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Considering the locals: coastal construction and destruction in times of climate change on Anjouan, Comoros

Beate M.W. Ratter, Jan Petzold and Kamardine Sinane

Abstract

The current discussion of anticipated climate change impacts and future sea level rise is particularly relevant to small island states. An increase in natural hazards, such as floods and storm waves, is likely to have a devastating impact on small islands' coastlines, severely affecting targeted sustainable development. Coastal erosion, notably human-induced erosion, has been an ongoing threat to small island biodiversity, resources, infrastructure, and settlements, as well as society at large. In the context of climate change, the problem of coastal erosion and the debate surrounding it is gaining momentum. Before attributing associated impacts to climate change, current human activities need to be analysed, focusing not only on geomorphological and climatological aspects, but also on political and traditional cultural frameworks. The objective of this paper is to demonstrate the importance of the social-political-ecological systems analysis for adaptation strategies, and thus for future sustainable development. Coastal use is based on human constructs of the coast, as well as local perceptions and values ascribed to the coast. We use the case study of Anjouan, Comoros to differentiate between constructive and destructive practices on the coast, from both a mental and technical perspective. Beach erosion is described as more than a resource problem that manifests itself locally rather than nationally. Divergent political scales of interest impact future development as much as local action. Local action is not least framed by mental contribution and attribution of coasts as places for living, recreation and resource use. The present case study demonstrates that mental constructs of coasts as valuable areas can, in some cases, lead to the protection and preservation of beaches by initiatives of collective action. At the same time, local communities see the negative impacts of sand mining as causes of coastal erosion and, therefore, it is difficult to mobilize them to adapt to climate change and sea level rise.

Keywords: Coastal erosion; climate change adaptation; small islands; SIDS; social-political-ecological-systems; Comoros/Anjouan.

1. Introduction

Current international discussions imply that global climate change represents a major threat to coastal ecosystems and coastal communities (Wong *et al.*, 2014). Small island developing states (SIDS) are considered most sensitive and vulnerable to global climate change due to their limited landmasses, restricted natural and environmental resources, and high concentration of activities and settlements along their coastlines (Barnett and Adger, 2003; Nicholls and Cazenave, 2010). Although future sea level rise may increase the risk of more frequent flooding and storm waves, other expected climate change impacts such as cyclones, coral bleaching, reef destruction and increased erosion and siltation are also likely to have devastating influences on small island coastlines (Pelling and Uitto, 2001; Nunn, 2009; Walker and Bellingham, 2011).

According to Adger *et al.* (2013: 112, after National Research Council, 2010), research and policy on adaptation and mitigation have problematically "largely focused on the material aspects of climate change, including risks to lives and livelihoods, the costs of decarbonizing economies and the costs of impacts on various sectors of the economy". Adaptation, however, is always culturally and socially framed. Many problems associated with sea level rise are in reality problems caused by human action, such as the removal of coastal vegetation, sand mining or maladaptation involving seawalls (cf. Pilkey and Young, 2009). Maladaptation can also be caused by taking action too early or too late due to lack of information, or by applying

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traditional solutions that are no longer sufficient (Barnett and O'Neill, 2010; Noble *et al.*, 2014).

At the same time, coastal erosion has been an ongoing threat to small island biodiversity, infrastructure, settlements, and society at large, even without the current stressors caused by climate change. Limited space and lack of resources (e.g., sand for construction) are pressing issues, especially on small islands. Most notably, human-induced erosion has caused problems on small islands for decades. In order to combat the likely impacts of climate change, a comprehensive analysis of the social-political-ecological systems is needed, which includes the cultural, place-based framing of resources, and acknowledges the political embeddedness of adaptation strategies to climate change, and thus for future sustainable development (Petzold and Ratter, 2015). As the large body of vulnerability literature shows, social contexts influence perception of risks, preference of adaptation options and actors involved (Blaikie, 1994; Cutter, 1996; Hay, 2003, 2013; Adger, 2006; Barnett and Campbell, 2010). As Eisenack (2012: 108) puts it: "diversity of local conditions is one crucial barrier to adaptation".

We propose that a comprehensive social-political-ecological-systems analysis, which includes a baseline analysis of existing coastal activities, needs to be carried out in order to differentiate between impacts caused by climate change and those caused by ongoing human activity (Eisenack, 2012). Coastal processes need to be analyzed not only from a geomorphological and climatological perspective, but also from a political and cultural perspective. Our main premise is that coastal use is based on mental constructs of the coast; in other words, how people perceive and value the coast, as well as what they consider to be the primary utility of the coast. In this paper, we use the case study of Anjouan, Comoros to differentiate between various mental constructs of the coast and their corresponding impacts on the coastal resource base. Focusing specifically on beach use and erosion, we point to the fact that some mental constructs are clearly more destructive of the resource base than others.

The impacts of coastal erosion are most immediately felt by local communities, yet it is clearly more than a resource problem, driven as it is by different interests at multiple scales. In order to deal with the problem, it is necessary to differentiate between divergent political scales of interest, ranging from the local to the national to the international levels, and to identify the specific local contribution and attribution (Petzold and Ratter, 2015). The analysis of climate change impacts cannot be reduced to a natural phenomenon. The objective is to demonstrate the importance of a complex understanding and analysis of interlinked social-political-ecological systems for future adaptation strategies, and thus for sustainable development.

Coastal areas are shaped by local human-nature interactions, which include intensive coastal urbanization, coastal infrastructure and environmentally-destructive activities such as sand mining, mangrove deforestation and unsuitable fishing techniques in reef areas, common on many small islands. These human activities accelerate shoreline modification and increase coastal risks; they progress on a short-term time scale in comparison to long-term sea level rise (Defeo *et al.*, 2009). Adaptation strategies in response to climate change on small islands should not be applied universally, but should to be diverse and plural, reflecting each island's local coastal situation. Analysis needs to encompass not only the specific geomorphological features of coastal erosion, but also the actors associated with the coastal zone, as well as possible adaptation measures (cf. Adger *et al.*, 2005). Who is active in the coastal zone and whose interests are primarily being implemented? What are the perceptions, motivations and objectives of the various coastal users? Which activities along the shorelines contribute to the construction and destruction of beaches? What are the methods used by local people to counteract erosion, and what are their limitations? From these questions, a broader question emerges: in which context do local adaptation solutions emerge, and who is involved in adaptation measures?

Section 2 provides the theoretical framing to analyse human-nature interaction and the particular setting of small island developing states, through a social-ecological systems analysis, extended by the aspect of a political systems analysis. Section 3 gives a concise overview of the mixed methods qualitative approach applied. In Section 4, we present the case study, Anjouan, and selected case study sites. Section 5 consists of the results, presenting coastal erosion problems and human activities in the respective sites. Section 6 finally discusses the results in the context of mental construction and physical destruction of beaches, and thus reviews the role of communities in the context of adaptation to future climate change.

