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Linking Coastal and Marine Resources Endowments and Climate Change Resilience of Tanzania Coastal Communities

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Abstract
This paper presents findings on the links between coastal/marine resources endowment and climate change resilience to coastal communities in Mchungu and Kivinja' A' village on the coastal zone of Rufiji District in Tanzania. The study focused on exploring the existing coastal resources and their support to communities' livelihood, climatic threats that are experienced, and the role of coastal resources in enhancing communities' resilience. It further sought to establish other enabling factors for climate change adaptation (e.g., gender, education, governance, by-laws, and membership in social networks). The study used focus group discussions, key informant interviews, and household surveys in data collection. Findings show that Mchungu village is endowed with fish, mangrove, natural canal, and floodplains as their major coastal resources, while Kivinja' A' is rich in salt and coconut production. Communities in both villages exploit these coastal resources for their livelihood activities such as fishing, agriculture, and business. The study further found that coastal communities are already experiencing the effects of climate change through temperature rise, flooding, drought, sea-level rise, and storm surges. These affect household food security in terms of fish catch and crop production. The study revealed that coastal and marine resources were important for increasing community resilience ($P \leq 0.05$) to climate change impacts in the studied villages. However, household resilience to climate change impacts was also influenced by gender, by-laws, education, and membership in social networks.

Keywords Climate change · Resilience · Coastal resources · Marine resources · Coastal communities

Introduction

It is widely acknowledged that coastal and marine resources are experiencing significant changes due to natural processes and anthropogenic induced causes (Bindoff et al. 2007; Nicholls et al. 2007, Doney et al. 2012; Barbier 2015; Doney et al. 2012). Results of these changes are observed through various forms. All these changes have been observed to affect the oceanic biogeochemistry[1], modify and intensify weather-induced hazards – such as storm and wind surges, flooding and erosion – in the coastal zones, and thus threatening the ecosystems and populations depending on them (Klein et al. 2002; Frost et al. 2012; Savo et al. 2017; Freduah et al. 2017; Weatherdon et al. 2016).

Global ocean temperature has risen by 0.10 °C from the surface to a depth of 700 m from 1961 to 2003. The increase has been observed even on the global ocean heat content from the surface to a depth of 3000 m (Bindoff et al. 2007; Church et al. 2013). Such an increase and the resulting thermal expansion have been linked with the rise of global mean sea level, that is observed to rise at an estimated projection of 9 to 88 cm between 1990 and 2100, with a central value of 48 cm (Church et al., 2001). Likewise, large-scale, coherent trends of salinity have been observed for the period 1995 to 1998, with pronounced increasing salinities prevailing over most of the Atlantic and Indian Oceans (Bindoff et al. 2007; Nerem et al. 2018).

Increased human's utilization of coastal and marine resources during the 20th century has induced changes within the coastal and marine ecosystems (Nicholls et al.

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[1] For instance, it is observed that the total inorganic carbon content of the oceans has increased due to a decrease in the depth at which calcium carbonate dissolves; the fraction of emitted carbon dioxide that was taken up by the oceans has decreased; and oxygen concentrations have decreased due to reduced rates of water renewal in the thermocline in most ocean basins from the early 1970s to the late 1990s (Bindoff et al. 2007).

2007; Abrantes et al. 2015; Brown et al. 2018; Seitz et al. 2014). There is a widespread conversion of natural coastal landscapes to agriculture, aquaculture, silviculture, as well as industrial, commercial, and residential uses (Nicholls et al. 2007; Li et al. 2018). These changes affect the drainage of coastal wetlands, accelerate deforestation and reclamation, discharge of sewage, fertilizers and contaminant into the oceans; hardening of the coast changed oceanic circulation patterns, and altered freshwater, sediment and nutrient delivery; and destruction of coral reefs by blast fishing (Rabbani et al. 2010).

Such anthropogenic induced changes compounded by climatic-induced changes are expected to expose the coastal populations and ecosystems into several dangers (Cinner et al. 2018; Licuanan et al. 2015). Rising sea levels could lead to saltwater intrusion into freshwater; warmer water temperature could degrade coral reef and threaten artisanal and commercial fisheries, and could severely damage infrastructures and facilities found in the coastal zones through associated storm surges (Rabbani et al. 2010). Such circumstances call for adaptation initiatives in coastal zones of developing nations that are expected to be severely affected due to low adaptive capacity (Nicholls et al. 2007; Lohmann 2016; Cinner et al. 2018).

Tanzania is highly endowed with the biological diversity found in the coastal and marine ecosystems. It is endowed with: coastal forests – with endemic tree species – covering about 70,000 hectares, extending from the east of Islands of Pemba, Unguja, and Mafia to the base of the Eastern Arc Mountains (Yanda 2013). The coastal area is also endowed with extensive coral reefs coverage of about 3580 km^2 (*ibid*) supporting artisanal fisheries. These coral reefs serve as habitat, nursery, feeding and spawning grounds for many fish species – and coastal tourism; seagrass beds, that are found in the sheltered areas of the coast around Kilwa, Rufiji, Ruvu and Moa bay (Francis and Brycesson 2001; Yanda 2013; Katikiro 2014).

