ORIGINAL PAPER

Understanding current and future vulnerability in coastal settings: community perceptions and preferences for adaptation in Zanzibar, Tanzania

J. Mustelin · R. G. Klein · B. Assaid · T. Sitari · M. Khamis · A. Mzee · T. Haji

Abstract Many developing countries are already affected by multiple stressors, which have increased their vulnerability to accelerated negative environmental change. Coastal erosion, deforestation and habitat fragmentation become even more serious problems in coastal locations when coupled with the projected impacts of climate change. However, anticipatory adaptation to such changes as increased coastal erosion and extreme events does not need to wait for specific climate scenarios, but is more reliant on the examination of current vulnerabilities and the range of possible no-regret strategies. These need to, however, accommodate multiple stakeholder preferences. This study therefore examines coastal communities' perceptions of environmental change in northeast Zanzibar, Tanzania and their preferences for adaptive strategies, while simultaneously examining physical change processes through change analysis. The study suggests coastal forest buffer zones as an anticipatory adaptation measure, which is based on soft measures such as vegetation planting, awareness raising and stakeholder cooperation.

Keywords Climate change · Vulnerability · Coastal communities · Coastal forest buffer zones · Zanzibar

Introduction

Although it is well known that developing countries will be most adversely affected by climate change and in the need of adaptation strategies (Füssel 2007), some countries in the developing world still have not even begun to discuss adaptation. This can be somewhat surprising as, for instance, in Africa many livelihoods are found in climate-sensitive sectors (agriculture, tourism, fisheries) and thus will be adversely impacted (Brown et al. 2007). Furthermore, human population densities are extremely high in coastal areas where sea level rise will cause increasing inundation, flooding, shoreline recession and salt water intrusion together with extreme climate events (Nicholls et al. 2007). However, despite these dire projections, developing countries have often other priorities as they are still dealing with poverty reduction, health care provision and economic growth (Mimura et al. 2007). These are indeed crucial actions as reduction of poverty and increased access to resources can reduce vulnerability and simultaneously increase people's adaptive capacity (Adger et al. 2005).

Nevertheless, although climate change impacts may not be the largest threat in developing countries, they become serious threats when coupled with anthropogenic impacts (Boko et al. 2007, Dubi 2000). For instance, non-sustainable resource use reduces the adaptive capacity of natural systems and thus decreases the resilience to respond to climatic changes (Dubi 2000). In addition, there are numerous examples from coastal environments where such factors as tourism development and population growth have fractioned the natural system leaving both the communities and the environment with increased vulnerability (Gössling 2003; Mustelin 2007; Nicholls et al. 2007). Vulnerability in turn consists of multiple underlying factors such as land rights and access, livelihood strategies, infrastructure and the environment, which determine society's opportunities and dependencies in a particular location (Barnett and Adger 2007). Understanding vulnerability thus has a priority in understanding adaptation options and strategies.

However, although impact and vulnerability assessments have largely driven the formulation of adaptation strategies and policies (Hinkel et al. 2010), it has been argued that the absence of such information does not mean that adaptation processes should or must wait (Adger et al. 2009). For developing countries, this approach has taken form through the development and formulation of National Adaptation Plans for Action (NAPAs) under the UNFCCC. Nevertheless, NAPAs do not always cover all areas equally and cannot thus produce a coherent understanding of specific challenges in local contexts. For instance, Tanzania has conducted its NAPA, which only briefly mentions Zanzibar that is an island state in union with Tanzania (NAPA 2006).

Some of the projected impacts for Tanzania suggest a decrease in rainfall and higher temperatures in inland areas and increases in rainfall on the coast (Mwandosya et al. 1998), which indicates more severe flooding on coastal areas (Paavola 2003), especially if these are low-lying (Ngusaru 2000). Moreover, the Tanzanian NAPA discusses coastal vulnerability and quite correctly cites environmental management programs as existing adaptation strategies. This correlates well with Paavola's (2006) view that effective natural resource management and equal

resource access are vital in effective adaptation. This is, however, based on the assumption that the existing structures are functional and that environmental management programs work, which is, for instance, not the case in Zanzibar (Mustelin et al. 2009). Furthermore, as Zanzibar is more likely to experience climate change impacts similar to those of the small island states (Paavola 2006), a discussion needs to begin which considers the adaptive capacity of the Zanzibari communities and institutions apart from the mainland context. One existing issue that provides a window of opportunity for such discussion is coastal erosion, environmental governance and the different adaptation options to deal with the problem.

Different adaptation options to deal with coastal erosion concentrate on hard (solid structures) and soft (vegetation) infrastructure options or retreat (Daniel and Abkowitz 2003; Phillips and Jones 2006). However, hard structures aggravate coastal erosion and disturb the natural processes of sedimentation (McFadden 2007). Furthermore, physical structures in a dynamic shoreline zone prevent natural flows and create new flows resulting in an alteration in erosion and in sedimentation patterns (Conway and Nordstrom 2003; Middleton 1999). Nevertheless, hard infrastructure solutions are often the preferred climate change adaptation measures. For instance, the Samoan islands have constructed seawalls to protect their shoreline from the projected climate change impacts (Sutherland et al. 2005) and the Tanzanian NAPA also calls for such hard-infrastructure solutions as adaptation strategies to climate change impacts (NAPA 2006). However, hard infrastructure, such as groins, seawalls and breakwaters, is often costly and requires long-term maintenance (Phillips and Jones 2006). Seawalls in particular exacerbate shoreline erosion by reflecting wave energy (Beatly et al. 2002). These options have also questions of social justice attached to them as costs and benefits fall to different actors (Cooper and McKenna 2008).

In these discussions, however, the soft strategies have remained somewhat underrepresented. This is somewhat peculiar although there have been already indications that a healthy shoreline environment with coastal vegetation can function as an important protective barrier, for instance, against tsunami waves. The most recent example is from the Indian Ocean tsunami in 2004 (Forbes and Broadhead 2007) where mangrove forests and casuarinas proved to be vital as coastal barriers (Danielsen and Suryadiputra 2005). In addition, in Sri Lanka coastal forest buffer zones have been created by moving communities away from the coast and establishing buffer zones between the sea and the communities (Ingram et al. 2006). Furthermore, coastal vegetation functions to prevent excessive erosion by stabilizing beach sand (Avis 1989; Goudie and Viles 1997; Lubke 1985). Vegetation cover absorbs wave energy, which otherwise erodes the beach, and therefore causes a decrease in erosion and offshore sedimentation (Türker et al. 2006). Vegetation also plays a role in beach development as sand accumulates on the lee of plants (Lubke 1985). In addition, a rich diversity of beach flora is most effective in mitigating wave action, as the vertical structure created by the roots, stems and foliage of different species reduces wave energy at various levels (Forbes and Broadhead 2007).

This article therefore tracks one of the first attempts to examine how an environmental governance problem, such as coastal erosion, is explained by coastal communities in north-east Zanzibar and what these explanations mean for climate change adaptation measures. This takes form in analysing stakeholder preferences in improving the state of the coastal environment and their perceptions on multiple stressors causing environmental change. These are then linked to a discussion on how no-regret strategies such as coastal forest buffer zones could be implemented as an adaptation strategy to address coastal erosion. The aim is thus to provide a contextual understanding of perceived change processes among the communities and discuss what implications this has for anticipatory adaptation within the specific coastal setting. The article contributes to the wider literature on climate change adaptation (Adger et al. 2005, 2009; Eriksen and Kelly 2007; Hinkel et al. 2010; Van Aalst et al. 2008) in developing countries in terms of presenting research from a context where no prior climate change scenarios, impact or adaptation assessments have been made but yet where there is an emerging concern for the discussion to begin.

The article uses data based on a previous multidisciplinary research project, which included methods such as semi-structured stakeholder interviews (community members, government officials, experts and hotel managers), sea level rise modelling based on Digital Elevation Models, land-cover and shoreline change analysis based on Geographical Information Systems, aerial photography, quantification of wave exposure and vegetation survey and GPS measurements. Of these data, this paper focuses on stakeholder perceptions accessed through semi-structured interviews, vulnerability mapping of erosion prone areas in the case study area and the implications of these findings in formulating a management strategy for coastal forest buffer zones. However, before presenting the research background, methods and results, there is a need to define and discuss some of the key concepts used in the study.

Vulnerability, adaptive capacity and adaptation

Vulnerability is often used to describe the fragileness of a community, ecosystem or society to external change (McFadden 2007), although, the concept is still not quite defined and agreed on (O'Brien et al. 2004). However, what is clear is that vulnerability is not a uniform concept that carries the same meaning for each stakeholder as it differs in scale and meaning. For instance, Wisner et al. (2004) argue that different groups have different levels of vulnerability within communities and not all stakeholders are affected in the same way. This is a rather common sense approach as individuals often have different concerns and interests, which also makes the identification of vulnerabilities complex (McFadden 2007). Thus, suggested adaptation measures should therefore aim to produce net benefits for all stakeholders, instead of producing benefits for few. This is one of the arguments why we explore coastal forest buffer zones as an adaptation measure as these produce benefits not only for the local communities but also for the environment and the tourism industry. Furthermore, as Eriksen and Kelly (2007, p. 11) points out,

instead of only considering technical solutions, we should ask "What can be done to strengthen people's own capacity to respond and adapt?"

The concept of differential vulnerability is thus used to describe the different perceptions on the double and multiple stressors for perceived environmental change (McFadden 2007), whereas vulnerability is understood to include both the physical setting and the socially constructed notion of exposure (Dolan and Walker 2004). In this study, our focus is on vulnerability, which we understand to mean both human and the environment's exposure and sensitivity to a negative external change, while also acknowledging the nature of that change (physical and/or anthropogenic). This is why we aim to provide an understanding of the changes in the physical environment and the perceived environmental changes among the communities and their linkage to vulnerability and adaptive capacity. Adaptive capacity in this study relates to stakeholders' ability to adjust to the changed or changing conditions shaped by political, social and environmental factors at local, national and global scales (Smit and Wandel 2006). Of these scales, our focus is first and foremost on local.

