Poverty Levels and Vulnerability to Climate Change of Inshore Fisher-Mangrove-Dependent Communities of the Rufiji Delta, Tanzania

Claude Gasper Mung'ong'o and Vicky H. Moshy

Abstract This chapter assesses how fisher-mangrove-dependent societies such as those of the Rufiji Delta in Southern Tanzania are being affected by and what is their capacity to adapt to climate change impacts that are occurring in the area. The objective of the study was not only aimed at improving linkages between the practice of community-level assessments and efforts to develop and implement vulnerability-reducing interventions; it was also an attempt to address the critique about the need for a more integrative, community-engaged approach to assessments in vulnerability scholarship. This study aimed to measure three key dimensions of vulnerability, i.e. exposure, sensitivity and adaptive capacity. Socio-economic data was collected from two purposely selected coastal communities in the Rufiji Delta. Sites were selected to provide a spectrum of social and environmental conditions. For each community, data were obtained on exposure, sensitivity and adaptive capacity. Findings show that, despite differences in wealth status, community members of the study villages generally shared similar socio-economic characteristics and were thus anticipated to be impacted in similar magnitudes. What was needed was community education on climate change impacts and the presence of social networks to assist in creating awareness on climate change impacts and livelihood diversification to reduce direct dependence on the fisher-mangrove ecosystem. Such livelihood diversification strategies included provision of capital for small businesses and establishing environmentally friendly activities such as compound-based livestock keeping (zero-grazing) and modern beekeeping.

C. G. Mung'ong'o (✉)
Institute of Resource Assessment, University of Dar es Salaam, Dar es Salaam, Tanzania

V. H. Moshy
Institute of Resource Assessment and Centre for Climate Change Studies, University of Dar es Salaam, Dar es Salaam, Tanzania

P. Z. Yanda et al. (eds.), *Climate Change and Coastal Resources in Tanzania*, Springer Climate, https://doi.org/10.1007/978-3-030-04897-6_5

Introduction

There is growing consensus among environmental change researchers that treating communities as separate from their ecological contexts can lead to research that overlooks critical socioecological interdependencies and subsequently to recommendations for reducing vulnerability that are not mindful of the effects remedial actions have on various social groups and ecosystems (McDowell et al. 2016). This point is in fact a confirmation of an earlier concern raised by authors such as Adger (2000) who argued that although 'there is a clear link between social and ecological resilience, particularly for social groups or communities that are dependent on ecological and environmental resources for their livelihoods, it is not clear whether resilient ecosystems enable resilient communities in such situations'.

This chapter sets out to answer the questions of critical importance to resource managers, stakeholders and scientists alike, i.e. of how fisher-mangrove-dependent societies such as those of the Rufiji Delta in Southern Tanzania are being affected by and what capacity do they have to adapt to climate change impacts that are occurring in the area. The objective of the chapter is not only aimed at 'improving linkages between the practice of community-level assessments and efforts to develop and implement vulnerability-reducing interventions'; it is also an attempt to address the critique offered by McDowell et al. (2016) about the need of a more integrative, community-engaged assessments in vulnerability scholarship. The data used in this chapter is derived from a socio-economic study done in the Rufiji Delta in May 2016.

Methods and Materials

Study Area

Location

This study was conducted in the mangrove ecosystem in the Rufiji Delta, Southern Tanzania. The delta covers 53,255 ha (Semesi 1992) located between latitudes 7°50′ and 8°03′ S and longitudes 39°15′ and 32°17′ E 7.47° E. Nyamisati and Mchungu villages are found in the northern part of the Rufiji Delta in Rufiji District (Fig. 1). The delta is about 250 km south of Dar es Salaam. Mchungu village which is in Mwambao ward has two hamlets, i.e. Mipekeso and Mititimbo. It has a total number of 392 households.

Geology and Soils

According to Semesi (1992), the land in the Rufiji Delta is not stable. Banks are scoured by the river currents and silt deposited again at the convexities of curving water channels. The rain-swollen river deposits its detritus load on reaching the

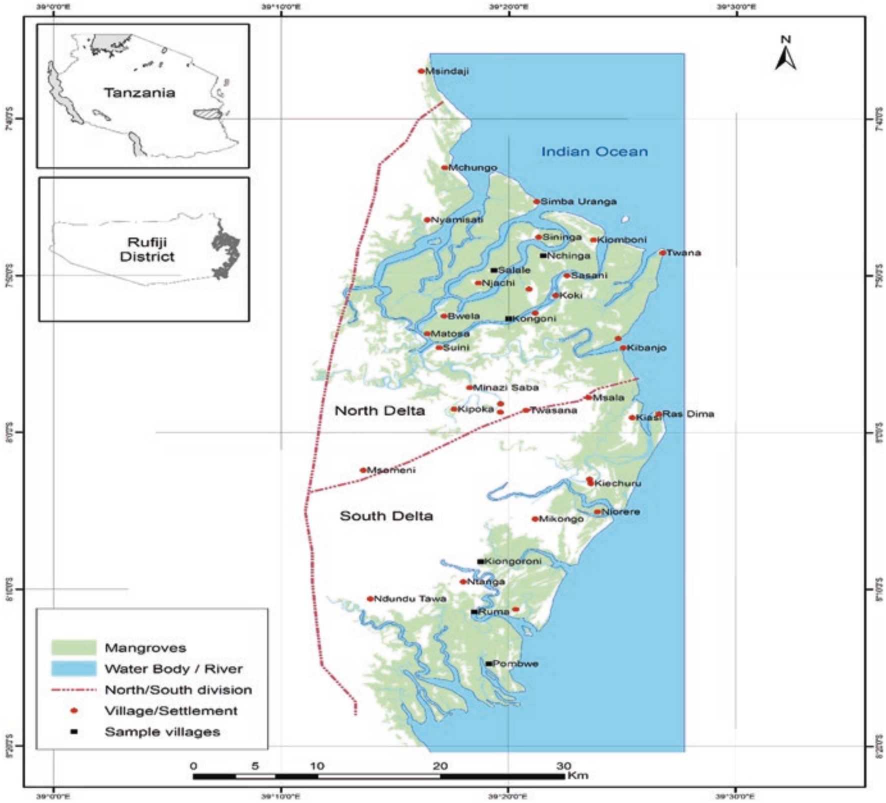

Fig 1 Location of the study area in Rufiji District, Tanzania. (Source: Adopted from Mwansasu 2016)

slack waters in its delta and rapidly builds up new mud banks. According to FGD, for example, in the 1980s, Mchungu village was bordered with a coastal beach. Following increment in the frequency of flooding paralleled with intensive and extensive siltation of Rufiji River in subsequent years caused the diversion of the river, filling the beach with mud and creating favourable conditions for germination of some of mangrove species in the places where there was a beach before (Plate 1).