2. Social-political-ecological systems analysis of beach destruction

For many years, coastal erosion has been a major challenge for SIDS. Coastal regions modified by human activities have been most strongly affected by erosion, resulting in increased exposure to natural risks (Nurse *et al.*, 2014). On small islands, erosion affects infrastructure, settlements, economic activities, and ecosystem services (MEA, 2005), many of which are generally located along the coastline. For many small islands, erosion is thus not only a matter of natural physical processes, but also one of interactions within the social-ecological system, which implies coastal modification (Hapke *et al.*, 2014).

Glaser *et al.* (2008: 78) and Glaser *et al.* (2012a: 49) define social-ecological systems as consisting of "a bio-geo-physical unit and its associated social actors and institutions". Complex and adaptive in nature, they are

"delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context,"[1] and are dependent on multi-level interactions of agents that generate emergent structures (Ratter, 2012). The various interactions between natural and social entities can be described as constituting "societal relations with nature," which must be regulated in every society so as to sustain the cross-generational continuation of societal processes necessary for life. Without such regulation, these processes collapse (Becker, 2012). The regulation of material and energy flows, however, is linked to a wide range of cultural symbolizations, and therefore embedded in societal structures and processes of communication (Becker, 2012). As Becker (2012: 44) puts it: "the concept of social-ecological systems (SES) has proven to be the strongest and most convincing candidate in the search for a boundary object relevant both to sustainability science and the study of the multiple interdependencies between natural and social processes along different temporal and spatial scales".

The management of current environmental problems requires an integrative understanding of social-ecological systems. Various systems approaches can help to make sense of and respond to the multiple interdependencies between the social and ecological dimensions of our *life world* (Liu *et al.*, 2007; Odum, 2007; Tretter and Halliday, 2012).

The coastal social-ecological system on small islands is composed of: (a) site-specific morphological characteristics encompassing, for example, the substrate, beach profiles, erosion processes and ocean currents; (b) societal influences on the coast, such as settlements, infrastructure and economic activities (e.g., fishing along the shoreline, sand mining on the beaches, and agricultural use in the hinterland); (c) political and institutional structures on the local, national and international level; and (d) cultural interpretations of the coast, such as images of the beach as a recreational site or a site for religious or traditional ceremonies.

Individual or group responses to coastal erosion can be constructive or destructive in the sense that physical constructions impede natural processes along the coast, but also in the sense that anthropogenic activities, coastal uses or sand mining might have an impact on beach development and destroy the beaches in the long run. Societal agents and individual interaction at the micro level is embedded in political frameworks, leading to the emergence of new policies at the macro level. This, in turn, feeds back into emergent constructs of beaches and with these, their literal construction or (unintended) destruction. Societal responses to coastal erosion may not necessarily be appropriate in that lack of awareness of the consequences and lack of long-term understanding may lead to unintended consequences. However, analysis of past and present processes has the potential to reveal the development of social-political-ecological systems and with this, the possibility of predicting future consequences of human action.

Analyzing local community engagement, especially in the peripheral coastal regions of small islands, is an important step in revealing the origins and impacts of coastal erosion, an aspect often neglected by national authorities and international organizations. If local community engagement is to play a role in the successful implementation of adaptation measures to coastal hazards, understanding of the relevance of different coastal uses, specific local problems and the national political framework within which coastal problems are embedded is needed. Adger (2003) emphasizes the role of social capital and collective action on small islands and peripheral areas (see also Ireland and Thomalla, 2011; Petzold and Ratter, 2015). Community actors and social structures are important in creating awareness of vulnerability and future risks (Hay, 2013), and can also help to mobilize local knowledge and skills (Mercer *et al.*, 2012), build trust within communities and institutions (Walker and Salt, 2006), and connect to higher level authorities, experts, and resources in an effective way through bridging organizations (Berkes, 2009; see also Ireland and Thomalla, 2011).

On the island of Anjouan, current measures to combat beach erosion are mainly justified through anticipated climate change and considered as adaptation measures, especially those supported by international organizations. But these existing measures result in an accelerated beach destruction, which then has to be handled at the local level. A scale sensitive analysis of the Anjouan coastal social-political-ecological system is thus an important step in revealing the origins and impacts of coastal erosion at a local level.

3. Methods

The results presented in this paper are based on background research and empirical work. A literature review of relevant publications related to climate change adaptation in the Comoros was carried out by content analysis, and included various technical reports published by the United Nations Development Program (UNDP), the government of the Union of the Comoros and the government of the autonomous island of Anjouan (PNUE, 2002, 2003; Commissariat Général au Plan, 2005; Ministère du Développement Rural, de la Pêche, de l'Artisanat et de l'Environnement, 2006; Union of the Comoros, 2006, 2012; McSweeney *et al.*, 2008; Thomassin, 2011). The content analysis of respective publicly accessible information is based on 'a priori' explicit coding, followed by an emergent implicit coding (establishing second order categories by coding meaningful terms or small phrases

[1]The term 'complex social-ecological system' describes a concept, a category of thought and an abstraction from reality, and not an actual entity. See more about the critical use of the term 'social-ecological system' in Becker (2012).

Table 1. Overview of the interview partners on Anjouan

Relevant actors from public authorities; elected and administrative officers	Relevant actors in civil society; civilians and businessmen
The governor of the island of Anjouan	The owner of the tourist cottage of Moya
The mayors and headmen of the coastal regions of Ouani, Moya, Sima, Pomoni, Chiroroni, and Hajoho	The owners of land adjacent to the beaches
The responsible personnel of the Centre National de Documentation et de Recherche Scientifiques (CNDRS) in Anjouan	The managers of community associations and NGOs: M'Roundra of Domoni, Fishermen's association of Moya, Association de Lutte contre la Pollution (ALCP), UMAMA-OPAS of Bimbini, Red Crescent Anjouan
The responsible personnel of the Office Anjouanais du Tourisme (Ofantour)	Relevant oral sources of coastal communities and traditional authorities

derived from the data in a contextual analysis; see Stemler, 2001). The empirical work on Anjouan included selected beach profiling measures to assess beach changes and socio-economic surveys, interviews and structured observation of beach frequentation (for further detailed information, see Sinane, 2013 and supplementary material 3), in order to analyze the local population's activities, their perception of and relationship with their built and non-built environment, as well as their appreciation of the beaches and their physical impact on them. In this way, mental as well as technical constructions, deconstructions, and reconstructions of the coast can be revealed. Beach attendance was systematically counted, and semi-structured expert interviews with 99 members of the communities were undertaken. Furthermore, 288 people participated in a structured questionnaire survey of coastal users on Anjouan, which contained open questions (for further information see supplementary material 1, 2).