When discussing climate change adaptation, we view adaptation as "…adjustments in ecological-socio-economic systems in response to…expected climatic stimuli, their effects and impacts" (Smit et al. 1999, p. 200). We perceive both vulnerability and adaptation as changing dynamic systems, which are the outcome of interlinking factors and processes on diverse scales (O'Brien et al. 2006). Furthermore, we acknowledge that adaptation is often not equal and individual adaptation might even trigger negative outcomes on others' part (Adger et al. 2005). In this study, however, we focus on anticipatory adaptation, which considers thus possible actions taken in anticipation of the expected changes and impacts (Carter 2007). Nevertheless, as climate change as such is rarely the only concern, we consider actions, which are also related to other stressors such as increased coastal erosion, flooding and protection from the storms. Coastal forest buffer zones in this study relate to zones along the coast, which are created to strengthen coastal vegetation in chosen locations.

Moreover, as adaptation strategies are based on the perceived system characteristics (Reilly and Schimmelpfennig 2000), it is important to understand the current factors perceived to cause change within the system, what those changes are and what can be done about them. This relates to the role of context as Barnett and Adger (2007) claim that the existing societal, political, environmental and economic contexts largely determine which adaptation strategies become available for communities and societies. Context is therefore critical in explaining the double and multiple stressors for negative change, which result or at least aggravate current and potential future vulnerability.

The structure of the article is as follows: first, we provide description of the context for the research, which we begin with a short account of the physical features of Zanzibar in terms of location, geology and seasonal variability. Next, we discuss the double and multiple stressors as identified by previous research in relation to Zanzibar's coastal areas. We expand this discussion also to coastal areas in developing countries and those stressors that are seen generally to affect the resilience of coastal environments. We then discuss aspects of regulatory framework

and practice regarding environmental governance in Zanzibar and what the issues are in relation to monitoring policy implementation. We then present the case study area and the research communities in question.

Secondly, we discuss the use of multiple methods in assessing the viability and possibility for cooperative environmental governance in the research area and explain in detail the used interview methods and change analysis based on GIS and aerial photograph analysis. In the third section, we present the results in terms of the stakeholder perceptions on the change factors, viable measures and the management strategy as proposed. Lastly, we discuss the proposed strategy within the framework of anticipatory adaptation and the challenges in even researching anticipatory adaptation in a developing country setting where climate change and especially adaptation are under-researched and not high priorities. We conclude the article with a discussion on the limitations of our study but also the value of the findings for further research and cooperation.

Zanzibar as a case study: the context and actors

Zanzibar's physical features

Unguja Island, the largest island of the Zanzibar archipelago (also known as Zanzibar), is situated 40 km from the Tanzanian mainland, just south of the equator (5°40′–6°30′S, 39°10′–39°40′E). The island is 85-km long (N–S) and 39-km wide (E–W) and covers an area of 1660 km^2. The western part of Unguja Island consists of Miocene limestone and is characterised by elevated, undulating terrain with deep sandy soil (Hettige 1990). The eastern part of the island is characterised by much younger (Quaternary; <2, 5 million years) deposits covered by a shallow layer of loamy soil and closer the shoreline covered often just by humid material. Despite the shallow and rocky nature of the soil, it is very nutrient rich and is able to sustain natural forest cover (Klein 2008).

The average annual rainfall on Unguja is ca. 1600 mm; however, a large spatial variation in precipitation occurs, ranging from 1100 mm in the eastern parts of the island to over 2000 mm over the higher elevations in the west. The rainfall pattern is bimodal, with the respective main rainfall seasons from March to June (masika) and October to December (vuli). The shorter vuli season is more significant in the western part of the island where it contributes a third of the annual precipitation. In the eastern part of Unguja it is less significant (up to 25% of the annual precipitation).

The coastal platform in Zanzibar stretches from the coral reef landward to a cliff or beach ridge plain 2–3-m above the mean high water. The stability of the beach ridge plain depends on equilibrium between sediment supply and sediment loss. Natural erosion occurs by changes in the prevailing conditions of sedimentation along the shore on annual to decadal timescales. The East African Coastal Current (EACC) prevails along the East African coast and comprises two alternating seasons (Dubi 2000), which result in a natural pattern of beach erosion and sedimentation (Odada 1993). The southeast is from April to October (kusi) and is characterised by

strong winds and significant beach erosion. The northeast is from December to February (kaskazi) and is a period of beach sedimentation. The EACC moves northward throughout year, and is accelerated during the southerly monsoons and retarded by the northerly monsoons (Newell 1957). Although losses of beach sediment are subject to temporal variation, presently it appears to be exacerbated by coastal storms and anthropogenic alterations to the shoreline (Arthurton et al. 1999; Odada 1993).

Double and multiple stressors in Zanzibar

Although Zanzibar has been a focus of much research (De la Torre-Castro and Rönnbäck 2004; Eaton 2008; Fagerholm and Käyhkö 2009; Gössling 2003; Klein 2008; Masalu 2000; Mohammed 2002; Orjala 2006; Sitari 2005; Tobey and Torell 2006), climate change has rarely featured in any of these efforts. However, this does not mean that the governing institutions would be oblivious to the issue. Although the climatic data itself is scarce to enable the conclusion that climate change is taking place specifically in Zanzibar, the Tanzanian Meteorological Agency, Zanzibar Section, has recently recorded extreme temperatures and extreme rainfall events that they link to possible climatic changes (Khamis 2008). In February 2007, the meteorological station at Zanzibar International Airport recorded 39.4°C, which is the highest temperature ever to be recorded for the past 68 years in Zanzibar. In April 2005, a station recorded 474 mm of rainfall just within 24 h, which is the highest recorded rainfall for the past 50 years. In March 2007, the highest sea-level rise was measured in Zanzibar Town where large parts of the town were covered by seawater (Khamis 2008). These events have led to an increasing concern among institutional stakeholders regarding future climate change impacts and adaptation (Mustelin et al. 2009).

The double and multiple stressors on environmental change have been well documented in Zanzibar. The somewhat uncontrolled growth of the tourism industry mostly focusing on international tourism (Gössling 2003; Mustelin 2007) has caused demand for coastal land and created disputes of land rights, ownership and sales among the tourism industry, government institutions and local communities (Mustelin 2007). Lucrative prices have increased the willingness to sell and some families have even sold family graveyard areas to tourism developers, which imply a change in the following of the local social and religious norms (Mustelin 2007). The assumed employment opportunities for locals have not materialised partly due to low levels of education, low investments in tourism education from the government, lack of foreign languages and lack of tourism-related skills among the local communities (Mustelin 2007).

Land scarcity has aggravated trends of deforestation in so far that forest conservation areas are used for firewood collection (Mustelin et al. 2009) and large-scale land cover change has also been well documented (Käyhkö et al. 2008). Poverty has contributed to an intensified use of the existing natural resources and there is an increasing pressure on water resources in the region due to the growing demand (Gössling 2001). Furthermore, the groundwater resources (aquifers) in the area are recharged during rainy seasons; the overflow discharge flowing into the sea

prevents salt water intrusion. However, with drought or over-consumption of water the discharge diminishes and creates a possibility of salt water intrusion; this is likely to occur due to sea level rise as the water table is close to sea level (Gössling 2001). The increasing conflicts regarding water consumption and use between communities and tourism industry in north-east Zanzibar are in danger to become intensified if the availability and supply change. In addition, most of the conflicts regarding natural resource use have materialised because the decision-making processes have not involved all the affected stakeholders (Masalu 2000).

As rural populations in Zanzibar are especially dependent on the natural environment and biodiversity (Orjala 2006) including species richness, any change or loss of species will be a significant factor in increasing community vulnerability. Currie (2001) argues that as species richness relates especially to temperature and precipitation, any climatic change leads to changes in species richness. Climate change causes new species to establish as species that are intolerant to local conditions disappear. Moreover, the extinction of species intolerant to the local conditions occurs quicker than the establishment of new species (Currie 2001). In a human-dominated landscape such as Zanzibar, deforestation and forest fragmentation put additional pressure on biodiversity. Forest fragmentation interrupts dispersal and migration of species, causing a decline in species richness. With increased human pressure, natural vegetation becomes smaller and more scattered within an anthropogenic matrix impermeable for dispersal (Opdam and Wacher 2004). Furthermore, Opdam and Wacher (2004) assert that the establishment of new species in an area caused by climatic changes is impeded or even blocked by habitat fragmentation. Moreover, species diversity also contributes to the stability of an ecosystem, therefore reducing vulnerability against natural and anthropogenic impacts (Kikkawa and Anderson 1986). The role of land cover changes and habitat fragmentation as multiple stressors thus needs to be considered and understood when looking at place-specific vulnerability.

Like coastal environments in many developing countries (Becken 2005; Nicholls et al. 2007), coastal areas in Zanzibar are changing due to anthropogenic factors. These factors are similar what Nyandwi (2001) identifies as the major anthropogenic factors contributing to coastal erosion in East Africa. These include (i) obstruction of natural water and sediment flow, (ii) removal of beach material, (iii) removal of protection against wave activity and (iv) poor planning. Erosion along the Zanzibar shoreline is exacerbated particularly by removal of beach sand for construction as well as construction of hotels and villages too close to the beach (Masalu 2000; Nyandwi 2001). Odada (1993) sketches a common scenario in East Africa in which construction occurs close to the beach. When erosion occurs, short-term solutions, such as walls, are used as prevention. Due to the temporary success, more buildings are built, however, erosion continues at a faster rate. This endless cycle makes beach stabilization and erosion management difficult and expensive. There have been several attempts to create guidelines for enhanced coastal management, such as the Integrated Coastal Management for Sustainable Development of Zanzibar's Coasts (UNEP/FAO/PAP/CDA 2000) but these have fallen short of actual implementation (Mustelin et al. 2009). Although not many stakeholders in the tourism industry have considered soft coastal management

strategies when building new large-scale luxury hotels, Eaton (2008) notes that on the southeast coast of Zanzibar, some hotels have planted Goat's Foot Creeper (Ipomoea pes-caprae) to stabilise their beach. This has had a positive outcome as sand has accumulated on the beach. Nevertheless, most hotels still choose sea walls as their first option (Eaton 2008).

Hotels especially alter the coastal landscape through various activities such as clearing the coastal vegetation, mining sand and building jetties; however, not all hotels modify landscapes in similar ways as some have left indigenous vegetation buffers on the beach (Mustelin et al. 2009). There is a regulation that no housing infrastructure can be built within 30 m from the high watermark in Zanzibar. As it is not enforced, rarely anyone building on the coast follows it. Commission of Tourism is responsible to approve coastal developments, such as jetties, but they also report cases where hotels built a jetty without consulting anyone. Even Environmental Impact Assessments (EIA) that could reduce the negative impacts of large-scale hotels are toothless as there is no effective monitoring of the hotels after submitting the EIA (Mustelin et al. 2009). The policy framework that could thus enable more sustainable planning in coastal areas is hampered due to inefficiency in the follow-up process combined with a lack of actual consequences. The responsible institutions themselves acknowledge this but in their view there is little they can do as they lack the capacity to administrate long-term and efficient monitoring systems (Mustelin et al. 2009).