Rufiji Delta is 23 km wide and 65 km long protruding 15 km into the Mafia channel. It is overlain by superficial alluvial material mainly sand, silt and clay resulting to a large degree from suspended sediments transported from the Rufiji Basin (Semesi 1992). Deposition of sediments at the middle of channels is still increasing; small islands are created and some channels are blocked. The sediments have an impact on transport in the delta because larger vessels can now no longer pass through most channels or passage is only possible during high tides.

Plate 1 Part of the beach at Mchungu impacted by sedimentation. The mangroves' covered area was part of the beach in the 1980s according to the local narratives. (Source: Photo by Anselm Mwajombe, May 2016)

Climate

The study area is characterized by a dry *Kiangazi* period (January to March); the long rainy *Masika* season (March to May); a mild cool and windy period locally known as *Kipupwe* (June to August/September), and the short rainy season (*Vuli*) coming in October and December. The average temperature of the study area varies between 24 °C during the months of June and July and 28 °C during the period of December to February. Temperature in Rufiji District ranges from 25 to 41 °C throughout the year and has two rainy seasons ranging from 750 to 1250 mm: short rains (October to December) and long rains (February to May) (Lupembe 2014; Mwansasu 2016). The population of the district is about 182,000 with the Ndengereko as the largest ethnic group (Mkindi and Meena 2005).

Hydrology

The study area is drained by the Rufiji River. According to Semesi (1992), the Rufiji River is the largest river in Tanzania. It has three main tributaries, i.e. the Great Ruaha, Kilombero and Luwegu rivers. The delta is also influenced by tides which reach about 25 km upriver. The delta is traversed by numerous deltaic branches of the Rufiji River. There are about 43 islands in the delta. The river has a mean flow of approximately 800 m^3/s with a strong seasonal flow pattern with flood peaks around April. Its fertile lower floodplain is up to 20 km wide, and maize and paddy cultivation is dominant. The river developed a delta partially covered by 500 km^2 of mangroves, the largest stand in East Africa (Semesi 1992).

Vegetation

Rufiji District is mainly covered with tropical forest and grassland vegetation types. The Rufiji Delta forms part of the Rufiji River basin which covers an area of 177,000 km^2. The Delta contains the largest area of estuarine mangroves in East Africa and provides nursery grounds for about 80% of Tanzania's prawn fishing industry. Eight of the ten mangrove species occurring in Tanzania are found in the Delta (Wagner and Sallema-Mtui 2010). Common mangrove species in the Rufiji Delta are *Rhizophora mucronata*, *Sonneratia alba*, *Ceriops tagal*, *Avicennia marina* and *Bruguiera gymnorrhiza*. Other species are *Lumnitzera racemosa*, *Heritiera littoralis* and *Xylocarpus granatum*. Mangrove species often occur in more or less pure stands, and where stands are mixed, a single species tends to dominate.

Generally, *Rhizophora mucronata* and *Avicennia marina* are the most common species. The inner, landward zone is frequently occupied by *Avicennia marina* and occasionally by *Ceriops tagal* or *Lumnitzera racemosa*, while the seaward zone is occupied by *Sonneratia alba* or *Avicennia marina* (Semesi 1992).

According to the Rufiji Delta Mangrove Forest Reserve inventory exercise of 2011, the Rufiji Delta is divided into three parts, namely, the northern delta, the central delta and the southern delta. The forested area in the northern delta has changed from 24,555.5 ha in 1991 to the present 17,555.7 ha due to rice farming and mangrove pole cuttings, among others. The central delta has an area of 15,172 ha, while the southern delta has a total area of 13,526.7 ha. The mangrove vegetation of the Rufiji Delta often occurs in more or less pure stands. In situations where stands of mixed species composition occur, a single species still tends to dominate.

The Rufiji Delta Mangrove Forest Reserve was officially gazetted as a forest reserve in 1928. The mangroves have been extending to over 500 km following the flooding of the Rufiji River during the El Niño rains in the 1980s. Flooding of the Rufiji River caused sedimentation due to erosion which created a favourable condition for mangrove growth. The Rufiji Delta Mangrove Forest Reserve is the only reserve in Africa that allows harvesting and occupies over 5000 ha.

Conceptual and Theoretical Framework

This study aimed to measure three key dimensions of vulnerability, i.e. exposure, sensitivity and adaptive capacity, as defined and expounded by Cinner et al. (2011) and Ellison (2012). Socio-economic data was collected from two purposely selected coastal communities in the Rufiji Delta. Sites were selected to provide a spectrum of social and environmental conditions. For each community we obtained data on exposure, sensitivity and adaptive capacity as described below.

Exposure

Past mangrove degradation data and associated oceanographic conditions across the sites/communities were collated from literature and/or documentary review of existing information and were used to produce a predictive model of mangrove susceptibility to thermal stress and associated mangrove as proposed by Malleret-King et al. (2006) and Maina et al. (2008). The variables investigated during this vulnerability assessment had the following components:

- Compilation of local community knowledge about climate change impacts, mangroves and fishery dynamics
- Information on mangrove resource usage and fish catches

Sensitivity

Consistent with other studies and protocols (e.g. Malleret-King et al. 2006; Marshall et al. 2010, etc.), a metric of sensitivity was developed based on the level of dependence on fisheries and mangrove harvesting by wealth groups. This indicator was developed based on *household surveys*. Sampling of households within the communities was based on wealth ranking, followed by a systematic sampling design. We conducted household surveys in the two selected villages, depending on the population of the communities and the available time to conduct interviews per community.

