Norwegian University
of Life Sciences

Master's Thesis 2017 30 ECTS
Department of International Environment and Development Studies,
(Noragric)

Social-Ecological Resilience of Gazi Bay and Vanga Mangrove Systems, Kenya

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Master of Science in International Environment Studies

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Declaration

I, Murungi Edwin Mutuma, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature………………………………..

Date…………………………………………

Dedication

To my family,

Near

and

Far.

Abstract

Mangrove forests are important, yet sensitive and highly threatened coastal ecosystems that require careful management and utilization. This study assesses, compares and contrasts social and ecological resilience of two mangrove forests of Gazi Bay and Vanga and their adjacent coastal communities. Assessment was done on mangrove forests structure, key disturbances in mangroves and social systems, and changes in mangrove management regimes. Sampling was done in 10m*10m quadrants laid along belt transects perpendicular to the shorelines. Socio-economic data was collected using semi-structured interviews and household questionnaires, and further data was obtained from field observations and analysis of satellite images. A historical timeline for the two mangrove systems was created to give insight on disturbance regimes and to reveal changes in systems' resilience over time. The results reveal that changes in mangrove management regimes have impacted resilience of mangrove systems differently. Damming of Mkurumuji River has led to loss of livelihoods and to death of *Sonneratia alba* trees at Gazi Bay due to excessive sedimentation. This is happening before the mangroves have had sufficient time to recover from a previous disturbance by clear cutting, presenting a major shock to the *S. alba* stand and fundamentally altering its state. Human population growth at Gazi Bay and Vanga is not causing a reduction in mangrove resource, as villagers are increasingly using concrete blocks as mangrove substitutes for building. Finally, pressure on Vanga mangrove forest is not due to local utilization, but due to harvesting for trade by traders living far away from the village. The study recommends that the government and other responsible stakeholders should commit to increasing people's income-generating opportunities to reduce poverty and increase resilience of mangrove systems. Further, scientists and mangrove resource managers should recognise local knowledge and foster its complementarity with scientific knowledge.

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List of acronyms

BMU - Beach Management Unit

CFA - Community Forest Association

FMA - Forest Management Agreement

GOGA CFA - Gogoni-Gazi Community Forest Association

GPS - Global Positioning System

KSh - Kenyan Shilling

KFS - Kenya Forest Services

KISCOL - Kwale International Sugar Company Ltd.

KMFRI - Kenya Marine and Fisheries Research Institute

KNBS - Kenya National Bureau of Statistics

MPCO - Mikoko Pamoja Community Organization

NGO's - Non-governmental organisations

SESs - Social-Ecological Systems

VAJIKI CFA- Vanga-Jimbo-Kiwegu Community Forest Association

Introduction

1.1 Background and problem statement

Mangroves are tropical and sub-tropical woody trees that grow naturally in brackish waters within the intertidal zone. Mangrove ecosystems are highly productive and rich in biodiversity and offer a variety of goods and services, both economic and ecological. The estimated total area of mangroves is just above 150,000 km^2, divided by 123 countries worldwide (Spalding et al., 2010). In tropical regions, these ecosystems constitute about 0.7 % of the total tropical forests (Jennerjahn & Ittekkot 2002). Even with their limited extent, mangrove are indispensable to tropical coastal regions as they form the economic foundation for many of these regions (Field et al. 1998).

Despite the many important services mangroves offer, they are often undervalued and seen as muddy wastelands, and they have consequently experienced persistent loss. Between 1980 and 2005, mangroves worldwide declined by 35, 600 km^2 (FAO 2007). In Kenya, 18% of mangrove was lost between 1985 and 2010 at a rate of 0.7% per year (Kirui et al. 2013). The perceived lack of valued for mangroves might be attributed to many of its ecosystem services occurring off -site, such as the support of fish stocks with the nursery grounds, or that the services do not have a direct market value, as the reduction of carbon emission (FAO 2007).

In Kenya, mangroves have also been used for many centuries. The earliest record shows that as early as 200 BC, Kenyan mangroves formed an important part of trade between East Africa, the Gulf States and Asia (Ferguson, 1993). The colonial government published Kenya’s first document forest legislation to protect the mangroves of Vanga in 1891 (Kojwang 1996). Later, the Ukambani Woods and Forest Regulation extended mangrove protection throughout the country’s coastline. The colonial government gazetted Kenyan mangroves as forest reserves and placed under management by the Forestry Department in 1932. Between 1947 and 1956, the mangrove trade between East Africa and Gulf States reached its peak, and harvesters in Kenya cut large amounts of mangroves to provide poles for export (Idha 1998). This was following a discovery of oil in the Persian Gulf and a belief that the demand for mangrove poles would fall. According to Fergusson (1993), lack of an effective national authority to effectively manage and resolve conflicting issues related to mangrove management and conservation in Kenya led to their over exploitation and subsequent degradation in 1970's. Widespread mangrove degradation led to a ban on their use for charcoal production in 1975, a ban on export of mangrove poles in 1982, and a ban on mangrove utilization in 1997 (Kairo & Dahdouh-Guebas 2004).

Several studies have been done in Kenyan mangroves, including Gazi Bay and Vanga. Some of these studies include: distribution and economic importance of Kenyan mangrove forests (Kokwaro, J. O. 1985), structure and regeneration patterns of Mida Creek and Tudor creek mangroves (Kairo et al. 2002; Mohamed et al. 2009), survival of replanted mangroves and colonization of non-planted ones at Gazi Bay (Bosire et al. 2003), mangrove users' valuation of planted mangroves and the users' perceptions on mangrove plantation initiatives (Rönnbäck et al. 2007), mapping of mangroves and land cover change along the Kenyan coastline (Kirui et al. 2013), economic valuation of mangrove forests of Kenyan south coast (Huxham et al. 2015), and wide-ranging insect infestation of the pioneer mangrove *Sonneratia alba* along the Kenyan coast (Jenoh et al. 2016). However, most of these studies have only addressed either social or ecological system separately. Those attempting to link the social and ecological systems are scarce and, often, inconclusive. Besides, social and ecological systems are linked and delineation between them is artificial and arbitrary (Berkes & Folke 1998). Management of natural resource that takes into account social and ecological influences at multiple scales, incorporates continuous change, and acknowledges a level of uncertainty have the potential to increase system's resilience to disturbance and its capacity to adapt to change.

1.2 Research question and objectives

This study assesses, compares and contrasts the social-ecological resilience of Gazi Bay and Vanga. The two sites have similar ecological conditions, have fishing as the main economic activity, and Muslim is the main religion. However, they differ in that villagers at Gazi Bay are actively involved in mangrove management unlike at Vanga, and ecotourism is relatively developed at Gazi Bay while Vanga remains untouched by tourism. Further, the size of mangrove forest is significantly different between Gazi Bay and Vanga.

By assessing resilience of Gazi Bay and Vanga social-ecological systems, this study will give insight on how to access social-ecological resilience in mangrove systems. Further, findings from this study can help in developing management strategies for dealing with both known and unexpected change in Gazi Bay and Vanga mangrove systems.

The research question for this study is:

Comparing Gazi Bay and Vanga, what factors and processes are building or eroding resilience of mangrove ecosystems and adjacent coastal communities?

To answer the research question, four objectives have been examined:

- To assess the changes in areal extent of Gazi Bay and Vanga mangroves and their volume over time.
- Identify ecological and human disturbances, and their impacts at the systems and connect them in spatial and temporal scales.
- Examine changes in mangrove management regimes, and participation of different actors and institutions in utilization and management of mangrove ecosystems at the study sites.

- To create a timeline of historical management regimes and key disturbance events at the two mangrove systems.

1.3 Literature review

Detailed studies on Kenyan mangroves were unavailable until 1930's. An account of African vegetation by Engler (1908-21) describes mangroves of Tanganyika, but only mentions the occurrence of mangroves at Lamu in Kenya. Dale (1938) did the first detailed study of mangrove in Kenya. Later, Birch (1963) provided a qualitative description of part of the Kenyan coastal vegetation, emphasizing climax forests and inner bushland formations on stable substrates. The first exhaustive mangrove forest inventory in Kenya was done on the Lamu mangrove forest by the Forestry Department in 1967 (Kairo & Dahdouh-Guebas 2004).

Since 1980's, there has been a sharp increase in the number of studies done on Kenyan mangrove forests. However, most of these studies have either looked at the ecological system and the area covered by mangroves, or they are socio-economic studies about the dependency on mangroves of communities around the mangroves. Studies linking the ecological and the social system are scarce, but have given important insight into the relationship between mangrove ecosystems and societies (Mohamed et al. 2009; Rönnbäck et al. 2007).

The resilience perspective is increasingly used as an approach for understanding the dynamics of social–ecological systems. Holling (1973) introduced resilience as a way to understand the capacity of an ecosystem to absorb change. Holling's discovery of multiple basins of attraction in ecosystem dynamics challenged the then dominant stable-equilibrium of ecosystem theories. Resilience and multi-basin attraction formed the theoretical foundation for adaptive management of ecosystems. Adaptive management recognises uncertainty and unpredictability in the behaviour and dynamics of complex systems, and emphasizes incorporating learning into the management of natural resources. Resilience approach started to influence work outside ecology like human geography, ecological economics, and anthropology (Folke 2016). Social and ecological systems are linked and delineation between them is artificial and arbitrary (Berkes & Folke 1998). Berkes and Folke emphasize on integrated concept of human-in-nature and hence use of a term social-ecological system. Currently, resilience is defined as the capacity of a system to absorb disturbance and re-organize while undergoing change to still retain essentially the same function, structure, identity and feedbacks (Walker et al. 2004). It is a dynamic concept focusing on how people, communities, societies, and cultures to persist with change. Further, resilience also about opportunities that disturbances create for recombination of structures and processes, renewal of the system and emergence of new trajectories (Folke 2006). In addition to the general ability to persist disturbance, resilience in social-ecological systems incorporates the idea of adaptation, learning and self-organization.

Studies analysing resilience building in social-ecological systems both, in terrestrial and marine habitats are mostly in the developed world, see for example (Adger et al. 2005; Berkes & Jolly 2002; Ernstson et al. 2008; Folke et al. 2004; Olsson et al. 2004; Sellberg et al. 2015). (Athuman, Katundu Yusuph 2006; Brown 2007; Himberg 2016; Othman, W. J. 2005; Schönig 2014) have studied social-ecological resilience in mangroves. However, in Kenya, there exist no research that has investigated social-ecological resilience in mangrove ecosystems and adjacent communities of mangrove users.

In earlier assessments of social-ecological resilience in mangrove systems, it was found that severe rules on mangrove use eroded trust between mangrove users and the government (Athuman, K. Y. 2006; Othman, W. 2005). Consequently, evoking unsustainable use of mangroves and hence reducing their ecological resilience. Athuman further argues that changes in mangrove resource are more affected by income generating opportunities than by population density. However, (Himberg 2016) has raised questions about the indirect effects of human population growth and urbanization on mangroves.

Mangrove species, (especially those of genera *Rhizophora, Bruguiera, Sonneratia*) occur in ecological conditions that approach the limits of tolerance to water and soil salinity, and inundation regime (Blasco et al. 1996). Changes in these conditions cause the species to either readjusts to the new conditions or succumbs to unsuitable conditions. According to Blasco et al., minor variations in mangrove hydrological regime can cause significant mortality.

Mangroves flourish on sedimentary shorelines. However, excess input of sediment to mangroves can cause reduced vigour and death, depending on the amount and type of sedimentation, and the species involved (Aleem 1990; Allingham & Neil 1995; Ellison 1999). Anthropogenic activities in upland catchments such as cultivation and dam constructions as well as coastal activities such as break-waters and sea-walls may have adverse impacts on the sediment delivery and thus on availability of mangroves (Saito 2001; Seto et al. 2013).

Background and conceptual framework

2.1 Resilience

The resilience perspective emerged from ecology in the 1960s - 1970s, and through Holling´s (1973) influential paper on resilience and stability in ecological systems. Holling introduced resilience as a way to understand the capacity of ecosystems to absorb change. He illustrated the existence of multiple basins of attraction in natural systems and how they relate to ecological processes, random events, and heterogeneity in temporal and spatial scales (Holling 1973). Since its introduction, resilience perspective has developed into an interdisciplinary concept that can be used to understand dynamics in both natural and social systems and the linkages between them (Folke 2006).

Resilience is a fundamental property of a system. By definition, resilience is *"the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedback"* (Walker et al. 2004). Resilience in social–ecological systems involves adaptation, learning and self-organization in addition to the general ability to persist with disturbance (Folke 2006). Resilience of a system relates to three aspects: the amount of change the system can undergo and still retain the same controls on function and structure, the degree to which the system is capable of self-organization, and the ability to build and increase the capacity for learning and adaptation (Carpenter et al. 2001). A small disturbances may cause dramatic results on a vulnerable system. On the other hand, resilient systems absorb the shocks and uses disturbances as opportunities to create new innovations. Management and utilization of mangroves can either enhance or erode resilience depending on how the social-ecological system (SES) organizes itself in response to change.

The conventional equilibrium-centered perspectives assume that ecosystem responses to human use are linear, predictable and controllable. In contrast, resilience approach recognizes that social and ecological systems are linked, dynamic, non-linear, uncertain, operating at different scales and capable of self-organizing (Berkes & Folke 1998; Berkes et al. 2003). Resilience approach emphasize management and governance of SES for flexibility and emergence rather than for maintaining stability (Carpenter et al. 2015; Peterson et al. 2003). By so doing, the perspective change policies from those aiming at controlling change in a system to assume stability, to managing the capacity of a SES to cope with, adapt to, and shape change (Berkes et al. 2003; Folke 2006; Smit & Wandel 2006).

Bigg et al. (2012) identifies a set of generic policy-focused principles for enhancing resilience of ecosystem services in the face of ongoing changes in SES. They include: maintaining diversity and complementarity, managing slow variables and feedbacks, managing connectivity, fostering an understanding of SESs as complex adaptive systems, encouraging learning and experimentation, broadening participation, and promoting polycentric governance (Biggs et al. 2012). Resilience theory has expanded from adaptively managing ecosystems to adaptively governing complex SESs (Folke 2016).

2.2 Resilience assessment

Resilience assessment is the process of identifying how resilience is created, retained or lost. Resilience assessment can help in developing strategies for coping with known and unexpected changes and hence prevent a possible shift into an undesirable state, or to transform the system into a desirable state if the current one is undesirable (Alliance 2010; Folke 2006; Walker et al. 2004).

Resilience assessment in this study is guided by the Workbook for Practitioners version 2.0 by the Resilience Alliance. A conceptual framework (Fig. 1) to delineating the scope of the SES is created based on the key stages of a resilience assessment outlined in the Workbook. The framework guide in understanding the current state of the system, identifying potential thresholds, and revealing factors building or eroding resilience. This can help creating strategies for dealing with both known and unexpected changes in a system, without compromising on its resilience.

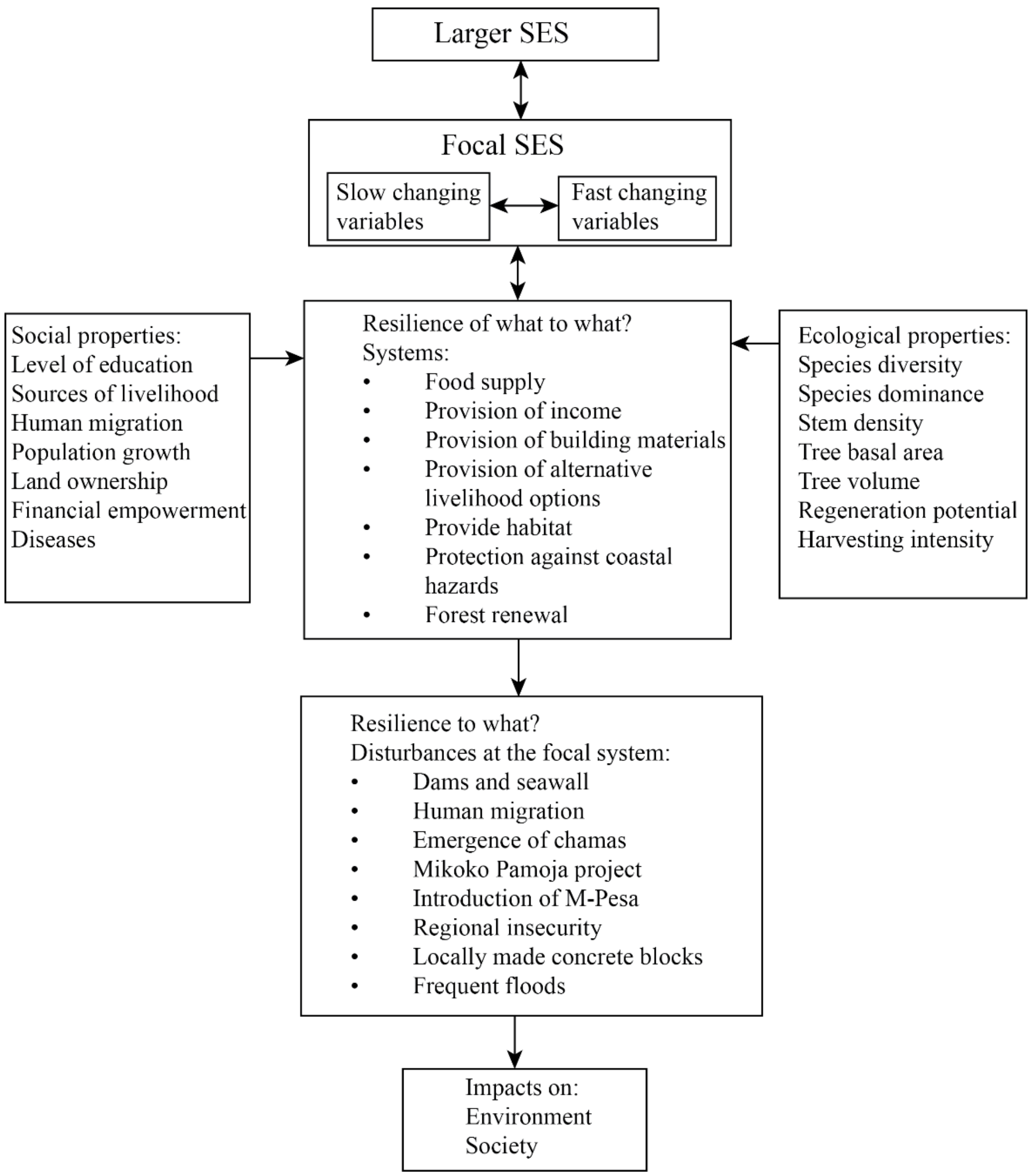

Figure 1. A conceptual framework of linked social-ecological systems

2.2.1 Integrated social-ecological systems

Concept of integrated SESs is key to resilience thinking. Management of natural resources has both social and ecological aspect (Berkes & Folke 1998). Systems where components such as, social, economic, political, and cultural interact are refered to as social-ecological systems. SESs respond to disturbances by feedbacks that have a stabilizing effect or that amplify change on the system. These interactions make it possible for the system to self-organize, innovate and adapt.