Research area and communities

The research area consists of three administrative units (Kiwengwa, Pwani Mchangani and Matemwe) on the east coast of Zanzibar (Fig. 1). The administrative areas are of different sizes as Pwani Mchangani consists of only one village, whereas Kiwengwa has three sub villages and Matemwe has over twelve subvillages. For Kiwengwa, all three subvillages (Cairo, Gulioni and Kumbaurembo) were chosen and for Matemwe, three subvillages were chosen (Kigomani, Kilima Juu and Tundangaa).

The research area is situated in the coral rag region, where the soil consists mainly of coralliferous limestone fragments and organic matter (Klein 2008). Beentje (1990) identified the vegetation in the region as dry evergreen bushland. The Kiwengwa–Pongwe forest reserve remains the last patch of forest that represents the biodiversity of the area (DCCFF 2004); however, it is experiencing increasing human pressure. Forest in the centre of the reserve reaches a height of 15–20 m, the vegetation on the outer edge of the reserve has an average height of 7 m and outside the reserve the landscape is dominated by shrubland, agriculture and open patches dominated by pioneer species (DCCFF 2004). It is prohibited by law to cut trees in the reserve (Mustelin et al. 2009).

The total population of North Zanzibar in 2002 was 136,953 with a population growth rate of 2.5% between 1988 and 2002. For example, in Kiwengwa, the total population was 560 persons in 1988, whereas it was 2,429 persons in 2002 (Orjala 2006; Tanzania census 2002). This rapid increase in population partly portrays the effect of tourism-related migration to Kiwengwa as the workforce in large hotel

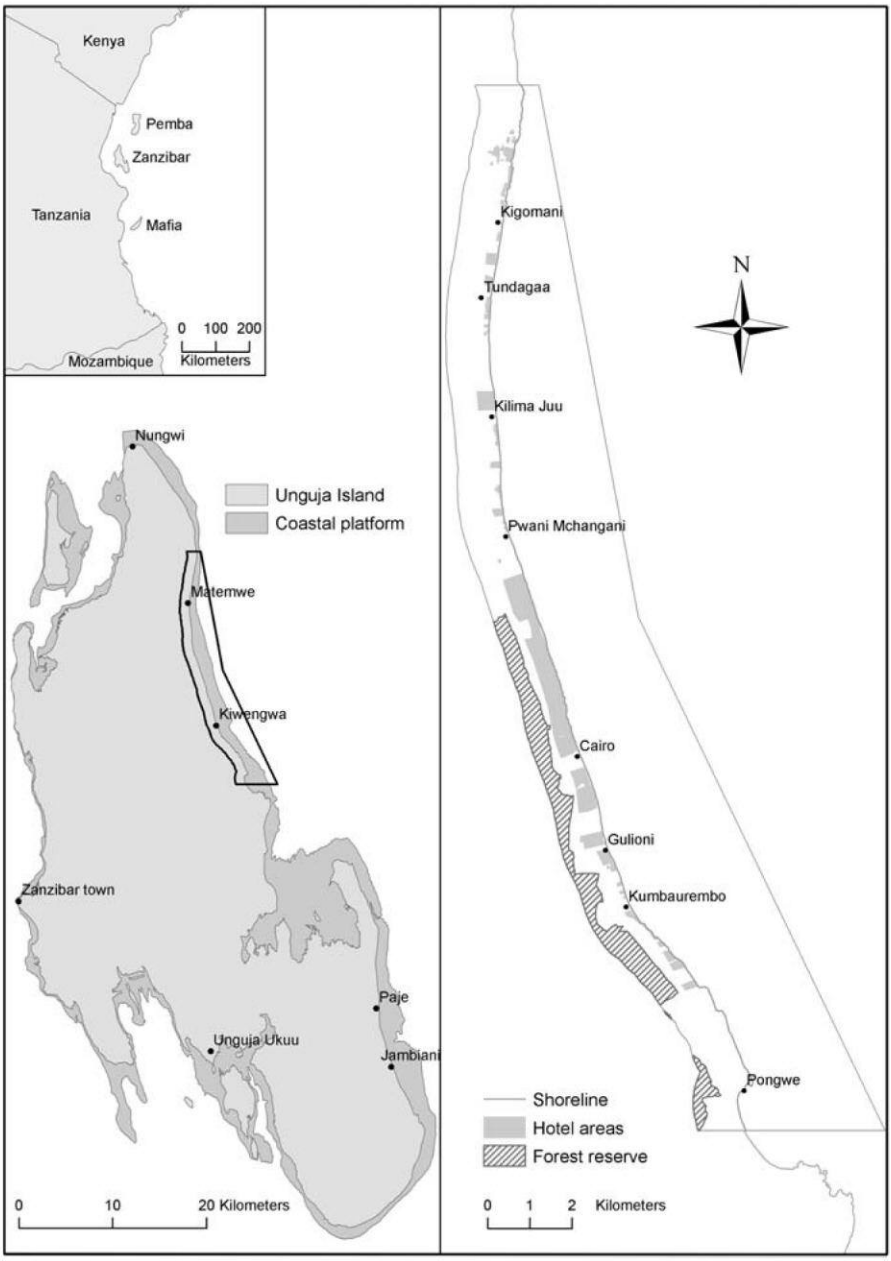

Fig. 1 The research area in northeast Zanzibar including the administrative areas and sub villages where the research was conducted

establishments comes mainly from mainland Tanzania and Kenya (Mustelin 2007). Tourism development has been uneven between the administrative units. Kiwengwa has experienced large-scale tourism since the 1990s (Gössling 2003) and has

currently eight international hotels, whereas there are only two international hotels in Matemwe. Pwani Mchangani has recently experienced similar large-scale tourism development as Kiwengwa.

The coastal communities' multiple livelihood strategies in utilising the coastal zone include fishing, subsistence farming, seaweed farming, tree planting, coconut farming, firewood and building pole collection. Tourism-related livelihoods have also materialised in recent years (Gössling 2003; Mustelin 2007). Most individuals practice several livelihoods simultaneously (Juntunen 2008). Plants are also used for medicine, food and construction besides firewood use. The value of the coastal landscape is thus strongly utility-related on the part of the communities (Fagerholm and Käyhkö 2009). Communities still rely heavily on wood for fuel, which results in heavy utilisation of natural vegetation resulting in environmental deterioration. Cases have been recorded in which people fetch fuel wood from the Kiwengwa–Pongwe forest reserve (Mustelin et al. 2009; DCCFF 2004). Moreover, the communities exhibit a traditional gender division of labour as women's tasks range from firewood collection to seaweed farming, whereas men concentrate on fishing and tourism services. Due to the traditional division of labour still intact in many parts of Africa, Paavola (2006) notes that climate change impacts can increase gender inequality as women's tasks and livelihoods are dependent on the environment in a greater extent than men's who often find employment in market-based systems.

However, unequal power relationships play a significant role in natural resource utilisation. For instance, seaweed farming has become in conflict with the tourism sector (Mustelin 2007). Seaweed farming relies on wooden poles that are placed in the intertidal zone (between the reef and the beach); seaweed grows on a string that connects the poles. The poles cannot be seen during the high tide as they submerge under water and hotels are afraid their customers get hurt when swimming. The hotels now prohibit seaweed farming opposite of hotel properties also on the bases that the farms are not visually attractive. However, Zanzibar's law dictates that all intertidal areas including the beach and the sea are public land and thus cannot be restricted by one party. Nevertheless, informally tourism industry imposes its own rules and seaweed farmers relocate to new areas. However, De la Torre-Castro and Rönnbäck (2004) have suggested that seaweed farming increases coastal erosion as women uproot all sea grass and other vegetation from the intertidal zone before seaweed farms are established. Forced relocation of livelihoods thus can shift resource pressure elsewhere along the coastline. Seaweed farming has, however, brought financial opportunities for women (Tobey and Torell 2006) and therefore negative impacts on this livelihood will first and foremost affect women in the communities (Mustelin et al. 2009).

Methods and datasets

The methods used in the research include semi-structured interviews with local communities, hotels and different institutional actors, vegetation surveys, GIS methods, aerial photograph analysis and literature survey. GIS methods have included change analysis (aerial photographs from 1953, 1978, 1989 and 2004),

Table 1 The datasets used in the research

Data type	Year	Scale	Source
Vertical aerial photograph	2004/2005	1:25000 flight scale	Department of Surveys and Urban Planning
	1989/1990	1:25000 flight scale	Photomap International Inc.
	1978	1:20000 flight scale	Directorate of Overseas Surveys (DOS)
	1953	1:18000 flight scale	Hunting AeroSurveys Ltd.
Topographic map	1985	1:10000	DOS

wave power and shoreline change calculations, modelling of sea level rise (according to IPCC 2007), and mapping of firewood collection points. GPS points have been taken on recently cleared areas, stretches of beach with natural vegetation, hotel areas and demarcated areas for construction and points of significant erosion on the shoreline. Based on the outcomes of the methods, vulnerable areas have been mapped along the coast. The data sets used for this research are presented in Table 1 or were derived from these data sets. The derived data comprise stereo models, a digital elevation model (DEM) and shoreline data. Additional data were obtained from GPS measurements, interviews and seminars. In this article, data is used from the aerial photograph interpretation, GIS methods, vegetation survey and community interviews.

Aerial photograph interpretation and GIS methods

The aerial photographs provide windows to analyse the continuous change process in the research area over the last 50 years (1953–2004). By visually interpreting the aerial photographs, conceptual land cover classes are created. These classes have to be common nominators throughout all four temporal layers to analyse changes. In the 2004 colour aerial photographs, a great deal of detail in the landscape can be identified, however, in the older grey-scale images it is at times hard to distinguish between different vegetation structures. Crude classes were therefore selected, namely: (i) continuous woody vegetation and (ii) open areas and fragmented vegetation cover. Continuous woody vegetation in this case refers to densely vegetated areas consisting of woody plants of substantial height (ca. <3 m). The second class is quite broad and contains low shrubland, sparse or fragmented woodland and open areas (both vegetated and built). This classification differentiates areas that provide ecological and livelihood services (species dispersion and migration, fuel wood, building material, etc.) from other areas.