The interviews, analysed through content analysis, addressed three main themes: the socio-economic evolution of the island; the history of coastal use and management; and the relationships between different coastal user groups. Information drawn from these interviews proved to be much more useful than the official reports published by the government in analyzing the island's socio-economic situation. Both public authorities and civilians were interviewed (see Table 1). Representatives of public and political authorities were chosen according to the relevance of their position in local decision-making, including the governor of the island and the mayors and headmen of villages. Civilians included businessmen, owners of land adjacent to beaches, and members of non-governmental associations. In addition, traditional authorities and people known to be relevant oral sources were interviewed.

To complement the interviews, a questionnaire-based survey among beach users[2] was carried out and qualitatively analyzed. The survey randomly drew 288 respondents, of which 112 were sand miners, 127 were village inhabitants, and 49 were fishermen. Open questions were used to obtain insights into the economic importance of the various beach uses and the coastal communities' perception of beach values and the causes, consequences and solutions to the problem of beach degradation. The aim was to analyze the logic of the various users regarding the damage they cause to the beaches. Moreover, the aim was to assess the feasibility of a joint beach preservation policy based on the assumption that collaboration and support are only possible if users are sufficiently aware of their practices' impacts on the beach (Sinane, 2013).

4. Case study: The island of Anjouan, Comoros archipelago

The Union of the Comoros is an archipelago composed of four islands: Grande Comore (Ngazidja), Anjouan (Ndzuwani), Moheli (Mwali), and Mayotte (Maore).[3] It is located at the northern entrance to the Mozambique Channel, equidistant (300 km) from East Africa and northwestern Madagascar (see Figure 1). The archipelago is of volcanic origin, and the islands' ages decrease from east to west: Mayotte (374 km^2) is the oldest and has a strongly eroded cone and a large lagoon, whilst Grande Comore (1,147 km^2), with its active volcano, is the youngest. Anjouan (424 km^2) and Moheli (290 km^2) both have dissected cones and are of medium age (Guilcher *et al.*, 1965; Battistini and Vérin, 1989).

4.1. Physical setting of Anjouan

Anjouan, this study's focus, is roughly triangular in shape and mountainous; the highest elevation is Ntringui Mountain (1,595 m), at the center of the island. From this central mountain peak, three peninsulas gradually extend out toward the coast: Jimilimé to the north, Nyumakélé to the south, and Sima to the west.

[2]Beach users are defined as persons actively involved in the main coastal activities observed, such as subsistence fishing and sand mining to obtain building material. Beaches are also used as litter dumps by coastal communities.

[3]Politically, the archipelago can be divided in two entities. Great Comoros, Anjouan, and Moheli form the Union of the Comoros, a sovereign state since 1975. Mayotte has been under French administration since 1975, and became a French overseas department in 2011 and an outermost region of the EU in 2014. The island is, however, still claimed by Comoros' authorities, who refer to a UN resolution that recognized that the four islands form one state.

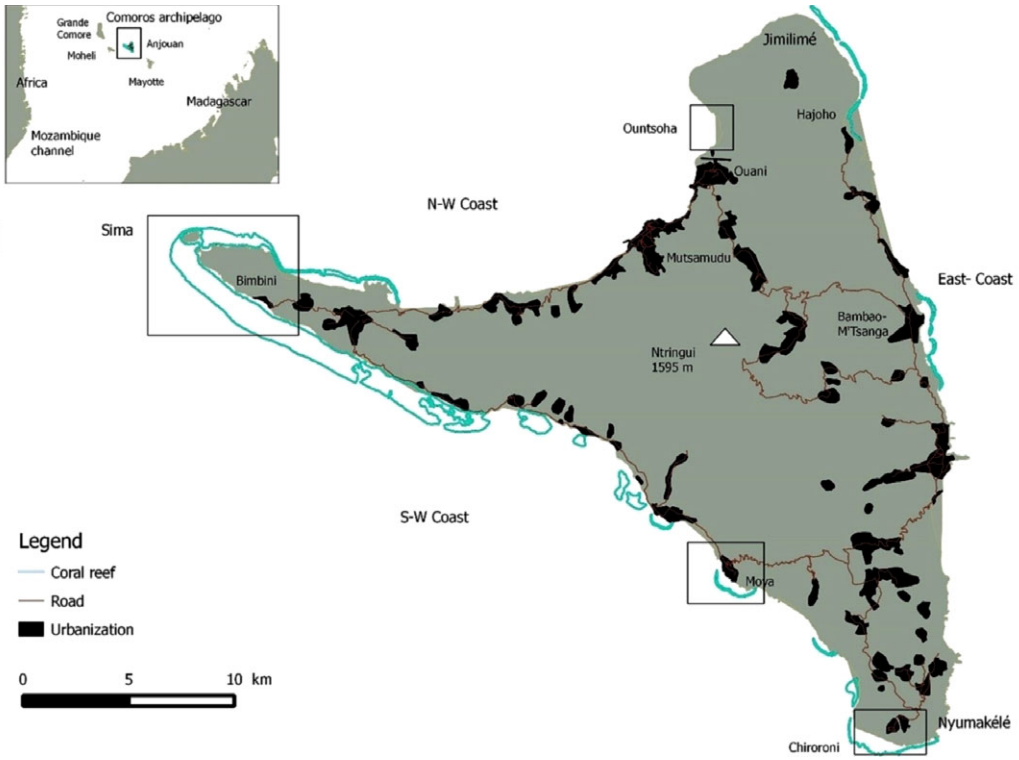

Figure 1. Location and topography of Anjouan; case study sites in boxes.
Source: K. Sinane (2014).

These three peninsulas form three main coastal strips: the northwest coast or Anjouan Bay, the southwest coast, and the east coast. Each coastline is characterized by distinct sediment accumulations. Three beach types can be observed: (a) coral beaches fronted by fringing reefs; (b) volcanic beaches that may be protected by an embryo or fringing reef and; (c) mixed sediment beaches (coral and terrigenous sediment) fronted by a barrier reef. A barrier reef is particularly characteristic of the Sima peninsula, which features mangrove vegetation. Beach profiles vary according to seasonal wave energies, which in a rural context with minimal anthropogenic pressure represent a sign of short-term natural variability on the beaches. In urban and more heavily utilized beaches, profiles tend to be concave, which is indicative of medium-term seasonal erosion due to human impacts (Sinane *et al.*, 2010).