2.2.2 The adaptive cycle

Slow and fast processes of change that result in a positive or negative feedback loop characterise SESs (Berkes & Folke 1998; Folke et al. 2010). The dynamics of a SES can be described using the adaptive cycle. The adaptive cycle (Fig. 2) is a model with four phases representing the various phases of change that most natural systems go through over time (Walker et al. 2004). These phases are: rapid growth (r), conservation of resources (K), release of resources (Ω), and reorganization (α). The fore loop of the cycle, the r- and K-phase, is characterized by a slow process of growth, increased connectedness and accumulation of resources in the system (Berkes et al. 2003; Fath et al. 2015). The r-phase is characterized by freely available resources, expansion of pioneers that are tolerant to variability and a high level of positive feedbacks. As resources get accumulated, they get locked at K-phase and the system become less flexible to disturbance. The system eventually collapses and is followed by Ω-phase that rapidly lead to α-phase. The Ω and α phase make up a fast and unpredictable back loop (Berkes et al. 2003). At α phase, opportunities for innovations are possible. The α phase then leads into a r-phase that might be similar to the previous one or might be different. Adaptive cycle does not however mean fixed, regular cycling. Alternative sequence of the phase transitions can happen.

Adaptive cycles in a SES exists as multiple connected scales called panarchy. What happens in a system at one scale affects what happens at another scale (Berkes et al. 2003; Folke 2016). Managing mangrove social-ecological systems require understanding of how they respond to constraints imposed from larger systems and innovation from the smaller nested systems.

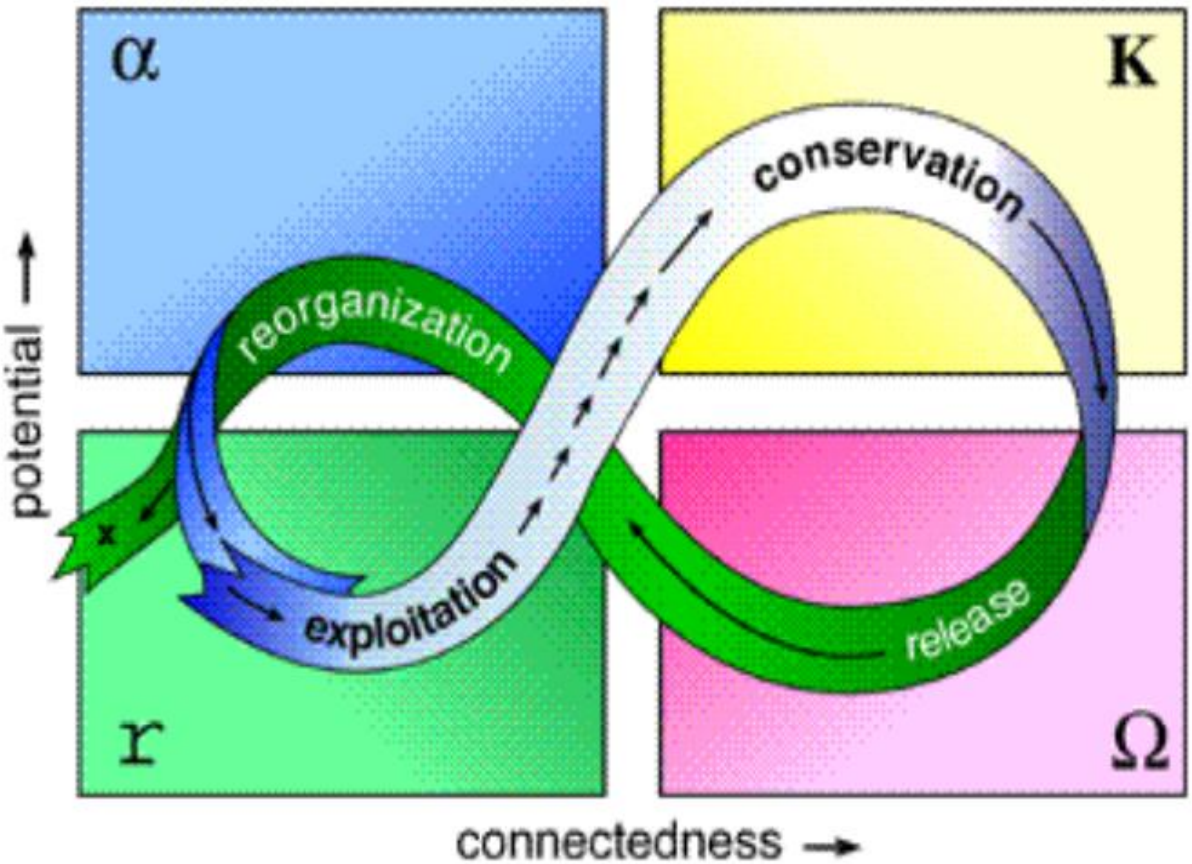

Figure 2. The adaptive cycle (Source: Resilience Alliance, 2005. Modified from Holling, 1986; Gunderson and Holling, 2002)

2.2.3 Multiple system states

Systems can change over time and can shift into a different system state. System state is a set of social and ecological variables that can change over time, through stabilizing feedback that keep the system within its current state, or amplifying feedbacks that push the system towards a new system state (Folke et al. 2004). The transition between states can be fast or slow and gradual. In mangrove SESs, being aware of the critical thresholds between different system states can potentially give insight into impending change as well as opportunities to prevent the system from shifting to undesirable state. The difference in distance between current mangrove SES state and critical threshold can be used to represent their resilience.

2.2.4 Adaptive governance

Societies have many rules, some informal and other formal. Codified rules make formal institutions while informal institution consists of rules expressing the norms within a society. Together, these institutions form governance systems that guide how society function and how it makes decisions (Dietz et al. 2003; Vatn 2005). Adaptive governance emphasize on the capacity to adapt to changing relationships between society and ecosystem in ways that sustain ecosystem services (Dietz et al. 2003; Huitema et al. 2009). It involves devolution of management rights and sharing of power to promote participation. According to Folke et al. (2005), characteristics of adaptive governance include experimenting: new policies for managing ecosystems, new ways of cooperation within and among stakeholders, news ways of promoting flexibility, and new institutional and organizational arrangements. Adaptive governance in mangrove SES can enhance resilience by fostering flexibility, inclusion, diversity and innovation.

Study area and methods

3.1 Study sites

This study was carried out in Msambweni Constituency (4^0 15’S 39^0 35’E and 4^0 40’S 39^0 12’E) of Kwale County in southeastern Kenya, and in particular, the two Locations of Kinondo and Vanga. Kinondo Location comprises of Gazi and Makongeni sub-locations, while Vanga Location consists of Vanga, Jego, and Kiwegu sub-locations. The research focused at the villages of Gazi, Makongeni, and Vanga, where the main religion is Muslim. The resident population at Gazi Bay is about 900 people (Dahdouh-Guebas et al. 2000), while Vanga sub-location (comprising the villages of Vanga, Jasini, Jimbo, and Mgombani) population is 4134 people and 832 households (Statistics 2010).

The climate of the two study sites is typical of the Kenyan coast and essentially influenced by monsoon winds, including northeast monsoon (December – March) and southeast monsoon (June- September). The southeast monsoon (Kusi) influence the long rains (April – June), while the northeast monsoon (Kaskazi) influence the short rains (October – November). Important sources of fresh water for the mangroves on the sites are: River Umba at Vanga, and the season rivers (Mukurumudzi to the south and Kidogoweni to the north) at Gazi Bay.

Artisanal fishing is a main livelihood activity at both research sites. Fishing takes place all year round, but the catch varies between Kaskazi (the high season) and Kusi (the low fishing season). The seasonality is mainly affected by fish migration, changes in thermocline depth, water temperatures, and fishing efforts (McClanahan 1988). At Vanga, fishermen auction fish landed, and their price differs according to season, size and type of fish. On the other hand, at Gazi Bay, fishermen sell fish through middlemen. At Vanga, the fishermen are mainly the locals, as opposed to Gazi Bay where fishermen from Pemba and Zanzibar in Tanzania often come fishing during high fishing seasons.

Tourism is almost non-existent at Vanga. Only often does the village receive local tourists, such as those on educational tours and research students from different school. On the other hand, tourism has been an important source of income at Gazi Bay, with the main attraction being the Gazi Women Mangrove Board Walk where visitors come to see mangroves.

Kenya Forest Services (KFS) Buda forest station manages the mangrove forest of Gazi Bay and Vanga. However, At Gazi Bay, the community co-manages the forest with KFS through Gogoni-Gazi Community Forest Association (GOGA CFA). This was following the CFA developing a participatory forest management plan for the area and then signing a forest management agreement with KFS. Within GOGA CFA are many user groups, including Mikoko Pamoja Community Organization (MPCO) that is implementing Mikoko Pamoja project. Mikoko Pamoja project is a carbon trading project that involves the villages of Gazi and Makongeni in protecting 615 hectares of mangroves at Gazi Bay. The project in return invests the fund from the sale of carbon to community projects. On the other hand at Vanga, the community are not yet legally involved in mangrove management as Vanga-Jimbo-Kiwegu Community Forest Association (VAJIKI CFA) is yet to come up with a participatory forest management plan. Nevertheless, it was noted during fieldwork that plans to expand Mikoko Pamoja project to Vanga mangroves were underway. However, this would probably happen after a forest management agreement between VAJIKI CFA and KFS.

Gazi Bay

The first research site is Gazi (Maftaha) bay, Kenya (4º 25'S and 39º 50'E) (Fig. 3). Gazi Bay is situated approximately 50 kilometers south of Mombasa in Kwale County. Two villages of Gazi and Makongeni are found here, and their histories differ. Gazi village dates back to the pre-colonial times, while Makongeni was founded in the late 1980s, when Ramisi Sugar Company operating in the area closed down and former employees decided to remain and settled in the area (Rönnbäck et al. 2007).

The mangroves at the bay are not under direct influence of fresh water as the two rivers of Mukurumudzi and Kidogoweni are seasonal and temporal. Further, ground water seepage is only restricted to a few points (GALLIN et al. 1989). During rainy season, the two rivers provide an important source of fresh water for the bay mangroves. The mangrove forest at Gazi Bay cover an area of approximately 617 hectares, while the area of the bay excluding that covered by mangroves is about 1000 hectares.

Gazi Bay has all the nine East-African mangrove species. They include: *Avicennia marina, Bruguiera gymnorrhiza, Ceriops tagal, Heritiera littoralis, Lumnitzera racemose, Rhizophora mucronata, Sonneratia alba, Xylocarpus granatum, and Xylocarpus moluccensis* (Tomlinson 1986). Mangroves of Gazi Bay have been exploited for many years, however, they were degraded in the late 1970's by intensive harvesting to provide industrial fuel (chalk, limestone and brick industries in the 1970s) and building poles (Dahdouh-Guebas et al. 2000). Clear-felling of the mangroves left some areas along the coastline completely denuded.

The Kenya Marine and Fisheries Research Institute (KMFRI) conducted a mangrove planting project to reverse this loss of mangroves. In 1990, the institute did the first experimental mangrove plantation in the area and later in 1994, it established large plantations (Abuodha & Kairo 2001). Ten hectares of this plantation is part of 615 ha of mangrove forest currently protected my Mikoko Pamoja project.

Vanga

The second research site, Vanga, lies within mangroves in south-east of Kenya (4º25’S, 39º17’E) close to the border with Tanzania (Fig. 3). The village has a high ethnic diversity and has a high percentage of immigrants, both internal and external from the neighbouring country of Tanzania, who come looking for a settlement. The immigrants engage mainly in fishing, farming, and shop keeping.

The mangroves of Vanga cover approximately 4265 hectares and are part of the second biggest mangrove complex (Vanga-Funzi) in the country (Kamau 1985). The first documented forest legislation in the Kenya was published in 1891 and was to protect the mangrove swamps of Vanga Bay (Kojwang 1996). River Umba, flowing from the Usambara Mountains in Tanzania, and River Mwena form an important source of fresh water for Vanga mangroves. The River Umba often burst its banks during rainy seasons, flooding the only road that leads to the village from Lunga Lunga. This cuts the village off from other villages in Kwale's Lunga Lunga Sub County and destroys property.

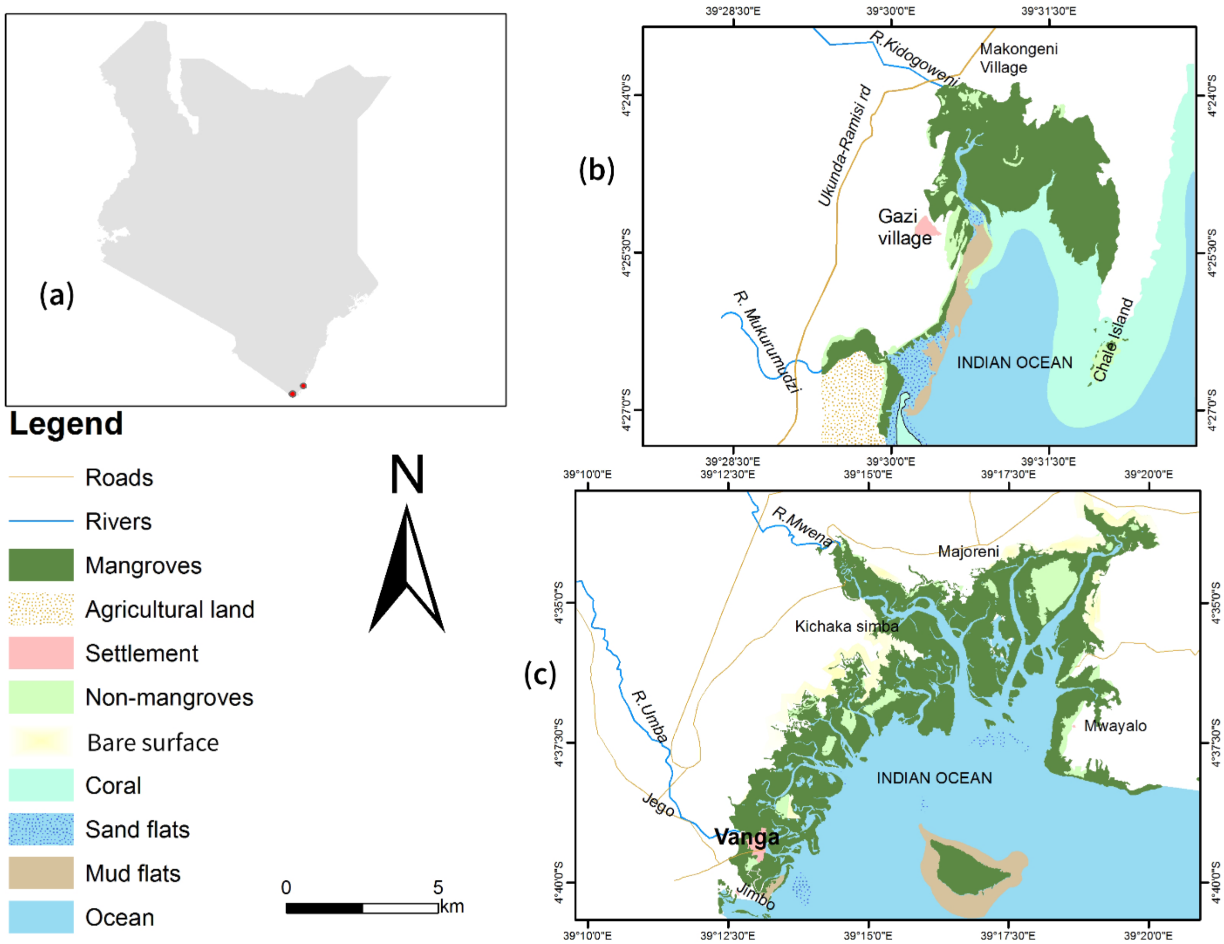

Figure 3. Map of Kenya showing Gazi Bay (b), and Vanga (c). Map created for this research by Mburu, F.M. (2017).