To develop the sensitivity metric, the respondents were asked through *FGDs* and *key informant interviews* to list all livelihood activities that brought in food or income to the household and ranked them in order of importance. Occupations were grouped into the following categories: fishing, selling marine products, tourism, and farming of cash crops, salaried employment, petty business, other, and 'none'. To better understand the sensitivity to the impacts of temperature events on fisheries, we considered fishing and fish trading together as the 'fisheries' sector and all other categories as the 'non-fisheries' sector. This grouping has parallels in agricultural economics where activities are classified as 'farm' and 'nonfarm'.

Our metric of sensitivity incorporated the proportion of households engaged in fisheries and mangrove harvesting by wealth groups, whether these households also engaged in other non-fisheries occupations (i.e. 'linkages' between sectors), and the directionality of these linkages (i.e. whether respondents ranked fisheries as more important than other activities). Firstly, the aim was to capture the ratio of fishery to non-fishery-related occupations. Secondly, it was to capture the extent to which households dependent on fisheries were also engaging in non-fishery livelihood activities, including mangrove harvesting. This approach decreased the level of sensitivity when many households were engaged in both occupational categories. Thirdly, it was meant to capture the directional linkages between fisheries and non-fisheries such that communities were seen as more sensitive when households engaged in fisheries and non-fisheries occupations consistently ranked the fisheries and mangrove harvesting sectors as more important than other livelihood activities.

Social Adaptive Capacity

Here, we employed a social adaptive capacity index developed by McClanahan et al. (2008). Based on both the *household surveys* described above and *key informant interviews*, we derived eight indicators of adaptive capacity as follows:

- Recognition of causal agents impacting marine resources (measured by content organizing responses to open-ended questions about what could impact the number of fish in the sea)
- Capacity to anticipate change and to develop strategies to respond (measured by content organizing responses to open-ended questions relating to a hypothetical 50% decline in fish catch)
- Occupational mobility (indicated as whether the respondent changed jobs in the past 5 years and preferred their current occupation)
- Occupational multiplicity (the total number of person-jobs in the household)
- Social capital (measured as the total number of community groups the respondent belonged to)
- Material assets (a material style of life indicator measured by factor analysing whether respondents had 15 material possessions such as vehicle, electricity and the type of walls, roof and floor)
- Technology (measured as the diversity of fishing gears used)
- Infrastructure (measured by factor analysis of infrastructure items such as hard top roads, medical clinic, schools, etc.)

The indicator of occupational multiplicity is fundamentally different from our measure of sensitivity since it builds on the households' complete portfolios of occupations and is, therefore, able to capture a household's general ability to adapt to change (McClanahan et al. 2008). The sensitivity measure, in contrast, only focuses on the extent to which households are engaged in fishery versus non-fishery-related occupations, including mangrove harvesting and how they rank their relative importance. These eight indicators of adaptive capacity were, therefore, combined into a single metric based on weightings derived from expert opinion as proposed by McClanahan et al. (2008).

Results and Discussion

Identifying Demographically Vulnerable Groups

Different groups in the same community or region may experience different levels of vulnerability to changing climate (Malleret-King et al. 2006). *Demographically vulnerable groups* are those that, because of their particular demographic or social characteristics, are more vulnerable than others in the broader community. Particular demographic characteristics may result in varying levels of exposure to certain types of climate hazards (e.g. location of home, needed resources and infrastructure in relation to hazard-prone areas), how sensitive people are to hazards (age, health condition, occupation, economic status or dependency on impacted resources) and their adaptive capacities (attitudes and knowledge, skills, economic status, social affiliation and willingness and ability to change). Demographic data from this study are presented below.

Livelihood Activities and Social Conditions: An Overview

Approximately 220,000 people live in Rufiji District, the majority in the Rufiji floodplain and the Delta. According to the 2012 National Census, Rufiji District had the lowest population density of any district in Tanzania, namely, 16 persons per km^2 compared to the national average of 50.6 persons per km^2. The level of education was comparatively low. For example, less than 60% of the respondents of a socio-economic survey carried out by Mbiha and Senkondo in 2001 had attended formal education.

According to the FGD and key informant interviews, household income in Rufiji Delta was generally derived from activities such as agriculture, fisheries and forestry. Cultivation occurred at the fringe zones of the mangrove area, and along some of the main rivers, where rain season flooding brought in fresh water to the fields. With time, the soil in the rice fields became too saline. New areas were then cleared for agriculture, while the old fields were abandoned. The location of rice farming demonstrates the natural dynamics of the delta. Contrary to the situation before the major river shift in the 1970s, it was observed during this study that rice farming was now mostly being carried out in the north of the delta where Mchungu village is located. After the river avulsion, the southern delta communities were forced to temporarily migrate to cultivate their rice outside the delta.

Agriculture was the main occupation (93% of the household) in the Rufiji floodplain and the delta. By 2014 the cash crops grown were paddy, cashew nuts and sesame (Lupembe 2014). Different crops were grown with rice as staple foods. These included maize, sweet potatoes and millet (being grown by 76% of the households in the lower Rufiji River Valley (Lupembe 2014)). Fruits such as mangoes, oranges, pineapples, paw paws and jack fruits were also grown for subsistence, with a proportion being sold for cash (Mkindi and Meena 2005).

Fishing was carried out in the upstream of the main Rufiji River, in the delta and in some of the inland oxbow lakes formed by the flooding of the river. To date, the delta waters support one of the richest wild prawn-fishing grounds in Tanzania, providing more than 80% of the country's prawn exports (Mwansasu 2016).