The land cover classes were digitized from the aerial photographs into vector polygons in ArcGIS 9.2. where needed aerial photographs were viewed in stereo to observe the height of vegetation. A separate data layer was created for each temporal layer and these were then converted into raster layers with a cell size of 10 m. Raster layers facilitate map algebra, which allows for the use of mathematical operations on individual cell values from two or more input layers to produce an

output layer (Heywood et al. 2002). The cell values of adjacent time layers were subtracted ($T_x - T_{x-1}$, where T_x is the raster layers at time x and T_{x-1} is the preceding temporal layer) resulting in an output layer showing changes between adjacent temporal layers. In this manner, changes during 1953 to 1978, 1978 to 1989 and 1989 to 2004 were quantified. All the changes were then combined into one output layer and were visually interpreted. During field work in 2008, GPS points of recently deforested land were collected, imported into GIS and overlain with the woody vegetation changes layer.

Vegetation survey and GPS measurements

Vegetation survey was chosen to investigate whether any species change has taken place in practice in the research area. Vegetation survey was carried with 30 sample plots containing natural vegetation. The plots were chosen to represent the least disturbed patches. The following items were recorded: species, species life form (tree, shrub), species dominance and diameter at breast height and height of all trees. The vegetation was statistically classified through using Cluster Analysis in which the similarity of plots was calculated using the Jaccard similarity coefficient in order to map vegetation patterns in the area (Barbour et al. 1999). Hierarchical Cluster Analysis was then compiled which shows effectively different patterns between the plots (Kent and Coker 2003). XY coordinates on hotel areas, recently cleared land, points of significant erosion and natural vegetation along the shoreline were recorded through GPS measurements (Garmin GPS60). These were transported into ArcGIS 9.2. and used to aid analyses. The results of the cluster analysis were compared to vegetation survey conducted in the same region in 1990 (Beentje 1990) for comparison. Species composition was also checked against Additon's (2004) and DCCFF's (2004) surveys.

Shoreline change

The accurate detection of shoreline position through remote sensing methods is problematic due to the dynamic nature of the coast as the short-term influence of tides and the long-term influence of relative sea level rise on the shoreline position (Appeaning Addo et al. 2008). For this reason the changes along the beach edge (boundary between beach and vegetation/settlement) were examined against the shoreline obtained from the 1:10,000 topographic map of 1986. The aim of this method is not to study the shift of the shoreline, but the shoreline was merely used as a fixed marker to measure fluxations of land and beach along the shoreline and thereby examining the vulnerability of communities along the shoreline to coastal changes. The beach edge in this case, should not be confused with the shoreline, which is where the sea and land meets and is represented by the 0-m contour line on the topographic map. A shift in the beach edge implies deforestation/reforestation processes caused by physical and anthropogenic processes such as wave action, forest clearance and construction. The beach edge from each of the four temporal sets of aerial photographs was delineated. The distance of the beach edge from the fixed shoreline was then plotted in a graph. During field work in 2008, GPS points

were taken from hotel areas along the shoreline. The location of these hotels as well as villages obtained from the 2004 aerial photographs were plotted along the beach edge, to envisage the significance of shoreline changes to the coastal communities.

Interview methods

The interview methods included semi-structured interviews with local community members and questionnaire interviews with hotel managers and staff. The statistical questionnaire used in hotel interviews included questions on hotels' coastal management plans, knowledge of Zanzibar's environmental regulations, environmental change and cooperation with the communities. Fifty-eight persons were interviewed in community interviews (Kiwengwa $n = 27$, Matemwe $n = 22$, Pwani Mchangani $n = 9$), 35 persons regarding firewood collection (Kiwengwa $n = 15$, Matemwe $n = 10$, Pwani Mchangani $n = 10$), 13 hotels were directly visited and interviewed (Kiwengwa $n = 6$, Matemwe $n = 4$, Pwani Mchangani $n = 3$).

The communities were chosen based on their location in the research area (close to the shoreline) and the informants were chosen by the local chief in every administrative area based on their livelihood activities. This method has been applied in previous research conducted in Zanzibar by the University of Turku (Sitari 2005). Parallel research using a systematic sampling method by Mcache (2004) with same research questions in the same area showed significant similarity in results; thus, the supposed bias (the chief choosing the informants) has not been proven to distort the interview results as such. However, it must be acknowledged that the chief can have personal preferences for the informants, which can lead to exclusion of certain community members or views.

The questions in community interviews addressed perceptions of changes in sea level, wave action, erosion, seaweed farming sites, fishing sites, wind conditions, sea water quality, rain seasons, state of coastal vegetation and the causes for the changes. Questions also addressed the best measures to enhance the coastal environment. The interviews were conducted in Kiswahili and translated to English by the researchers of the Department of Commercial Crops, Fruits and Forestry. The interviews were transcribed after each day and saved as Microsoft Word files for further analysis. The village was visited the day before the interviews to meet with the local chief and to request the number of people to be interviewed the next day. This was done to ensure the availability of the informants the next day. This procedure had been effective previously and was used by the local department (Sitari 2005; Käyhkö et al. 2008).

Seaweed farmers and fishermen were chosen as these livelihoods utilise directly the coastal environment. In addition, teachers, community group members and village elders were targeted as these groups interact within the community and are assumed to be knowledgeable on change processes. Gender was an important selection variable for the informants as livelihood strategies in the communities are still divided according to one's gender (Juntunen 2008). For instance, seaweed farmers were all female, fishermen and teachers were male, whereas older informants included both the genders as did community group members. In addition, Paavola (2006) has noted that such traditional labour division can lead to

differential vulnerability between genders, which is why it was important to discuss change factors with both the genders. Children were excluded from the sample due to the preference of speaking with adults based on the assumption that adults would have a longer memory of the area.

Research in climate change and environmental change is, however, difficult to conduct due to the complexities of change processes. For instance, Van Aalst et al. (2008) note that the informants may not have a real understanding of such phenomenon as sea level rise due to a lack of awareness of the issue or they might exaggerate their perceptions to please the researcher. Furthermore, issues given most priority might be completely different than what the researcher is trying to focus on (Van Aalst et al., 2008). This was apparent in community interviews as the prioritised discussion topics centred on sanitation and health, tourism, lack of employment and seaweed farming instead of environmental changes. However, this is not necessarily a negative issue if the answers are analysed in the context of differential vulnerability as representatives of perceived priorities. It was understood prior to the interviews that such long-term processes as sea level rise would not be detected through interviews. The aim with the question was mainly to spur discussions on large-scale coastal impacts rather than sea level rise per se.

Therefore, it was not surprising that some informants gave conflicting answers to different questions regarding sea level rise and wave action. Nevertheless, these distortions have been acknowledged in the analysis of the data as the informants were asked multiple times to explain what they really meant with different answers. The final answer was noted down and used in the analysis. The analysis consisted of organising research questions into different categories (sea rising, wave action, rain season changes and best measures) and then counting the answers (times cited). These answers were placed in Excel worksheets to define general trends in perceptions and conduct comparisons between the research areas. Next, the mapped environmental changes are presented, where after the examination of community perceptions follow.

Research results

Environmental changes during the past 50 years

The analysis of the four different time layers (1953–2004) shows different patterns of change for different areas (Fig. 2). In the southern part of the research area, between Pongwe and Cairo, most of the vegetation clearance has taken place over the last 20 years in the narrow strip between the Kiwengwa–Pongwe forests and the coast. This strip of land is experiencing considerable pressure due to restrictions on wood collection in the adjacent forest reserve. Some villagers, however, admit to collecting wood from the forest reserve due to a lack of wood elsewhere in the region. Pressure on the forest reserve will inevitably increase as the environment outside the reserve continues to degenerate. The black-lined polygons in Fig. 2 show areas which have been cleared in 2008 by means of slash and burn, and there are also many of these patches between Pongwe and Kumbaurembo that were being

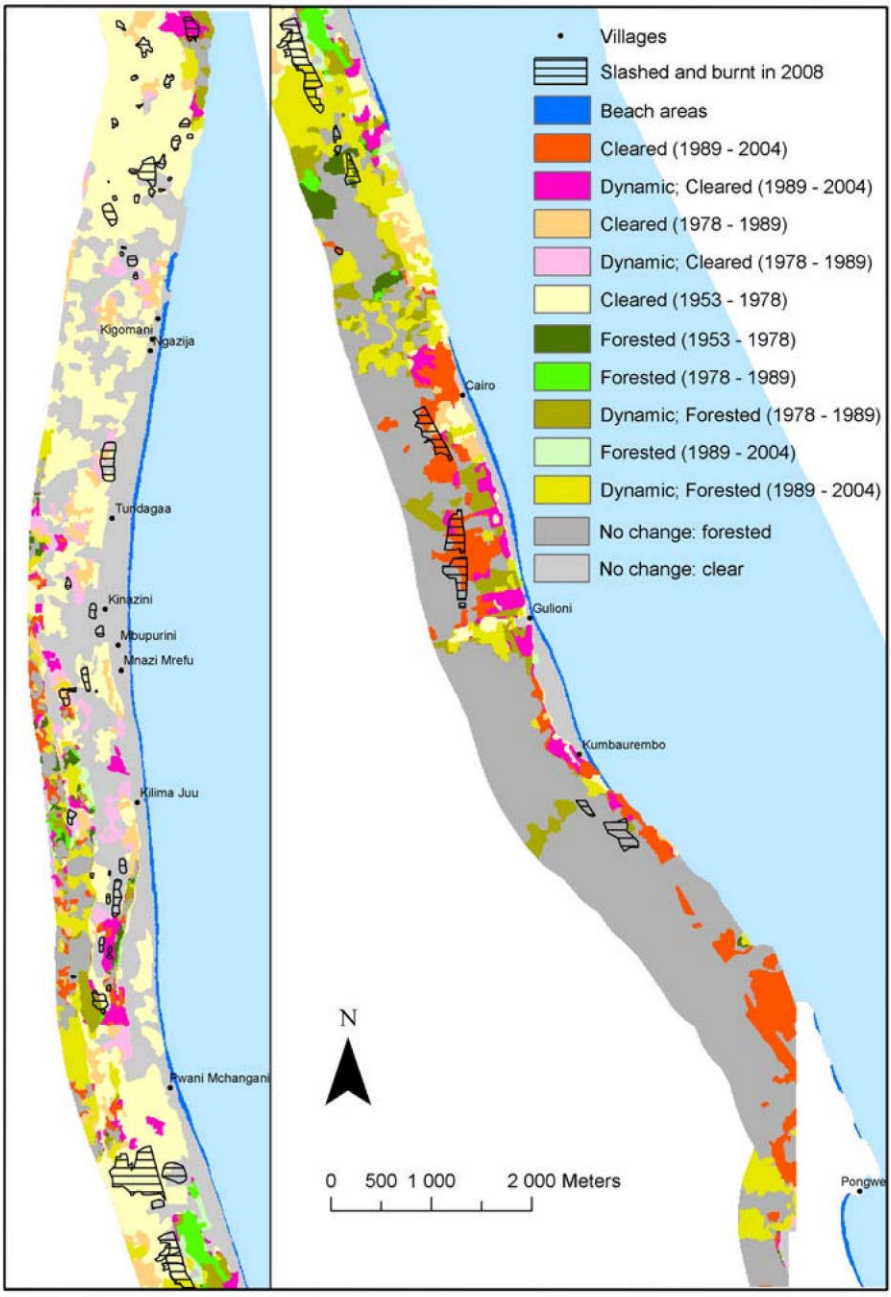

Fig. 2 Changes in vegetation structure during 1953–2004. Due to the scaling of the maps, the map on the *left side* is the northern part of the coastline and the map on the *right* is the southern. The point connecting the maps is the *long slash* and burn area shown in *stripes* in both the maps (between Pwani Mchangani and Cairo)