3.2 Methods

3.2.1 Mixed methods and triangulation

This research used mixed-methods approach to enable a more complete analysis of the research sites. According to Berg & Lune (2012), whereas qualitative research refers to meanings, quantitative research refers to measures. A mixed-methods research approach uses both methods either combined or to complement each other within one research. Mixed-methods encourages the use of multiple sources of evidences and methods to gain a deeper understanding of a case (Berg & Lune 2012). This allows triangulation, and provision of a more complete answer to the research question (Bryman 2008: p.635). By using multiple sources of data (semi-structured interviews, questionnaires, forest inventory data, satellite imagery, secondary sources, and observation), I could ensure validity of my research findings.

3.2.2 Sampling design

Ecological data

For ecological data, the study sites were stratified at two levels of existing conservation activities, and of mangrove zonation. For existing conservation activities, the following strata were identified at Gazi Bay: Rhizophora plantation, denuded Sonneratia plantation, protected natural forest, and unprotected natural forest. Systematic random sampling was adopted for data collection where transects (100 meters apart) were laid on the established strata. The first 10 x 10 m quadrant was placed randomly on transects but the subsequent quadrants were placed systematically with 10m interval along transects running perpendicular to the shoreline.

Socio-economic data

Purposive sampling was used to select interview informants while systematic sampling was used to select household survey participants for socio-economic data. Data was collected from households within 2.5 kilometers from the edge of the mangrove forest. Interview was used as the main tool for data collection as it was believed that the informants might have important unique as well as common experiences regarding resource management and utilization. Semi-structured interviews were preferred for their flexibility and ability to provide a huge breadth of context information (Berg & Lune 2012).

Participants

For the household surveys, every n^{th} households along the village roads (12th at Gazi and 20th at Vanga) were sampled. Where the n^{th} household was not available for sampling, the last available household on the count was sampled. On the other hand, informants for the interviews were selected based on their leadership roles, village records and participation in mangrove resource management and utilization. This selection was done with the help of a KMFRI staff, village chairs at Gazi and Makongeni, and Community Forest Association (CFA) chair at Vanga. Key informants included: a researcher from KMFRI, a forest ranger from KFS, Environmental Manager from Base Titanium, Chief of Vanga Location, Sub-Chief of Gazi Sub-location, village chairs, Mikoko Pamoja project management representatives, chair of the VAJIKI CFA, the secretary of GOGA CFA, leaders of the Beach Management Units (BMUs) at Gazi and Vanga, executive representatives from different forest user groups both at Gazi and Vanga, unlicensed mangrove harvesters, fishermen, and small business owners. A total of 22 interviews and 36 household surveys were done from 599 households at Gazi Bay while at Vanga, 25 interviews and 47 household surveys were carried out.

3.2.3 Procedure for data collection

Ecological data

Transects were laid on the study sites running perpendicular to the shoreline with the help of a Global Positioning System (GPS). A 10 x 10 m quadrant was randomly established 5 meters away from the creek. The subsequent quadrants were systematically placed with 10m interval along transects. The DBH of all trees with diameter >2.5 cm was measured and recorded while trees with diameter <2.5 were recorded as saplings. Other data collected from the quadrants included tree species, tree height, number of stumps, number of saplings and their respective species, tree form class depending on its suitability (quality) for construction, and % estimate of mangrove vegetation cover. Where the sapling density within a quadrant was high, the quadrant size was reduced to 5 x 5 m quadrat (within the main 10 x 10 m) and this indicated on the data sheet (Appendix 1). The number of plots laid on each of the two research sites were 36.

Socio-economic data

For the interviews, an interview guide (Appendix 2) with a checklist of 'issues' for discussion was used. The interviews were done in Swahili and the responses were transcribed into English. Interviews were started by introducing the research and then asking easy questions to build rapport. Probing questions were asked during the interview to validate the responses. Some of the information the questions aimed to find out included: system's (social and ecological) past disturbances and responses, valued attributes of mangroves, participation of different actors and institutions in the resource management, policy changes in mangrove management, access and utilization of mangrove resource, and occurrence of natural hazards. Interviews were taped for later analysis following respondents' approval.

Further, a household survey (Appendix 3) was used to collect household data. The data collected included the age, level of education, household occupation and income, land ownership, good and services from mangroves with their level of importance, and threats to mangroves.

Observation

Further data was collected through field observations on the status of mangrove forests, mangrove utilization, and infrastructural development during field work (9^{th} January to 10^{th} February 2017).

Satellite imagery

Satellite images were retrieved from Google Earth Pro 7.1.8.3036 (including its "historical imagery") to analyse changes in mangrove cover and in sand accumulation. The images covered a period of 14 years and were chosen according to their time of capture to avoid biases in seasonal fluctuation. This duration (14years) was decided on as it was the only period with clear images of the bay and the river mouth. The chosen images for Gazi Bay was from 2001, 2005, 2012, and 2015. However for Vanga, analysis of satellite image was not done as there were no available clear images of the site taken earlier than the year 2013.

Secondary data

Additional data included analysis of unpublished mangrove forest inventory data obtained from KMFRI during fieldwork. Further, published work acquired through the Norwegian University of Life Sciences library and was used for comparison to show changes in the state of the resource over time and also to create a mangrove management historical timeline.

3.2.4 Materials

A tree calliper to measure DBH, a graduated pole to estimate the tree height, a measuring tape to demarcate the quadrants and establish distance between quadrants, a GPS to align transects, field forms, a plastic folder to carry the field forms, and a phone to record interview conversations.

3.2.5 Analysis

Ecological data

Forest structure data was analysed using Microsoft Excel spreadsheet. The stands were divided into six diameter classes of <5, $5<10$, $10<15$, $15<20$, $20<25$, $25>$ labelled as 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th} and 6^{th} diameter class respectively. The following parameters were calculated: species diversity, species dominance, regeneration potential, harvesting intensity, number of stems per hectare, basal area, and volume. Species diversity was calculated using the Shannon Weiner index, while tree basal areas was calculated using the formulae:

Tree Basal Area (TBA m^2) = $(DBH/200)^2 \times 3.142$

Where DBH is the Diameter at Breast height (cm) and 3.142 is π.

Tree volume was calculated using allometric equation developed by (Lang'at et al. 2009) to estimate standing volume of a 12 year old *Rhizophora mucronata* plantation at Gazi Bay, Kenya.

$Y_i = aX_i^2 + bX_i + c$

Where, Y_i is wood volume of the i^{th} tree, X_i is DBH combined with Height and a, b and c are constants.

Socio-economic

Content analysis was used to analyse qualitative data from interviews. Transcription of the recorded interviews and coding of interview notes was done to reveal the major themes. Quantitative data was analysed using Microsoft Excel to reveal the social-economic characteristics of the mangrove resource users. Respondents' value of mangrove product and services were divided into three categories (not important, important, and very important) and were labeled as -1, 0, and 1 respectively. Not important (-1) meant that a respondent did not collect a good from the mangroves or thought that a service from the forest was not beneficial. Important (0) meant that a respondent collected a good from the mangroves, but could easily replace it with another alternative. For services, it indicated that they were thought to be partially beneficial. On the other hand, very important (1) meant that a respondent collected a good from mangroves and it was almost impossible to replace the good. For services, this meant that a service from the mangroves was thought to be highly beneficial.

3.3 Data quality assessment

Ethical considerations

One of the basic principles in research ethics is “to do no harm”. Doing harm to respondents can occur directly or indirectly, in the research process or long after the research was done. Whereas direct harm includes physical injuries to the respondents, indirect harm includes psychological injuries (e.g., stress). Additionally, failure to observe confidentiality and lack of proper data storage and disposal can bring about future harm to respondents. In this research, I observed ethical principles to avoid harming participants in the research process and by the results. Ethical principles, for instance, honesty and openness, are core issues in any research; and have therefore been an integral part of this research. To ensure ethics in a research, one should: avoid harming the respondents, ensure prior and informed consent, respect respondents’ private life, and should not deceive the respondents (Bryman 2012). Due to the impracticability of using a signed consent statement at the research site and a possibility of un-educated respondents, I replaced it with an oral agreement. Before every interview, I informed participants about the research topic, and the intent, before agreeing to participate. Respondent’s consent was also obtained whenever digital voice recording was done. I also emphasized that all data collected would be treated anonymously. Further, I ensured confidentiality by referring to participants by identifiers during reporting findings, and securely store collected data (Berg & Lune 2012).

Limitations Kazikazi is the high fishing season experienced between September and February. Fishing is a major source of livelihood at the two research sites. Fieldwork was done in January - February, which is part of the high fishing season of Kazikazi, presenting a challenge getting male respondents. This was because many were fishermen who went fishing at night around 03:00 am, and got back at around 11:00 am. Once back, the fishermen would proceed to sell their catch and then go to sleep after long hours of fishing. Further, the main religion within the villages of Gazi, Makongeni and Vanga is Muslim and therefore the villagers observed praying hours and frequently went to the mosque. This meant that to get a gender balance on my research, I had to modify the sampling method to fit the local realities. I sometimes had to do interviews and surveys in the evenings when most male fishermen were back in their houses. Further, the timing had to be between prayer hours when the villagers are not in mosques.

Two research assistants were therefore involved. They helped in identifying key informants and introducing me to respondents. I conducted interviews in the absence of the assistants to relax respondents, get more honest responses, and overcome ethical limitations. This is because one assistant was associated to KMFRI and the other one had a leadership role at Vanga.

Results

4.1 Ecological characteristics of the mangrove ecosystems

4.1.1 Species composition and dominance

The two forests were relatively similar in terms of mangrove species composition, but varied slightly in dominant tree species. While Gazi Bay had only *Rhizophora mucronata* as the dominant species, Vanga had *Ceriops tagal* and *Rhizophora mucronata* (Table 1). Seven tree species were encountered at Gazi Bay, while six were recorded in Vanga mangrove forest. The species found at Gazi Bay were: *Avicennia marina*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Lumnitzera racemose, Rhizophora mucronata*, *Sonneratia alba*, and *Xylocarpus granatum*. On the other hand, those found in Vanga forest were: *Avicennia marina, Bruguiera gymnorrhiza*, *Ceriops tagal*, *Rhizophora mucronata*, *Sonneratia alba*, and *Xylocarpus granatum. Lumnitzera racemose* and *Xylocarpus granatum* were the least dominant species in the two forests.

Table 1.Species composition and dominance at Gazi Bay and Vanga mangrove forests.

Species	Percentage (%) dominance	
	Gazi Bay	Vanga
A. marina	7.6	1.6
C. tagal	22.39	45
R. mucronata	48.27	44.5
B. gymnorrhiza	11.56	5.4
S. alba	5.9	3.1
X. granatum	4.2	0.4
L. racemose	0.08	0

4.1.2 Structural complexity of the mangroves

Gazi Bay mangroves were structurally more complex than Vanga mangroves (Table 2). They had a higher density, basal area, and volume. Both Gazi Bay and Vanga mangrove forests had a higher stem density for trees in lower diameter classes as compared to those in higher diameter classes (Fig. 4).

Within Gazi Bay site, the forest structure varied considerably. Denuded *S. alba* stand had the lowest stem density (1800 stems/ha) and basal area (5.732 m^2ha^{-1}), the 23 years old *R. mucronata* plantation highest basal area (37.167 m^2ha^{-1}), while the natural forest had the highest stem density (Table 3). It was further observed that within the *R. mucronata* plantation, trees (of both planted *R. mucronata* and other non-planted species) shorter than the average stand height (11m) were dying, possibly due to lack of sufficient sunlight.

Table 2. Stem density, basal area, and volume of Gazi Bay and Vanga mangrove forests

Site	Total No. of stems	Density (stems/ha)	Basal area (m^2ha^{-1})	Volume (m^3ha^{-1})
Gazi Bay	1239	3350	21.1	193.3
Vanga	817	2269	9.96	93.7

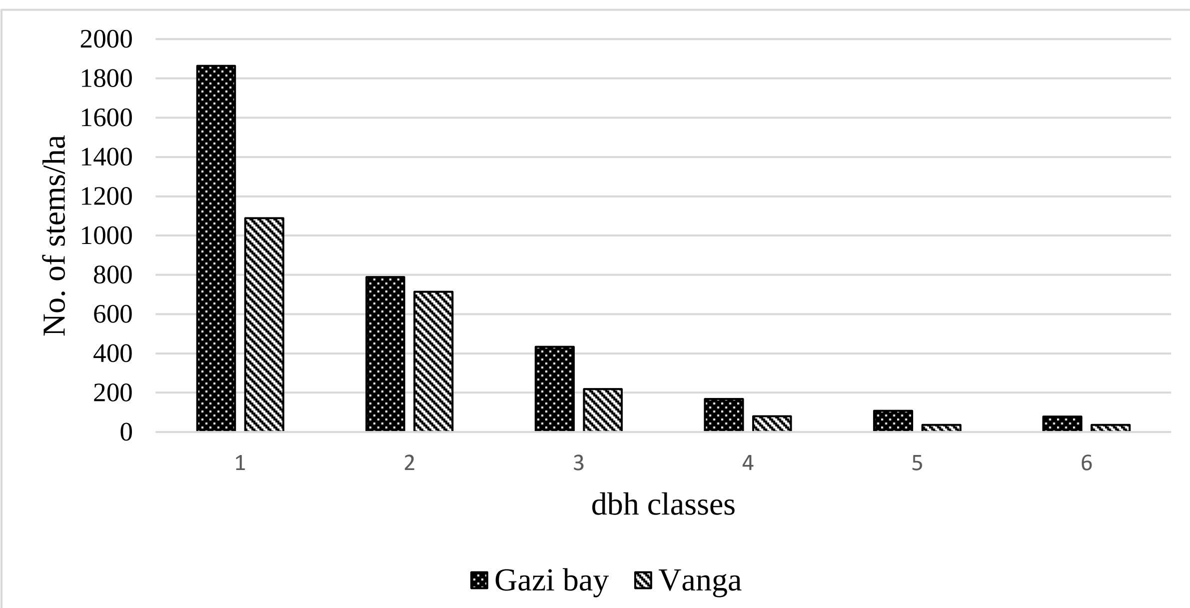

Figure 4. Distribution of stems density within different tree diameter classes at Gazi Bay and Vanga mangrove forests.

Table 3. Stem density, basal area, and volume of *R. mucronata* plantation and natural forest at Gazi Bay mangrove forest

Section	Stem density (stems/ha)	Basal area (m^2ha^{-1})	Volume (m^3ha^{-1})
R. mucronata plantation	2750	37.167	410.1
natural forest	3650	13.08	85.17

Figure 5. A section of denuded *S. alba* stand. Photo: Murungi, E.M. (2017, January 24).

4.1.3 Harvesting intensity at the forests

Harvesting intensity was calculated from recorded stumps within the sampling plots. There were 254 and 350 stumps at Gazi Bay and Vanga mangrove forest respectively. This yielded non-significantly different harvesting intensities of 706 stumps/ha at Gazi Bay and 972 stumps/ha at the Vanga mangrove forest. Within Gazi Bay site, *R. mucronata* plantation had a harvesting intensity of 250 stumps/ha, while unprotected natural forest had a higher harvesting intensity (933 stumps/ha) compared to the protected natural forest (573 stumps/ha).

4.1.4 Forests' regeneration potential

A total of 5041 and 3619 juveniles was recorded at Gazi Bay and Vanga mangrove forests respectively. Gazi Bay had a higher regeneration potential with a seedling density of 14,002 seedlings ha^{-1} compared to 10,052 seedlings ha^{-1} at Vanga forest. Seedlings of *R. mucronata* were the most common at Gazi Bay, comprising 58.8% of the total seedlings encountered. On the other hand, at Vanga, 60.2% of all seedlings recorded were of *C. tagal*. Within Gazi Bay site, *R. mucronata* plantation and denuded *S. alba* stand had the least stand renewal with juvenile densities of 2,400 seedlings ha^{-1} and 860 seedlings ha^{-1} respectively. It was also observed that most of planted seedlings at the denuded *S. alba* stand were dying following smothering by sand.