During the time of this study, mangroves in the delta contributed to much of the forest harvesting for timber and logging in the area. The mangrove products were extensively used locally in canoe construction and as building materials. But trading in mangrove poles also occurred outside the delta, including in places like Dar es Salaam and Zanzibar. Although regulated through a system of permits issued by government authorities, poor control and enforcement of laws have occasionally led to some illegal harvesting (Mwansasu 2016).

Plate 2 The road to Mchungu village during the rainy season. It is a hub called 'Fulanguo' connecting the village and the main road that a person must pass through using motorbikes or on foot. (Source: Photo by Anselm Mwajombe, May 2016)

In general, however, trade in fish and other marine products is encumbered by poor infrastructure. Many of the roads in the delta are impassable during the rainy season (Plate 2). In addition, market opportunities are erratic. In the case of fish, electricity is in poor supply, which causes problems with storage facilities (Mbiha and Senkondo 2001).

On the positive side, one study in the area (Lupembe 2014) has shown that, if sustainably managed, the Rufiji Delta mangrove ecosystem could have a high potential as a carbon sink useful for climate change mitigation. The ecosystem was estimated to have 40.5 t ha^{-1} of aboveground carbon, 21.08 t ha^{-1} of belowground carbon (roots) and 98.57 t ha^{-1} of soil organic carbon (Lupembe 2014).

Social Stratification in Nyamisati and Mchungu Villages

Poor people tend to be the most natural resource-dependent communities in many developing countries. They are the most severely affected when the environment around them is struck by a serious hazard like drought, floods or climate change-induced sea level rise or simply degraded '…or their access to the resources is limited or denied' in any way (Ireland et al. 2004).

On the other hand, the coastal communities also have many opportunities to improve their livelihoods if well utilized. To get a clear picture of what the social stratification of the communities looked like, a wealth ranking exercise was done in Mchungu and Nyamisati villages in the Rufiji Delta a la Grandin (1988). The ranking was performed by teams of selected villagers from each village categorized by

Table 1 Percentage distribution of wealth groups in Mchungu and Nyamisati villages (2016)

Wealth group	Villages	
	Mchungu (%)	Nyamisati (%)
Well-off	8.8	25.0
Middle	23.5	34.1
Poor	67.6	40.9
Total	100.0	100.0

age and gender. Lists of assets that were perceived as 'wealth' in the villages were, first of all, compiled.

In both villages these included block/brick houses with iron roofs, cultivable land of four acres and above, country motor vehicles or motorized boats and livestock (mainly goats). The groups were also identified by the nature of businesses they were involved in, such as running shops/kiosks, harvesting and sale of mangrove products, prawns and crabs. The importance of each of these assets as criteria for assessing wealth or social status of villagers was then determined.

Characterizing wealth groups in the two communities was then done by determining the importance of each of the assets mentioned above as criteria for assessing wealth or social status of villagers. This activity was followed by establishing the definition of a 'household' among coastal communities.

After a protracted discussion on the ranking criteria, the ranking teams then ranked all the names of heads of the households. The names were read out aloud from *Vitongoji* (sub-villages – the smallest administrative unit in rural Tanzania; sing. *Kitongoji*) registers developed by the respective *Vitongoji* chairpersons in collaboration with the Village Executive Officers of the two villages. Placing a particular name in a specific group category was based on consensus of all the participants in the ranking exercise. Table 1 illustrates the wealth groups identified and categorized in Mchungu and Nyamisati villages with their different socio-economic characterizations.

The *well-off* group had a variety of the identified assets, including one or two block/brick houses with iron roofs (Plate 3), cultivable land of four acres and above, a car and one or two fishing boats for renting to fishers from the middle and poor groups. A boat and its fishing gear were rented at Tsh 2000 per boat per day. Some of these households had 20 or more goats. The group was also identified by the nature of businesses they were involved in. Some households were running shops selling a variety of household items, while others were involved in harvesting and selling of mangrove products, prawns and crabs.

Households in the *middle group* had fewer and less valuable assets, among them. These included hard wood mud houses with corrugated iron roofs as exemplified by Plate 4, some pieces of cultivable land of 1–2 acres, a motor bike, a bicycle and/or three to five fishing canoes. Some kept between 50 and 100 poultry for sale. The main economic activities of these households in the village were fishing using local canoes (*mitumbwi*) and some subsistence agriculture using the hand hoe.

Many of the households who practised agriculture in this wealth group grew food for household consumption and for sale. The range of productivity was, however,

Plate 3 An iron-roofed brick house for a 'well-off' household in Nyamisati village. Note the TV dish on the roof. (Source: Photo by Anselm Mwajombe, May 2016)

Plate 4 A hard wood mud house with corrugated iron roof OF 'middle wealth group' in Nyamisati village. (Source: Photo by Anselm Mwajombe, May 2016)

relatively low with households harvesting between 40 and 60 bags of paddy per season. By the time of this study, a bag of rice cost about Tshs 40,000.[1] Some of the households that farmed in this group also fished, both for household consumption

[1] The exchange at the time of this study was 1US$ = Tsh 2170.

Plate 5 A twig and mud house with makuti (dried palm fronts) thatched roof in Mchungu village. While such houses are widespread in Mchungu, in Nyamisati, they are commonly seen in the periphery of the village indicating that poverty was much more widely spread in Mchungu than in the latter village. (Source: Photo by Anselm Mwajombe, May 2016)

and for sale. In a good season, those who held fishing permits could earn between Tsh 500,000 and Tsh 700,000.

Generally, households of the *well-off* and *middle wealth groups* were multi-active with the ability to switch between economic activities through livelihood diversification. Households in the *poor* were, characteristically, the least economically endowed. The majority had twig mud houses with *makuti* (dried palm fronds) thatched roofs (Plate 5). Very few of them owned bicycles as a means of transport. Their main economic activities included small-scale fishing, mainly for subsistence by hiring canoes from others. They had no fishing gears or permits as they could not pay for them. Many of the women in this group of households engaged in petty business such as food vending (*mama ntilie*), making mats and other raffia handcrafts, day labouring, fire wood collection and charcoal making for sale.

