievable since Mida Creek is an inter-tidal site hence not inundated 100% of the time. From these results, it can be concluded that the wider the width of the mangroves, the greater the wave attenuation service. This implies that in the conservation scenario, where there would be wider mangrove width, the mangrove forest would offer better protection services as opposed to the business as usual scenario.

5.1.5 Value of Coastal Protection in the Current and Future Scenarios

There was a projection in the increase in the value of coastal protection services in the conservation scenario. This is because of the presence of more mangrove trees in the conservation scenario presenting a greater obstacle hence better wave attenuation. The values obtained by Marwa and Evan (2012) were significantly more devised (range US$ 10.42 to US$ 8,044) according to the methods of valuation used. Values reported for coastal protection and stabilization are higher when the Replacement cost method is used than Contingent Valuation Method (Marwa and Evan, 2012). Contingent Valuation Method (CVM) involves the use of surveys to elicit responses from people about their maximum willingness-to-pay (WTP) or willingness-to-accept (WTA) for hypothetical changes in environmental quality.

The replacement cost method (RCM) assumes that the value of the ecosystem service is equal to the cost of replacing it with a manmade alternative. These values were also within the findings of Kairo *et al.* (2009) which reported a value of US$ 1,586.66 hectare per year on coastal protection value of replanted mangroves in Kenya. Coastal protection is one of the most undervalued mangrove ecosystem services, yet mangroves can provide protection to coastal communities up to 5km inland (Barbier *et al.*, 2008).

5.2 Conclusions

i. The most important drivers of change facing the mangroves in Mida Creek are mostly of anthropogenic nature and they include overfishing and harvesting of other aquatic resources, agriculture and aquaculture, severe weather patterns and conservation actions.
ii. Mangrove cover in the conservation scenario would significantly increase. This means that sustainable use of the resources within Mida creek would mean an increasing mangrove cover hence continued provision of the important ecosystem services.
iii. Mangrove forest of Mida Creek has a high realized and potential monetary value hence there is a need for a proper resource management plan to ensure sustainability. The value of harvested goods and coastal protection services are likely to increase in conservation scenario and reduce in the business as usual scenario hence a need to conserve the forest.

iv. Wave attenuation service provision is higher in areas with a higher bandwidth of mangroves. Wave attenuation service in Sudi Island (mangrove bandwidth 442.92 meters) was 6 times higher than that of Uyombo (mangrove bandwidth 41.27)

v. The results of this research will enable the stakeholders improve the existing management strategies hence ensure the sustainable use of the creek.

5.3 Recommendations

i. The locals should be sensitized on cheaper alternatives of fuel to avoid cutting of mangroves for firewood.

ii. There is a need for a proper resource management plan with the community involvement which explains the roles of each institution and stakeholders in its implementation. The policy makers should also engage with the private sectors on ways of conserving the ecosystem. There is also a need to develop a Land Use Plan for Mida Creek accompanied by a Strategic Environmental Assessment to ensure that all ecosystem services provided by the creek are adequately recognized and protected.

5.3.1 Recommendation for Further Research

This study recommends that a further detailed assessment on the value of other ecosystem service like carbon sequestration and tourism in the current and future states be done to establish the full value of the creek in the future scenarios.

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APPENDICES

Appendix I: Preliminary Scooping Appraisal Form (Focus Group Discussion).

PART 1 – IDENTIFYING ACTIVITIES IMPACTING THE SITE

A. Identify the threats and activities impacting the site

Identification of pressures impacting on an ecosystem is important to determine how the ecosystem services provided by the site may change in the future**.**

Table A

Status of mangroves (Tick the most appropriate box)	Highly degraded	Somewhat degraded	Good	Excellent
Drivers of change	Timing 1. Likely in long term (beyond ten years) 2. Likely in short term (within 10 years) 3. Happening now	Scope (% of site affected) 0. Little of area (<10%) 1. Some of the area (10 – 49%) 2. Most of the area (50- 90%) 3. Whole area (>90%)	Impact (degree of change in the next 10 years) 1. Low (1-10%) 2. Moderate (10–30 %) 3. High (>30%)	Score (Timing + Scope + Impact)
Residential & commercial development				
Agriculture & aquaculture				
Logging / wood harvesting				
Gathering terrestrial plants				
Fishing and harvesting other aquatic resources				
Climate change and severe weather				

Energy production				
Pollution				
Human disturbance				
Conservation actions				

B. Comparison of site under current state and plausible alternative state

Using the results from Table A, consider how the most significant activities impacting the site could affect the land cover map (Table A) e.g., over the next 10 years / if the current development plan is realised / if management of the site is altered.