4.2 Socio-economic characteristics of mangrove resource users

4.2.1 Levels of education and sources of livelihood

The number of household surveys done at Gazi Bay was 36 while at Vanga were 47. Both sites had a higher percentage of men participating in the surveys than women (58%, 62%) at Gazi Bay and Vanga respectively. Respondents from both Gazi Bay and Vanga had a low-level of education, with primary school being the highest level of education achieved by the majority of the respondents. Lack of adequate income was the most cited reason for failure to progress to further studies.

Artisanal fishing was the main livelihood activity and important for other small business at both Gazi Bay and Vanga. Fishing had two important seasons of Kusi and Kazikazi. Kusi is a low fishing season, between March and August, characterized by strong SE monsoon winds. However, fish caught during this season fetch better prices. On the other hand, Kazikazi is the high fishing season experienced between September and February.

The demand for fish both at Gazi Bay and Vanga was higher compared to ten years ago. Respondents cited increasing local population and expanding fish market away from the villages as factors causing increased demand for fish. One fisherman at Vanga said “like 13 years ago, we would catch 1 ton of fish a day, but could only sell half and the rest would go bad. But now, 1 ton of fish is not enough for consumers in Mombasa.” Expanding fish market had also led to a demand for dried sardines, a fish that were not traditionally caught.

While the demand for fish was higher, the quantity of fish caught by each fisherman was lower as compared to ten years ago. Respondents cited damming of River Mukurumudzi, increase in the number of fishermen, high fishing of fingerings, and inappropriate fishing methods like the use of poison and beach seine nets as reasons causing decrease in fish catch. One respondent at Gazi village said “about 12 years ago, one fisherman would catch about 50 kilograms of fish in a day, but now struggle to catch 8 kilograms a day.” Construction of Mukurumudzi dam and KISCOL dam on the Mkurumuji River at Gazi Bay was leading to a loss of the indian white shrimp (*Penaeus indicus*). Further, respondents reported a significant decrease in grunter (*Pomadasys spp.*), milkfish, mullet fish, and crabs following construction of the dams. At Vanga, immigrants from other coastal areas (mainly Samburu and Mariakani) were leaving other traditional activities and engaging in fishing. Villagers reported that the immigrants lacked experience in fishing and often engaged in inappropriate fishing practices like beach seine fishing and use of poison.

Fishing at both sites was more technologically advanced as compared to ten years ago. Use of motorized boats for fishing was observed, though more at Vanga than at Gazi Bay. Further, fishermen utilised ice boxes at both sites and an ice plant at Vanga to preserve fish.

Employment rate was low (11%, 14%) at Gazi Bay and Vanga respectively. At Makongeni village, waged labourers working mainly at Kwale International Sugar Company Ltd (KISCOL) comprised 16% of the respondents. However, wages at KISCOL were very low, KSh 220 per day for working on the farms and KSh 300 for tractor drivers per day, and were often not paid on time. Most people coming from other parts of the country, mainly from the western region, looking for jobs at KISCOL ended up quitting and doing other small businesses within the village. Base Titanium offered better employment opportunities, though it rarely employed anyone from Gazi and Makongeni villages due to low levels of education.

Livelihood sources were diverse both at Gazi Bay and Vanga. Women earned income mainly from selling food, weaving makuti (roof thatches made from coconut fronds), running small grocery shops, and collecting molluscs and crustaceans. At Gazi village, income from selling food significantly varied between Kusi and Kazikazi depending on the number of fishermen arriving at the village. A food vending small business owner at Gazi village said "businesses here are seasonal. During high fishing season fishermen come from Tanzania and then businesses thrive. But in the low fishing season, some of us do other businesses like collecting crabs and shrimps". Male respondents juggled between fishing, small-scale farming, making concrete blocks, carpentry, mangrove harvesting, masonry, and thatching. Other economic activities included: waged labour, boat building and repair, and shop keeping.

4.2.2 Human migration and changes in population

Human population at Kinondo and Vanga Locations more than doubled between 1979 and 2009 (Fig. 6). This had led to an increase in demand for land, though the majority of villagers at Gazi Bay and Vanga were still squatters. At Gazi village, increase in the number of family members and need for bigger houses led to some villagers extending their houses to areas reserved as village roads. In terms of annual population growth rate, that at Kinondo Location has been increasing since 1979, as compared to that of Vanga Location that fell between 1979 and 1989, but and then rose between 1999 and 2009 (Fig. 7).

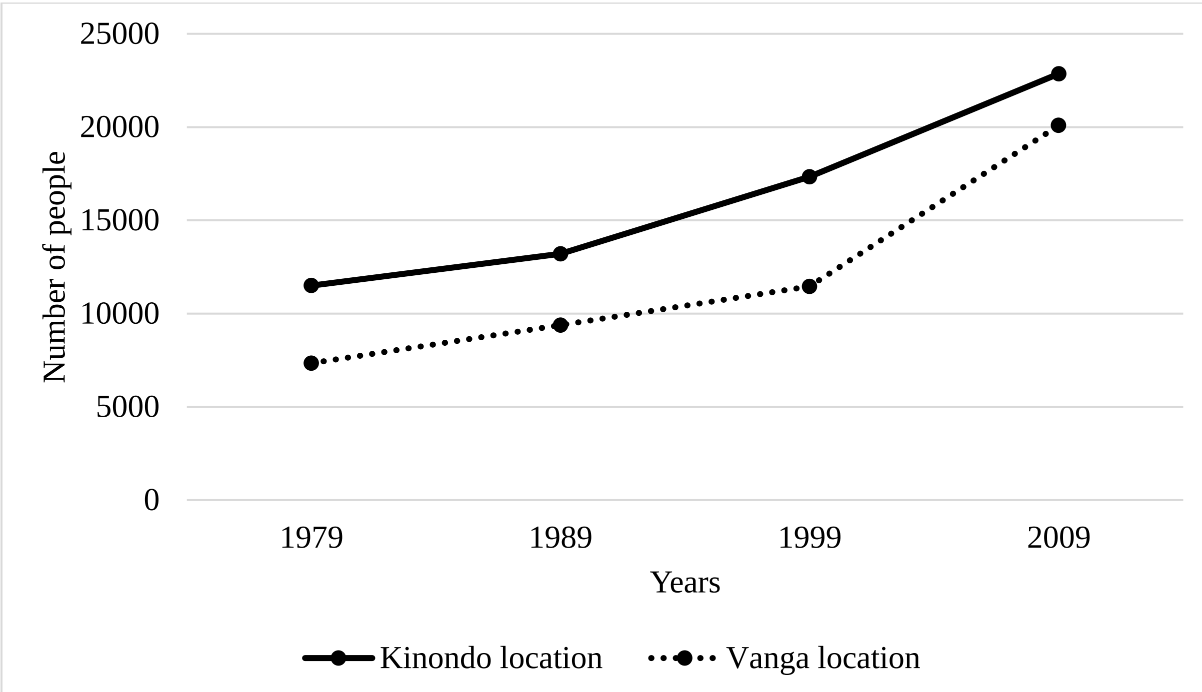

Figure 6. Changes in human population at Kinondo and Vanga Locations between 1979 and 2009.

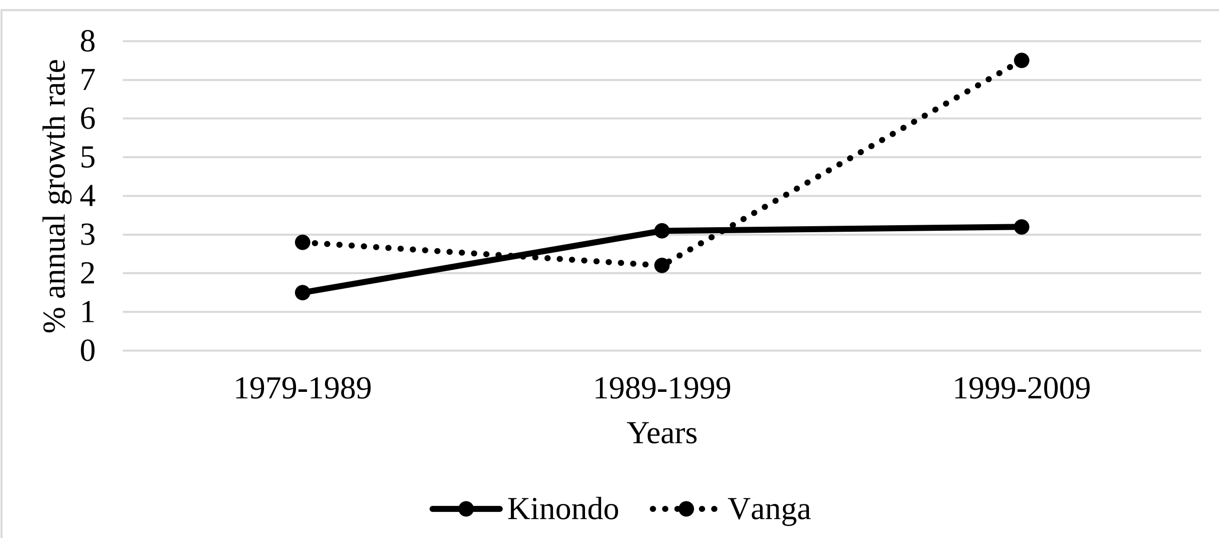

Figure 7. Changes in percentage annual human population growth rate at Kinondo and Vanga Locations between 1979 and 2009.

Internal and external migration were both contributing to population changes both at Gazi Bay and Vanga. The percentage of the respondents who had moved from other parts of the country and from Tanzania (temporarily or permanently) was 33% and 27% at Gazi Bay and Vanga, respectively. At Gazi village, human migration was mainly fishermen who move seasonally between the village, and Zanzibar and Pemba in Tanzania. Further, migration at Gazi Bay was also composed of people moving from different parts of the country in search of a settlement, notably following the 2007-2008 post-election violence in Kenya. Human movement at Vanga was from both within the country and from Tanzania and were mainly in search for a settlement.

Human migration had both positive and negative impacts at Gazi Bay and Vanga. Visiting fishermen at Gazi Bay were an important source of income to the food vending businesses. On the other hand, those seeking settlements contributed to the knowledge diversity. A native respondent at Gazi Bay said "settling visitors ignite economic progress by bringing new ideas, spotting business opportunities, and sharing their way of life. Otherwise, if we remained a community only for the Digo and Duruma, we will only bewitch each other". Ukunda, a medium-sized town close to Gazi Bay, was often pointed as an example of how human migration and diversity of ideas contribute to rapid economic progress. In contrast, the main reported disadvantage of human migration was that it caused land disputes. At Vanga, the conflicts were mainly because the immigrants illegally settling on land belonging to absentee owners. On the other hand, at Makongeni village, the native Digo ethnic group elders had planned to evict non-locals living at *Kambi* (a section where workers at Ramisi Sugar Company lived), after the expiry of land leasehold by the company. The occupants of *Kambi*, mainly migrant laborers of Luo and Luhya ethnic groups, had acquired plots after the collapse of company with unpaid salaries. Digo tribe members intimidated the immigrants by calling them "*wananchi*" (inhabitants) as opposed to the natives who referred who called themselves "*wenyenchi*" (land owners), a matter they were following up with the District Commissioner.

4.2.3 Land ownership

Residents of Gazi Bay and Vanga were initially squatters. The existence of squatters dates back to the pre-independence, when the Persians, Arab Sultans and Britons controlled land along the Kenyan coast. Nevertheless, at Vanga, about 61% of the respondents owned land and had title deeds, after efforts by the government to resettle squatters. At Makongeni, the resettlement plans were in progress. The land had been surveyed, subdivided and plans to award title deeds in progress.

Respondents reported nonviolent disputes on land at both Gazi Bay and Vanga. While the disputes were ethnic and between native and non- native ethnic groups at Makongeni and Vanga villages, that at Gazi village was between villagers and adjacent plantation owners who had leased the land from the Mazrui family. A public authority representative at Gazi Bay explained that the Mazrui family was the land trustee for locals at Gazi village and upon independence, the family kept the title deeds on behalf of the locals and leased the land to the Indians. He further explained that the growth in population had further motivated the locals to repossess their ancestral land. Consequently, the villagers had stormed a neighboring mango plantation farm and had demarcated the land among themselves. A case regarding this was, however, pending in court.

4.2.4 Financial empowerment

The villagers at the two research sites rarely did any bank saving. Only a few of the respondents had bank accounts, but none had applied for a formal bank loan. Respondents reported insufficient savings and property to secure loans, high bank interest rates, lack of steady monthly income to pay instalments, and religious reasons as Islamic religion did not allow for payment of interest (*riba*) on borrowed money as the reasons for lack of interest in bank loans. Nevertheless, villagers did saving mainly through M-Pesa (a mobile-phone based saving service by Safaricom). Formation of *chamas*, mainly composed of women, was also common both at Gazi Bay and Vanga.

Chamas (and in plural *chama*) simply means a group. Members of a *chama* regularly (weekly for some and monthly or others) contributed an agreed amount of money with an aim of helping each other grow economically. The collected money was then given to one member and the process is repeated until all members get their share. Some *chamas* operated as self-help groups (investment groups) registered by the Ministry of Gender, Children and Social Development. Self-help groups acted as tools through which villagers would get access to donor funding support and interest-free government loans towards group investment. Some of the self-help groups included; sea-weed farming, and a boardwalk for eco-tourism at Gazi Bay, and crab rearing, bee keeping, and fish ponds at Vanga. However during data collection, some of the groups had already collapsed while the others were hardly generating income. At Vanga, group projects for fish ponds, crab rearing and a mangrove boardwalk, were no longer operational. Villagers attributed the collapse to poor management, theft of mature fish from the ponds by villagers, and lack of commitment as some villagers abandoned fish ponds once they got a share of donor money. On the other hand, Gazi women boardwalk was hardly generating income as the number of tourists visiting the village had significantly reduced.

4.2.5 Diseases

Diseases were a major hindrance to economic progress both at Gazi Bay and Vanga. The most prevalent diseases, according to the respondents, were HIV/Aids, cholera and malaria. Malaria and cholera broke mainly during the rainy season, through villagers reported that their prevalence was reducing every year. Villagers attributed a reduction in malaria incidences to efforts by the government and donors to distribute mosquito nets, and advancements in malaria preventive measures. Vanga was the most affected by cholera, as the disease was also reported during dry seasons. This was due to lack of safe drinking water as some villagers fetch drinking water from contaminated open holes and from Umba riverbed during dry seasons. Shortage of toilets was observed, especially at Makongeni and Vanga. Several villagers shared a few toilets, while others did open defecation in bushes and on the adjacent mangrove forest.

4.2.6 Frequent floods at Vanga

Flooding of River Umba is common at Vanga during the long rainy seasons. Floods displaced families and left them in need of emergency relief. Further, floods led to loss of income as fish caught could not be transported out of the village. Pit latrines collapse during floods, contaminating most water sources, and leading incidences of cholera. Due to lack of drainage facilities at Vanga, water from the flooding river often stagnated at the village, forming mosquito breeding sites and contributing to the problem of malaria.

4.3 Utilization of mangrove resources

There was a high dependence on mangrove products from the research sites, with 80% and 75% of respondents collecting mangrove products at Gazi Bay and Vanga respectively. The most valued mangrove products collected from the forests were firewood, fisheries, poles and beams. The demand for mangrove poles was lower at both sites compared to five years ago. Villagers perceived the use of mangrove posts and mud for house walls as a traditional practise. Several respondents said that the villagers were now ‘enlightened’ and that they were moving away from such a practice, and increasingly using concrete blocks for house building. Further, increase in income, and availability of locally sand-made blocks, especially at Vanga, were contributing to the increased use of concrete blocks. A respondent said “people here no longer build with mud and mangrove as we traditionally did because incomes have increased. If you use mud for building, you never get finished as you make major repairs after about every 10 years”. It was further observed that villagers progressively replaced old mud walls on their houses with block walls (Fig. 10), though also more common at Vanga than at Gazi Bay. At Vanga, informants explained that the blocks were made from mixing locally available sand from their farms with cement. On the other hand, at Gazi Bay, the blocks were mainly carved from coral stones. At Gazi Bay, alternative source of poles from planted casuarina trees and sensitization campaigns by Kenya Marine and Fisheries Research Institute (KMFRI) and other civil society groups on the importance of conserving mangroves also played a role to decreased demand of mangrove poles.

Services offered by mangroves were generally more valued than products collected from the forests. Storm protection, erosion control, habitat and nursery ground were the most values services from the two research sites (Fig. 8 & 9). Carbon sequestration, and provision of recreational were more valued at Gazi Bay that at Vanga. This could be due to the presence of Mikoko Pamoja project, and a mangrove boardwalk at Gazi Bay. Use of mangrove forest for cultural and religious functions were the least valued services.