Social Infrastructure in Mchungu Village

During the time of this study, Mchungu village had only 1 primary school with 5 teachers, (3 women and 2 men) and 300 pupils. The school had only three teachers' houses. The village had no secondary school. A student had to travel some 13 km to Nyamisati where there was a secondary school. The village had one dispensary with only one nurse. They had no ambulance and depended on the government ambulance at Nyamisati dispensary. When needed, a patient had to contribute fuel costs which amounted to Tsh 60,000 (an equivalent of US$ 30) a trip.

Transportation was poor with the village depending only on motor bikes for transportation. Communication was via mobile networks Airtel and Halotel whose connectivity was fairly strong. There was no electricity which negatively impacted fish business, especially for refrigeration. There was no tap water. Some people who had corrugated iron roofs used rain water harvesting techniques and water from shallow wells. Water for drinking and cooking was bought at Tsh 800–Tsh 1000 per 20 L plastic container (*dumu*).

Socio-economic Conditions in Nyamisati Village

Nyamisati village, on the other hand, is in Salale ward. It had three hamlets, i.e. Mjengea, Kihigi-Shule and Pwani, with a total number of 567 households. The total area of the village was 2225 ha. The main economic activities included agriculture, fisheries, businesses and handcrafts. Agriculture was mainly mixed farming comprising of cultivation of cassava and cashew nuts, whereas paddy was a stand-alone crop. On average, 574 acres was under paddy cultivation, whereas cashew nut farming covered almost the same area. Cassava cultivation covered 266 ha. Each household in the 'well-off' and 'middle wealth' groups had an average of two acres of arable land. Agriculture was overwhelmingly characterized by the hand hoe. Hence, productivity was low, with farmers harvesting around ten bags of paddy, six bags of cashew nuts and 1 ton of cassava. Paddy was the main crop used both as a food and cash crop. Data from this study show that a half of the households (i.e. 287 households) grew paddy (Plate 6).

Plate 6 Paddy cultivation within the delta of Rufiji River. Ever since the Rufiji mangrove forest was declared a forest reserve, it has been a legal quagmire, with 'legally established villages' being located in a reserved forest where human habitation is prohibited by law. (Source: Photo by Anselm Mwajombe, May 2016)

Fishing was the second economic activity engaging about 60% of villagers of Nyamisati. As shown above, most of the fishers were from the *middle wealth group.* Types of fish caught included prawns and other species like *chewa*, *kungu*, *papa* (sharks), *hongwe*, *sanje* and *kolekole.* The average number of kilogrammes fished per year was between 25,000 and 30,000. The fishing gear mostly used for fishing included hooks and nets (*mishipi*).

Data from FGD and key informants show that temperature variations in sea water impacted the fish catch. During the rainy season, for example, sea waters were cooler, and fish were often available on the shallow shoreline fishery. Subsequently, fish became plenty and fish catches increased. However, during the dry season when temperatures were high, sea water remained warmer most of the time, and fish migrated to the deep sea to seek favourable temperature conditions. Consequently, the number of fish in the shallow shoreline fishery declined and fish catches decreased.

The data also show that a sizable number of households from the *well-off* and the *middle wealth groups* were also engaged in small businesses selling some mangrove products, running small shops, etc. As shown for Mchungu village, businesses related to natural resources included sale of firewood, timber, traditional medicines, building materials and charcoal making. Timber, building poles and charcoal are mostly derived from mangroves. Some households from the *poor* engaged themselves in handcrafts, especially mat making, mainly for subsistence, although some artefacts were also sold to raise household incomes. Similarly, petty businesses included running of supply kiosks and food vendors (*mama ntilie*).

Dependence on Vulnerable Resources and Services

Dependence on resources and services is a measure of how dependent households are on local resources that are vulnerable to climate impacts for their food security, income, physical protection or other sociocultural aspects (Malleret-King et al. 2006). These resources might be natural, such as ecosystems and their products and services, or man-made infrastructure, such as jetties, coastal roads and other facilities and services, including schools, public health centres and utilities (e.g. power plants and water reservoirs). The man-made resources of the study area have been described in Mbiha and Senkondo (2001). Let us here dwell a little bit on the characteristic behaviour of the main natural resource in the study area, the delta of the Rufiji River.

As already pointed out, paddy was the main crop grown in the study area. Formerly, the crop was grown in upland areas. However, due to climatic variability and land exhaustion, farmers migrated to the delta which offered favourable conditions for paddy. This can be explained as follows: during the rainy season, the Rufiji River floods, and delta areas become occupied with fresh water. The salinity is eventually washed away, and since the plains are naturally fertile due to siltation from the upstream, the conditions so created become favourable for paddy. Conversely, during the dry season, river flow declines, and salty water dominates

Plate 7 Farmers weeding rice farms in Rufiji Delta. Apart from the clearance of the mangrove forests for paddy farms, communities in Rufiji District also rely on the mangrove forest reserve for forestry business through both legal and illegal harvesting. Illegal harvesting and encroachment have contributed to unsustainable clearance of mangroves where large trees are harvested for timber and logging. (Source: Photo adopted from Lupembe 2014)

the flood plains creating saline conditions, which do not support crop growth. Meanwhile, weeds are permanently suppressed from germinating. Farmers are thus attracted to practice paddy farming that entails clearing of mangroves (Plate 7).

Data from the present study show, however, that mangrove utilization by sample households was fairly low. At Mchungu village, for example, only 17.6% of the sample households used mangroves as building material, charcoal and firewood. And among those who used mangroves for such purposes, 11.8% came from the *poor*. In Nyamisati only 6.8% of the households used mangroves for building material, charcoal and firewood. Out of these households, some 4.5% belonged to the *poor*.

Clearance of mangrove forests for agriculture and logging has, nevertheless, affected an important economic activity in the area – fishing. Despite being the major economic activity, fishing was said to be declining due to continued degradation of mangrove fish breeding sites. Agriculture also caused water pollution through fertilizers that farther impacted the integrity of some of the breeding sites.