Other coastal resources include beaches, which provide key ecological and economic services such as breeding, nesting, and feeding sites from marine and bird species. Beaches also act as buffer zone against wave action, and as sites for recreational and touristic activities; and fishery resources[2] found along banks and coral reefs (Dallu 2004; Wilkinson 2008). Unfortunately, most of these resources and their diversities are under immense degradation pressures as a result of rapidly growing human activities along the coastal zones and marine environments (Bryceson 1978; Ngusaru 2000; Julius Francis et al. 2002; Dallu 2004; Wagner 2004; Ahrends 2005; Wilkinson 2008; Rocliffe and Udelhoven 2010, Burgess et al. 2017; Staehr et al. 2018).

Some of the human-induced activities threatening the sustainability of coastal and marine resources include illegal and destructive fishing practices[3], live coral and sand mining, intensive trampling on seagrasses, and municipal wastewater. Other threats include clearing of mangrove and other coastal forests for commercial and domestic purposes – such as for aquaculture ponds, timber, industrial development, fuelwood, and construction materials (Francis and Brycesson 2001; Wagner 2004; Ahrends 2005; Ligate et al. 2017). Despite efforts to manage and conserve mangroves forests, the interventions have not been able to reverse the situation (Katikiro et al. 2017; Burgess et al. 2017)

Additionally, previous studies (e.g., Kebede et al. 2010) indicate that such anthropogenic pressures upon the ecosystems are likely to be exacerbated by climatic-induced pressures. Tanzania, one of the countries found in the Indian Ocean region, appears to be highly vulnerable to climatic-induced changes, especially rising sea level and increasing ocean temperatures (Kebede et al. 2010; Rabbani et al. 2010). However, what are not well articulated in the literature are the extent to which coastal natural resources endowments will be affected, and the ultimate consequences on the resilience of coastal communities to climate change impact, particularly on the East African coastal zone.

It is against this background that this study focused on analyzing the inter-linkages between natural resources endowments and climate change resilience of communities along the coastal region of Tanzania. It analyzed the relationship between coastal and marine resources endowments and their contribution to coastal livelihoods. The study examined the role of coastal and marine resources in climate change adaptation of coastal communities and how the interrelationships are influenced by gender, education, by-laws, and membership in social networks.

Conceptual Framework

Human-induced environmental changes coupled with climate change impacts are compromising the integrity of coastal resources, particularly coral reefs and mangroves ecosystems (Kennedy et al. 2002; Obura and Grimsditch 2009; Ellison and Zouh 2012; Chou 2014). These environmental changes put the resilience of about 500 million people worldwide, who depend on them to the test (Hughes et al. 2005; Wilkinson 2008; Cinner et al. 2009; Monirul Alam et al. 2017, Alam et al. 2018). Such impacts have

[2] There are about 8000 species of invertebrates, 1000 species of fish, 5 species of marine turtles and many seabirds (Francis and Brycesson, 2001).

[3] Such as fishing through the use of poison, dynamite, beach seine, sticks, spears and dragged fishing nets (Francis and Brycesson, 2001).

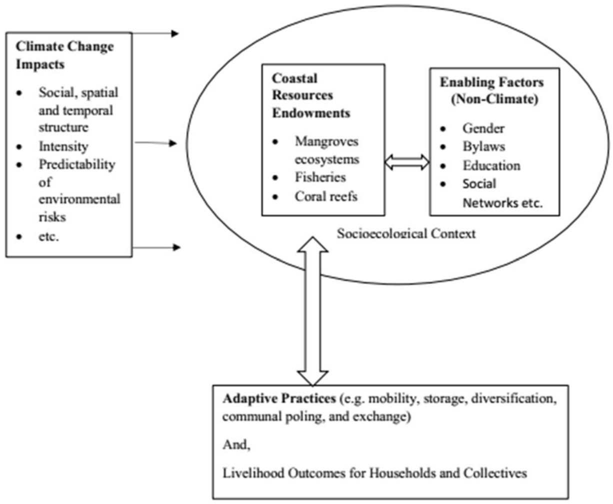


Fig. 1 Coastal resources endowments and climate change adaptation. Source: Adopted and modified from Agrawal (2008)

negative implications on community livelihoods that depend on those resources, particularly fisheries[4]. On the other hand, literature shows that non-climate factors such as socio-cultural, poverty vs. wellbeing, location, age, gender, education political, etc. have the potential to aggravate or relieve a livelihood from climate stressors (Nicholls et al. 2008; Alam et al. 2018; Fischer 2018)

The conceptual framework used for this study was adopted and modified from Agrawal's, "*Adaptation, Institutions, and Livelihoods*." Agrawal's conceptual framework looks at the role of institutions in adapting to climate risks and hazards. However, based on the linkages that exist between the coastal resources and coastal communities, the framework **"***Role of Coastal Resources Endowments and Climate Change Adaptation***"** (Fig. 1) examines the coastal resources endowments and their role in building the resilience of coastal communities to climate changes impacts. Building resilience to climate change impacts depends on enabling environments, which are mainly the non-climate factors. The framework consists of climate change impacts, coastal resources endowments, enabling factors (such as social networks, and access to natural resources) as well as adaptation practices as major interrelated components (Fig. 2).

Coastal resources endowments increase the adaptive capacity of households to impacts associated with climate risks in a given ecological and social context (Adger 2006; Agrawal 2008; Brooks and Adger 2005; Kuriakose et al. 2009; Marshall et al. 2010; Schmitt et al. 2013; Chow 2017, 2018). However, sustainability in the utilization of coastal resources depends on enabling factors such as level of education, governance, social networks, and access to natural resources (Steinfeld 2000; Fischer 2018),which are virtually none climate. The exact manner in which coastal and marine resources increase adaptive capacity depends on a variety of factors. These include the nature and severity of climate events and trends, the local context, household, and community endowments. Besides, adaptive capacity requires the flexibility to experiment and adopt novel solutions (Steinfeld 2000; Levin et al. 1998) as well as genetic diversity, biological diversity, and heterogeneity within landscapes (Carpenter and Gunderson 2001; Peterson 2002).