cleared during the fieldwork (May–June 2008) which are not represented in Fig. 2. In the vicinity around Cairo village vegetation clearance shows a pattern of continuous expansion over the last 50 years with very little net gain in forest area.

Another distinct pattern occurs between Cairo and Pwani Mchangani. This is an area of vegetation regeneration, where a large part of the land has been cleared at some point in the past, presumably for agriculture. Some patches in this area have again been cleared in 2008. The area between Pwani Mchangani and Tundagaa is a very dynamic environment, typical for a shifting agricultural landscape. Towards the sea there is a net decrease in woody vegetation cover, however, further inland almost equal amounts of forested and cleared land have been sustained. The area in Matemwe North of Tundagaa has contained fairly open and/or fragmented vegetation cover since the 1950s. However, there is already evidence of species change in the research area. For instance, those plant species identified as abundant and common in 1990 by Beentje in the area were not found or occurred very seldom in 2008. Common firewood species used by communities, such as *Rhus natelensis* (shrub/small tree) or *Flueggia virosa* (shrub/tree), occurred seldom in the sample plots. Other useful species for communities, such as *Pittosporum viviridoflorum*, which are used for medicine, are disappearing from the area (for more details see Mustelin et al. 2009).

The analysis of shoreline change shows significant changes along the beaches of Kiwengwa and Matemwe. In Kiwengwa, built areas correlate with significant beach encroachment. Most large hotel developments have taken place since 1989 and the developments have caused the beach to shift inland. It is common for hotels to clear natural beach vegetation in front of the hotel area causing the beach to encroach inland; this has taken place at hotel areas in Kumbaurembo, Gulioni and the area between Cairo and Pwani Mchangani. Where natural beach vegetation grows along the beach, beach encroachment is reduced or absent. Many of the built areas (villages and hotels) occur in the past beach areas. For instance, when more coastal vegetation is eroded and/or cleared, houses and shops are built on the new available area making them very vulnerable to coastal erosion and flooding. Many built structures along the Kiwengwa shoreline show signs of wave attack and flooding. In some cases buildings were completely destroyed by the sea and only the foundations of the buildings remain. This was related in the community and hotel interviews to a mosque in Cairo that no longer stands due to increased wave activity: "The hotel industry came in 1993 and now the mosque in Cairo is already gone due to wave action and erosion" (Assistant manager, Kiwengwa).

In Matemwe, natural beach vegetation is more common than in Kiwengwa. In Matemwe, Goat's Foot Creeper was observed to grow on the beach slope near small hotels. Other beach species in the area also help to prevent erosion, such as Salt Bush (*Scaevola sericea*) and Screw Pine (*Pandamus kirkii*) to name a few. During field observations it was noted that there are very few signs of erosion along the beach in Matemwe. One reason for the good condition of beach vegetation in Matemwe is the large cemetery areas, which are not utilised for any other purpose, therefore allowing the vegetation to flourish. The cemeteries exhibit the indigenous coastal vegetation which used to grow along most of the beaches in the area. A clear difference between the beaches in Kiwengwa and Matemwe is that the beach slope

of the latter is steeper. In Kiwengwa, beaches appear flat and as a result waves travel much further inland.

Community perspectives on change

Coastal change and processes causing change

The responses for questions on observed coastal environmental changes included stronger waves, weaker waves, sea rising, vegetation loss, erosion and stronger winds (Fig. 3). In both Kiwengwa and Matemwe, sea rising (65%) was the most serious environmental change. This relates to waves encroaching further and further inland and eventually flooding the villages but it does not mean sea level rise per se. In Pwani Mchangani, vegetation loss (26%) and weaker waves (26%) were the most prominent concerns with sea rising also mentioned (17%). It was noted during the interviews that although wave activity is reaching higher, the power of the waves is not as strong as previously. Erosion was mentioned in all communities as a noticed change (Kiwengwa 23%, Matemwe 25% and Pwani Mchangani 17%), whereas stronger winds were only mentioned in Kiwengwa (4%). Vegetation loss along the shoreline was attributed to tree cutting for firewood, hotel activities and land clearing for farming.

The villages adjacent to the beach are flooded once or twice a year. The cause of the flooding is partly seen as an act of God, a punishment for turning away from the Islamic religious practices and partly due to increased erosion, falling of trees and vegetation loss on the shoreline. In the village of Cairo, flooding was said to occur once a year: "Sea is rising, the water comes into the village once a year" (Male, Development Committee member). Another informant in Cairo noted that in 2006, the water had been knee-deep in the village when the sea had risen. This was also the case in Pwani Mchangani where the seaweed farmers said that flooding of the

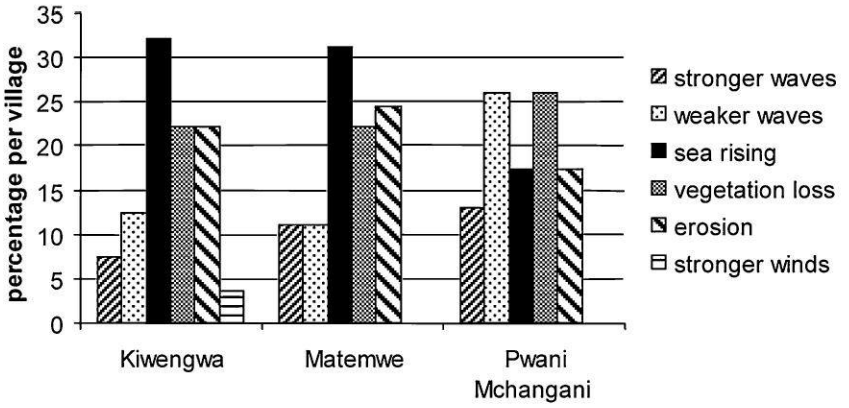

Fig. 3 The noticed changes in the coastal environment according to the informants in Kiwengwa ($n = 27$), Matemwe ($n = 22$) and Pwani Mchangani ($n = 9$). Note that informants have mentioned often several changes; thus, the percentages represent the number of times an option has been mentioned within a research area

whole village took place once a year. This was mostly related to the response "sea rising" and the role of vegetation clearance in waves reaching further inland as noted by teachers in Kumbaurembo (Kiwengwa): "Vegetation clearance takes place because of coastal erosion rather than human-caused deforestation. Hotels use beach sand for construction. Beach vegetation tolerates seawater and acts as a buffer but when it is removed, water reaches to other vegetated areas (not tolerant to salt water) and reaches settlements and hotels".

Coastal erosion and human interference were directly linked for some informants: "Humans can also cause problems, vegetation stops erosion but hotels and houses clear vegetation and thus increase the erosion" (Male, Development Committee member, Kumbaurembo, Kiwengwa). Illegal felling of trees to make fish traps was also directly connected to deforestation as noted by the village leader in Pwani Mchangani. Seaweed farmers in Tundagaa (Matemwe) noted that "Hotels destroy the environment by cutting trees and building walls, they destroy shrubs". This sentiment was related to the conflict between hotels and seaweed farming areas in which seaweed farming was seen as the sole hope the women had for increased income but which hotels did not appreciate: "Hotels and investors are telling us not to seaweed farm because it destroys the environment, they wish tourists to enjoy the beach only…The government perhaps says that seaweed farmers are destroying the environment but thanks to God for mwani (seaweed) because now we can get some money". However, when asked about any changes in the livelihood itself, seaweed farmers consistently claimed that the quality of seaweed was suffering. This was related to stronger winds and wave activity as noted in Kilima Juu (Matemwe): "The quality of the seaweed is getting worse, seaweed gets washed away due to waves and wind" and there was also a notion of increased algae and leaves in the water (seaweed farmers, Kigomani (Matemwe)).

A typical response regarding environmental change in the coastal area is given by two male informants (Gulioni, Kiwengwa): "There are many changes, the sea is rising and vegetation has been lost; the beach used to have such vegetation as palm trees and pine trees but nowadays the wind is just blowing directly to the villages. The villages are no longer protected by the trees and vegetation". This became also apparent when discussing the state of beach vegetation, all the respondents said it used to be so thick 20 years ago that the villages could not be seen from the beach. Village elders' remark in Gulioni (Matemwe): "Twenty to thirty years ago, the coastal vegetation started about fifteen meters closer to the sea than today. In Cairo, there was a mosque twenty-five years ago, which was inland. Nowadays that spot is flooded by the sea. At night time, one could not see the lights of the villages from the beach, so dense was the coastal vegetation". This remark was echoed by many informants in other villages such as the seaweed farmers in Cairo (Kiwengwa): "Twenty to thirty years ago there were lots of trees and vegetation…The waves have also taken the mosque during this time" and village elders in Kigomani (Matemwe): "There used to be a dense forest along the beach. Villages could not be seen from the beach". Some informants went even further in their timescales as, for instance, fishermen in Tundangaa (Matemwe): "The beach was previously 'stabilised' by vegetation. Thirty to forty years ago there was a huge forest between the beach and the village".