All these notwithstanding, a recent study by Mwansasu (2016) has shown that no major destruction of mangroves has taken place in the study area and that there is no evidence that prolonged flooding due to, e.g. the 1997–1998 El Niño has permanently damaged the mangrove forest. The results show that mangroves appear to be more or less in a stable equilibrium although the potential of over-exploitation exists. However, another study that analysed land cover change using Landsat images data of 2000 and 2011 (Peter 2013) showed that while the bare land in the delta had increased by 7412.8 ha (2.62%), *Rhizophora* dominance improved by 3076.47 ha (1.09%), *Sonneratia* almost pure stands were enhanced by 1998 ha (0.71%) and *Sonneratia* dominance was amplified by 129.06 ha (0.05%). Elsewhere, *Heritiera* almost pure stands increased by 900.45 ha (0.32%), and their dominance was added by 3872.1 ha (1.37%). On the other hand, *Avicennia* dominance decreased by −1962.9 ha (−0.69%), and it's almost pure stands reduced by −1681.83 ha (−0.59%). A mixture of *Avicennia* and *Ceriops* degraded by −15,222.8 ha (−5.38%), while *Ceriops* dominance dropped by −2302.56 ha (−0.81%) within the period of observation.

Pressures on mangroves in the Rufiji Delta were observed to be mostly human-induced as pointed out above and as argued by Ellison (2015) in another study in the same area. The latter study showed that, though the Rufiji Delta had inherent resilience owing to location on an uplifting coastline with a macro tidal range, the area was vulnerable to human impacts and low local community management capacity. The most critical components to the vulnerability of the area, according to Ellison (2015), were exposure components of relative sea level trends and sediment supply and sensitivity components of forest health, recent spatial changes and net accretion rates.

These findings are corroborated by a reef baseline inventory carried out in 2007 and repeated in 2009 at key coral reef sites offshore of the Rufiji mangrove area (Obura 2010). The inventory found the reefs to be in fairly good condition and on a recovery trajectory from a previous coral bleaching event. The inventory commented on the protective functions that coastal mangroves provided to offshore coral reef health.

Awareness of Household Vulnerability to Climate Hazards

Awareness of household vulnerability of climate hazards measures a household's knowledge of susceptibility to climate hazards and its ability to cope with, recover from or adapt to those hazards (Malleret-King et al. 2006). Households may be at risk for different types of climate-related events. Some may be transient, characterized by rapid onset and identifiable termination (such as storms, floods or droughts). Others may result from a longer-term change in climatic variables resulting in phenomena such as sea level rise, mass coral reef bleaching or ocean acidification.

In this study we investigated the households' awareness to tropical storms, storm surges, beach erosion, beach intrusion and flooding as evidence of the existence and magnitude of these risks. We noted also that different households in the same community may experience each of the factors at a different level and thus have different levels of awareness about their vulnerability to the same types of hazard due to the influence of some socio-economic attributes. So we investigated the household awareness to the five climatic hazards by wealth groups, by educational level and by age groups.

Awareness to Tropical Storms

Generally, only 38.2% reported that they were aware of the occurrence of tropical storms in their villages. Out of those who claimed to be aware of the climatic phenomenon, 29.4% belonged to the *poor*, a majority of whom (23.5%) had primary education and 14.7% had no education at all. Only 8.8% came from the *middle wealth group.* Awareness of tropical storms by age groups for Mchungu Village is shown by Table 2. Again, only 37.5% reported to be aware of the occurrence of tropical storms in their village. A majority of these (18.8%) were from the age cohort 36–55 indicating that tropical storms were very recent phenomena in the study area.

Awareness to Storm Surge, Beach Erosion, Beach Intrusion and Flooding

A similar trend of awareness was observed for storm surge, beach erosion, beach intrusion and flooding in both villages. Relatively few households were aware of the occurrence of these climatic hazards in their villages, again indicating that such occurrences were recent happenings in the study area. Out of those who claimed to be aware of a climatic phenomenon, many came from the *poor*; a majority of whom had primary education and/or no education at all.

Table 2 Awareness of tropical storms by age groups in Mchungu Village (2016)

Age cohort	Responses		Total
	Yes	No	
18–25	0.0	6.2	6.2
26–35	6.2	9.4	15.6
36–55	18.8	28.1	46.9
56–65	0.0	9.4	9.4
66+	12.5	9.4	21.9
Total	**37.5**	**62.5**	**100.0**

Access to and Use of Climate-Related Knowledge

Access to and use of climate-related knowledge measures household access to different sources of information related to climate change, climate variability and its impacts and how this information is used (Malleret-King et al. 2006). It also includes access to any type of early warning system and can, therefore, include past experience, traditional or local knowledge of climate patterns and events as well as other sources of education, media and communications. Data from this study shows that access and use of climatic information was through modern conventional sources such as radio, cellular phones and such other information media. In fisheries, climate information from modern sources was often used in deciding to abstain or to continue with fisheries activities depending on official weather forecasts.

Nevertheless, not all the people in the study area could access the climate information they needed. According to the interviews and FGD responses, most of the barriers lay in the lack of efficient early warning systems at the district and local levels. Failure of government institutions at those levels to predict climatic events such as floods, occurrence of storms in the sea, etc. was mostly due to lack of modern devices for accessing the climate information. Also climate information often required clarifications from experts who were not always there.

From the FGDs it was clear that communities conversely used traditional knowledge usually gained through observation of some local indicators. For example, when the sunrise was associated with red skies in the east, there was a strong possibility that strong winds could occur during the day. Similarly, diminishing brightness of stars associated with fast-moving light clouds indicated the occurrence of rain later in the day. Also, during *mwezi mwandamo* (half-moon), sea voyages were said to be safe as the sea waters were normally calm and safety was guaranteed. However, during *mwezi mpeuzi* (crescent moon), sea waters were said to advance towards the coast with powerful crests that normally made sea voyages unsafe. On the other hand, people could also recognize occurrence of high or low tides using the *hijri* calendar and the onset of *hilari kiza* (full moon). *Hilari kiza* normally occurred from the 25th to 30th day of the Islamic month.