The Study Area

The study was conducted in the Rufiji District on the coastal area of Tanzania, which lies between 6–8°S and 37.5–40°E. It covers an area of ~14,500 km^2, with a mean altitude of 500 m from the sea level. The study was conducted in the delta area, whereas two villages from two wards were selected in consultation with district authorities. The study sought to address the role of coastal resources endowments in enhancing resilience to climate change impacts of the coastal communities. The selection of the villages in the delta zone was based on the spatial variation of coastal resources, socio-economic characteristics of the communities, including community livelihoods in the area. Mchungu village located at Salale ward and Kivinja 'A' village located in Mwambao ward was selected for the purpose of this study.

Approach

The study adopted both descriptive and explanatory research designs. Qualitative data were collected using Focus Group Discussion (FGD), and Key Informant Interview (KII) and quantitative data were collected using a questionnaire survey at the household level. The sampling units were individuals' who were residents to the study area and engaged with different livelihood activities related to coastal and marine resources such as fishing.

The Focus Group Discussions (FGD) were conducted at the village level. The selection of the FGD participants was based on their livelihoods activities related to coastal and marine resources, community members with long personal experiences with the coastal areas and those who were well knowledgeable on the socio aspects of coastal communities. The focus group participants were also asked to map in terms of percent the dependence level of the villagers to coastal and marine resources, and the availability of the existing coastal resources using bean seed where a single seed represented 10%.

[4] Fisheries is conceptualized as fishing and fishing business, all considered together

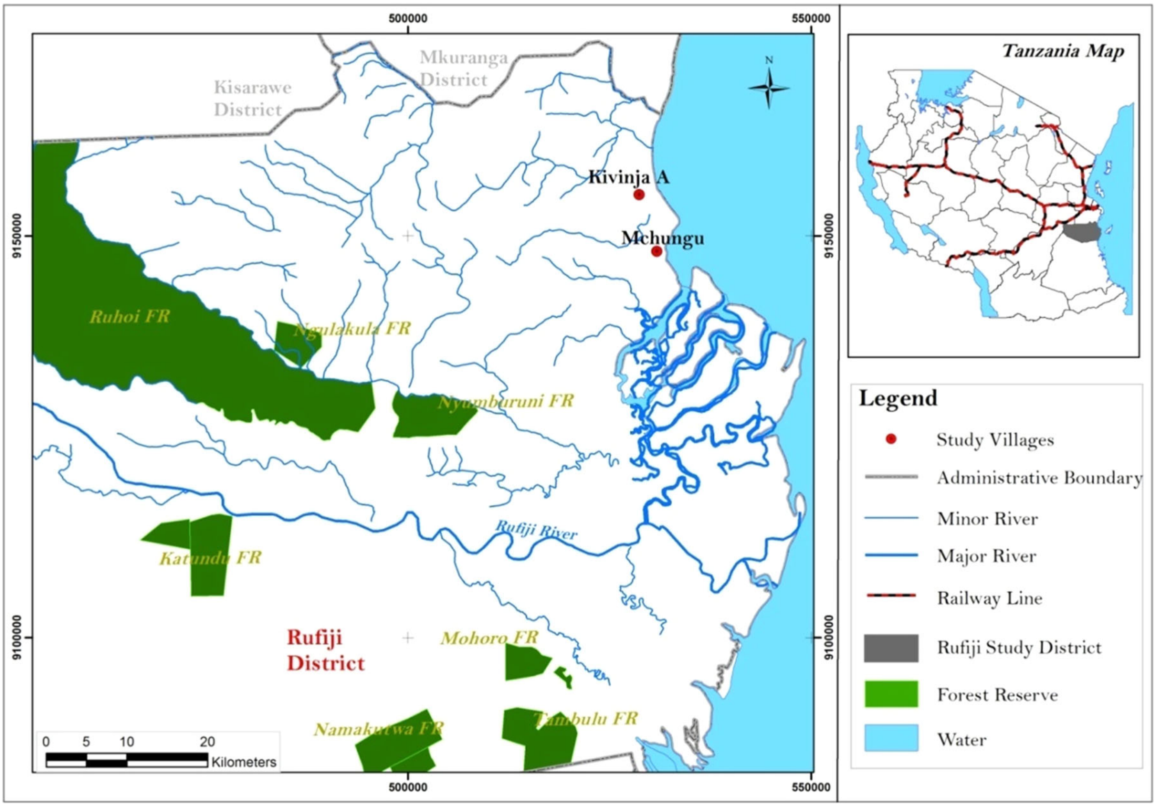


Fig. 2 Kivinja A and Mchungu villages, Rufiji district. Source: IRA-GIS, University of Dar es Salaam

Key Informant Interview (KII) was guided by a checklist that engaged district technical officers such as Livestock and Fisheries Officer, Land Use Specialist and Planning, District Fisheries Officer, and Forest Officer. KII was set to obtain exploratory information relating to climate change impacts on communities' livelihoods and coastal and marine resources. Key informants interview was also used to collect information on the role of coastal and marine resources on community adaptation to climate change impacts.