The intertidal zone was also said to become shallower as noted by village elders in Kigomani (Matemwe): "We used to fish in the intertidal zone during low tide. It was much deeper: adults could not walk to the reef during low tide, now even children can". Fishermen in Tundangaa (Matemwe) also noted that "The intertidal zone used to be much deeper; a young boy could not reach the reef during low tide by walking". This was related to increased sedimentation in the intertidal zone during the two main seasons: "Process of erosion and sedimentation is normal. During Kusi waves bring sand from the sea and sedimentation occurs. During Kaskasi erosion occurs and exposes the rocks. However, now there is sedimentation in the intertidal zone, even during Kaskasi" (fishermen, Cairo, Kiwengwa). The increased sedimentation in the intertidal zone was perceived to be negative especially by these fishermen who said that they could not fish in the intertidal zone any longer due to the shallowness. Seaweed farming sites and fishing sites had changed. Seaweed farming sites were relocated due to pressure from the hotels and fishing sites had changed due to population pressure as there are nowadays more fishermen than previously.

Another significant environmental factor which informants report is the changes in the annual rainfall pattern. *Masika* (March–June) has become irregular compared to continuous rain for weeks in the past. *Vuli* (October–November) has almost disappeared. Teachers in Tundangaa (Matemwe) said that decreased rainfall has impacts already on the rural livelihoods as plants do not grow in their usual phase; this has direct implications for subsistence farming, which is an important livelihood among the communities. The teachers noted further that "There have been changes in rainy seasons: there is no vuli anymore and masika bas become weak. Maybe it is because climate change and tree cutting". Village elders in Pwani Mchangani echoed a similar kind of response in saying that "many changes in the rainfall, especially Masika rain is too short and sometimes there is no Vuli", which was almost the exact wording of seaweed farmers within the same community.

Best measures to enhance the coastal environment

Six different responses were mostly cited when asked about the best measures to enhance the coastal environment. (Fig. 4) These included vegetation planting (trees, shrubs and creepers), seawalls (physical structures), debris (placing litter on the beach), prohibiting sand mining (hotels extracting beach sand), awareness raising (harmful effects of tree cutting) and cooperation (working on environmental issues with hotels). 80% of all the informants propose planting of vegetation as the most important adaptation measure. This includes planting of indigenous trees, shrubs and creepers. Nevertheless, the community responses differ between the research areas. For instance, in Kiwengwa, cooperation (28%) and vegetation planting (48%) feature prominently, whereas awareness raising (11%) is mentioned only in Matemwe. In Pwani Mchangani, vegetation planting is the primary measure (50%), whereas prohibiting sand mining is the second most popular suggestion (32%). In Pwani Mchangani, cooperation is not acknowledged at all. This discrepancy reflects the different experiences and perceptions for changes in areas along the same coastline as, for instance, Kiwengwa has a longer tradition of cooperating with the

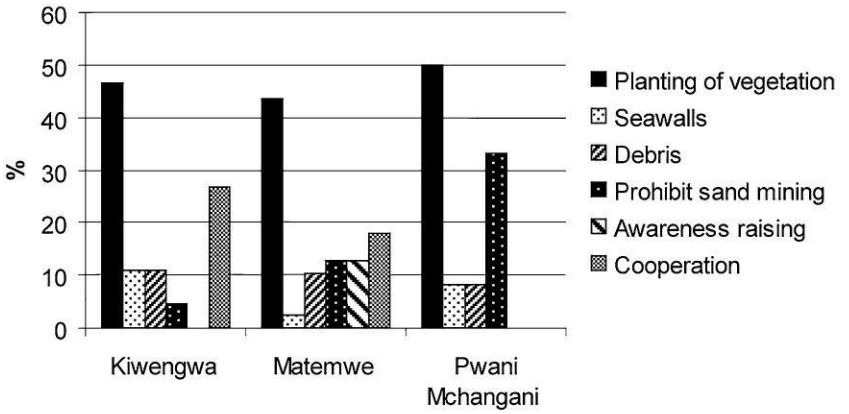

Fig. 4 The proposed measures to strengthen the coastal area as mentioned by the informants in the community interviews (Kiwengwa $n = 27$, Matemwe $n = 22$ and Pwani Mchangani $n = 9$). Note that informants have mentioned often several options; thus, the percentages represent the number of times an option has been mentioned within a research area

hotels than in Matemwe or Pwani Mchangani. However, what these responses show is that the community members are aware of the changes and all have an opinion what should be done.

Teachers in Kumbaurembo (Kiwengwa) noted that hotels should be built further inland and sand mining should be stopped but that although "Regional commissioner put restrictions on sand mining from the beach, local security allows some people to collect sand at night". This relates to monitoring and enforcing of environmental regulations, which was also experienced as a problem by local leaders. Seawalls were suggested as a measure in all communities but it was acknowledged that these were not useful if constructed only on certain places: "The seawalls constructed by investors reduce erosion only for one place but not the whole beach area. Avoid partial construction of these walls. But if necessary, construct such walls to all beach sites" (village elder, Pwani Mchangani). Seaweed farmers and fishermen in Kumbaurembo (Kiwengwa) further noted that such walls are too expensive to build by communities in any case. In Kilima Juu (Matemwe) the female village elder thought that such walls could be an option to protect the village, whereas the male village elder noted that such walls only worsen erosion and are not viable. This was echoed by the comments of fishermen in Gulioni (Kiwengwa), who noted that "…protection of the coast with walls is not an option, trees are better to hold land; this is why tree planting is a good option".

Although tree planting was favoured as an adaptation strategy, there were clear reasons for this as seaweed farmers explained in Kumbaurembo (Kiwengwa): "Tree planting is a good option but it must be community-based, individuals cannot do anything by themselves". This also related to cooperation and responsibility: "There is no cooperation among different stakeholders; people just bother about money but not about the environment. Cooperation is not possible because local leaders are being paid by the hotels not to intervene" (seaweed farmers, Tundangaa, Matemwe). This was in contrast to what the fishermen from Tundangaa said as they

wanted to encourage cooperation between the stakeholders although: "…the government and investors should be in the front line to support tree planting". The community members showed willingness to participate but it was unlikely that they would be ready and willing to start planting just because it was a good idea: "Planting activity can be done by community but the community needs some incentives to do so. They need compensation for tree planting" (village elders, Kigomani, Matemwe). Thus, any suggested measure needs to be seen as viable not only out of sheer good will but also on the proposed benefits such strategies could deliver.

Nevertheless, just mere planting of any vegetation is not an answer in itself. For instance, pine trees are less popular as other crops will not grow under them. Casuarinas collapse easily due to erosion if planted straight next to the beach: "Planting of natural vegetation should be considered…but not exotic trees like casuarinas, this species will only encourage erosion" (village elders, Pwani Mchangani). The communities favour native species and therefore any planting effort must begin with identification of the most suitable species together with the communities. Another significant factor that has prevented planting efforts in the past among the communities has been free grazing of animal husbandry. Goats especially eat most of the seedlings while roaming free. This was seen as an important obstacle for any future planting and maintenance of the plants.

The placing of debris on the beach (household and plant matter) was mentioned in all the administrative areas (Kiwengwa 11%, Matemwe 10% and Pwani Mchangani 8%). In Kigomani (Matemwe), the fishermen noted that "The only problem is the investors building hotels. They sweep away all debris from the beach causing erosion to accelerate. In areas where there are no hotels, there is no erosion". This view was confirmed by village elders in Kigomani, by village head, fishermen and seaweed farmers in Pwani Mchangani and village elders in Gulioni (Kiwengwa) as they all expressed the idea of gathering debris from the environment and from the villages and placing the debris on the beach to stabilise it further. This has been done in Pwani Mchangani where the informants all expressed their view on the viability of this practice as it in their view had stabilised the beach. This was in contrast to hotels' view and practice, which aimed to keep the beaches clean from all the debris.

Discussion and conclusions

Vulnerability consists of diverse actions and processes in both environmental and human systems and their interaction (Dolan and Walker 2004). Vulnerability is thus a sum of actions and processes, which take place simultaneously in both physical and social settings. The change analysis showed increased trends of deforestation, environmental degradation and areas with strong erosion trends. These corresponded with community perceptions of environmental change in which both anthropogenic and natural causes were given as causal change factors: the stressors causing change related to growing pressure on natural resources and land and natural changes in the coastal environment. Building too close to the beach (Masalu

2000; Nyandwi 2001) was reported and confirmed by the shoreline change analysis. In addition, the importance of vegetation cover in stabilising beach slopes (Avis 1989; Goudie and Viles 1997; Lubke 1985) is highlighted in the case of Matemwe where there is much less erosion than in Kiwengwa and Pwani Mchangani. Interestingly enough, in community interviews erosion was mentioned somewhat more in Matemwe than in Pwani Mchangani and Kiwengwa. Less coastal vegetation was perceived to affect the impacts of winds as now winds blow directly to the villages.

In addition, the locations of the villages also make them directly vulnerable to impacts from coastal erosion and such projected impacts as sea level rise: the shoreline change analysis shows that villages have also expanded seawards as the coastal vegetation has decreased between the village and the beach making more area available. Vegetation clearance in turn increases erosion (Türker et al. 2006) and contributes to waves reaching higher inland than previously, resulting in "sea rising" perception of environmental change among communities. Other actors along the shoreline, such as hotels, also contribute to change through their own adaptive measures as they deal with erosion and the aesthetics. Increased sedimentation in the intertidal zone is perceived to affect fishing places to some extent but its effect on seaweed farming is more of a concern as this is one of the livelihoods purely practiced by women. If indeed winds and waves are reducing the quality of seaweed as perceived by seaweed farmers, then that adds to the already existing stressors (conflicts between hotels and farmers on suitable farming areas). This does become a differential vulnerability as it changes the monetary value of the seaweed and women's possibility to gain income from it. The intertidal zone then is thus valued for its utility by these farmers, whereas hotels see its value in providing leisure areas for tourism industry.

Moreover, the vegetation survey showed the gradual disappearance of important species for the communities, which relates to changing land-cover and growing demand for natural resources rather than climatic changes per se. This has, however, important implications for species diversity and ecosystem stability (Kikkawa and Anderson 1986) but also to the communities' way of life as they still depend on natural resources (Orjala 2006). The mentioned perceived decrease in rainfall can also affect the way communities are able to practice their livelihoods in the future. Unfortunately, no recorded figures could be attached to the change in rainfall pattern as no official weather monitoring takes place in this part of Zanzibar. This impedes the establishment of a long-term trend in the weather pattern as well as in local adaptation to weather and possible climatic changes.