Networks Supporting Climate Hazard Reduction and Adaptation

Formal and informal networks are institutional and social networks that support preparedness for climatic hazards and adaptation. Formal institutional networks may include those that are formalized with clear structure and supported by governmental authorities or institutions, such as hazard mitigation networks, health service networks or protected area networks. Informal networks, on the other hand, are often formed through social connections in a group that shares common values, interests, engagement or purpose (Malleret-King et al. 2006). They could be large families, clans, church groups, women's groups or occupational groups. In some communities, such networks may have been in place for a long time but only recently begun to address climate hazards. In other communities, such networks may have already dealt with climate-related hazards that regularly impact the community.

No such networks could be observed in the study area. Those that were available included religious groups, clan groups, women's *vicoba* groups, etc. that did not specifically address climate-related hazards. However, since about 75% were estimated to be impacted by climate hazards owing to their low-income status, these groups could still be useful networks to cushion climate hazard impacts when and if they occurred. What was needed, according to FGD responses, was the presence of social networks to assist in creating awareness on climate change impacts and livelihood diversification to reduce direct dependence on natural resources. Community education on climate change was also mentioned as an important input.

Ability of Communities to Reorganize

The ability of a community to reorganize refers to the degree to which it is able to collectively learn, plan and make necessary changes to their lives to cope with climate-related impacts in such a way that the main functions of the community are sustained (Malleret-King et al. 2006). This may require restructuring organizations, changing plans, shifting priorities, adjusting roles, carrying out activities in a different way or applying lessons from the past to better face a climate hazard. The degree of community reorganization is a critical indicator of resilience to changing climate. The level of community reorganization is a function of factors including cooperation and collaboration among community members, planning for climate change, level of collectivism in the culture, community leadership, shared goals and responsibilities and access to and support from other sources in reorganization.

This study found out that the administrative structure of the study area is fundamentally based on the Village Council system (Commonwealth Local Government Forum 2009). The intended links between the local government and the residents of a given village are the *Vitongoji* (sub-villages; singular: *Kitongoji*) which are designed to mobilize citizens' participation in local development. Priorities for local service delivery and development projects from the *Vitongoji* are brought to the Village Councils (VCs) for discussion before being forwarded to the Ward Development Committees (WDCs). A ward comprises more than three but less than five villages.

The VCs have three standing committees, i.e. for finance and planning, for social services and for defence and security. The VCs also have statutory committees such as HIV/AIDS committees, water committees and animal health committees in pastoral areas. The VCs have discretion to establish further committees, although there is a maximum limit for each type of authority. Committees for particular climate change hazards can be established under this prerogative as the role of such committees is to oversee the work of specific projects in the villages.

Table 3 Village Councils by number of committees, constituent members and gender

Village council	No. of committees	No. of members	No. of women
Nyamisati	3	25	5
Mchungu	3	19	3

VCs must have 25 members consisting of a chairperson elected by the Village Assembly (VA). The VA comprises all adults in the village who are over the age of 18, all chairpersons of the *Vitongoji* within its area and other members elected by the assembly. Women must account for 25% of the council members.

In this study, both the study villages had full-fledged VCs although they differed in the number of constituent members and gender as shown in Table 3.

Governance and Leadership

Governance is a very broad indicator that measures a variety of characteristics that together indicate how process and decisions are made to serve the best interests of the community and stakeholders (Malleret-King et al. 2006). We focus here on leadership and stakeholder participation in management and decision-making. Leadership measures the presence of community leaders or government officials who can mobilize climate change responses and resources to support adaptation and their effectiveness or credibility. This indicator is important because communities with strong, trustworthy, effective leaders will be more able to adapt. Stakeholder participation in management and decision-making is critical to buy-in of any new programme related to climate change.

The most important governance and leadership institutions in this context were the Tanzania Forest Services (TFS) and the Beach Management Units (BMUs). The TFS is a central government agency that has the responsibility to conserve and protect mangrove forests. Collaborating with village natural resources committees, the TFS verifies mangrove reserve boundaries, formulates by-laws for mangrove forest management, conducts patrols and supervises replanting of new mangroves in degraded areas.

The BMUs, on the other hand, are community conservation initiatives whose responsibilities include the collective conservation and management of both coastal and marine resources and approval of the eligibility for issuance of fishing and mangrove forest harvesting permits. An example of such an institution in the study villages is the beach conservation and management initiative for four villages, Mchinga, Mfisini, Mchungu and Nyamisati (MCHIMCHUNYA).

Firstly, according to the FGDs and key informant interviews, stakeholder participation in the management of coastal and marine resources in the study area was facing serious challenges. For instance, issuance of forest harvesting permits is managed by TFS whereby village authorities have no voice even for reserves that fall under areas of their jurisdiction. Thus verification by village authorities of the legitimacy of permits issued is not possible.

Secondly, there is often lack of value for money spent in the implementation of mangrove reforestation projects. Often the amount of money that is quoted to have been spent in a particular project are not translated into quantity and/or quality work in actual project implementation. For example, in 2011, donors granted Tsh 700 m for a mangrove reforestation project in the degraded areas, but such an amount could not be translated into actual project implementation, clearly portraying the tendency of embezzlements of funds allocated for particular projects.

Thirdly, there were clear interferences in duties and responsibilities between stakeholders. For example, BMUs have been mandated to manage both coastal and marine resources. However, in practice they have been working on marine resources only and not on coastal resources because mangroves were said to be government resources. In addition, BMUs are mandated to approve eligibility of granted coastal and marine resources harvesting permits. In practice, however, those permits were issued by government agents without BMU's approval. This tendency by permit-issuing agents demoralized the BMUs from accomplishment of given tasks.