The household questionnaire was used to obtain quantitative information to complement qualitative data. A total of 77 respondents were interviewed through the household questionnaire, where 33 respondents came from Mchungu, which had 392 households and 44 from Kivinja' A' which had 447 households. Secondary data were collected through documentary review. Both qualitative and quantitative data were analyzed depending on their nature. Qualitative data were thematically analyzed, while quantitative data were coded, entered into SPSS Version 16.0, and analyzed using descriptive and inferential statistics. Results were expressed in frequencies, percentages, significance tests (P values), and averages. These were presented in different formats, including tables, graphs, and numerical statistical values.

Results and Discussion

Coastal and Marine Resources Endowments

The heritage, history and economic prosperity of Rufiji District are closely connected to coastal and marine resources. Their characterization was based on the type of coastal resources available and their status in terms of distance, availability, condition and distribution in the two villages.

Types and Distribution of Coastal and Marine Resources

Table 1 shows that the two villages are distantly located. Mchungu village is surrounded by the coastal resources at a strip of ~100 m from the extreme households, unlike Kivinja' A'. Mchungu which is also well endowed with fish, mangroves forest reserves, a natural canal, Mchungu Forest Reserve, the beach, and the floodplains. On the other hand, coconut farms and salt deposits were abundant in Kivinja A.

Status of the Coastal Resources

Mchungu and Kivinja A villagers reported that there is an increasing demand for fish while its availability is

Table 1 Availability of coastal resources

Village name	Types of coastal/marine resources:	Distance to coastal/ marine resources:
Mchungu	Fish	0–100 m
	Mangroves forest reserves	
	Natural canal	
	Beach/Shoreline	
Kivinja A	Rufiji floodplains	Above 2000 m
	Coconuts	
	Salt	

Source: Field Data (2016)

threatened by reduced water depth along the coast and weather change. They reported that during *kaskazi* and cold season, fishers are compelled to go very far to get a catch, as confirmed by Pecl et al. (2017), who found biodiversity redistribution due to changes in sea temperature. Other challenges included low recharge of the Mchungu River, shallow water due to siltation and cementations. The use of dynamite fishing and inappropriate fishing gears had detrimental impacts, particularly degradation of fishing breeding grounds (see also Bryceson 1978; Rocliffe and Udelhoven 2010; Wagner 2004). In this study, strong enforcement of by-laws guaranteed the mangroves regeneration as reported in other studies (see also Katikiro 2014; Mwaipopo et al. 2011; Samoilys and Kanyange 2008). However, it was further found that the other factor that influenced mangrove regeneration in the studied villages included silt deposits from silt-laden waters in the rivers whilst dispersing mangrove seeds.

Communities Livelihoods in Relation to Coastal and Marine Resources

Findings revealed that coastal and marine resources serve an important role in coastal communities through direct provision of food and household income (see Loc et al. 2010; Mbaiwa and Sakuze 2009; Motsholapheko et al. 2011). The study observed that fisheries, agriculture, cutting and selling mangroves are the main economic activities (Fig. 3)

Fisheries

In this study, fisheries denote all activities related to fishing and fish business. Fisheries symbolize a sector that employs most of the community members in the studied villages (Fig. 3). Approximately 60% of the total populations from the two villages were found to be engaged in fisheries activities. Other scholars also reported that fishing and fish business are essential source of food and household incomes to the coastal communities (e.g., Hanazaki et al. 2013; Holvoet and Allison 2008; Sarker et al.2010; Uychiaoco et al. 2000; Wanyonyi et al. 2008). In this study, fishers were of small scale, often used crude fishing utensils e.g., canoes, which in some cases mounted with small boat engines.

It was reported by key informants, focus group discussion participants, and households that fish are either consumed locally as fresh, dried, or smoked and a substantial amount of the smoked and dried fishes are transported to major markets within and outside the district. Respondents mentioned that large cities such as Dar es Salaam as the major markets. The District Fisheries Officer emphasized that freshwater and saltwater fish were two major categories of fish in Mchungu and Kivinja' A' villages. Accordingly, interviews with key informants revealed that freshwater fish were usually found along the Rufiji River and small lakes and creeks which emerge during the rainy season, whereas the saltwater fish were located along the Rufiji coast. Types of fishing gear include hooks and fishing nets.

Agriculture

Agriculture is much practiced at Kivinja' A' village than at Mchungu village. Meena et al. (2006) indicated that agriculture is the main occupation (93% of the households) in the Rufiji floodplain and delta. Agriculture in Kivinja 'A' village is favored by fertile land that supports both food (e.g., vegetables and fruits) and cash crops (e.g., cashew nuts and sesame), unlike Mchungu village where agriculture is limited to floodplains entailing mainly paddy production. Also, paddy is often grown in the delta area, utilizing the fresh-salt water dynamics potential within the deltaic branches of the Rufiji River (e.g., Motsholapheko et al. 2012; Ogilvie et al. 2015; Smith et al. 2013). However, farmers pointed out that the durations for cultivation in the delta areas are variable over recent years, depending on the freshwater-salty water dynamics. According to interviews, paddy is cultivated by timing the rainy season when the delta areas become flooded with freshwater from the Rufiji River. Communities are often sensitized and encouraged to practice agroforestry for food production (paddy) and coastal ecosystem integrity.