Table B. Land cover change due to current drivers

Main activities causing this change	**Affected feature**	**Expected change e.g., new land cover / land use / habitat quality**

PART 2 - IDENTIFYING ECOSYSTEM SERVICES

Table C. Complete the table for the current and alternative state

Service category / benefits	**Specific services**	**Current state (score 0-5) 5= highly important**	**Top five services in the current state (tick box)**	**Plausible future (score 0 – 5) 5 = highly important**	**Top five services in the alternative state (tick box)**
Global climate regulation	e.g., storage of carbon in trees				
local climate and air quality regulation	E.g., shade, removing pollutants, influence on rain.				
Water related services	**Water quality regulation** e.g., purification of water waste treatment				
	Water for human use e.g., domestic human consumption, irrigation, industry				
	Water flow regulation e.g., natural drainage, irrigation, flood prevention				
Erosion control	e.g., avoiding land slide				
Coastal protection	e.g., storm protection				
Harvested goods	**Fibre e.g.,** timber				
	Food e.g., fish, fruits, honey				
	Natural medicine				
	Sources of fuel e.g., charcoal, firewood				
Cultivated goods	**Food e.g.,** livestock, farmed fish, honey				
	Fibre e.g., timber				
Recreation / tourism	Recreation / tourism				

Aesthetic benefits/ inspiration					
Spiritual/ religious experiences					
(Other)					
(Other)					

D. Consideration of the way in which ecosystem services might change

For each of the ticked services identified in Table C (for the current state and alternative state), complete Table D.

Table D. Service change in the alternative state

Most important service identified in Table C	**Trend in provision of the services over the past 5 years** **Increase +** **Stable =** **Decrease -**	**Expected change in service availability in the site's alternative state** **Increase +** **Stable -** **Decrease**	**Service beneficiaries** Local/District/ National/Global (identify which of these geographic scales apply - there may be more than one - and circle the one where the greatest impacts of the change will be felt)	**Relevant activities impacting the site** (Select all that apply from the list in part 1, Table A**)**

F. Presenting a summary of ecosystem service change

Using the results in Table E for 'Expected change in service availability', draw bars to represent the expected direction and magnitude of change (for example, large increase, small increase, no change, small decrease, large decrease) in each category of the most important ecosystem services.

Appendix II: Questionnaire on Coastal Protection

The purpose of the workshop is to identify any coastal hazards that may be affecting the creek. The result of this workshop will inform sustainable management action.

With the help of the maps provided, answer the following questions on coastal protection.

1.	What coastal hazards are people aware of in this area?	
2.	Have people ever been affected by them? If yes, move to 3.	
3.	When?	
4.	What happened?	
5.	What damage did they do?	
6.	What areas was worst affected?	
7.	Where did the water reach?	
8.	What factors affected the amount of damage? E.g., were some people more affected than others? Were there coastal defence?	
9.	Do they feel the coastal ecosystem may have played a role in reducing the impacts of the hazards? If yes, in what ways?	
10.	How often does such hazard occur?	
11.	Does the area experience storm?	
12.	Do storms cause raised water levels are results in flooding?	
13	Have storms previously damaged coastal defenses?	
14.	Have storms previously damaged coastal ecosystems?	
15.	Are local people aware of erosion occurring?	
16.	Do landslides happen?	
17.	Have people lost land to the sea?	
18.	Are there stories of villages that have been lost in the past?	
19.	Can older members of the community remember times when the local land extended further into the sea? How far? When did it change and how?	

Appendix III: Household Questionnaire for Ecosystem Services Assessment, Mida Creek

INTRODUCTION:

This questionnaire for collection of information for a detailed assessment of the ecosystem services provided (harvested goods) by Mida Creek's mangroves. The findings from this assessment will inform the sustainable management of the creek ecosystem.