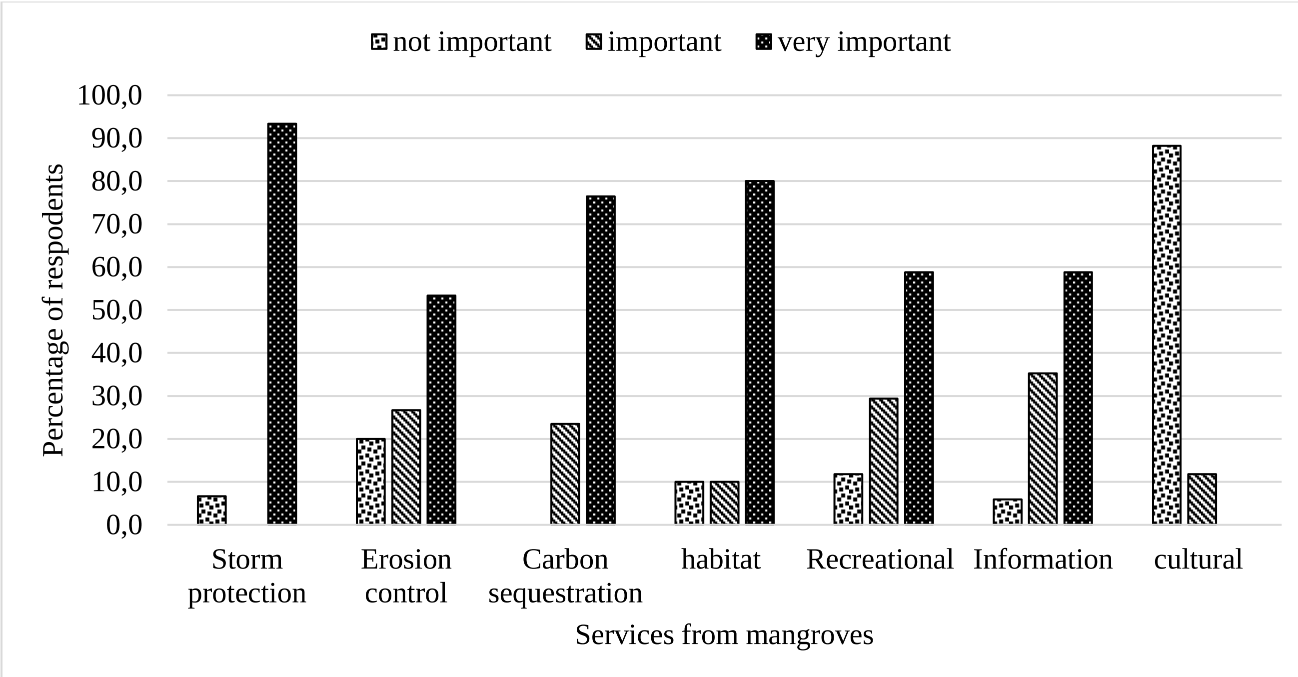

Figure 8. Services offered by mangroves with their level of importance as reported by respondents at Gazi Bay.

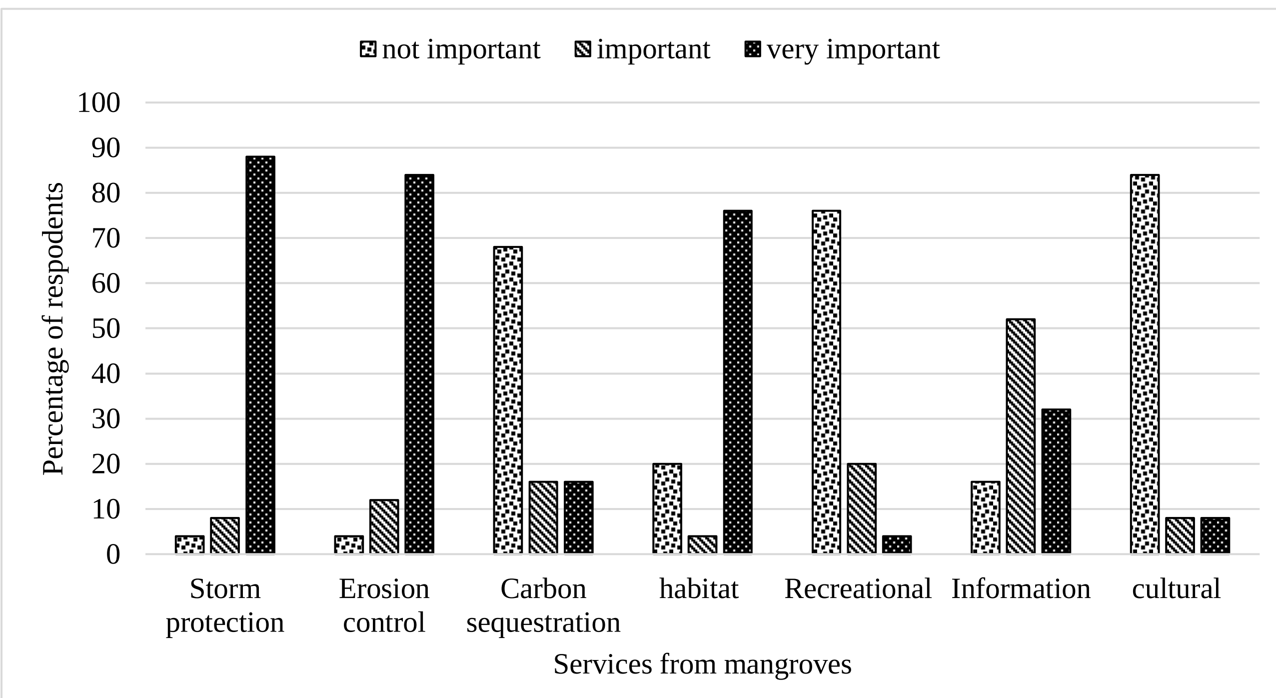

Figure 9. Services offered by mangroves with their level of importance as reported by respondents at Vanga.

Figure 10. Mangrove poles and mud made walls on a house being replaced by concrete block walls at Vanga. Photo: Murungi, E.M. (2017, February 1).

Figure 11. Concrete blocks made of locally available sand and cement at Vanga. Photo: Murungi, E.M. (2017, February 2).

4.4 Threats to the mangrove forests

According to the respondents, the main threat to mangrove were harvesting at Vanga and sedimentation, and insects at Gazi Bay (Fig. 12). Respondents at Gazi Bay reported that harvesters were relocating to other mangrove forests where community involvement in forest management was weak. A Kenya Forest Services (KFS) forest warden at Gazi Bay reported that since the community formed Gogoni-Gazi Community Forest Association (GOGA CFA) and protection of mangrove forest by Mikoko Pamoja here at Gazi Bay, harvesters were moving out to other areas like Vanga and Bodo where communities were not yet involved in mangrove forest management. This was again brought up by informants at Vanga as they reported that commercial harvesters at Vanga mangrove forest were mainly from areas outside Vanga Location.

Villagers explained that commercial harvesters caused more damage to mangrove forests than unlicensed local harvesters. Commercial harvesters caused double damage to the mangrove forests by cutting many trees and clearing juvenile trees to make way for loading trees into boats. In contrast, unlicensed local harvesters cut fewer trees and they usually carried the harvested trees on their shoulders, without the need to clear juvenile trees. Villagers at Vanga had previously forced a licensed commercial harvester out of the mangrove forest as he was cutting a lot of trees. A local authority representative said “about four years ago, the villagers revolted against a licensed harvester, forced him out of the forest, and shared the posts amongst themselves. Had he continued, he would have cleared the forest in 2 or 3 years”. Further, Villagers blamed KFS for its failure to enforce regulations and to regulate mangrove harvesting. A forest warden at Gazi Bay though attributed KFS shortcomings to shortage of wardens and equipment, especially at Vanga, where there was only one forest warden locally stationed.

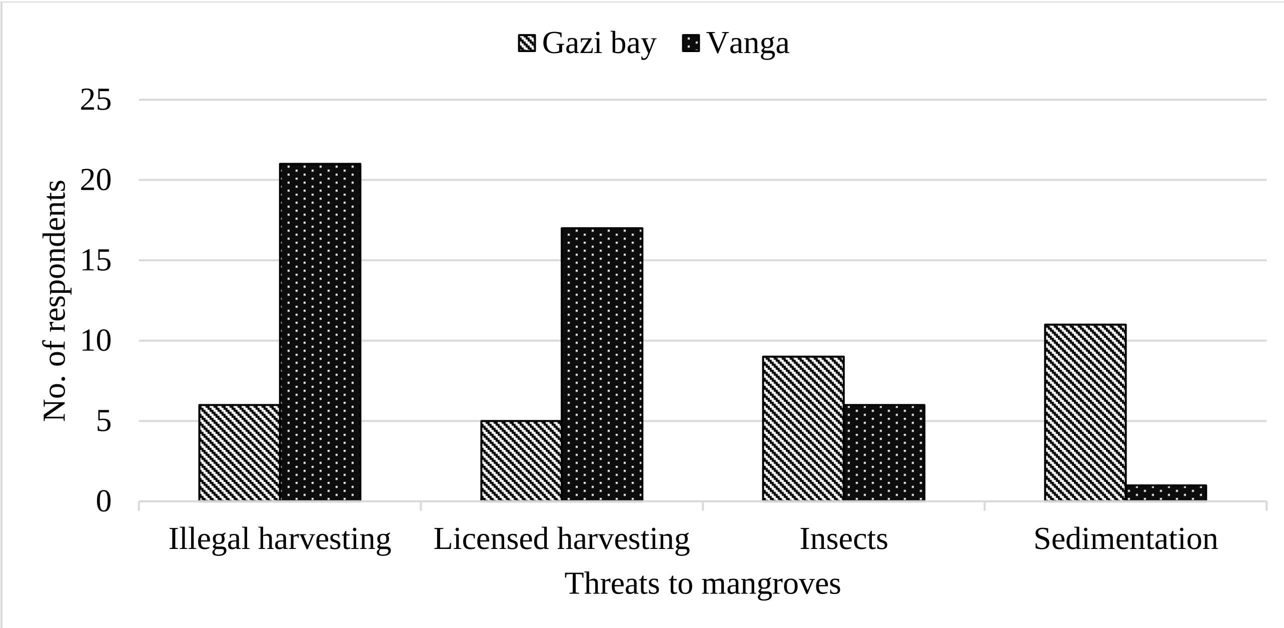

Figure 12. Threats to mangroves at Gazi Bay and Vanga

4.5 Dams at Gazi Bay and a sea-wall at Vanga

A sea wall and dams were impacting villagers and mangroves at Vanga and Gazi Bay. At Gazi Bay, KISCOL and Base Titanium had constructed a total of three dams on Mukurumudzi River basin that drain into Indian Ocean via Mukurumudzi River. The dams were: upper and lower Koromojo dams with a total storage of 5.5 Mm^3, and Mukurumudzi dam with a storage capacity of 8.4 Mm^3. From the interviews, impacts after the dam construction were loss of fisheries downstream, loss of sources of income, and degradation of *S. alba* stand by excessive accumulation of sand. Some of the fisheries reported to have been lost were: *kamba* (indian white shrimp), *kamamba* (small spotted grunter), and crabs.

Vanga sea-wall degraded *A. marina* stand. This was by clearing the mangroves for wall construction, and by restricting flood regime and the flow of sediments to the stand. Further, the wall blocked the flow of rain water to the ocean and hence accelerated the problem of flooding during rainy season. The wall also blocked rain water from flowing to the ocean, hence forming breeding grounds for mosquitoes and causing malaria. On the other hand, villagers considered the sea-wall important for protecting the village from ocean tides and storms. Though, some villagers reported incidences when sea water had flown over the wall to the adjacent houses.

4.6 Mangrove resource governance

In Kenya, the government owns mangrove forests and the forests are managed by KFS. Villagers thought that the community, and the government through KFS should be responsible of managing the mangrove forests. Through the Forest Act of 2005, Kenya devolved forest management and decision-making from central government to local communities through community forest association. At Gazi Bay, GOGA CFA was an operational forest association and consisted of several forest user groups. On the other hand, at Vanga, Vanga-Jimbo-Kiwegu Community Forest Association (VAJIKI CFA) was in the process of developing a management plan and therefore the community was not yet legally involve in forest management.

GOGA CFA involved Gazi Bay villagers in formulating and implementing new rules on the mangrove resource access and utilization. Within the CFA, villagers had many forest user groups involved in different activities in the mangrove forest. Some of the user groups were: Gazi Women Boardwalk, and The Mikoko Pamoja Community Organization (MPCO). MPCO was implementing a carbon trading project at Gazi Bay mangroves called Mikoko Pamoja project. The project was protecting 117 hectares of mangrove forest at Gazi Bay on a 20 year initial period and invested finances from the sale of carbon to community projects. From the sale of carbon credits for 2015-2016 reporting year, the project bought books for Gazi primary school worth KSh 150000 and purchased a 15,000 litres water tank to provide safe drinking water for Makongeni village. Villagers in Gazi Bay collaborated with KFS to protect the forest. They report suspicious mangrove harvesting activities to the project official who then informed KFS through monthly reports, though KFS was slow in responding to information on illegal activities in the forest. Additionally, the project had given the villagers a stronger sense of ownership of the mangrove forest. A respondent said “for once, the entire community was able to see direct benefits from conserving the mangroves. We have safer drinking water, and children were getting books in school. This motivates us to protect our forest even better”.

Sharing of indigenous knowledge about mangrove resource between the villagers and KMFRI was inadequate. Villagers reported that the KMFRI only shared with them scientific knowledge but did not inquire about their traditional knowledge. A respondent said:

> “We know the mangroves are dying due to lack of fresh water. If you look the white sand at the Mukurumudzi River mouth, it easily gets blown away by wind during low tide. This only happens when the sand is mainly soaked by sea water and not fresh water”.

4.7 Analysis of satellite images

Analysis of google earth satellite images for the southern edge of Gazi Bay mangrove area, and of the Mukurumudzi River mouth between 2001 and 2015 showed a northward Longshore drift (Fig. 13). Eroded sand from southern beaches (Kairu 1997) and the reduced amount of sediments transported downstream by River Mkurumuji contributed to formation of a sand spit at the mouth of River Mukurumudzi. The shape of the spit changed with time as the sand moved further up the river mouth (Fig. 14). The eroded sand by the drift was lost on the northern section of the bay and on denuded *S. alba* stand. On the shallow creeks, the sand was accumulating as sand bars. Villagers reported that coastal erosion at this southern section of the bay has happened for the last thirty years.

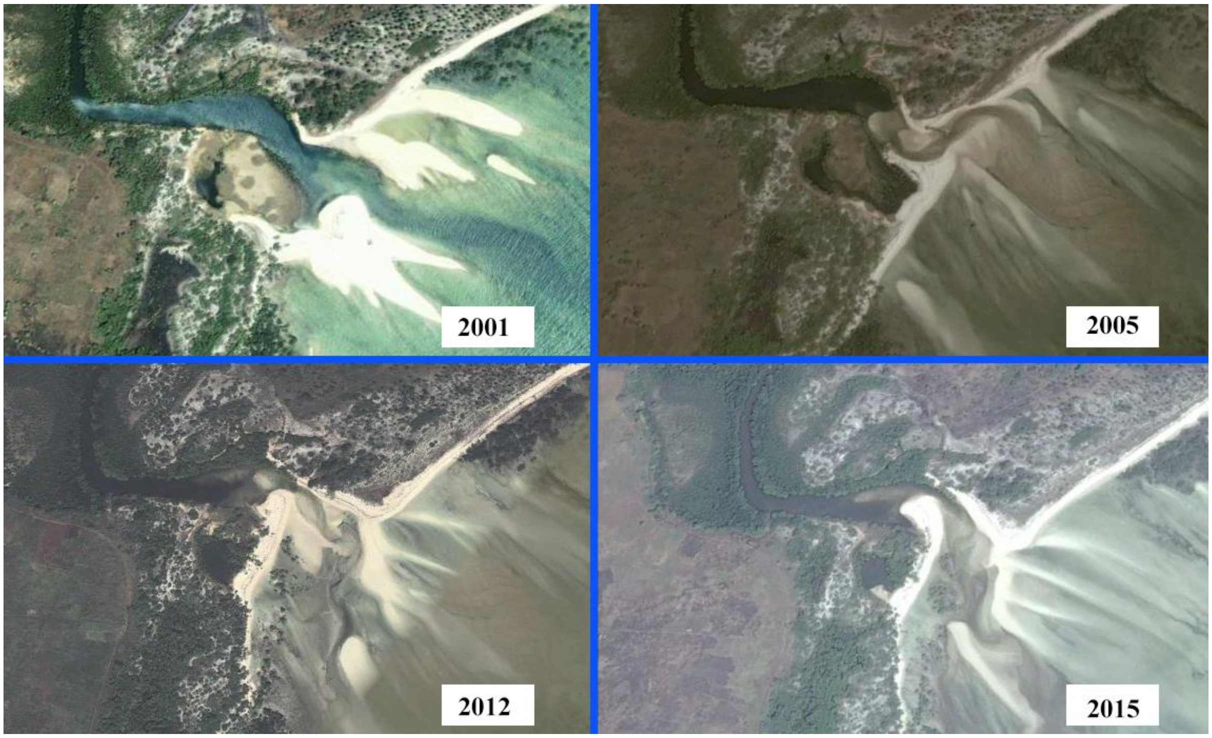

Figure 13. Satellite images of Mukurumudzi River mouth in 2001, 2005, 2012, and 2015. (Google Earth, 2017).