Business

The study revealed that the availability of mangrove forest reserves has greatly influenced cutting and selling mangroves for sale in both internal and external markets. Communities sell fuelwood, timber, and charcoal from mangroves. Cutting and selling mangroves activities are increasing due to increased demands of fuelwood at the household, fishermen (construction of boats) as well as building materials for houses, carvings, and other

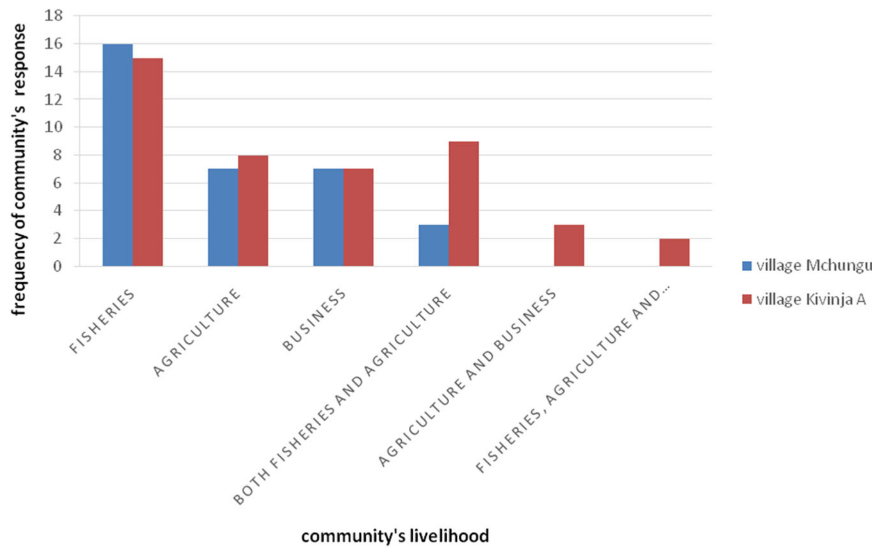


Fig. 3 Sources of community livelihoods. Source: Field Data (2016)

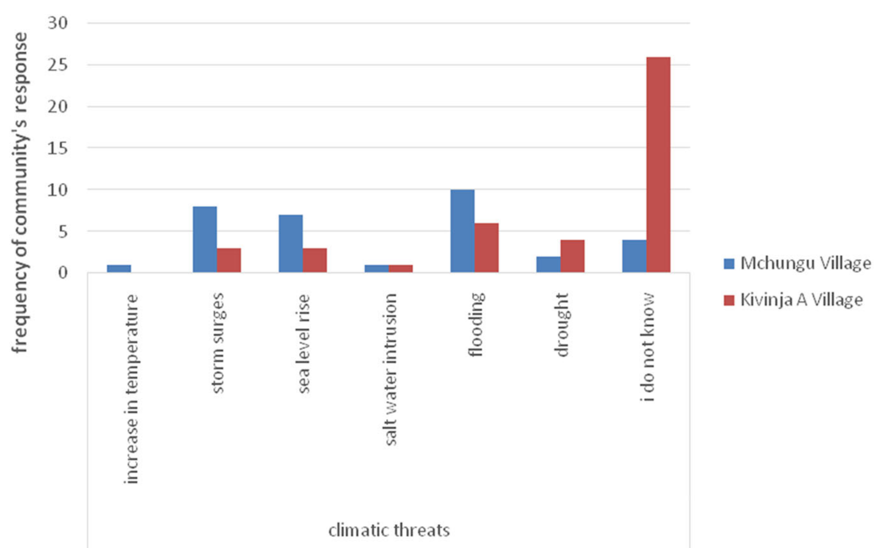


Fig. 4 The common climate events experienced in the study area. Source*:* Field Data (2016)

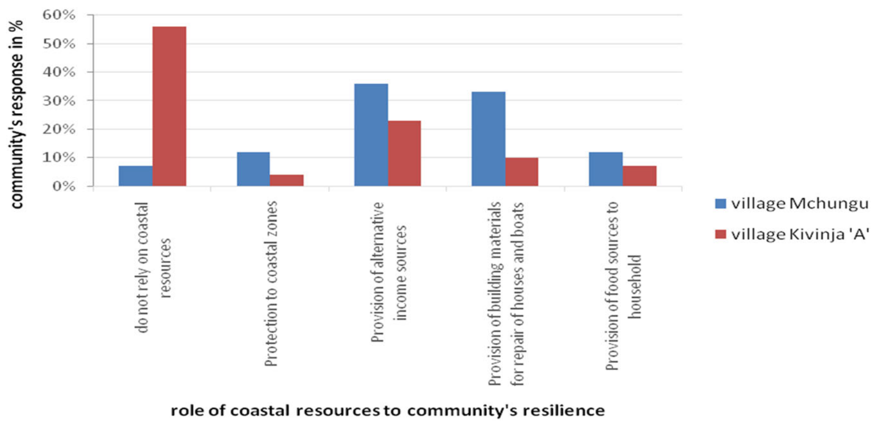
woodworks. The potential of coastal natural resources related business influenced other businesses to flourish, particularly retail (such as kiosks) and street vending of household goods.

Moreover, mangroves bear an important habitat for the crab to multiply and the associated business. As habitats, mangroves also provide protection to crabs against their predators. Crabs Business is growing, whereby a kilogram costs ranging from 9000–15000 TZS owing to the expansion of export potential mainly to Asian countries. It was further noted that earning from a crab business is up to 150,000 TZS a day. Crabs are usually transported to Dar es Salaam where they are processed. Crabs are often packed and exported to China. Moreover, communities at Mchungu village exploit Mangrove Forest Reserves 'potential for honey beekeeping. The honey business earns 6000–10000 TZS per liter.