The overall perception of change was negative and communities felt very vulnerable due to the array of harmful activities (such as sand mining, tree cutting and vegetation clearance). The communities are not, however, passive victims (Wisner et al. 2004) but suggest a variety of measures to reduce the impacts of coastal erosion. The array of the proposed measures all reflect the adaptive capacity of the communities (Smit and Wandel 2006) as these are measures that communities more or less perceive possible and effective. The most popular measure, planting of vegetation, is a no-regret measure and produces benefits even in the absence of climate change impacts; it is also a soft measure to increase the resilience of the

physical and social setting. The other options did not have such unified support. For instance, hard infrastructure measures usually preferred as adaptation strategies such as seawalls (NAPA 2006; Sutherland et al. 2005) are discussed but they mostly receive negative comments as these measures have been used by hotels and are linked to increasing erosion. However, seawalls are deemed too costly for communities to build or maintain although the responsibility is perceived to rest more on other actors if such options would be considered in the area. Communities' suggestions on placing debris on the beach to stabilise it is based on its perceived functionality; however, its ecological value is obviously not high if the litter contains plastic or other non-degradable items. The coastal environment and perceived measures for its maintenance thus carry different values as communities try to protect their livelihood space, while tourism industry works to maintain an aesthetically pleasing landscape.

However, these values and measures do not necessarily have to be in conflict as they can be incorporated into an adaptation strategy such as coastal forest buffer zones. These zones are only emerging as options for anticipatory adaptation with the aim of reducing coastal erosion through the increase of shoreline vegetation. For instance, in Sri Lanka the creation of such zones has resulted in relocations of communities (Ingram et al. 2006) although this is not the approach considered here. The preferences for soft strategies among the communities suit well with approaches that seek to address both environmental and social vulnerability; they also suit the coastal tourism sector as the environment is enhanced. In the case of Zanzibar, such zones can be implemented through planning in shoreline areas (identification of vulnerable areas). Based on the project results and community preferences a draft coastal forest buffer zone management strategy has been therefore compiled by the Department of Commercial Crops, Fruits and Forestry. This plan includes identified native species for planting, costs of seedlings, planting areas, protective measures to ensure seedling growth, awareness rising and cooperative and training elements between the communities, government institutions and the hotels in the area (Mustelin et al. 2009). These plans require, however, a longer timeframe since the different species need time to form the vertical structure needed for effective stabilisation (Forbes and Broadhead 2007). Thus, they are anticipatory and no-regret in nature if followed through.

There are several impediments to the study, which have influenced the generation of the results. First, there was a difficulty in accessing meteorological data as the Tanzanian Meteorological Agency in Zanzibar considers their data confidential and is inaccessible to the public. Only average values can be obtained which is insufficient to analyse long-term trends. In addition, meteorological stations are unevenly distributed on the main island of Zanzibar as the majority of rainfall stations are located on the western side (Klein 2008). Therefore, rainfall data for the case study areas (north-east Zanzibar) is insufficient to make conclusions that would verify the stakeholder perceptions on rainfall variability and seasonal change. In addition, as detailed research on the status of the coastal erosion in particular has not been carried out previously in the case study area, long-term analysis was not possible otherwise than through GIS methods (aerial photography analysis).

However, although meteorological data is inaccessible and comprehensive assessments of climate change are absent in Zanzibar, this does not mean that research must first wait for climatic data before assessments can begin. There are plenty of adaptation strategies, which can be utilised as no-regret strategies such as implementing rainfall monitoring systems, conducting biodiversity inventories and strengthening monitoring mechanisms for environmental regulations. Unified coastal management approaches (UNEP/FAO/PAP/CDA 2000) are timely for Zanzibar's coastal areas as they can aid in better adaptation to negative change. Government institutions in Zanzibar are beginning to discuss climate change and adaptation and in these discussions, research has a crucial role to play. Therefore, further research is definitely needed in Zanzibar that brings together different institutions, communities and decision-makers and promotes cooperation that increases the adaptive capacity of both human and environmental systems in terms of anticipatory no-regret strategies, which have both social and environmental benefits.

Acknowledgements The article is based on the research project "Practical measures to tackle climate change: coastal forest buffer zones and shoreline change in Zanzibar, Tanzania", which is funded by the Ministry for Foreign Affairs of Finland. The views in this article, however, are of the authors and do not necessarily represent the views of the Ministry. The authors also wish to thank all anonymous reviewers for their constructive comments; any errors remain the authors' responsibility. The authors would also like to thank Dr David Gritten for his useful comments and insights in the preparation of the article. The research project is conducted within the current laws of Zanzibar, Republic of Tanzania.

References

Additon, T. (2004). *Vegetation survey of Kiwengwa-Pongwe Forest Reserve: A baseline study of regeneration and disturbance*. Zanzibar: SIT: Zanzibar Coastal Ecology.

Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change, 15*, 77–86.

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D., et al. (2009). Are there social limits to adaptation to climate change? *Climatic Change, 93*, 335–354.

Appeaning Addo, K., Walkden, M., & Mills, J. P. (2008). Detection, measurement and prediction of shoreline recession in Accra, Ghana. *ISPRS Journal of Photogrammetry and Remote Sensing, 63*(5), 543–558.

Arthurton, R. S., Brampton, A. H., Kaaya, C. Z., & Mohamed, S. K. (1999). Late quaternary coastal stratigraphy on a platform-fringed tropical coast—a case study from Zanzibar, Tanzania. *Journal of Coastal Research, 15*(3), 635–644.

Avis, A. M. (1989). A review of coastal dune stabilization in the Cape Province of South Africa. *Landscape and Urban Planning, 18*, 55–68.

Barbour, M. C., Burk, J. H., Pitts, W. D., Gilliam, F. S., & Schwartz, M. W. (1999). *Terrestrial plant ecology* (3rd ed., p. 649). Menlo Park: Addison Wesley Longman, Inc.

Barnett, J., & Adger, W. N. (2007). Climate change, human security and violent conflict. *Political Geography, 26*, 639–655.

Beatly, T., Brower, D. J., & Schwab, A. K. (2002). *An introduction to coastal zone management* (2nd ed., p. 285). Washington, DC: Island Press.

Becken, S. (2005). Harmonising climate change adaptation and mitigation: The case of tourist resort in Fiji. *Global Environmental Change, 15*, 381–393.

Beentje, H. J. (1990). A reconnaissance survey of Zanzibar Forests and coastal thicket. Zanzibar Environmental Study Series (vol. 7). The Commission for Lands and Environment, Zanzibar.

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R., & Yanda, P. (2007). *Africa*. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden & C. E. Hansen (Eds.), *Climate change 2007: impacts, adaptation and vulnerability* (pp. 687–716).

Contribution to the Working Group II to the Fourth Assessment Report on the Intergovernmental Panel for Climate Change. Cambridge: Cambridge University Press.
Brown, O., Hammill, A., & Kelly, P. M. (2007). Climate change as the 'new' security threat: implications for Africa. *International Affairs, 83*(6), 1141–1154.
Carter, T. R. (2007, January 25–27). Local climate change impacts, adaptation and vulnerability. Paper prepared for the Workshop the future climatic window: Local impacts of climate change, 2007, Seggau Castle, Leibnitz, Germany.
Conway, T. M., & Nordstrom, K. F. (2003). Characteristics of topography and vegetation at boundaries between the beach and dune on residential shorefront lots in two municipalities in New Jersey, USA. *Ocean and Coastal Management, 46*, 635–648.
Cooper, J. A. G., & McKenna, J. (2008). Social justice in coastal erosion management: The temporal and spatial dimensions. *Geoforum, 39*, 294–306.
Currie, D. (2001). Projected effects of climate change on patterns of vertebrate and tree species richness in the conterminous United States. *Ecosystems, 4*(3), 216–225.
Daniel, E. B., & Abkowitz, M. D. (2003). Development of beach analysis tools for Caribbean Small Islands. *Coastal Management, 31*, 255–275.
Danielsen, F., Sørensen, M. K., Olwig, M. F., Selvam, V., Parish, F., Burgess, N. D., Hiraishi, T., Karunagaran, V. M., Ramussen, M. S., Hansen, L. B., Quarto, A., & Suryadiputra, N. (2005). The Asian Tsunami: A protective role for coastal vegetation. *Science, 310*, 643. Accessed April 30, 2008, from www.sciencemag.org.
DCFF. (2004). *Vegetation reconnaissance survey of Kiwengwa Forest, Zanzibar*. Zanzibar: Department of Commercial Crops, Fruit and Forestry.
De la Torre-Castro, M., & Rönnbäck, P. (2004). Links between humans and seagrasses—an example from tropical East Africa. *Ocean and Coastal Management, 47*, 361–387.
Dolan, A. H., & Walker, I. J. (2004). Understanding vulnerability of coastal communities to climate change related risks. *Journal of Coastal Research* Special Issue 39, Proceedings of the 8th International Coastal Symposium.
Dubi, A. (2000). Coastal erosion. In A. S. Ngusaru (Ed.), *Tanzania coastal management partnership: The present state of knowledge of marine science in Tanzania synthesis report*. Tanzania Coastal Management Partnership Support Unit, Science and Technical Working Group.
Eaton, L. (2008). *A historical case study of beach erosion in Paje, Bwejuu and Jambiani: Possible Methods of Prevention*. Zanzibar: SIT Zanzibar, Coastal Ecology.
Eriksen, S. H., & Kelly, P. M. (2007). Developing credible vulnerability indicators for climate change adaptation policies. *Mitigation and Adaptation Strategies for Global Change, 12*, 495–524.
Fagerholm, N., & Käyhkö, N. (2009). Participatory mapping and geographical patterns of the social values of rural communities in Zanzibar, Tanzania. *Fennia, 187*, 1, 43–60.
Forbes, K., & Broadhead, J. (2007). The role of coastal forests in the mitigation of tsunami impacts. Bangkok: Food and Agriculture Organization of the United Nations. Accessed May 9, 2008, from http://www.fao.org/forestry/site/tsunami/en/.
Füssel, H.-M. (2007). Adaptation planning for climate change: Concepts, assessment approaches, and key lessons. *Sustainability Science, 2*, 265–275.
Gössling, S. (2001). The consequences of tourism for sustainable water use on a tropical island: Zanzibar, Tanzania. *Journal of Environmental Management, 61*, 179–191.
Gössling, S. (2003). Market integration and ecosystem degradation: is sustainable tourism development in rural communities a contradiction in terms? *Environment Development and Sustainability, 5*, 383–400.
Goudie, A., & Viles, H. (1997). *The earth transformed: An introduction to human impacts on the environment*. Cambridge: Blackwell Publishers.
Hettige, M. L. (1990). *Land evaluation and land sustainability classification: Unguja and Pemba Islands*. Food and Agriculture Organization of the United Nations.
Heywood, I., Cornelius, S., & Carver, S. (2002). *An introduction to geographical information systems* (2nd ed., p. 123). Essex: Pearson Prentice Hall.
Hinkel, J., Bisaro, S., Downing, T. E., Hofmann, M. E., Lonsdale, K., McEvoy, D., et al. (2010). Learning to adapt: Re-framing climate change adaptation. In M. Hulme & H. Neufeldt (Eds.), *Making climate change work for us: European perspectives on adaptation and mitigation strategies* (pp. 113–134). Cambridge: Cambridge University Press.
Ingram, J. C., Franco, G., Rumbaitis-del Rio, C., & Khazai, B. (2006). Post-disaster recovery dilemmas: Challenges in balancing short-term and long-term needs for vulnerability reduction. *Environmental Science & Policy, 9*, 607–613.