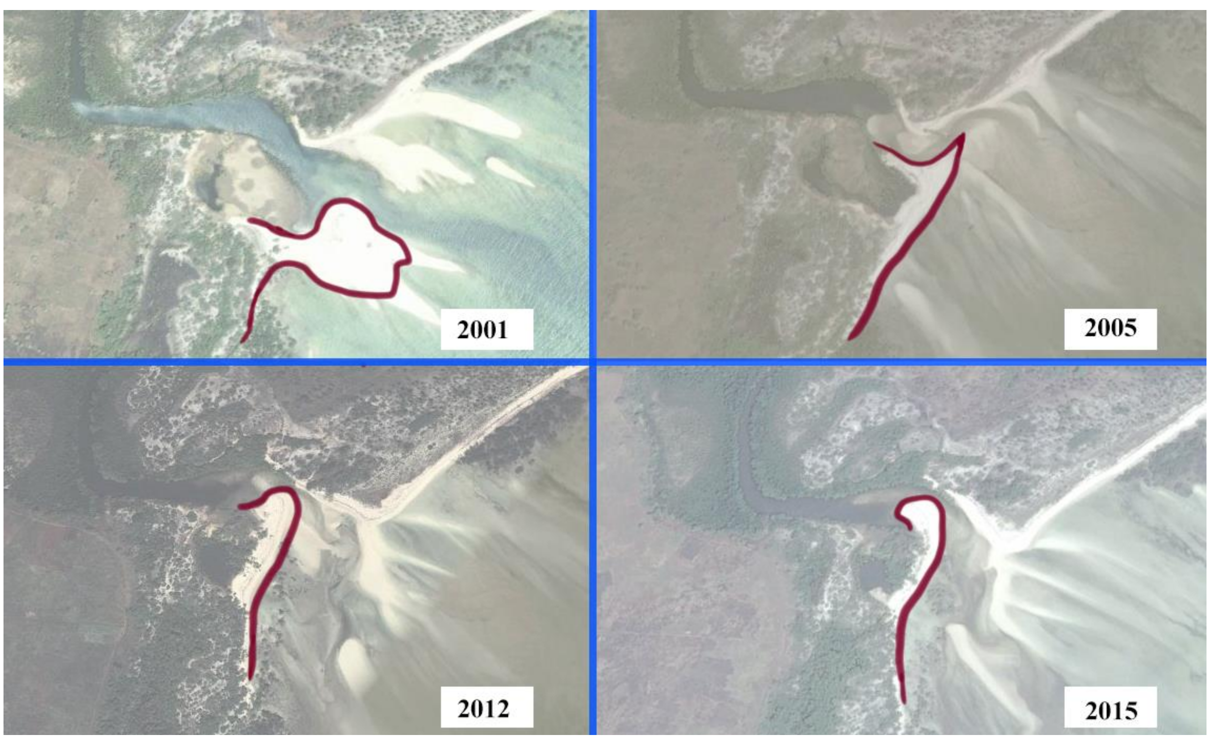

Figure 14. Changes on the shape of a sand spit (shown by the outline drawing) at Mukurumudzi River mouth between 2001 and 2015. (Google Earth, 2017).

Discussion

Disturbances and uncertainty and their magnitude and timing present challenges to the management of social-ecological systems (SESs) and their provision of ecosystem services. The magnitude of disturbance required to fundamentally disrupt a system, causing a shift to another state controlled by a different set of processes indicate the amount of resilience a system (Berkes et al. 2003). Resilient social-ecological systems absorb temporary changes and remain within the same domain of attraction. Resilience in a mangrove SES depends largely on underlying, slowly changing variables such as hydrological regime, household income, human values and policies. A resilient mangrove system is able to absorb disturbances (like changes in harvesting intensity) and remain within the same domain of attraction. It has a high biodiversity, encourages learning through management decisions, and a diverse group of stakeholders share the resource management. Loss of biodiversity, closed and inflexible management institutions, and unsustainable use of resources can lead to loss of resilience in a mangrove SES. Combination of disturbances in a mangrove system and their timing can cause interaction effects. In situations where a disturbance occurs before a mangrove SES have had time to recover from earlier disturbance, the system is faced with a major shock and might not be able to survive without structural changes. By comparing Gazi Bay to Vanga, this study will analyse key factors and processes building or eroding resilience of mangrove ecosystems and adjacent coastal communities.

5.1 Changes in structural complexity of Gazi Bay and Vanga mangrove forests

Pressure on Vanga mangrove forest is not caused by harvesting local utilization, but by traders who living far from the village. Vanga mangrove forest (4265 ha) is significantly larger than Gazi Bay forest (617 ha). Considering that larger forests are more resilient than smaller ones

(Thompson et al., 2009), and that use of locally made blocks as mangrove substitutes is more common at Vanga than at Gazi Bay, one would expect a significantly lower harvesting intensity at Vanga forest. This is because reduced harvesting activities in the forest due to use of blocks as mangrove substitutes would be spread on a much large forest area. However, the results show the opposite; a higher harvesting intensity at Vanga forest (972 stumps/ha) compared to Gazi Bay (706 stumps/ha). Further, compared to results by Lang'at (2008), the Vanga forest basal area and volume has reduced by 4.32 m^2ha^{-1} and 17.93 m^3ha^{-1} consecutively; indicating a declining mangrove resource. In contrast, Gazi Bay forest basal area and volume have increased by 3.1 m^2ha^{-1} and 43.9 m^2ha^{-1} respectively compared to results by Bosire, et al. (2003). Declining mangrove resource at Vanga can be attributed to an increased cutting of mangroves by commercial harvesters who, according to the results, are moving to mangrove forest areas where the local communities are not involved in mangrove management, including at Vanga. Further, involvement of mangrove users at Gazi Bay in mangrove management has therefore encouraged inclusiveness and flexibility as the villagers are able to influence the regulations on forest use through Gogoni-Gazi Community Forest Association, which according to (Biggs et al. 2015), enhances the social-ecological resilience.

Increase in forest basal area and a decrease in stem density is typical for a developing forest (Twilley & Hall 1995). The 23-year-old *Rhizophora mucronata* plantation at Gazi Bay has a lower stem density and a higher basal area compared to a stem density of 4864 stems/ha and a basal area of 17.12 m^2ha^{-1} reported by Kairo et al. (2008), agreeing with the finding by Twilley and Hall (1995). A significant decrease in the stand regeneration potential by 2486 seedlings ha^{-1} compared results by (Lang'at et al. 2006), and observed self-thinning symbolize entry of the stand to the conservation phase of the adaptive cycle. In this phase the system is characterised by negative feedbacks and rigidity as resources become locked up (Walker et al., 2004).

5.2 Livelihoods and social-ecological resilience

Artisanal fishing is the main livelihood activity at both Gazi Bay and Vanga. However, it was practiced more in the villages of Gazi and Vanga, than at Makongeni. This would probably be due to a closer proximity to the ocean of these two villages as compared to Makongeni. According to the results, there is a distinct knowledge patterns among resource users, both at Gazi Bay and Vanga. Mangrove harvesters had more detailed understanding of mangrove species and their respective uses, while fishermen generally had a better understanding of the services offered by mangroves.

Limited livelihood options reduce response diversity and erodes social-ecological resilience (Biggs et al. 2015). Land is a crucial resource and necessary for livelihoods. Since the colonial government in Kenya established the Land Titles Act of 1908, there has been a disregard of customary land ownership. Powerful people gained control of Kenya's most productive land, creating a continuum of deprivation for indigenous people who lost their valued ancestral land. As few people continued to grab large tracts of land, a majority of the population, including Gazi Bay and Vanga, became landless squatters. In-spite of the Kenyan government resettlement efforts, a large majority of the community, especially in Gazi Bay, continues to fall into the category of landless squatters. Continued disregard of customary land ownership has encouraged rigid institutions on land ownership, unresponsive to local demands for land and according to (Barnes 2013), erodes the social-ecological resilience. Further, Waged labour at KISCOL pays little, often with delayed payment, making it difficult for Gazi Bay villagers to accumulate finances to invest in other types of income generating activities.

5.3 Utilization of mangrove resource

Villagers in Gazi Bay and Vanga highly depend on mangrove resources, with fisheries, firewood, and poles being the main resources collected from the forests. This confirms earlier studies by (Kokwaro, J. 1985; Rönnbäck et al. 2007) on the importance of mangroves for life-support functions to local communities on the Kenyan coast. Mangrove services are generally more valued than good collected from the forest, with protection from storms being highly valued service of the seven services included in this research. This is probably due to recognition of roles mangrove forests have played in reducing impacts from mild cyclones that have previously occurred at Gazi Bay and Vanga. This confirms findings elsewhere, for example by (Adger et al. 2005; Hoang Tri et al. 1998), on the importance of mangrove forests to adjacent coastal communities.

Increase in the human population adjacent to mangroves does not necessarily lead to a decrease in mangrove resource. Considering the population at Kinondo and Vanga Locations has more than doubled since 1979, one would expect a higher local demand for mangrove poles for building houses. Considering that harvesting mangroves for building poles had degraded Gazi Bay mangroves before (see for example Kairo 1995, Dahdouh-Guebas et al., 2000), an increased demand in mangrove poles would therefore lead to significant reduction in mangrove resource. However, the results show that harvesting pressure on mangroves for local building poles has reduced. The villagers consider mud house walls, made of mangrove poles, as a practise of the past and are increasingly using concrete blocks as mangrove substitutes. This contradicts finding by (Rönnbäck et al. 2007) that the villagers in Gazi Bay considered use of concrete blocks for building as prohibitively expensive. Increased use of blocks can be attributed to a discovery of cheaper methods to making blocks from the locally available sand (especially at Vanga). Further, increased household income from higher fish market prices, financial support from chamas, and more income by villagers from making building blocks as a source of income could probably have contributed to an increase in the use of blocks. Therefore, growth in the human population at Gazi Bay and Vanga does not led to an increase in harvesting of mangroves, hence supporting findings at Dar es Salaam by (Athuman 2006).

5.4 Critical disturbances at Gazi Bay and Vanga social-ecological systems

Disturbances, uncertainty of their timing, and their magnitude all present challenges to Gazi Bay and Vanga SESs. Disturbances can occur as relatively discrete event or as gradual pressure on a system and can be part natural variability of a social-ecological system (Alliance 2010). Some of the critical disturbances at Gazi Bay and Vanga include: dams at Gazi Bay and a sea-wall at Vanga, human migration, emergence of chamas, Mikoko Pamoja project, and introduction of M-Pesa.

Dams at Gazi Bay

Construction of Mukurumudzi and Koromojo dams in the basin of River Mukurumudzi has reduced social-ecological resilience at Gazi Bay by reducing ecological diversity and response diversity of livelihood options. Being seasonal, Mukurumudzi River experienced large inter-seasonal variations in flow, in sediment load, and in temperatures, as also reported by (Kitheka 1997). Construction of dam causes changes in river's flow regime downstream. At River Mukurumudzi, this led to less and clear water flowing downstream, reduced the inter-seasonal variation in flow, and got the water temperatures to a near-stable though out the year, as also found on McKenzie River by (Ligon et al. 1995) and in Australia by (Bunn & Arthington 2002). These changes in river flow regime have had unforeseen consequences by loss of fisheries downstream, and degrading pioneer *Sonneratia alba* stand.

River flow regime is an important determinant of the physical habitat in a stream. This determines river's biotic composition, as aquatic species have evolved strategies directly responding to the natural flow regime (Bunn & Arthington 2002). Settling of sediments at the dams on River Mukurumudzi has reduced the amount of transported fluvial sediments downstream. Consequently leading to a negative sediment budget at Gazi Bay coastal system. The reduction in sediment budget, together with erosion of beaches south of the bay reported by (Kairu 1997), has contributed to a northward Longshore drift and formation of a spit at the mouth of River Mukurumudzi (Fig. 14). Further, reductions in the amount of water flowing downstream and inter-seasonal flow variation has reduced the reduced the refraction force of the river water at the river mouth. Consequently, more sea water moves further up the estuary at a higher velocity during high tide. This washes more marine sediment up the estuary (as also shown by changes on shape of the spit over time), shifts the marine and fluvial influenced boundary, and hence changing the estuarine habitat, as also found in Changjiang estuary by (Dai et al. 2010) and on Ebro River estuary by (Ibàñez et al. 1996). The excessive marine sand at the estuary changes the sediment grain size favourable for fish spawning, and buries and fragments habitats and food sources, as also found in Puget Sound by (Czuba et al. 2011). At Gazi Bay, this has led to loss of indian white shrimp, milkfish, grunter fish, and mullet fish. Consequently, loss of source of protein, income and livelihoods, especially by women who traditionally fished for shrimps, hence reducing the social-ecological resilience by loss of response diversity in livelihoods.

Degradation of *S. alba* stand to the south of the bay can also partly be attributed to damming of Mukurumudzi river. Longshore drift is transporting and depositing sand on the stand, as also found by (Kairu 1997). This buries mangrove seedlings and *S. alba* pneumatophores, causing them to be under stress and to eventually die. Due to this stress, the mangroves have become prone to attack by insects, see for example (Jenoh et al. 2016) on wide ranging infestation by metarbelid moth and *Bottegia rubra* beetle at the *S. alba* stand. Having been the most affected forest section by clear felling of mangroves at Gazi Bay in 1970's, the section had not fully recovered following rehabilitation efforts by Kenya Marine and Fisheries Research Institute (KMFRI) before experiencing the impacts of upstream damming. Response diversity is important for social-ecological resilience (Walker et al. 2006). *S. alba* is a pioneer species and therefore a functional group, and its continued death at the section is reducing resilience of Gazi Bay SES. Further, the stand is approaching a threshold and the mangroves might be lost and transition to a less desirable state and become a beach.

Construction of dams in the Mukurumudzi River basin has therefore reduced resilience of the Gazi Bay SES. They have changed the state of the system from a more desirable state to a less desirable state, providing less goods and ecological services.

The Vanga sea-wall

Vanga sea-wall has increased resilience of the villagers to cyclones and storm surges by providing protection from wave action, but eroded the ecological resilience of the mangrove by degrading pioneer *Avicennia marina* stand. Before construction of the Vanga sea-wall, salinity levels in adjacent *A. marina* stand varied widely within a day due to tidal inundation. The nutrient rich, high tide brought marine aquatic conditions, while low tides exposed mud and roots to aridity, heat and desiccation. The mangrove trees in the stand slowed down the tidal water so that sediments settled as the tide come in, and left only the fine particles when the tide ebbed.

According to the results, construction of the sea-wall led to clearing and draining of the *A. marina* stand, an important pioneer species valued by the villagers for fuel and carpentry.

Further, the wall physically restricted flooding regime, and subsequently, flow of sediments and nutrients to the stand. *A. marina* seedlings do not grow on less than 5% supply of seawater (Nguyen et al. 2015). Therefore, absence of regeneration at the stand can be attributed to insufficient supply of seawater, as the wall restricts flooding regime, causing a shortage of sea water at the *A. marina* mangroves.

Human migration

Human migration can enhance or erode resilience depending on how a system respond to the disturbance. According to the results, immigrants enhance resilience when they have different types of knowledge and preferences for resource utilization from the natives. Further, if migration as a disturbance happens in a system with weak informal institutions, the system's resilience is negatively impacted. Human migration enhanced resilience of Gazi Bay SES as it acted as a source of innovation, but it reduced resilience at Vanga SES by eroding the institution of trust.

At Gazi village, movement of fishermen during high fishing season from Zanzibar and Pemba is common. These visiting fishermen are a major source of income to local food selling businesses, mostly owned by women. This movement of fishermen as a livelihood adaptive strategy diversified income for the village women, especially following loss of income in fishing shrimps and crabs. Functional diversity is important for social-ecological resilience (Walker et al. 2006). Settling migrants in Gazi village, especially after the 2007 post-election violence in many parts of the country, enhance diversity in roles within the SES. The migrants have different type of knowledge and, according to the results, acted as visionaries and entrepreneurs. Villagers of native ethnic groups acknowledged their important role in igniting economic progress by spotting business opportunities, and bringing new ideas to the village.

Vanga social system has weaker connectivity and norms as compared to Gazi Bay. For example, villagers stole mature fish and crabs from group projects, and upon receiving money from a donor, members abandoned projects that they would benefit on a long-term. Human migration at Vanga has both positive and negative impacts on the resilience of the system. Migrants with different livelihood preference (like shop keeping) than exploiting coastal resources, enhanced resilience as, just like at Gazi Bay, they enhanced functional diversity of actor groups. However, those involved in fishing and originating from non-fishing coastal communities, like Samburu, are reducing system's resilience. They break traditional norms guiding fishing activities, negatively impacting livelihoods and eroding the institution of trust among the villagers and further, weakening social networks. Yet, trust is important for resilience of a SES (Chapin et al., 2009).