Climatic Change Perceptions in the Study Villages

Owing to their experience with the local environment, over time, communities noticed changes in weather patterns, particularly temperature rise, changes in winds patterns, as well as the unpredictability of rainfall onsets and cessations. The associated impacts were evident through sea-level rise, storm surges, flooding, prolonged droughts, and saltwater intrusion into freshwater wells. Communities often sensitized on weather changes using conventional and traditional climate information dissemination systems on possible occurrence hazards. However, they do not easily recognize the long term climate change. This could be a possible explanation for the great number of household members' responses (61% - *'I do not know'*) at Kivinja' A'. Despite this difference in both communities from the two villages experiences similar climatic threats as elaborated below in Fig. 4.

Fig. 5 : Role of coastal resources in enhancing climate change adaptation. Source: Field Data (2016)



Saltwater intrusion

Field observations confirmed that long-time freshwater wells have turned to saltwater. The saltwater intrusion was associated with sea-level rise, whereby all studied villages were equally impacted. Saltwater intrusion causes freshwater shortages during dry seasons (May–November), rendering water stress. During this period, community members walk 2–5 km in search of freshwater. As a consequence of water stress, particularly in the dry season, water vending business becomes high during this time in which 20 l of freshwater are sold at 1500 shillings. The saltwater intrusion was critical in 1997 caused by prolonged drought; the record was highest and unbroken over the years (Fig. 5).

Storm surges/Tropical storms

Storm surges/Tropical storms have double implications; firstly on the fishing activities, where fish tend to migrate into the deep sea – calm environment. Respondents acknowledged that fishing during this period was described as risky and dangerous given the poor vessels they owned and, for that reason, cannot reach to deep water to catch fish. Secondly, storm surges tend to ravage coastal areas and accelerate coastal erosion by removing protective natural buffer areas that absorb storm energy and consequently destroying wetlands and mangroves. Such impacts were also observed by other scholars (e.g., Agrawal 2008; Barbier 2015; Kebede et al. 2010; Ngusaru 2000). Storm surges were also reported to impair fish breeding sites, coupled with water turbulences from the Rufiji River.

Sea-level rise

Sea-level rise and extreme water events (droughts and floods) have significant implications to coastal environments and ecosystems, including low-lying coastal plains, islands, beaches, mangroves, corals, coastal wetlands and estuaries. Impacts of sea-level rise along the coast of Tanzania were reported by other scholars (e.g., Kennedy et al. 2002; Lyimo et al. 2013; Obura and Grimsditch 2009). However, in the studied villages, sea-level rise is largely culminated by siltation within the delta areas from the Rufiji River. According to interviews, sea-level rise swept a strip of nearly 300 m, impacting coconut farms that pre-existed (Plate 3).

Plate 3: Left photo shows coastal beach erosion in Msinga village, whereas the right photo shows coastal beach siltation in Mchungu village.

Source: Field Data (2016)

According to narratives, the mangroves covered area in the background of the right photo was once a sand beach up to the 1970s.

Frequency of Occurrence of Climate Hazards/Threats

Communities described climate events such as droughts and floods as a natural phenomenon. However, respondents were worried about increased frequencies and intensities over recent years. Whereas climate events such as sea-level rise were steadily increasing over time, other climate events such as drought were reported to occur in cycles of three years, with the length of periods decreasing as years pass by, as indicated in Table 2.

There were concerns about increased frequency in cycles of expected hazards (such as drought after ten years) they were accustomed to. This has disrupted the preparatory measures to cope with those events. The duration for resource mobilization for coping with the next climate hazards is often

Table 2 Frequency of occurrence of climate events

Year	Climate threat experienced	Remarks
2015	Increase in temperature	Discomfort, fish migration and acute water stress in both Kivinja A and Mchungu villages
2006, 2011, 2013, 2014, 2015, 2016	Storm surges	Deaths, loss of properties and decline of fish catch in the study area in Mchungu village
Constantly from 1972	Sea-level rise	Settlement displacement leading community members to shift from building houses from near shore to far uplands in Mchungu village
2015	Saltwater intrusion in wells	Water stress, acute in both Kivinja A and Mchungu villages
1997, 1998, 2015	Floods	Occurs yearly but acute in 1997/98 rainy season, lead to the diversion of Rufiji River from Southern to Northern orientation.
1974, 1984, 1997, 2013, 2014, 2015	Drought	Food insecurity in both Mchungu and Kivinja A villages

Source: Field data (2016)

hampered by shortened cycles due to unpredictability. Hence, communities' adaptive capacities are lowered because before resources are sufficiently mobilized to cope with the event, another climate event comes in between.

Roles of Coastal Resources in Enhancing Resilience to Climate Change Impacts

Use of Coastal Resources

This study was concerned about whether there was any relationship between resource endowments and climate change resilience in the studied villages. Although other studies show that communities rely on coastal resources in adapting to climatic threats (e.g., Deb and Haque 2017; Phuong et al. 2017; Phuong et al. 2017), this study shows that majority of respondents do not directly depend on them (see Fig. 6). The implication of not depending on coastal resources means that they are engaged in agriculture and business-related activities more often. This explains the rising graph for Kivinja' A' village whereby 56% of community members do not rely on coastal resources, mainly retailers, small scale farmers and/or petty business people (e.g., kiosks and street vendors) discussed in previous sections. Interviews and discussions in the studied villages indicated that the business activities in the area are sustained by coastal natural resources directly or indirectly.