In an effort to improve stakeholder participation, villages have been instructed to prepare management plans, whereby they are required to sign contracts with the TFS so that the illegally harvested mangrove forest products seized and/or confiscated during various management operations shall be handed over to village authorities for village use. Of the revenues collected from the sale of the products, 5% should be given back to the community through the Village Environment Committee. The system was introduced as a benefit-sharing scheme to engage communities in sustainable management of mangroves.

Conclusion and Recommendations

This chapter set out to answer the questions of how fisher-mangrove-dependent societies such as those of the Rufiji Delta in Southern Tanzania were being affected by and what was their capacity to adapt to climate change impacts that were occurring in their area. The objective of the paper was not only aimed at 'improving linkages between the practice of community-level assessments and efforts to develop and implement vulnerability-reducing interventions'; it was also an attempt to address the critique offered by McDowell et al. (2016) about the need for a more integrative, community-engaged approach to assessments in vulnerability scholarship.

Social vulnerability assessment is a process that engages those who are impacted by changing climate to provide input on their strengths, weaknesses, opportunities and limitations in addressing climate events and impacts (Malleret-King et al. 2006). In this study, despite differences in wealth status, in general community members of the study villages shared similar socio-economic characteristics and were thus anticipated to be impacted in similar magnitudes.

What was needed was community education on climate change impacts or what Lance Gunderson calls 'the need for experimentation and learning to build adaptive capacities' (Gunderson 2010) and the presence of social networks to assist in creating awareness on climate change impacts and livelihood diversification to reduce direct dependence on the fisher-mangrove ecosystem. Such livelihood diversification strategies included provision of capital for small businesses and establishing environmentally friendly activities such as compound-based livestock keeping (zero-grazing) and modern beekeeping.

Such capacity building of communities and other relevant stakeholders to effectively respond to climate change impacts in agriculture, fisheries and mangrove conservation sectors envisaged three key outcomes:

- Improved output and income through supported sustainable agriculture and fisheries practices.
- A critical mass of vulnerable communities and other relevant stakeholders are capacitated and equipped and practice low-cost and efficient wood-saving technologies that will reduce significantly the impacts of mangrove deforestation.
- Strengthened institutional capacities to plan, govern and respond to climate change impacts in agriculture, fisheries and mangrove conservation in the study area.

References

Adger WN (2000) Social and ecological resilience: are they related? Prog Hum Geogr 24(3):347–364

Cinner JE, McClanahan TR, Graham NAJ et al (2011) Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. Glob Environ Chang 22:12. https://doi.org/10.1016/j.gloenvcha.2011.09.018

Commonwealth Local Government Forum (2009) Local government system in Tanzania (sine anno). http://www.clgf.org.uk/userfiles/CLGF/File/2008_Country_Files/TANZANIA.pdf

Ellison JC (2012) Climate change vulnerability assessment and adaptation planning for mangrove systems. World Wildlife Fund (WWF), Washington, DC

Ellison JC (2015) Vulnerability assessment of mangroves to climate change and sea-level rise impacts. Wetl Ecol Manag 23:115–137. https://doi.org/10.1007/s11273-014-9397-8

Grandin BE (1988) Wealth ranking in smallholder communities: a field manual. Intermediate Technology Publications, Rigby

Gunderson L (2010) Ecological and human community resilience in response to natural disasters. Ecol Soc 15(2):18. http://www.ecologyandsociety.org/vol15/iss2/art18/

Ireland C, Malleret D, Baker L (2004) Alternative sustainable livelihoods for coastal communities: a review of experiences and guide to best practices. The IDL Group/IUCN, Crewkerne, Somerset, UK

Lupembe IB (2014) Carbon stocks in the mangrove ecosystem of Rufiji River Delta, Rufiji District, Tanzania. Dissertation, Sokoine University of Agriculture, Morogoro, Tanzania

Maina J, Venus V, McClanahan TR et al (2008) Modelling susceptibility of coral reefs to environmental stress using remote sensing data and GIS models. Ecol Model 212:180–199

Malleret-King D, Glass A, Wanyonyi I et al (2006) Socio-economic monitoring guidelines for coastal managers of the Western Indian Ocean. SocMon WIO.CORDIO East Africa, Version 1

Marshall NA, Marshall PA, Tamelander J et al (2010). A framework for social adaptation to climate change: sustaining tropical coastal communities and industries. IUCN, Gland, 36 pp

Mbiha ER, Senkondo EMM (2001). A socio-economic profile of the Rufiji floodplain and delta. Environmental management and biodiversity conservation of forests, woodlands, and wetlands of the Rufiji delta and floodplain. Technical Report No. 6, Rufiji Environment Management Project, Dar es Salaam, Tanzania

McClanahan TR, Cinner JE, Maina J et al (2008) Conservation action in a changing climate. Conserv Lett 1:53–59

McDowell G, Ford J, Jones J (2016) Community-level climate change vulnerability research: trends, progress, and future directions. Environ Res Lett 11. https://doi.org/10.1088/1748-9326/11/3/033001

Mkindi AR, Meena HE (2005) Rufiji district residents and adaptation to environmental changes over time. Envirocare. CEEST Foundation. 14 pp

Mwansasu S (2016) Causes and perceptions of environmental change in the mangroves of Rufiji Delta, Tanzania: implications for sustainable livelihood and conservation, Dissertation, Stockholm University, Sweden

Obura D (2010) Vulnerability and resilience to climate change of coral reefs of Mafia and Songosongo Islands, Tanzania. Turbidity and fisheries as driving forces. WWF Tanzania Country Office, Dar es Salaam

Peter L (2013) Assessment of the status of mangrove vegetation and their degradation in Rufiji Delta in Tanzania. Dissertation, University of Ghana, Legon

Semesi AK (1992) Developing management plans for the mangrove forest reserves of mainland Tanzania. Hydrobiologia 247:1–10

Wagner GM, Sallema-Mtui R (2010) Change analysis of Rufiji- Mafia-Kilwa mangroves, Tanzania, in relation to climate change factors and anthropogenic pressures. WWF US/GEF Coastal Resilience to Climate Change Project. WWF Tanzania Country Office, Dar es Salaam. 158 p