Migrants at Vanga who engage in fishing activities are usually inexperienced in fishing. They therefore engage in highly non-selective and illegal beach seine fishing to maximize they catch, as also found by (espa 2016). However, beach seine fishing at the Kenyan south coast discard a high percentage (6.5%) of daily fish catch in the sea as it is too small and land the highest percentage of juvenile fish (68.4 ± 15.7%) (Mangi & Roberts 2006). Therefore, increasing fishing pressure on juvenile fish contributes to reduction in mature fish caught, an important source of livelihood at Vanga. The native fishermen blame the migrants for reduction in fish catch, due to an increasing number of fishermen and fishing pressure on juvenile fish. On the other hand, the migrants blame the beach management unit, mainly composed of natives, for unfairly targeting them due to their immigration status. This reduces the level of connectivity between different social groups in the system, eroding the trust among villagers, and so reducing the social-ecological resilience.

Emergence of chamas

A chama (and in plural chamas) simply means a group. The term chama is used in Kenya to refer mainly to women's groups, and has its origin in late 1980's where women would meet to discuss their problems and contribute money to give to each in-turn to alleviate their monetary problem. Chamas in Kenya have grown to combine welfare and investment, depending on the income by the members. They have grown from being local-informal practices, to empower women at a global arena, also found in England by (Kitetu 2013).

At Gazi Bay and Vanga, friends and neighbours form chamas and they are geared towards members' welfare. Members contribute money to a chama, which is then given to one of the members with each turn, rotating until all the members have received the money. The money received goes towards personal activities like paying school fees, and building a house. Therefore, chamas help tackling the problem of income volatility, empower women. Further, through regular meeting, chamas act as act as social networking platform where member through frequent interaction maintain closer social ties. This result to a better connectivity, increased information sharing and build trust, and according to (Biggs et al. 2015), enhances resilience.

Mikoko Pamoja project

According to the results, Mikoko Pamoja has enhanced social networks within Gazi Bay but reduced the ecological resilience of protected mangroves. The project invests funds from the sale of carbon to community projects such drilling boreholes for safer drinking water to the villagers, and also providing books to local schools. From the sale of carbon credits for 2015-2016 reporting year, the project bought books for Gazi primary school worth KSh 150000 and purchased a 15,000 litres water tank to provide safe drinking water for Makongeni village. These direct benefits of mangrove protection, and an acknowledged transparency in project operations by the villagers, have given the villagers a stronger sense of mangrove ownership and motivated them to collectively protect ‘their’ forest. Consequently, strengthening social network through information sharing and collaborative mangrove monitoring activities. Further, the project strengthens trust between stakeholders through annual community benefit consultation via barazas (open village meetings).

However, protection of the mangroves by Mikoko Pamoja project is reducing their ecological resilience, especially at the *R. mucronata* plantation. Low regeneration potential in the stand, and observed self-thinning are signs of locked-up resources in a rigid and an even aged, monospecific stand. Small disturbances in this stand might therefore have huge consequences, and the stand might not to cope with disturbances like harvesting without protection.

Introduction of M-Pesa

M-Pesa is helping enhance resilience at Gazi Bay and Vanga by providing response diversity and enhancing connectivity. M-Pesa is a Kenyan based mobile phone financial service. The service has grown rapidly following its introduction in March 2007 by Safaricom, Kenya's largest mobile operator. The application facilitates a variety of financial services through a mobile phone. By use of a mobile phone, a user can open a bank account, make deposits and withdrawals, check their account balance, access instant micro credits, pay bills, buy mobile phone credit, and transfer money to other users. The growth of the service user base has been enormous, having over 40,000 agents and about 25 million active customers countrywide (Safaricom 2016). By saving money from their little income, the villagers at Gazi Bay and Vanga are able to accumulate financial capital, attain positive livelihood outcomes and hence increase their resilience to shocks.

Sending of money by migrants in urban areas and in foreign countries to their relatives in the village is a common in Kenya, as also found in Nakuru town by (Owuor 2004). At Gazi Bay and

Vanga, M-Pesa provides a platform for migrants to instantly send money home to address urgent shocks such as floods or illness. This act of sending money home has a practical and symbolic function, as also found in Nairobi by (Morawczynski 2009). By sending money back home, migrants send an important message that they have not forgotten their obligations to the village. Increased connectivity enhances social-ecological resilience as it safeguard a system against a disturbance either by facilitating recovery or by preventing a disturbance from spreading (Biggs et al. 2015). Therefore, M-Pesa enhances SES by helping villagers at Gazi Bay and Vanga maintain social networks with their family members living far from the villages.

5.5 Interaction of the systems with larger and smaller scale systems

Regional insecurity

Regional insecurity cause loss of income from tourism and hence reduced functional redundancy. Regional insecurity is mainly due to the Somalia based Al-Shabaab militia group, that has kidnapped tourists and carried attacks in Kenya before. This led to issuance of travel advisories by UK, US, France and Austria - the Kenya's top tourism markets. In consequence, the tourism industry was negatively affected, as also reported by (KNBS 2016). Kenyan's earnings from the tourism sector dropped from KSh 97.9 billion to KSh 84.6 billion between 2011 and 2015 (Fig. 15). This had direct impacts at Gazi Bay as opposed to Vanga where the village has potentially attractive sites such, as an old British customs house from late 19th Century, but remains untouched by tourism, as also reported by (espa 2016). At Gazi Bay, regional insecurity has caused loss of income as the number of tourists visiting Gazi Women Boardwalk from hotels in neighbouring towns has significantly reduced.

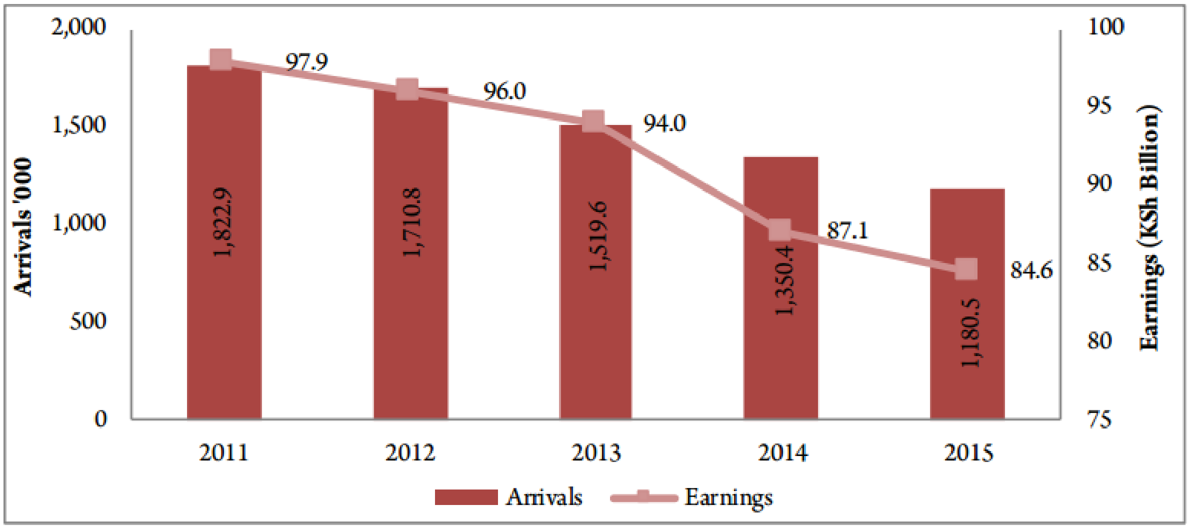

Figure 15.International Visitor Arrivals and Tourism Earnings in Kenya between 2011 and 2015. Adopted from KNBS (2016).

Locally made concrete blocks

Use of blocks for house construction was traditionally uncommon at Gazi Bay and Vanga. This is because villager considered it very expensive, and only the wealthy who would use coral blocks for construction. Even for the wealthy at Vanga, using coral blocks for house construction is more expensive than at Gazi Bay, as the village lack corals from the Pleistocene period (Oosterom 1988), and therefore blocks have to be transported from the mining site far from the village. At Vanga, frequent flooding of River Umba washes away mud-walled houses and leads to loss of property at Vanga. This has acted as a window of innovation for, strong, and yet cheaper building blocks made from mixing of locally dug sand with cement. Further, increased household income from fishing by men (as fishermen sold fish at higher prices), and financial support from chamas (mainly by women) are helping the villagers meet the cost of cement. This in-return reduced demand for mangrove poles and consequently, the harvesting pressure on mangrove forests due to local use. Further at Vanga, brick walled houses are stronger than mud-walled ones and are helping villagers enhance resilience against floods.

5.6 Historical timeline of Gazi Bay and Vanga SESs

Gazi and Vanga social-ecological systems have undergone changes over time. A historical profile of the systems showing patterns of past disturbances and changes in mangrove management regimes between 1891 and 2017 reveals changes in their resilience over time (Fig. 16).

Mangroves swamps managed separately from terrestrial forest (1891 – 1931). The colonial government in Kenya published the first documented forest legislation in 1891 to protect the mangrove swamps of Vanga Bay, as also reported by (Kojwang 1996). The Ukambani Woods and Forest Regulation followed in 1897 and extended mangrove protection throughout the country's coastline. During this period, the colonial government managed mangroves separate from terrestrial forests. Mangroves were perceived as inexhaustible and their poles ('boriti') formed an important part of the trade between Kenya and the Middle East.

Gazettement of mangroves as forest reserves (1932 – 1941). Following the giving of concession rights to mangrove harvesting in Tanzania, more Arab and Indian buyers to turn to a cheaper source in Kenya (Sunseri 2014). In Kenya, the colonial government valued mangroves for their revenue generation. To regulate their harvesting, the colonial government gazette Kenyan mangroves as forest reserves in 1932 and under management by the Forestry Department. County officers would supervise licensing, offtake and conservation. Restrictions, a dampening feedback to the rise in demand for mangroves, were not properly implemented and mangroves were subsequently heavily harvested for trade.

Centralising forest management (1942 – 1956). The Forest Act of 1942, chapter 385 of the law of Kenya provided the legal framework for forest management (Ongugo et al. 2014). The purpose of the Act was reserving, protecting, centralizing, and controlling of forests (including mangroves) within the goals of the colonial government. The Act authorized the director of forest to issue permits, collect loyalties from permitted users, and accept compensation for forest offences. On mangrove forests, the conservator of forest gave temporary concession rights to harvester upon payment of royalties. At Gazi Bay and Vanga, the harvesters also got right to harvester mangrove trees capable of producing tannin bark, and had to cut the barked trees for fuel. Concession rights by the colonial government severely curtailed the traditional rights of the local chiefs and the villagers to utilize mangroves. Between 1947 and 1956, mangrove trade reached its peak. Harvester in Kenya cut large amounts of mangrove poles for export in the belief that with the discovery of oil in the Persian Gulf, the demand for mangrove poles there would soon drop (Idha 1998).

In 1951, the Forest Department introduced a mangrove working plan following noted mangrove degradation in mid to late 1940’s. The aims of the plan was to manage mangrove forests to ensure: the mangrove trade with Arabian and Persian Gulf countries would be unaffected, continued supply of firewood to local industries, sustained supply of domestic building materials to urban areas along the coast and poles for export (Kairo & Dahdouh-Guebas 2004). The plan introduced a 20 year harvesting cycle on mangroves, starting at Lamu. At Gazi Bay, harvesting did not start until 1964.

First formal forest policy (1957 – 1994). The white paper number 85 of 1975 introduced the first formal forest policy in Kenya (Kojwang 1996). Restated in 1968, the policy denied communities or private groups’ rights to own or manage gazetted forest resource, including mangroves. The following were the primary purposes of the policy: for forest reservation for water catchment protection, provision of forest products, protection of gazette forests from destruction, promotion of principles of sustainable yield, and development of a vibrant forest products industry (GoK 1968). However, the strength of the Forest Department as an institution to manage forest resources in Kenya steadily declined from mid-1970's (Kojwang 1996). This coincided with a period of heavy mangrove clearing at Gazi Bay to provide industrial fuel and building poles in 1970's.

Widespread mangrove degradation, including at Gazi Bay and Vanga, led to a ban on their use for charcoal production in 1975, and a ban on export of mangrove poles in 1982. In late 1980's, international organisations, donor agencies, non-governmental organisations (NGO's) and community groups came up to help deal with the destruction problems in forests, including in mangroves. These organisations, through their activities, have made it very difficult for policy makers to ignore forming new policies to address and promote forestry for rural development and environmental conservation.

Forest master plan (1995 – 2004). With help of finance from donors, the Ministry of Natural Resources embarked in preparing a forest master plan and completed it in 1995. The policy emphasised a need for active participation of all stakeholders in forest management and conservation. The overall objectives of the policy were to sustainably and competitively meet the needs of the present and future Kenyan generations in forest products and services. Further, the policy aimed at enhancing contribution of the forestry sector to national and rural economic development through more participation by communities and better sharing of benefits from forestry.

The objectives of the plan on mangrove forests were: conservation of mangrove areas to serve protective functions and maintain habitats, recognition of the needs of the communities living by the forests and depending on mangrove resources, and improving capabilities of the Forest department for mangrove conservation (GoK 1994). Contrary to the provisions by the policy, the government imposed a ban on local mangrove utilization in 1997. However, the government lifted the ban in 2002 following protests by local communities and lobbying by civil society organisations (Nicoll 2003).

Participatory forest management (2005 – present). The Forest Act of 2005 introduced participatory forest management and set up Kenya Forest Service (KFS) to replace the Forest Department created by the colonial government. The Act was a move by the government to devolve power of forest management and decision making from the government to the local communities to promote sustainable forest management. For communities to participate in state-owned forest (including mangroves), they need to form a Community Forest Association, come up with a Participatory Forest Management Plan for the area, and then sign a Forest Management Agreement (FMA) with the Kenya Forest Service. Gogoni-Gazi Community Forest Association already has an agreement with KFS. Involving a diversity of stakeholders in the management of a resource can help build resilience by improving legitimacy, expanding the depth and diversity of knowledge, and helping detect and interpret perturbations (Biggs et al. 2015). According to the results from Gazi Bay, devolution of mangrove management has enhanced resilience as it has resulted in a better co-ordination and collaboration between the stakeholders. The villagers and KFS closely shared information on mangrove utilization and collaborated in the forest protection, while KMFRI offered technical support based on scientific research. On the other hand, Vanga-Jimbo-Kiwegu Community Forest Association was in the process of preparing a management plan during the time of field work.

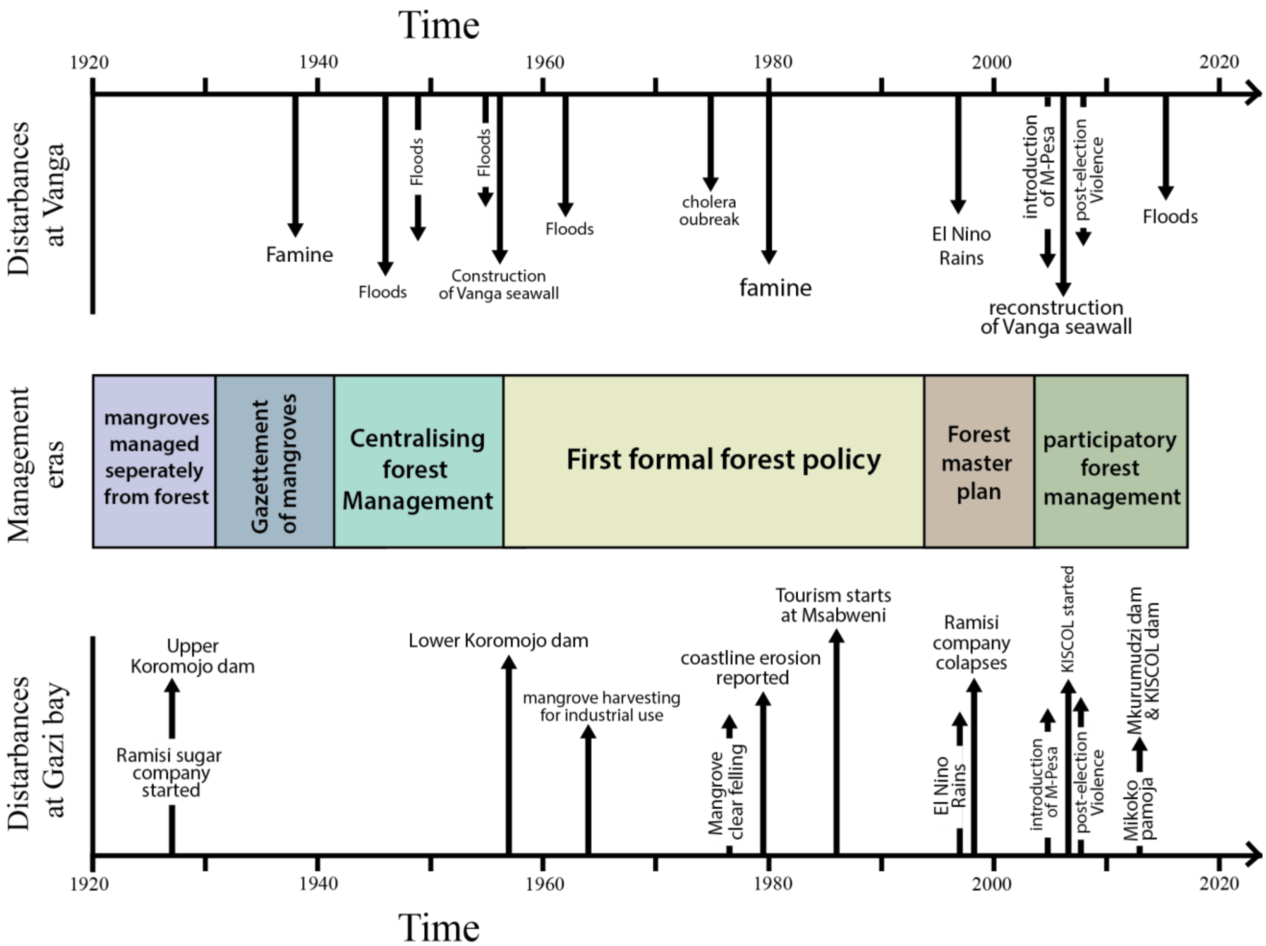

Figure 16. A timeline of key disturbances at Gazi Bay and Vanga social-ecological systems and their management regimes between 1920 and 2017.