The role of coastal natural resources to increase the resilience of coastal communities to climate change impacts appears to be statistically significant ($P \leq 0.05$). The relationship implies reliance on coastal resources by coastal communities is particularly high. Hence, the majority of the community members derive their livelihoods from the coastal natural resources, particularly in Kivinja A. It was earlier shown by other scholars that natural resources

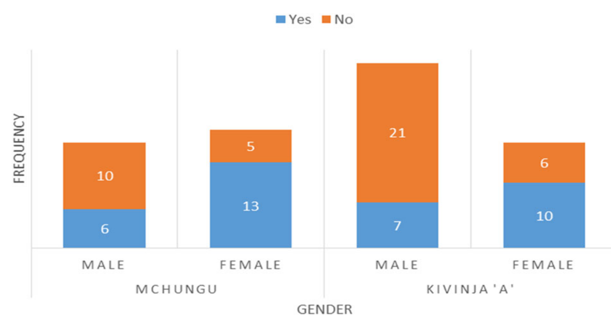


Fig. 6 Community participation in social networks. Source: Field Survey (2016)

related socio-economic activities attract population in coastal areas (e.g., Gornitz and Couch 2000; Martínez et al. 2006).

Provision of Food Sources to Household

Mangrove ecosystems are used as breeding and protection sites for crabs. Respondents pointed out that crabs are highly nutritious in terms of providing proteins. Villagers linked abundant availability of crabs with the restoration of mangroves, the main habitats for crabs' multiplication. Hence the existence of these mangrove forests also provides a conducive environment for the growth of grass species locally named '*kilo*' used as vegetable' food source' particularly when fish availability is low in the study villages. Recognition of this value of mangroves means that villagers would feel the ownership of mangroves forests and hence become part of mangrove conservation efforts.

Provision of Building Materials

During floods and storm surges seasons, the community's houses and fishermen's boats are often destroyed. Such houses and boats are often locally constructed using timber from the Mangrove forests (Table 3). During stressful moments such as flooding and storm surges, communities often acquire their construction resources from the Mangrove forest. Harvesting is often done legally, where mature trees are allowed for harvesting.

Provision of Alternative Income Sources

Mangrove forests were described to bear the potential for alternative income generation sources in the studied villages. There was market potential for coastal natural resources in the area due to the growing population (also see Carbonell and Meffert 2009). In this study, timber felling, and the sale of wood or charcoal is an important economic activity. Mangrove forests in the studied villages are widely used as a source of cooking energy (i.e., firewood and charcoal).Moreover, activities such as lime production, salt drying, extraction of construction materials (i.e., house and boats) as well as agriculture contribute to the degradation of the forest ecosystem. Hardwood species are exploited for woodcarvings and woodwork (Table 3) are also practiced in the area.

Honeybee keeping activities dominated in both villages. The harvested honey is sold and used as an alternative source of income that provides income to households. Other scholars reported these benefits from coastal natural resources (e.g., Kahyarara et al. 2002; Meena et al. 2006; Wilkinson 2008; Burgess et al. 2017; Katikiro et al. 2017; Staehr et al. 2018). In this study, villagers reported that money generated through coastal natural resources is used to buy food and other household needs. There were multipliers effects, whereby money generated from the sale of coastal natural resources related products are also used as capital to some other economic activities.

Table 3 Different forms of mangrove forest utilizations

Form of utilization	Frequency	Percentage
Using mangroves products like building materials at the household level	70	90.9
Selling mangrove products like building materials	1	1.3
Using mangroves as firewood at the household level	5	6.5
Selling mangrove-based firewood	22	28.6
Using mangrove-related firewood at the household level	72	93.5
Selling mangrove-related charcoal	6	7.8
Using mangroves for fisheries for household use	3	3.8
Using mangroves for fisheries for sale	51	66.2
Lime making	2	2.6
Salt drying	3	3.8
Woodwork activities	4	5.2
Use of mangrove forests for honeybee keeping	7	9.1

Source: Field Survey (2016)

Protection to Coastal Zones

Communities recognize the dynamic nature of coastlines, with erosion cycles described as important in ecological terms. Long term or short term wind, waves, and currents are often associated with extreme events. Sea-level rise moves unconsolidated sand and soil in the coastal areas. Thus rapid changes result in the shoreline alignment coupled with erosion due to anthropogenic activities. In this regard, the mangrove forest in coastal areas improves soil stability, consolidate sediments and reduce wave energy moving onshore, therefore, protecting the shoreline from erosion (see Blomley and Iddi 2009; Blomley et al. 2008; Wunder et al. 2014). However, efforts are being made by the communities to replanting the mangroves upon being cut.

Regulation of Microclimates

Respondents in both Mchungu and Kivinja A villages are aware of the importance of coastal resources in the regulation of coastal microclimate, particularly mangroves. Microclimate also provides favorable condition for the growth of various crops such as coconut, pyrethrum, maize and fruits. Other studies also reported the role of coastal resources in microclimates regulation (see Julius et al. 2002; Rabbani et al. 2010). Communities embraced ecosystem services provided by these coastal resources. Apart from mangroves' re-plantation, the study found that villagers participate in platforms that provide environmental education on the necessity to preserve mangroves and improvement of community livelihoods.