The Comoros are characterized by two main seasons – the hot season from December to July, with on average 200–250 mm of precipitation per month, and the dry season from August to November, with 50–100 mm of rainfall. Temperatures are generally high (27°C) from December to February and lower (24–25°C) from June to August. Although the Comoros are located within the high-risk area for tropical cyclones, the islands are generally protected. Nevertheless, between 1910 and 1990, 40 cyclones were registered in the Comoros (LeGoff, 2010), which has led the UNDP to consider the islands to be one of the ten most vulnerable regions of the world (LeGoff, 2010). Within the Comoros archipelago, cyclone hazards decrease from Mayotte to Grande Comore. Some cyclones have remained in people's memories, including the cyclone of 22 December 1950, Elyna in 1983, more recently Gafilo in 2003, and most recently Elita in 2004, reaching more than 500 km/h of wind speed along the exposed coast.

According to the Comoros climate change profile, the mean annual temperature could increase by 0.8–2.1°C by 2060, and by 1.2–3.6°C by 2090 (McSweeney *et al.*, 2008). The Comoros Ministry of Environment estimates that climate change will cause a loss of 734 ha of agricultural land and a displacement of about 10% of the population across the entire archipelago by 2050 if sea levels rise by 20 cm (Ministère du Développement Rural, de la Pêche, de l'Artisanat et de l'Environnement, 2006). For Anjouan, projections assume that 10, 15 and 90% of the respective inhabitants of Mutsamudu, Ouani and Bimbini will have to move away from the coast (Ministère du Développement Rural, de la Pêche, de l'Artisanat et de l'Environnement, 2006). In the context of global climate change and sea level rise, regional and international organizations such as the World Bank, the European Union (EU), the United Nations Development Program (UNDP), the Indian Ocean Commission (IOC), and others attempt to support Comoros' authorities and associations in their fight against coastal degradation and climate change. The case of Anjouan, however, can show how the local implications

of their ad hoc activities are not always sustainable and, in some cases, are counterproductive.

4.2. Coastal use and the socio-economic situation in Anjouan

The coast of Anjouan has been considered the most valuable area of the island, in contrast to the inland mountain (Robineau, 1966), where settlement is difficult. With 243,732 people and 574 people/km^2 (Commissariat Général au Plan, 2005), the coast is the most densely populated area, even though population density inland is also high (Gérard, 2006). Out of the entire archipelago, the people of Anjouan are considered to be the most poverty-afflicted, especially in the coastal communities. According to the human development index (HDI), human development on Anjouan is estimated at 0.528 the national Comoros level (PNUD, 2003). Of the population 60.9% suffers from poverty, compared to 55.9% on Moheli and 34.3% on Grande Comore. This recent socio-economic situation contrasts with the former potential of Anjouan, which was considered the 'Pearl of Comoros' until the 1970s (Vérin, 1994). Resource degradation can be blamed for this downturn over the last 30 years, and linked to long-term political instability characterized by more than 20 political coups. A recent separatist crisis complicates the struggle of Anjouan in finding a better way of development (Taglioni, 2008). Apart from administrative jobs provided by the government, the economy on Anjouan is based on non-sustainable resource use, with subsistence agriculture and cash crops (e.g., cloves, vanilla, and ylang-ylang) providing 80% of employment (PNUD, 2003). Due to activities such as casual fishing on the reefs and sand mining, erosion is gradually extending to all of the island's coastline, increasing communities' vulnerability to natural hazards in a context of climate change and sea level rise.

5. Results: Contradictions and problems with coastal use

In order to understand the coastal problems and responses to those problems on Anjouan and the other Comoro islands, it is necessary to consider the actors involved at different levels. On one hand, coastal erosion is tackled by national top-down climate change adaptation measures, such as the building of sea walls. On the other hand, local coastal user groups compete for the same coastal space and resources in addition to fighting erosion problems by lay approaches. While national sea wall programmes are restricted mainly to urbanized areas close to the decision center, the local, mainly grassroots, engagements happen in the more peripheral areas. The questions we ask are the following. Which activities along the shorelines contribute to the preservation and concurrent destruction of beaches? What are the perceptions, motivations, and objectives of coastal users and local authorities with regard to beach use and erosion? How do coastal users respond to the impacts of their practices, especially coastal erosion?

5.1. Climate change adaptation policies

Generally speaking, adaptation policies designed to cope with erosion and sea level rise on small islands can be grouped in top-down policies and bottom-up engagements. In SIDS, top-down adaptation policies against erosion and sea level rise are mainly developed by national authorities in the context of global policies – often supported by international or regional programmes, in which donors supervise the use of the funds (Huang, 1997). In general, top-down adaptation policies focus on quickly stopping erosion in a specific (often urban) area, often after an extreme weather event, when authorities concentrate on coping with impacts on central infrastructure and settlement zones (O'Connor *et al.*, 2009). In many of these instances, engineers are asked to find adaptation solutions, commonly leading to the proposal of hard infrastructure, such as sea walls. While such hard infrastructure is commonly considered a success by political authorities and donors because of its visible contribution to coastal erosion management, its efficiency is questionable. In addition to their high cost of construction and maintenance, sea walls actually increase erosion by modifying coastal dynamics by generating and increasing seaward currents (Kundzewicz, 2002). This top-down approach to adaptation is therefore often short-sighted; furthermore, it tends to be applied without analyzing the local coastal anthropogenic disturbances that contribute to erosion on many small islands (Mimura and Nunn, 1998).

But there are also community activities against coastal erosion that have to be taken into consideration. In peripheral regions, characterized by agro-pastoral regimes and little infrastructure or settlement near the coastline—and under the negligence of national authorities—local people must find their own adaptation solutions to erosion. Community activity is usually directed at the same local anthropogenic pressure, as sand mining is a common culprit behind erosion, and accelerates the impacts of climate change and sea level rise. Bottom-up solutions observed at the local level can be very diverse and differ from one region to another. They can be individual (e.g., action taken by the landholder), led by a group of users (e.g., fishermen), or supported by a part of the coastal community (coastal village inhabitants). Their variability is related to the multiple local causes of coastal erosion and its varying impacts on the local economy, such as degradation of fishing resources and the loss of other ecosystem services. But it also relates to conflicts between coastal users due to "differences among people with respect to their awareness of the risks of climate change, preferences for the distribution of benefits and costs of action and inaction, associations and attachments to places, and hopes for the future" (Barnett *et al.*, 2014: 1103; see also Adger *et al.*, 2005).