Name/ Number of respondent

Date

Location/name of village

SECTION A: HARVESTED GOODS

Are the questions being answered per individual, household or business? (circle the one which is applicable)	○ **Individual** ○ **Household** ○ **Business**				
Name of product *This will include items like* **Food** (e.g. fruit, seeds, bush-meat, fish), **firewood, livestock fodde**r, **Fibre** (e.g. straw, timber, skins, leather, wool), **Natural medicines, Energy** (e.g. firewood, charcoal)	**1.**	**2.**	**3.**	**4**	**5**
Quantity and value of product					
a. Total quantity collected from the site in last 12 months* _					
b. Unit _					
c. Percentage for own use					
d. Percentage sold/ bartered					
e. Average price obtained per unit** _					
Family labour					
f. Annual time taken by respondent and family members (unpaid) to harvest and process the product (person days) * _					

Hired labour					
g. Annual input of hired labour for harvesting and processing (person days) * _					
h. Typical daily wage rate paid for hired labour					
Equipment costs* **					
i. What capital items (tools, materials, equipment) do you need for harvesting and processing this product? _					
j. How long do you expect each of these tools etc. to last? _					
k. How much did each item cost to buy? _					
Transport and marketing costs					
l. What are the annual costs of transport and marketing this product? * _					
* If respondents find it difficult to recall accurately the harvest for the past 12 months, then break these questions down. For example, ask for the harvest on a monthly basis (and then add these figures up yourself, to get an annual total). Do the same for each of these questions (price, inputs of labour, costs of equipment and other inputs etc.).					
** If the individual respondent does not sell the product they gather, but others do, then apply the mean price recorded from other respondents.					
*** If any tools or equipment have a lifetime of more than one year, divide the initial purchase cost by their expected lifetime and add typical repair/maintenance costs. If tools are not specifically used/purchased for this product but are for general use, apply a sensible percentage of their cost/maintenance					

SECTION B: HONEY PRODUCTION

1.	Do you engage in honey harvesting?	○ Yes ○ No
2.	If yes how many hives do you have in each of the following areas	○ Own land ○ Forest ○ Other area: specify …….
3.	Do you harvest honey from natural hives	○ Yes ○ No
4.	Last year, how much honey did you produce per hive? Include units_	○
5.	What is the average amount of honey produce per year	○
6.	Last year, what was the average price obtained per unit?	○
7.	Percentage for own use	○
8.	Percentage sold/ bartered	○
9.	Did you, or family members, spend (unpaid) time taking care or/harvesting/ processing this honey?	○ Yes ○ No
10.	If yes, how many person-days did you or your family taking care or/harvesting/ processing this honey last year?	○
11.	Did you hire people to take care of bees/harvesting/ processing this honey?	○ Yes ○ No
12.	If yes, how many person-days did hired people spend taking care or/harvesting/ processing this honey last year? _	○
13.	What is the average daily wage rate you paid these hired people (outside of any reciprocal arrangements)?	○
14.	What capital items (tools, materials or equipment) do you need for honey production? _	
15.	How long do you expect each of this tools / equipment to last (years)?	
16.	How much did each tool / equipment cost to buy?	
17.	Last year, what was spent on transporting and marketing this honey?	

Appendix IV: Approval of the Research Proposal- Kenyatta University

KENYATTA UNIVERSITY
GRADUATE SCHOOL

E-mail: dean-graduate@ku.ac.ke
Website: www.ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 020-8704150

Internal Memo

FROM: Dean, Graduate School
DATE: 21st January, 2019

TO: Ms. Cecilia Oyuga Olima
C/o Department of Plant Sciences
REF: I56/37007/2016

SUBJECT: APPROVAL OF RESEARCH PROPOSAL

This is to inform you that Graduate School Board, at its meeting on 9th January, 2019, approved your Research Proposal for the M.Sc. Degree entitled, **"Provision of Coastal Protection Services and Wild Goods by Mida Creek's Mangrove Forest in the Current and Future Scenarios."**

You may now proceed with your Data collection, subject to clearance with the Director General, National Commission for Science, Technology & Innovation.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed Supervision Tracking Forms per semester. The form has been developed to replace the Progress Report Forms. The Supervision Tracking Forms are available at the University's Website under Graduate School webpage downloads.

Thank you.