Factors Influencing Climate Change Adaptation to Coastal Communities

Gender

Historically, in all fishing communities, including those of Mchungu and Kivinja' A' men are predominantly doing fishing activities. They as well control fishing gears or tools of production. They have, therefore, greater access to the benefits and increased incomes from the fishing activities than women. This result is supported by other scholars (e.g., Kleiber et al. 2015; de la Torre-Castro et al. 2017); In this study, women were engaged in weaving of mats, subsistence agriculture and food vending (*mama ntilie*). Although women bear significant contributions in small scale fisheries (e.g., Harper et al. 2013), in this study male-headed households are likely to gain more incomes from mixed incomes generating activities than female-headed households. Hence, male-headed households have a relatively high level of resilience to the impact of climate change, including famine, hunger, and flooding, which are regularly reported to have been occurring in both Mchungu and Kivinja' A' villages. This study also revealed that gender imbalances are slowly changing. For example, it was noted that, during the extensive dry period, both women and men do take part in fetching fetch water from distant water sources. This is an activity which was considered as women's responsibility. According to

Existence of by-Laws

This study found that by-laws were used for monitoring mangrove utilization and fishing. It was further found that local communities were allowed to access non-timber forest products, including vegetables, fruits, fixing of beehives, and dry fuelwood without permission. The use of inappropriate fishing methods and gears such as dynamite fishing and the use of mosquito nets were restricted by existing by-laws. Mangroves and fish were classified based on species diversity and maturity. Based on their classification, first and second grade (i.e., wattle for the building purposes) could be harvested by special permission from the local government while the mangroves of stage 3.4 and five mainly immature were restricted. Certain fish species like dolphins were not allowed for the catch. The village government enforced these by-laws through Beach Management Units (see Wilkinson 2008; Rocliffe and Udelhoven 2010) formed in partnership with the District Council Officials.

Social Networks

Communities in the studied villages have been vibrant in participating in different social networks. It is evident from this study that there is an existence of several social networks that were formed for various roles. However, over recent years, the roles and responsibilities of such social networks have been flexible to accommodate emergent issues, including climate hazards. However, this study shows that there are more by women than men in these social networks (Fig. 6). The ramifications of lack of involvement of men in social networks mean that the adaptive capacity of men is tempered by being excluded from potentials to increase resilience to climate change impacts.

Respondents acknowledged that social networks offer options to increase resilience to climate change impacts by providing material resources such as loans when a member is considered to be in a hard time. They also provide humanitarian needs such as providing food to disabled families and rescue programs during catastrophic weather events such as heavy rains and/or floods.

The social networks available in the area included Village Community Banks (VICOBA), REDCROSS, and MAENDELEO group. Although social networks have been reported to be useful in social aspects in coastal communities, (e.g., Arkema et al. 2017; Carbonell and Meffert 2009; Katikiro 2014), in this study, social networks were described to play a vital role in climate change adaptation. VICOBA, for instance, became particularly important through the provision of small loans, particularly during bad weather and when fishing activities fail. Moreover, the loans enabled small business, purchasing household food, and other household expenditures. Networks such as RED CROSS provided humanitarian assistance during famine and floods, such as food aid.

Education

This study found that there were relatively low levels of education in the studied villages. It was found that about 29.5% had never attended any formal school, whereas 60.3% appended only the primary education level. Only 10.2% completed ordinary level secondary education (Table 3). Such education levels offer low capabilities for livelihood diversification (e.g., Mbwambo et al. 2012; Alam et al. 2018) compared to educates societies. In this study, such education levels may be reflected in the sorts of livelihood activities, whereby most of them demand low skills. This may have implications on the adaptive capacities to climate change impacts (Table 4).

Conclusion

This paper discusses the importance of coastal and marine resources on coastal climate change adaptation by coastal communities in Rufiji district, whereas Mchungu and Kivinja' A' were the study villages. This study reveals that the Mchungu and Kivinja' A' village are endowed with coastal resources such as fish, mangroves, coconuts, beach/shorelines, salt, natural canal, and Rufiji floodplains. The availability of the resources to community members at Mchungu is easy due to the close proximity of the village to these resources, whereby at Kivinja' A' coastal resources are distantly located over 2000 m. Community livelihood in both villages is derived from coastal resources such as fisheries (fishing and fish business), while activities such as agriculture (involving both cash and food crops) are grown where –paddy cultivation is done in the delta. Business such

Table 4 Education levels in the studied villages

Education level	Frequency	Percentage
None	23	29.5
Primary	46	60.3
Secondary	8	10.2
Total	77	100.0

Source: Field Survey (2016)

as cutting and selling mangroves also prevail involving exports.

The study site experiences climatic threats, notably increased temperatures, drought, flooding, sea-level rise, and storm surges that impaired the community livelihoods. Changing climatic conditions and environmental disturbance causes fish to migrate into the deep sea where it is calm, this reduced fish availability and fish catch whereby current fish that are caught are usually small-sized fish. Consistently the agriculture production is reduced where excessive flooding cause loss of crops while increased temperature and drought increase salinity to the soil, particularly in the Mangroves where paddy cultivation is done.

The coastal resources are highly dependent on building climate change resilience building to communities through the provision of building materials for repair of houses and boat construction. Alternative income sources include selling of harvested timber and wood as well as fuelwood. Mangrove Forest also provided food sources to the households through harvesting of crabs. Mangroves Forest also protects the shoreline from erosion that is attributed by wind, waves, and current resulting extreme events and sea-level rise.

Besides, gender, by-laws, social networks, and education have differently implicated the community resilience to climate change impacts. Whereas membership in social networks becomes instrumental for access to financial and material resources necessary for climate change adaptation, by-laws are meant to restrict and guarantee sustainability in the utilization of coastal natural resources. However, low levels of education among community members limit the potential for livelihood diversification, an essential increase of community resilience to climate change impacts.

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Compliance with Ethical Standards

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