5.2. Constructs of 'beach' at a local level

Analysis of beach attendance on Anjouan by counting beach users and the observation of the flow of beach frequentation provides a first estimate of anthropogenic uses and pressures on the beach. In general, beach traffic is more intense at low tide than at high tide and is greatest at two similar moments of the daily tidal cycle in the morning and in the afternoon. Outside the port area of Anjouan, fishing boats generally land on the upper beach between two outlets. Customers buy their fish directly from the fishermen after their return from the trip. Beaches are also used as trails or footpaths by farmers to get to their fields or to neighbouring villages. Predominantly young people from adjacent villages use the beach for sportive activities such as football or other beach games, as well as for swimming. Moreover, the beaches are used as dump sites and for sand mining. This points to parallel mental constructs of the beach, which can be summarized as "the beach as a site for cultural activities" and "the beach as an extraction and dumping site". The latter is physically destructive of the beach, implying that one particular mental construct actually contributes to the destruction of others.

The following four local case studies of Chiroroni, Ountsoha, Moya and Bimbini coastal regions (Figures 2–5) exemplify different local perceptions of beach value, beach use and beach destruction. As stated previously, beach construction and deconstruction need to be analyzed from the perspective of existing economic and traditional cultural activities, in order to understand the origins and impacts of coastal erosion. Moreover, the case studies analyze the relevance of social capital mobilization in the peripheral regions as a solution against erosion. We compare local solutions with the official solutions observed on the urbanized coast, which are supported by the local and international authorities.

The Chiroroni coastline (Figure 2) is a part of the southern peninsula of Nyumakélé. The population of the Sadampoini village is mostly farmers and some fishermen living about a hundred meters from the coast. People tend to identify with the coastline of Chiroroni, the name of which is also associated with the village itself. Even though there are no official tourism activities, the coastline is famous among the people of the region, and the reef is considered the most beautiful diving site in Anjouan (Klotchkoff, 2006). A visit is often suggested to the few tourists on the island, and during the holidays, students regularly visit this beach to celebrate the end of the school year. In addition, the beach is used by fishermen as the main landing site for their traditional boats. Since 2006, the beach has been used for sand mining.

The village chief, who collected taxes for each lorry load of sand sold, controlled sand mining. Nevertheless, beach erosion spread, and beach rock was exposed along large parts of the beach. The exposed beach rock causes severe damage to fishing boats and a loss of income, as fishermen had to stay away from work for longer to repair their boats. It is noteworthy that common law forbids the use of fishing nets on Chiroroni reef, with the exception of the month of Ramadan, during which fishermen find it difficult to fish outside the reef. A group of fishermen, however, broke this common law by using fishing nets in June 2009. The headman of the village fined the group of men, but they rejected the sentence. As a condition to accepting the fine, they

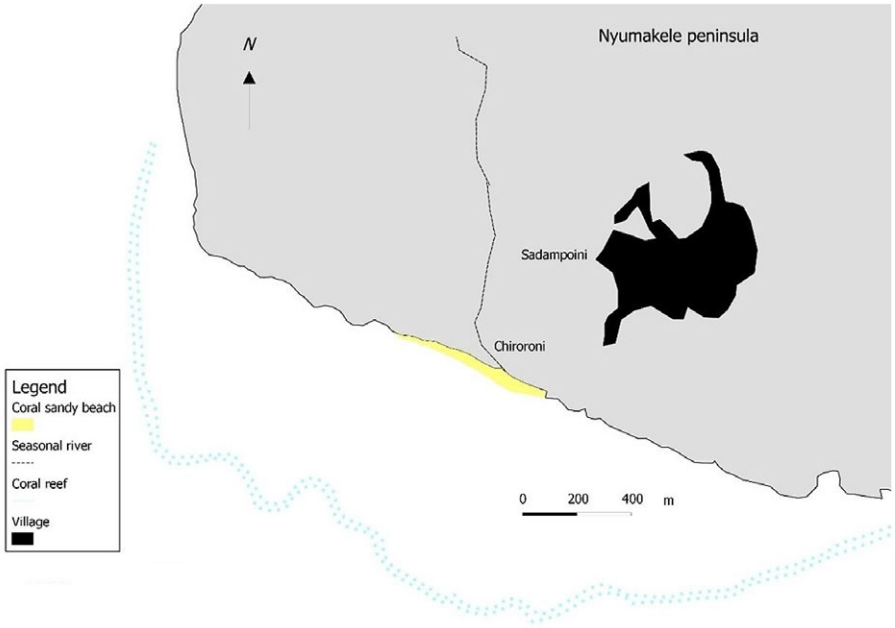

Figure 2. Coastline of Chiroroni.
Source: K. Sinane (2009).

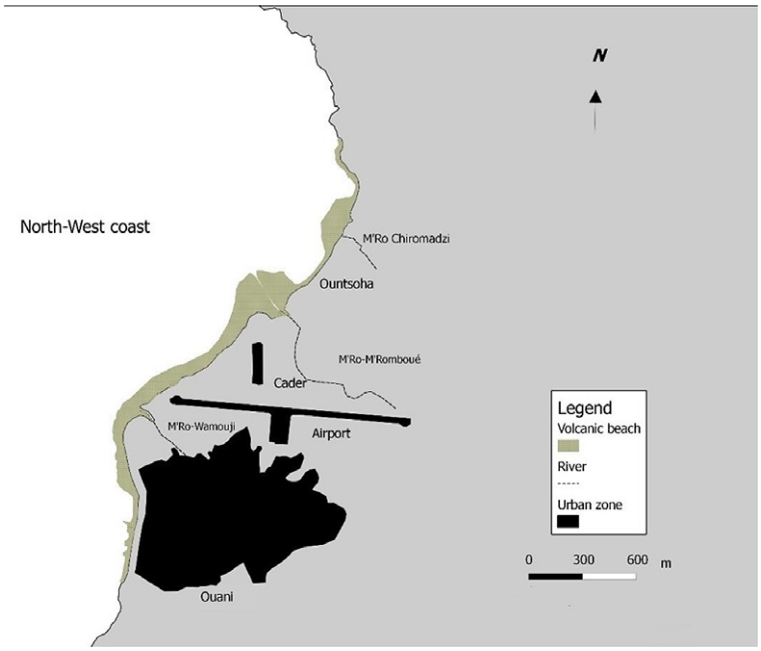

Figure 3. Ountsoha beach and the coast of Ouani.
Source: K. Sinane (2009).