ELIJAH MUTUA
FOR: DEAN, GRADUATE SCHOOL

KENYATTA UNIVERSITY OFFICE OF DEAN
19 MAR 2021
GRADUATE SCHOOL
P. O. Box 43844-00100 NAIROBI

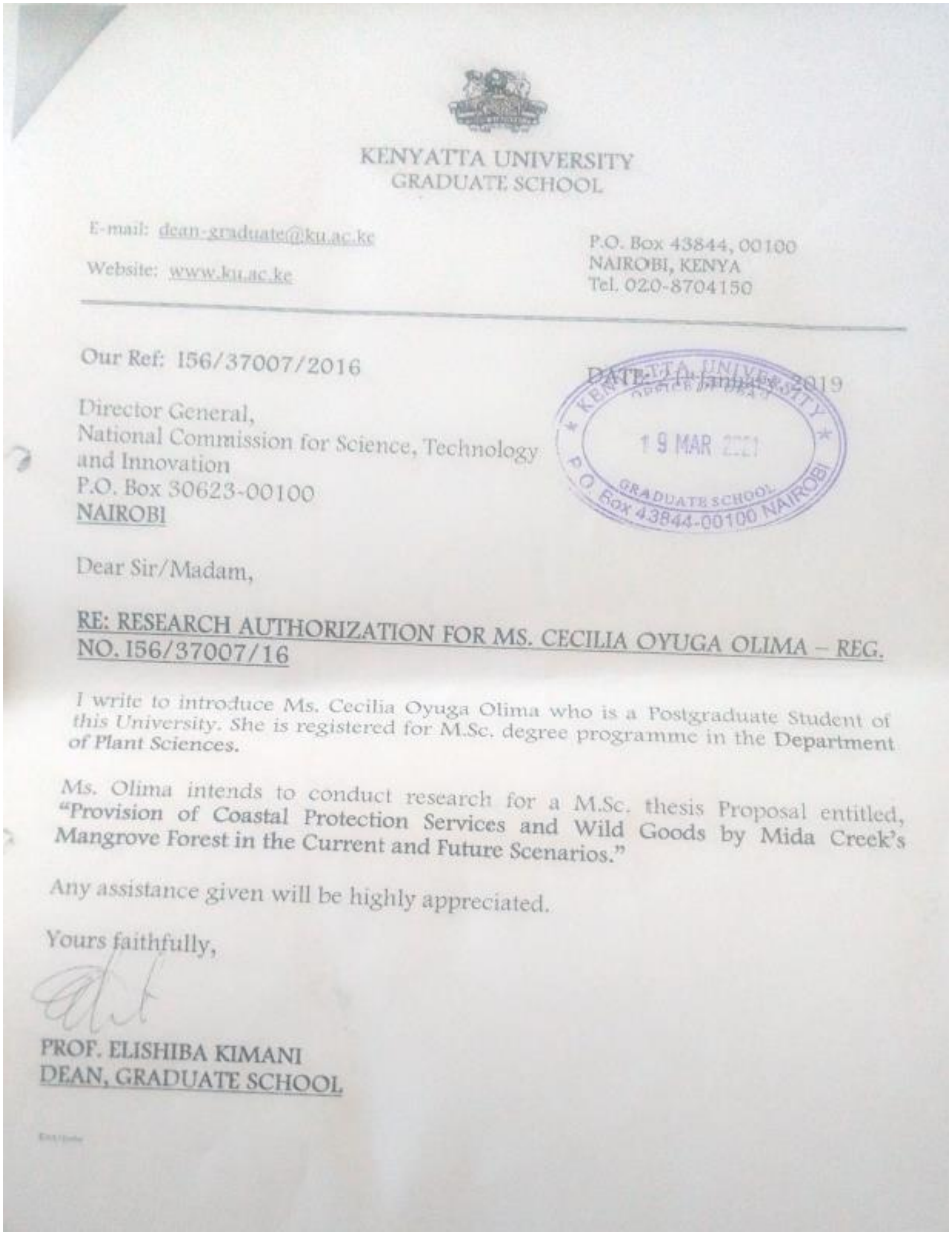
CC. Chairman, Department of Plant Sciences

Supervisors:

1. Dr. Paul Muoria
   C/o Department of Plant Sciences
   Kenyatta University

2. Dr. Margaret Awuor Owuor
   Dept. of Hydrology & Aquatic Sciences
   South Eastern Kenya University
   C/o Department of Plant Sciences
   Kenyatta University

Appendix V: Research Authorization - Kenyatta University



KENYATTA UNIVERSITY
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P.O. Box 43844, 00100
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Our Ref: I56/37007/2016

DATE: 21st January 2019

KENYATTA UNIVERSITY
19 MAR 2021
GRADUATE SCHOOL
P.O. Box 43844-00100 NAIROBI

Director General,
National Commission for Science, Technology and Innovation
P.O. Box 30623-00100
NAIROBI

Dear Sir/Madam,

RE: RESEARCH AUTHORIZATION FOR MS. CECILIA OYUGA OLIMA – REG. NO. I56/37007/16

I write to introduce Ms. Cecilia Oyuga Olima who is a Postgraduate Student of this University. She is registered for M.Sc. degree programme in the **Department of Plant Sciences.**

Ms. Olima intends to conduct research for a M.Sc. thesis Proposal entitled, **"Provision of Coastal Protection Services and Wild Goods by Mida Creek's Mangrove Forest in the Current and Future Scenarios."**

Any assistance given will be highly appreciated.