Juntunen, S. (2008). *Rural livelihoods and community lifeworlds: Examining village economies and individual livelihood strategies in Unguja, Zanzibar*. Turku University Department of Geography Publications B: 12 Turku: Digipaino.

Käyhkö, N., Orjala, M., & Mustelin, J. (Eds.). (2008). *Sustainable landscapes in Zanzibar* (152 pp.). Turku University Department of Geography Publications A: 172. Turku: Digipaino.

Kent, M., & Coker, P. (2003). *Vegetation description and analysis: A practical approach* (p. 363). New York: Wiley.

Khamis, A. S. (2008). An overview of climate change-Zanzibar perspective. Presentation prepared for stakeholder workshop in 15th of May 2008 at Department of Commercial Crops, Fruits and Forestry, Zanzibar, Tanzania.

Kikkawa, J., & Anderson, D. J. (Eds.). (1986). *Community ecology: Patterns and process* (p. 432). Boston, MA: Blackwell.

Klein, R. (2008). *The edaphic landscape of Unguja Island, Zanzibar: An exploratory study on the relation between soil variability and landscape* (85 pp.). Turku University Department of Geography Publications B: 11. Turku: Digipaino.

Lubke, R. A. (1985). Erosion of the beach at St Francis Bay, Eastern Cape, South Africa. *Biological Conservation, 32*, 99–127.

Masalu, D. C. P. (2000). Coastal and marine resource use conflicts and sustainable development in Tanzania. *Ocean and Coastal Management, 43*, 475–494.

Mcache, E. (2004). *Impacts of tree planting on the livelihood of communities in Unguja, Zanzibar*. Turku University Department of Geography Publications B: 1. Turku: Digipaino.

McFadden, L. (2007). Vulnerability analysis in environmental management: widening and deepening its approach. *Environmental Conservation, 34*(3), 195–204.

Middleton, N. (1999). *The global casino: An introduction to environmental issues* (2nd ed.). London: Arnold Publishers.

Mimura, N., Nurse, L., McLean, R. F., Agard, J., Briguglio, L., Lefale, P., Payet, R., & Sem, G. (2007). Small Islands. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden & C. E. Hansen (Eds.). *Climate change 2007: Impacts, adaptation and vulnerability* (pp. 687–716). Contribution to the Working Group II to the Fourth Assessment Report on the Intergovernmental Panel for Climate Change. Cambridge: Cambridge University Press.

Mohammed, S. M. (2002). Pollution management in Zanzibar: The need for a new approach. *Ocean and Coastal Management, 45*(4–5), 301–311.

Mustelin, J. (2007). *Tourism, resource access and power in Zanzibar, Tanzania: examining the linkages between tourism, coastal communities and the coastal environment* (108 pp.). Turku University Department of Geography Publications B: 10. Turku: Digipaino.

Mustelin, J., Assaid, B., Haji, T., Khamis, M., Klein, R., Mzee, A., & Sitari, T. (2009). *Practical measures to tackle climate change: coastal forest buffer zones and shoreline change in Zanzibar, Tanzania* (106 pp.). Turku University Department of Geography Publications B: 13. Turku: Digipaino.

Mwandosya, M. J., Nyenzi, B. S., & Luhanga, M. L. (1998). *The assessment of vulnerability and adaptation to climate change impacts in Tanzania*. Dar-es-Salaam: Centre for Energy, Environment, Science and Technology (CEEST).

NAPA. (2006). National Adaptation Program for Action (NAPA) for Tanzania. Division of Environment, April 2006 (48 pp.). United Republic of Tanzania, United Nations Environment Program, Global Environment Facility. Accessed March 31, 2008, from http://databases.sardc.net/books/NAPATanzania/download.php?Tfile=NAPATanzania.pdf.

Newell, B. S. (1957). Cited in: Dubi, A. (2000). Coastal erosion. In A. S. Ngusaru (Ed.), *Tanzania coastal management partnership: The present state of knowledge of marine science in Tanzania synthesis report*. Tanzania Coastal Management Partnership Support Unit, Science and Technical Working Group.

Ngusaru, A. S. (Ed.). (2000). *Tanzania coastal management partnership: The Present state of knowledge of marine science in Tanzania synthesis report.* Tanzania Coastal Management Partnership Support Unit, Science and Technical Working Group. Accessed April 14, 2008, from http://www.crc.uri.edu/download/2001_5047_TCMP_Knowledge.pdf.

Nicholls, R. J., Wong, P. P, Burkett, V. R., Codignotto, J. O., Hay, J. E., McLean, R. F., Ragoonaden, S., & Woodroffe, C. D. (2007). *Coastal systems and low lying areas* (pp. 315–356). In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden & C.E. Hansen (Eds.). *Climate change 2007: Impacts, adaptation and vulnerability*. Contribution to the Working Group II to the Fourth

Assessment Report on the Intergovernmental Panel for Climate Change. Cambridge: Cambridge University Press.
Nyandwi, N. (2001). Survey of the extent of human-induced beach erosion problems in Tanzania. Accessed July 3, 2008, from gridnairobi.unep.org/chm/EAFDocuments/Tanzania/Human_induced_beach_erosion.pdf..
O'Brien, K., Eriksen, S., Schjolden, A., & Nygaard, L. (2004). What's in a word? Conflicting perceptions of vulnerability in climate change research CICERO Working Papers. Oslo, CICERO.
O'Brien, K., Eriksen, S., Sygna, L., & Naess, L. O. (2006). Questioning complacency: Climate change impacts, vulnerability, and adaptation in Norway. *Ambio, 35*(2), 50–56.
Odada, E. O. (1993). Coastal erosion and flooding in East Africa and the Western Indian Ocean. In O. Linden (Ed.), *Proceedings of the workshop and policy conference on integrated coastal zone management in Eastern Africa including the Island States: Report from the Swedish agency for research cooperation with developing countries marine science program.* University of Dar es Salaam, Ministry of Tourism, Natural Resources and Environment Tanzania, Swedish Agency for Research Cooperation with Developing Countries.
Opdam, P., & Wacher, D. (2004). Climate change meets habitat fragmentation: Linking landscape and biogeography scale levels in research and conservation. *Biological Conservation, 117*, 285–297.
Orjala, M. (2006). *Lifeworld and its reflections in rural communities: The interaction between an individual, a village community and nature on the Island of Unguja in Zanzibar.* Turku University Department of Geography Publications B: 8. Turku: Digipaino.
Paavola, J. (2003, June 19–21). Vulnerability to climate change in Tanzania: Sources, substances and solutions. A paper presented at the inaugural workshop of Southern Africa Vulnerability Initiative (SAVI) in Maputo, Mozambique, 2003. Accessed May 2, 2008, from www.gechs.org/savi/workshop/maputo/papers/paavola_tanzania.pdf.
Paavola, J. (2006). Justice in adaptation to climate change in Tanzania. In W. N. Adger, J. Paavola, S. Huq, & M. J. Mace (Eds.), *Fairness in adaptation to climate change* (pp. 201–222). Cambridge: Massachusetts Institute of Technology. The MTI Press.
Phillips, M. R., & Jones, A. L. (2006). Erosion and tourism infrastructure in the coastal zone: Problems, consequences and management. *Tourism Management, 27*, 517–524.
Reilly, J., & Schimmelpfennig, D. (2000). Irreversibility, uncertainty, and learning: Portraits of adaptation to long-term climate change. *Climatic Change, 45*, 253–278.
Sitari, T. (2005). Forestry in the community Lifeworld in Unguja, Zanzibar. In T. Sitari (Ed.), *Forestry, community and biodiversity in Zanzibar* (pp. 37–58). Turku University Department of Geography Publications B: 3. Raisio: Newsprint.
Smit, B., Burton, I., Klein, R. T. J., & Street, R. (1999). The science of adaptation: a framework for assessment. *Mitigation and Adaptation Strategies for Global Change, 4*, 199–213.
Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change, 16*, 282–292.
Sutherland, K., Smit, B., Wulf, V., & Nakalevu, T. (2005). Vulnerability in Samoa. (vol. 54, pp. 11–15). Tiempo, January 2005. Accessed May 3, 2008, from www.tiempocyberclimate.org.
Tanzania Census 2002. (2002). 2002 population and housing Census. Accessed September 1, 2008, from http://www.tanzania.go.tz/census/regions.
Tobey, J., & Torell, E. (2006). Coastal poverty and MPA management in mainland Tanzania and Zanzibar. *Ocean and Coastal Management, 49*, 834–854.
Türker, U., Yagci, O., & Kabadaşh, M. S. (2006). Analysis of coastal damage of a beach profile under the protection of emergent vegetation. *Ocean Engineering, 33*, 810–828.
UNEP/FAO/PAP/CDA (2000). Progress in Integrated Coastal Management for Sustainable Development of Zanzibar's Coast: Unguja Island Coastal Profile and Management Strategy. East African Regional Seas Technical Reports Series No. 7. Split, Croatia, UNEP/FAO/PAP, 2000.
Van Aalst, M. K., Cannon, T., & Burton, I. (2008). Community level adaptation to climate change: The potential role of participatory community risk assessment. *Global Environmental Change, 18*, 165–179.
Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At Risk: Natural hazards, people's vulnerability and disasters* (2nd ed.). London, New York: Routledge Taylor & Francis Group.