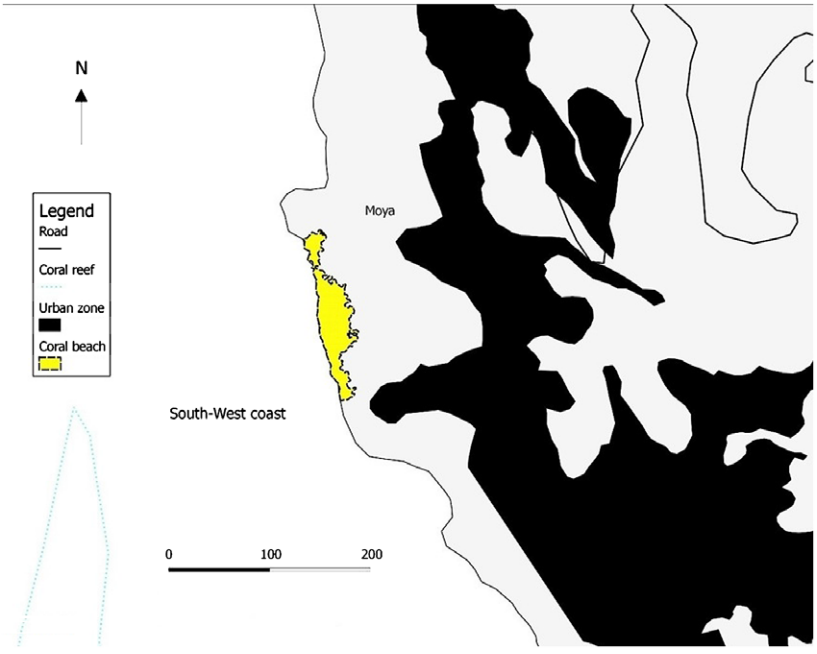

Figure 4. Moya beach and Moya town.
Source: K. Sinane (2009).

demanded the end of sand mining in the region, because they considered sand mining much more harmful to the coastal environment than the use of fishing nets in the reef. In their eyes, the village chief acted as both judge and jury because of his support of sand mining. Consequently, they refused to pay any fine. Competing values and interests in the beach led to increased destruction of the common *life world* in this case study area.

The fishermen's position was echoed by the majority of the villagers. They believed that they were being harmed by the village chief and his followers, who were destroy their greatest wealth: the beach. Moreover, they felt offended by the sand extractors claiming that poverty was the main motivator for their activities. On the contrary, many members of the local population considered those responsible for the sand mining to be the richest and most

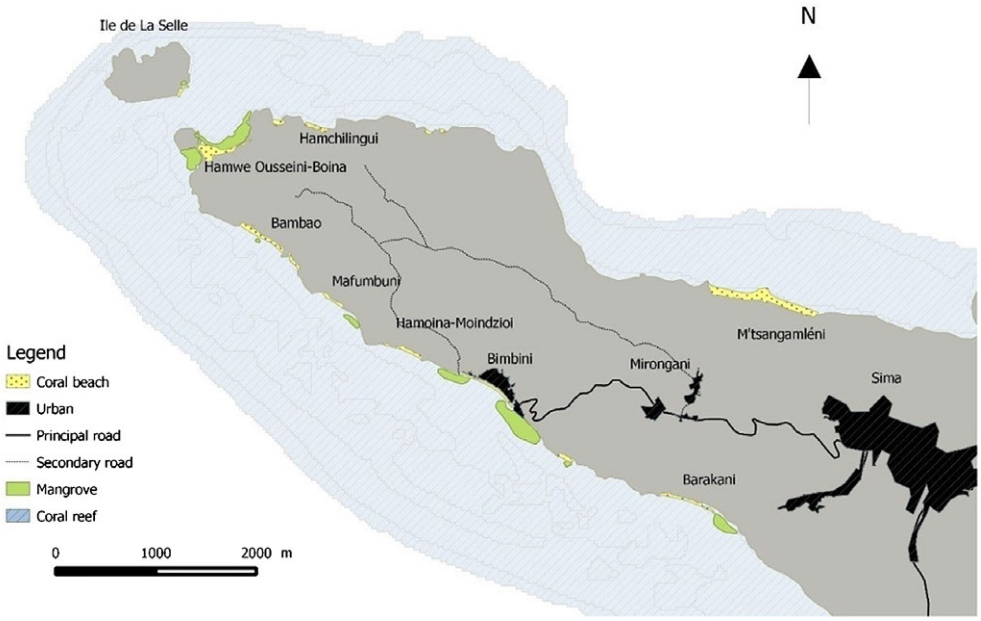

Figure 5. Western coastline of Sima peninsula and Bimbini.
Source: K. Sinane (2015).

influential people in the community. They, therefore, complained about the village chief's behaviour to the regional administration. Finally, in a joint agreement, the villagers decided to stop sand mining. To save a former French settler's building, which they used to protect their fishing gear, fishermen built a rock fill wall along the beach from the exposed beach rock. This technical construction, which relies on taking out beach rock from the beach, has the side effect of helping to accumulate sediment, which counteracts erosion.

Ountsoha beach (Figure 3), a coastal strip in northwestern Anjouan, is a large volcanic sand beach some meters away from Ouani airport. The coastline is fed by the sediment of three major rivers. At Ountsoha, the main sediment budget is driven by the long shore drift of sand. The beach is backed by farmland owned by several people. As a beach, Ountsoha supported an African local feast called Nkoma, which used to be organized every three years. Ountsoha beach was also the main coastal road to reach the high mountain village of Jimilimé from Ouani, and farmers used this beach to reach their lands. The beach was a natural port for the fishermen's boats.

The coastline has been degraded by a decade of sand mining, facilitated by both authorities and some coastal landholders. Some sand mining has taken place on this coast for decades, but the activity recently increased rapidly due to support it receives from municipal authorities who collect taxes (6,000 KMF[4] = 13 US$) for each lorry brought by each truck driver. More than 10,000 m^3 were estimated to be extracted daily in 2004 (Sinane, 2013). Although some landholders protested against this practice, they were unable to stop it since sand mining taxes were considered a principal source of revenue by the mayor of Ouani and by the island's separatist authorities, who were under an African Union embargo during the separatist crisis. In this context, even protesting landholders had started sand mining, most of them forming groups between two and seven sand miners. One of the landholders actively involved in sand mining was supported by both the mayor and the traditional authorities because he was providing them with material for building a mosque. Because of the expected revenue, local authorities supported this activity despite their awareness of the resulting coastal degradation. People hoped that coastal erosion would be slowed down by river sediment but in 2012, the French construction company Colas started taking out river sediment for road works. The progressive erosion observed is confirmed by many geoindicators and seasonal beach profiles. The most important geoindicators for evaluating coastal erosion—vegetation destruction and micro-cliff and sediment budget destruction—have all reached their maximum levels. Erosion is now directly threatening agricultural land and food crops, as evident in the progressive removal of several rows of coconut trees. The social impacts of this coastal erosion are considerable: the Nkoma traditional feast cannot be held on the beach anymore, people were forced to find alternative roads, and fishermen have to land their boats on other people's land, thus risking conflict.