Yours faithfully,

PROF. ELISHIBA KIMANI
DEAN, GRADUATE SCHOOL

Appendix VI: Research Permit –NACOSTI

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: **862121**

Date of Issue: **16/April/2021**

RESEARCH LICENSE

This is to Certify that Ms.. Cecilia Oyuga Olima of Kenyatta University, has been licensed to conduct research in Kilifi on the topic: PROVISION OF COASTAL PROTECTION SERVICES AND WILD GOODS BY MIDA CREEK'S MANGROVE FOREST IN THE CURRENT AND FUTURE SCENARIOS. for the period ending : 16/April/2022.

License No: **NACOSTI/P/21/9783**

862121

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Appendix VII: Published Journal

WIO Journal of Marine Science 19 (2) 2020 105-115 Original Article 105

Valuation of harvested goods in Mida Creek with application of the TESSA approach

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Abstract

Mangroves are considered a highly productive blue forests resource providing services that are important to the community both locally and globally. In recent times there has been an increase in studies on valuation of ecosystem services provided by mangroves. However, there is need to provide a simplified approach to identify, assess and quantify ecosystem services. In this study the Toolkit for Ecosystem Services Site-based Assessment (TESSA) was used to assess the value of harvested goods provided by the mangroves of Mida Creek in the current state and under plausible alternative scenarios. Spatial methods (GIS) were used to collect data for the period 1985-2019, and household interviews were used to collect data on harvested goods. Descriptive statistics were used to summarize quantitative data. Results show that the estimated current annual value of harvested goods in Mida Creek is US$ 11.2 million. This value increased to US$ 14.3 million under the conservation scenario and reduced to US$ 10.9 million under the business as usual scenario (BAU). These findings add to the growing literature on ecosystem service valuation and the need to use site-specific non-modelling tools like TESSA.

Keywords: current scenario, ecosystem services, plausible alternative scenario, mangrove

Introduction

Mangroves are important coastal ecosystem providing numerous ecosystem services and critical ecological functions (Kauffman and Donato, 2012). These services include: provisioning services including wood products, medicine, honey and fish; regulating services such as climate regulation, coastal protection and air quality regulation (Millennium Ecosystem Assessment, 2005; Bosire *et al.*, 2008; Donato *et al.*, 2011); supporting services including primary production, nutrient cycling, and breeding and nursery grounds for marine and pelagic species (Millennium Ecosystem Assessment, 2005; UNEP, 2014); and cultural services such as recreation, spiritual enrichment and aesthetic features (TEEB, 2010; Anam and Thomas, 2017). The sustainable provision of these ecosystem services is essential for human wellbeing (Hooper *et al.*, 2012). However, approximately 60 % of the world's ecosystem services have been degraded or unsustainably used (Millennium Ecosystem Assessment, 2005).

Globally, mangrove cover has declined by 30 – 50 % over the past decades (Donato *et al.,* 2011) because of anthropogenic activities (Halpern *et al*., 2008; Butchart *et al*., 2010; Malik *et al*., 2016). This degradation has led to loss of coastal protection services thus increasing coastal vulnerability to natural disasters (Alongi, 2002; Barbier *et al*., 2008; Bosire *et al*., 2008). With many competing uses of marine and coastal ecosystem and their services, there is need to formulate and implement policies that will inform effective management of natural resources in order to reduce the continued degradation of these important ecosystems (Owuor *et al.,* 2017).

Economic valuation of ecosystem services allows policy makers to appreciate the value of ecosystem services to society, and the cost of their imminent loss (Ruckelshaus *et al.,* 2013; Laurans *et al.,* 2013), enabling them to integrate ecosystem services into policy and decision-making processes (Fisher *et al.*, 2008; Fisher *et al.,* 2010). Valuation also contributes

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