5.7 The adaptive cycle

Resilience of Gazi Bay and Vanga SESs is examined using the adaptive cycle (Fig. 2). The cycle consists of the four phases of growth or exploitation (r), conservation (K), release or collapse (Ω) and the reorganization phase (α) (Gunderson and Holling, 2002). The adaptive cycle can help in understanding how these systems change over time, and their position in a cycle can inform timing of management interventions (Berkes et al. 2003).

Mangrove forests in Kenya, including Gazi Bay and Vanga, were for long perceived as an inexhaustible resource. Initially, mangrove management by the Forest Department was envisioned to serve economic development, as mangrove poles formed an important part of the trade between Kenya and the Middle East (Kokwaro, J. 1985). Following World War 1, the British colonial government in Tanzania sought concessionaires to exploit mangroves at an annual royalty. Consequently, concessionaires in Tanzania raised the price of poles to meet the increased cost in acquiring concession rights, a move that prompted the Arab and Indian buyers to turn to a cheaper source in Kenya (Sunseri 2014). The colonial government in Kenya responded by gazetting mangroves and offering licenses to harvest mangrove forests, already mature and in conservation [K] stage. In late 1940's and early-1950's, the demand for mangrove poles in Kenya reached its peak following discovery of oil in the Persian Gulf (Idha 1998). This led to huge harvesting in the country, including at Vanga, for trade. This led Vanga mangrove forest into a collapse [Ω] phase. On the other hand, at Gazi Bay, mangrove harvesting started in 1964, following introduction of mangrove harvesting cycles by the Forest Department (Dahdouh-Guebas et al. 2004). In mid mid-1970's, the strength of the Forest Department to manage forest resources in Kenya dropped (FAO 1996). This drop was followed by clear felling of Gazi Bay mangroves in late-1970's to provide fuel for limestone and brick industries. This subsequently degraded the mangroves, left some areas along Gazi Bay coastline completely denuded, and entered the system into a release [Ω] phase. Widespread mangrove degradation, including at Gazi Bay and Vanga, led to the Kenyan government banning their trade and use in charcoal making.

In late 1980's, international organisations, donor agencies, non-governmental organisations emerged to help the Kenyan government deal with the problem of forest degradation. The organisations formed an avenue through which rural communities In Kenya, including Gazi Bay and Vanga, influenced the formation of forest policies. In 1991, KMFRI with the help of funding from the government of Belgium, conducted a mangrove planting project to reverse their loss at

Gazi Bay (Kairo 1995 as cited in Kairo et al. 2009). With a further help of a donor fund, the Ministry of Natural Resources prepared a forest management master plan that it completed in 1995. The policy increased the capacity of the Forest Department to manage mangrove forests, including mangrove forests. Events during this period entered Gazi Bay and Vanga systems into a reorganization [α] phase, ready to progress into a new adaptive cycle. Currently, both Gazi and Vanga systems are in exploitation [r] phase, characterised by high stem density and low basal area, high regeneration potential, and moderate harvesting intensity. At Gazi Bay though, the *S. alba* sub-system is trapped in a collapse phase, with a high possibility shifting to a less desirable state of a bare white sand beach. The sub-system has been hit by impacts following river damming, before fully recovering following a critical clear-felling in late-1970's.

Altogether, Vanga is more social-ecologically resilient than Gazi Bay. Gazi Bay social-ecological resilience has been negatively impacted by mangrove clear-felling, construction of dams in the Mukurumudzi River basin, regional insecurity, and lack of land ownership by the villagers. Impacts of dam construction include losses in livelihood strategies, food sources, and further degradation of *S. alba* stand; a key ecological functional group. Further, regional insecurity has led to losses in household income and reduced functional redundancy. On the other hand, Vanga SES resilience is negatively affected by construction of a sea-wall, flooding of River Umba, and human migration. Construction of the sea-wall has led to degradation of *A. marina* stand, but increased resilience of the villagers against cyclones and storm surges. Further, invention of use of locally available sand to make construction blocks is helping the villagers minimize loss of property during floods.

Conclusion and recommendations

Mangroves in Kenya have been used for many centuries. As early as 200 BC, they formed an important part of trade between East Africa, the Gulf States and Asia (Ferguson, 1993). The earliest documented mangrove legislation in Kenya was published by the colonial government in 1891 to protect mangroves of Vanga. This legislation extended to protect mangroves of the entire Kenyan coastline in 1897 (Kojwang 1996). However, even with the established regulations and conservation efforts, Gazi Bay and Vanga mangroves have been greatly lost. Resilience in mangrove social-ecological systems (SESs) is the ability to persist with change and uncertainty and largely depend on slow changing variables in a system. Disturbances and uncertainty and their magnitude and timing present challenges to management of Gazi Bay and Vanga mangrove SES. When a disturbance occurs before a mangrove system has had sufficient time to recover from previous disturbance, the system is faced with a major shock and might not be able to survive without structural changes. As a disturbance, human migration enhances resilience in mangroves SES when the migrants have different types of knowledge and preferences for resource utilization. Involving mangrove users in mangrove management strengthens trust between stakeholders and improve the legitimacy of a management regime. However, conservation of mangroves for carbon offsetting purposes reduces the ecological resilience of mangroves through prohibited utilization. Further, increase in human population does not necessarily lead to a reduction of mangrove resource.

Gazi Bay SES illustrates the interaction effect that a disturbance can have on a system, when occurring before the system fully recover from a previous disturbance. The forest experienced degradation in 1970’s following clear cutting for industrial fuel and building poles. Before the system could recover, dams were constructed on River Mukurumudzi that drains at the forest.

This has changed the river's flow regime downstream. The amount of water flowing downstream, transported fluvial sediments, and the inter-seasonal variation in flow has all reduced. These changes have impacted both social and ecological systems at Gazi Bay. Shifts in the marine and fluvial influenced boundary has changed the estuarine habitat, leading to loss of fisheries (for example indian white shrimp, milkfish, grunter fish, and mullet fish) and consequently, livelihoods. On the other hand, changes in sediment budget have led to deposition of sand on *Sonneratia abla* stand, covering their pneumatophores and causing the mangroves to die. Consequently, the stand is approaching threshold and might transition to a less desirable state and become a beach.

Human migration enhance resilience when migrants have different types of knowledge and preferences for resource utilization from the natives. Migrants at Gazi Bay and Vanga, mainly those not involved in utilizing coastal resources, enhance functional roles in the system. They bring new ideas to the villages, spot business opportunities and therefore act as visionaries and entrepreneurs. However, human migration can degrade resilience when it occurs in a system where trust between actors is already weak. At Vanga, petty theft cases of fish and crabs by villagers from group projects illustrate weak social networks and trust between villagers. When migration as a disturbance happens on such a system with undesirable social characteristics, norms guiding resource utilization can easily be ignored by the migrants, further eroding trust and reducing resilience.

Involvement of mangrove users in mangrove management encourages inclusiveness and enhance social-ecological resilience. At Gazi Bay, participation of villagers in mangrove management through Gogoni-Gazi Community Forest Association strengthen trust between stakeholders and improve the legitimacy of the management regime. Further, it improves collaboration between

Kenya Forests Services and Kenya Marine and Fisheries Research Institute through joint forest monitoring activities. However, carbon trading projects, like Mikoko Pamoja project, in mangrove forest reduce forest ecological resilience. This is because a key goal for such initiatives is to maximize carbon sequestration, often prohibiting utilization of mangrove forest. Such management interventions are rigid and are based on systems near equilibrium views and will probably create conditions for large-scale crisis later. They encourage an accumulation and locking up of resources in a system, and consequently, reducing ecological resilience in mangroves. Harvesting activities in mangrove forest, when moderate, enhance resilience of the forest. Such activities allow disturbances to enter into the forest at smaller scales instead of accumulating to larger scales, thereby avoiding large-scale collapse.

Increase in human population adjacent to a mangrove forest does not necessarily lead to a decrease in mangrove resource. When the population increases, the level of household income increases, people have, better social networks and financial support, and there exists a locally available substitute to mangroves use, then the harvesting pressure on mangrove forest reduces. Human population at Gazi Bay and Vanga has been increasing, but the harvesting of mangrove by the villagers for local use, especially for building, has reduced. Higher income from fishing, the main livelihood activity at the two sites, and increased social connectivity and financial support through chamas, and making of blocks as a livelihood options have all contributed to increased use of blocks as mangrove substitutes in building and hence reduced harvesting pressure in mangrove forest. In particular, pressure on Vanga mangroves is due to harvesting for trade by traders living far away from the village.

This study recommends that in order to achieve a resilient and a desirable future for Gazi Bay and Vanga mangrove SESs, it is important to integrate collaborative learning where research finding by scientists are communicated to forest management, and mangrove resource users. This will help make the values of ecosystem services offered by mangroves more explicit, and in adapting methods of harvesting mangroves that do not hinder forest regeneration. Additionally, scientists and mangrove forests managers need to recognise the importance of local indigenous knowledge of mangrove resource users in detecting and interpreting disturbances.

Further, the government should accelerate the process of relocating the squatters and commit to making substantial efforts to increase people's income-generating opportunities that have real economic returns to reduce poverty. At Vanga where there exist potential for diversified income from tourism, the government and other responsible stakeholders should make efforts to realize such potential for the benefit of the local community.

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Appendix

Bio-physical data form

Observer………………………………………………………….   Date ……………………2017

Name of forest ………………………..…………………….. No. of stumps observed……………………….

Transect number……………………… study plot no……………………..Forest type………………………..

Eastings…………………………..…. Southings………………….……………… Forest cover………………………

<u>Mangrove species and regeneration.</u>   Remarks……………………………….…………………….

10*10 plots					Regeneration (less than 2.5 cm of DBH)			
Tree no.	Form	Species code	DBH (cm)	Height (m)	Species code	<0.4 RC1	0.4-1.5 RC2	1.5-3.0 RC3

Interview guide

Site………………………… informant no………………………. date………..2017

Mangrove resource

What is the condition of the mangroves now compared to 10 years ago? How and what has caused the change?

How is the demand of mangroves now compared to 10 years ago? If the demand has changed, how and what has caused it?

What are the past to present mangrove management interventions chronologically?

How quantity and quality of fish do caught compare now and 10 years ago? Are they related to state of mangroves? How?

What do you think are the current threats to the mangroves?

How is the mangroves today compared to before Mikoko pamoja project started?

Social- economic

What goods and services do you value from the mangroves in their order of importance to you?

Has your access and utilization of mangrove changed? How and why?

Do the community participate in mangrove management? If so, how?

What is the role of CFA in mangrove management?

Do you think the current use of mangrove is sustainable both economically and ecologically?

Is the community involved in decision making during designing and implementation of coastal related projects? What is the criteria of selecting representatives? Are local representative recommendations considered in the process? Do you think the participation is sufficient?

How is the exchange of information between the community and resource management regarding resource state? How often does this happen?

Is there exchange of local knowledge and scientific knowledge between the local community and scientific community?

Who do you think should be responsible for management of mangrove resources and why?

How strong the traditional institutions are now compared to 10 years ago? what has caused the change? Are there any risks following the change?

How the security situation currently? Has this changed overtime? When did it start changing and what caused it?

What is the community land tenure system? Are there any conflicts related to land within the community?

What is the ethnic composition of the community? How well is the cohesion between the different ethnic groups? What do you think are the benefits of the ethnic diversity?

How many religions are within the community? How is the tolerance between members of different religions? Has this changed over time? What has caused the changes?

Is there a religious or tribal conflict within the region? When were they, how long did they last?

How do the general and by-elections affect the peace and cohesion between different ethnic groups within the community? How do you think the upcoming general elections will affect the community?

Are there seasonal outbreak of diseases? Which are they and when? Has their prevalence changed over the years? Why?

What are the main social and economic challenges do the community face?

What restrictions on access and utilization of mangroves does Mikoko pamoja have? What alternatives does the project offer following restriction? How preferable are the alternatives?

How is the sharing of benefits from the sale of carbon from Mikoko pamoja? Is the process transparent?

What impacts do you think Mikoko pamoja has had on the community?

What are your economic activities? Has income from any of the activities changed? Why and how do you adjust to the changes?

Do you have any access to credit services or loans from financial institutions like banks? If no, why and how do you think this affects you and the community? If yes, how important do you think it is?

Do you belong to any social network? What activities do the network do? How does the network benefit you?

How profitable is tourism business now compared to 5 years ago? Why do you think it has been changing?

What are your sources of fuel and building materials? Has their costs changed? If so, how are they changing and why?

Has the price of food been changing? If yes, how has the change been compared to income?

What are the impacts of Base titanium and Kiscol sugar to village and the environment?

What it the criteria for awarding mangrove harvesting licenses?

<u>Hazards</u>

What natural hazards has the community experienced or is at risk of experiencing? How was it handled?

Is there hazard warning system? How are the warnings communicated? Are they in goodtime?

The sea-wall in Vanga, what do you think are its impacts (positive and negative) to the community and the ecosystem? What could have been its alternative?

Was there an EIA carried out for the project? If so, has the recommendation to reduce/avoid environmental impact been implemented? How successful was the implementation?

Why did people vacate kijiji cha Ngoa? When did they vacate and how long had they been living there before vacating?

Household survey form

Site……………………………..……. Observer…………….……………

date…………………

Sex?

( ) Male ( ) Female

Age?

( ) Below 20 ( ) 20-30 ( ) 31-40 ( ) 41-50 ( ) 51-60 ( ) Above 61

Highest level of education achieved?

( ) None ( ) Primary ( ) Secondary ( ) Tertiary ( ) Adult literacy

( ) Others, specify……………..

Household occupation?

( ) Fishing ( ) Small holder farmer ( ) Waged labour ( ) Makuti crafting

( ) Shop keeping ( ) Others (specify) …………….

Were you born in your locality?

( ) Yes ( ) No

If no, how long did you come here?

( ) Less than 1 year ago ( ) 1-3 years ago ( ) 4-7years ago ( ) 5-10 years ago

( ) more than 10 years ago.

Why did you relocate/move here?

( ) For employment ( ) Seeking a settlement ( ) To fish

( ) Others (specify)…………………………

Do you own land?

( ) Yes ( ) No

If you own land, do you have title a deed?

( ) Yes ( ) No

What management activities are you doing in mangrove forests?

( ) Planting ( ) Utilizing (harvesting) ( ) Protection

( ) Others, (specify) ……..…………..…

Do you think there is more mangroves now that 15 years ago?

( ) Yes ( ) No

What products do you get from mangroves with their level of importance? [(-1) not important, (0) important, (1) very important].

Firewood (-1) (0) (1) Charcoal (-1) (0) (1) Timber (-1) (0) (1)

Poles, beams, paneling (-1) (0) (1) Boat building (-1) (0) (1) Fish (-1) (0) (1)

Shrimps (-1) (0) (1) Honey (-1) (0) (1) Molluscs (-1) (0) (1)

Birds and eggs (-1) (0) (1)

Others, (specify) (-1) (0) (1) ………………………………………………

What services do you get from mangroves with their level of importance? [(-1) not important, (0) important, (1) very important].

Storm and flood protection (-1) (0) (1) Erosion control (-1) (0) (1) Water quality maintenance (-1) (0) (1) Climate regulation (-1) (0) (1) Habitat and nursery grounds (-1) (0) (1) Cultural and religious values (-1) (0) (1)

Recreation and tourism (-1) (0) (1) Information function (-1) (0) (1) Others, (specify) (-1) (0) (1)……………………………………….

What are the current threats to mangroves?

( ) Illegal harvesting ( ) sedimentation ( ) Climate change ( ) sea level rise ( ) Diseases ( )Other, Specify……………………….

Level of household income in Kenyan shillings?

( ) less than 250 ( ) 250 – 449 ( ) 500 – 749 ( ) 750 – 999 ( ) 1000 – 1499 ( ) 1500 – 1999 ( ) 2000 and above

How is income from tourism here now compared to 5 years ago?

( ) Better ( )Has not changed ( ) Has dropped ( ) Do not know

Natural hazards that the community has experienced?

( ) Floods ( ) Hurricanes ( ) Storms ( ) None ( ) Do not know