There have, however, been attempts to prevent the further spread of erosion. The first strategy of planting mangroves was proposed by a local coastal conservationist who planted the trees himself. But this was of limited success because the development of mangroves is slow in comparison to the speed of erosion. For this reason,

[4]Comoran Franc.

another landholder decided to build a sea wall to protect his farmland. This, however, accelerates erosion as waves and storms progressively take out sand in front of the sea wall—and ultimately weaken the shore. Building sea walls in only one part of the coastline can also lead to accelerated erosion in the other parts without sea walls (Sinane, 2013). Thus, a collective solution is necessary, such as rock fill, which is cheaper and easier to repair after damage. In contrast to the cases described above, the coastlines of Moya and Bimbini are relatively well-preserved by the local communities.

Moya beach (Figure 4) is a coralline sandy beach protected by a fringing reef on the southwest coast of Anjouan. This beach is terraced and situated on a volcanic cliff. The houses of Moya town are perched on the hillside, and there are tourist bungalows at the bottom of the hill facing the beach. Moya beach is considered the most beautiful beach on the island and has been protected for many years by the communities, especially fishermen and young people. Young people use the beach to play football, and it is also the main sports ground for local schoolchildren. Any sort of sand extraction or sand mining is prevented by the village population; people also carry out beach cleans. According to the local people, the presence of the tourist bungalows plays an important role in the preservation of the beach. The first bungalow was built in the 1970s by a former French administrator. People are very aware of Western tourist preferences for tropical island beaches, and understand that the potential of developing a tourism industry depends on attractive and inviting beaches. Thus, the type of coastal use, in this case, is also shaped by a different mental construct of the beaches as tourist attractions.

Although tourism-related revenue is limited, Moya residents are satisfied, as the hotel provides some employment, and visitors buy goods and souvenirs in the village. In recent years, the beach has increasingly been occupied by fishing boats, which reduces the space available for visitors, since the surrounding beaches have been eroded by sand mining. This situation causes conflicts among fishermen, who all want to park their boats on the same beach. Some visitors now find the beach to be ugly in comparison to previous years. To solve the problem of parking fishing boats, the fishermen's association wants to build a jetty, which again could cause erosion, as well as sedimentation of the coral reef. A further problem faced by this beach is the runoff from watersheds and from water pipes built during the construction of the road from Moya to Nyumakélé road, especially in the rainy season.

Sima peninsula (Figure 5) is the only continuous and relatively well-preserved coastline of the island. Bimbini is the main coastal village of the Sima peninsula, which is mostly inhabited by fishermen. The other villages are dominated by agriculture. People on the peninsula are aware of the potential of the coastline, and are waiting for better coastal management. This is due to the fact that Bimbini suffers from erosion and is progressively protected by sea walls, funded by 10th European Development Fund (EDF) after the impact of the cyclones Gafilo in 2003 and Elita in 2004 (Sinane, 2013), and there is a feeling that other parts of the coastline, which are still relatively well-preserved, should also be protected. On paper, the coastline is declared a marine park, but there is no real control or protection, and only a sign mentioning its existence. The coastline features the largest coral reef and the most developed mangroves on the island; its preservation can be partly explained by its isolation. The lack of road access largely prevents sand mining activities, which are still rare in this area.

Nonetheless, there are signs of small-scale sand mining for personal use. Some people secretly use motorized boats for sand extraction. Unknown to many locals and the authorities, people started to extend a road to M'tsangamléni, the largest rural beach of the island. Road building began in 2008, at the time of the first site visit, and in 2012, with the help of the authorities, the road had reached the coast, even though it is impossible to access the beach by car due to the steep incline. The construction of the road shows that preservation of the coastline is unlikely to be achieved in the long-term. Local communities are divided between supporting tourism activities and allowing sand mining. To preserve the coastline of the peninsula from degradation, the local non-governmental organization (NGO) UMAMA (Ulanga, Maesha, Mayendreleo – English: Environment, Life and Development) tries to promote activities such as beach cleaning and the planting of mangroves in association with the local population. The preservation of this coastline seems urgent in the face of its social and economic value, but preservation ultimately depends on local communities' perceptions of the beach and corresponding priorities for its use.

6. Discussion

Different perceptions of the coast and its subsequent use can lead to coastal degradation and preservation, showing that mental constructs of 'beach' and the physical destruction or preservation of beaches are interrelated. The following section shows how local perceptions and mental constructs are influenced by socio-economic contexts, political interests, larger-scale events and actors, and which role collective action can play, especially in a context of climate change adaptation.

6.1. Beach values (mental) construction and beach (physical) destruction by sand mining

In a context of climate change and sea level rise, sand mining remains the major threat to the coasts of Comoros and Anjouan. Many locals perceive the beach as a source of building material. Sand mining can be considered an established traditional activity and different events—natural,

socio-economic and political—contribute to making the practice more or less acceptable to the island community. One such an event was the cyclone of 22 December 1950, which destroyed most of the island's houses, still constructed from wood at the time. Consequently, people needed to find alternative construction material, and Zanzibar's stone houses, which were considered much safer, served as a prototype. People then began extracting sediments from the coast for building—first from coral reefs and then from the sandy beaches. During the course of these developments, sandy beaches were thus re-framed as a physical resource—a mental shift or re-construction took place, which led to the destruction of most of the island's tourist beaches. Some coastal areas, where access is difficult, such as the Sima peninsula, are the only ones spared by massive sand mining activity. Nonetheless, even in such regions, people use boats to access the beaches for sand mining (Figure 6).

The proliferation of sand mining is not only due to the ongoing demand for building material, but also to the lack of coastal management. Strangely enough, at a national level, the island's coasts have never been considered capable of supporting development. The embryonic tourism industry, which began in the 1980s, was never able to unfold, mainly because of the political instability created by different political coups between the 1970s and 1990s, and the separatist crisis between 1997 and 2003. Anjouan and Comoros, in general, can be considered among the few non-touristic islands of the Indian Ocean (Gay, 2000), in contrast to the neighbouring islands of Seychelles, Mauritius and Reunion. Despite its strong physical impact, sand mining for building material developed into the most important economic activity on the beach. As shown above, this activity has many ramifications in the island community. Generally, we can observe different types of actors and different interests held by coastal users and authorities. Sand miners, who are part of the community and who use the beach to take out sediment, form one group of coastal users. Another group is comprised of coastal landholders who appropriate the beachfront as part of their land, violating coastal law. Yet another is political and traditional authorities, who collect taxes from the truck drivers. Sand mining is widely accepted by the population because many people need building material for their houses and sand miners are considered relatively vulnerable and poor, but in reality, sand mining is an auxiliary activity, and the people concerned are not always the poorest of society.

The vicious circle of people degrading the beaches by sand mining has caused irreversible erosion in many coastal areas. Due to their inability to solve the island's socio-economic problems, local authorities prefer using climate change and sea level rise as arguments to obtain funding for sea walls, instead of finding solutions to the sand mining problem, which is causing coastal erosion in the first place. In general, it is difficult to identify and distinguish between the impacts of sea level rise and other local factors as causes of coastal degradation. The local communities see the negative impacts of sand mining as causes of coastal erosion, and, therefore, it is difficult to mobilize them to adapt to climate change and sea level rise. As the case studies showed, mental constructs of coasts as valuable areas can, in some cases, lead to the protection and preservation of beaches by initiatives of collective action. This, however, is not necessarily motivated by environmental protection or climate change adaptation, but depends on the perception of the coastal environment, as will be shown in the following subsection.

6.2. *Collective action for coastal protection*

For more than 30 years, local political authorities used poverty as the main explanation for any environmental

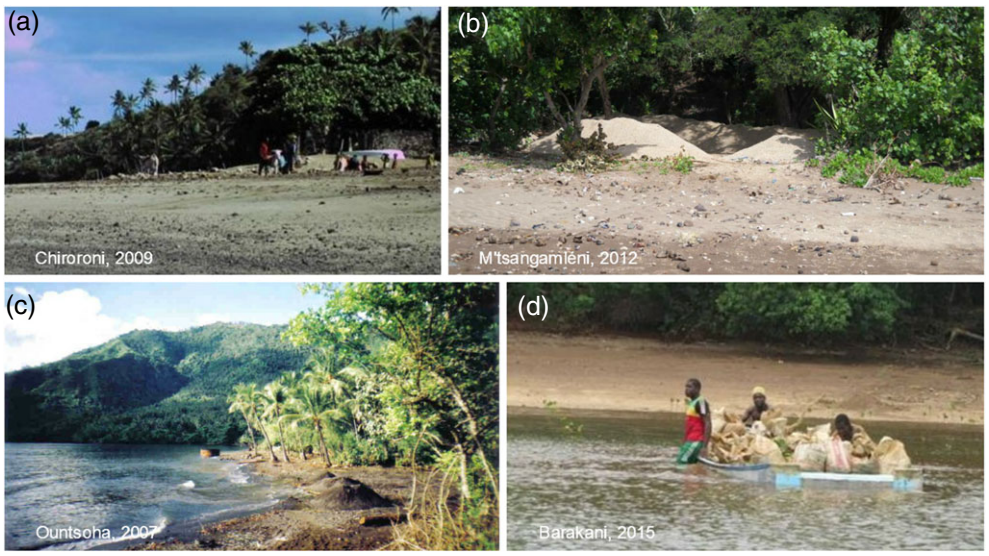

Figure 6. Beach sand mining (a–c) directly on the shore or (d) using a boat.
Source: Photos: K. Sinane.

Figure 7. Examples of collective action for coastal protection observed, (a, b) building sea wall and encroachment, (c) beach cleaning, and (d) planting mangrove.

degradation, both in the forests and on the coast. Poverty is also put forward as a reason behind the lack of effective coastal protection measures. As described above, in Anjouan there is little mobilization of the coastal communities against climate change and sea level rise impacts.

The main problem for the coastal ecosystem and local communities is degradation caused by sand mining, to which authorities have responded by building sea walls. Sea walls have recently been built in front of many roads and villages with degraded beaches, and there is a need to build more sea walls as a response to widespread anthropogenic coastal erosion. The construction of sea walls is financially supported by the European Union and Indian Ocean Commission (e.g. RECOMAP (Regional Coastal Management)) funds, which are specifically dedicated to protecting coastal regions impacted by anthropogenic pressures.

In addition to official policy, collective action plays an important role in adapting to climate change and coastal degradation. Social capital on Anjouan is distributed differently among the four case study areas of Chiroroni, Ountsoha, Moya and Sima Peninsula. Mobilization of the local population and different bottom-up approaches can especially be observed in the peripheral coastal regions. Active people include individuals, groups of coastal users, village-level mobilization initiatives, and environmental associations, for example, *Ulanga*.[5] These local mobilization initiatives, however, do not explicitly address erosion and sea level rise impacts, but rather the impacts of anthropogenic activities, notably sand mining.

The major factors initiating community mobilization for coastal protection are conflicts between different coastal user groups and the hope of development through local *Ulanga* associations. Conflicts emerge when people realize they are directly affected by coastal erosion. Conflicting parties usually involve landholders, fishermen or even whole villages in opposition to sand extractors. People resolve these conflicts by using certain skills to adapt to erosion, for example, encroachments in Chiroroni, or contentious measures such as sea walls in Ountsoha, supported by local authorities. Apart from building coastal infrastructure, we also find 'soft solutions,' especially in the planting of mangroves, observed in the Bimbini peninsula and Ountsoha (Figure 7). Other examples of collective action include beach cleans and the construction of tourist bungalows in Bimbini and Moya. While these activities do not directly contribute to the reduction of erosion, they can foster future development of the local community with the support of local associations, and they also prevent people from further degrading the coastline. Thus, local people consider these activities a means of combating coastal erosion. In the context of climate change and sea level rise, however, local solutions cannot succeed without the support of the local government and the international community.

7. Conclusion

Social-political-ecological system analysis is a way of exploring the interlinkages between perception, political interests, people's demands and human activities impacting the natural system. These types of analysis are also a way of embedding adaptation solutions in local situations that might otherwise be unreceptive. The different case studies on the island of Anjouan show how different coastal users technically and mentally construct, deconstruct and re-construct the coastal

[5] *Ulanga* (environment) are local associations in some Comorian villages engaged in environmental activities.

zones according to cultural values and economic needs, resulting in contradicting interests on a local level, and varying impacts of national and international influences. Climate change adds to existing socio-economic pressures but, in this case, is used as justification for neglecting existing pressures. On the island, anticipated climate change impacts have been linked to the ongoing instability of the social-ecological system. This instability can only be understood by analysing different coastal users' perceptions of the beach, beach values and interests. Case studies reflect local situations, but local impacts are embedded in a national and international context and discourse.

People destroy the protective character of the sandy beaches, coral reefs, and mangroves, which increases coastal erosion risks and community vulnerability to sea level rise. This is due to the absence of coastal management, combined with the problem of securing a livelihood. Lack of awareness on the part of the authorities and inadequate analysis by the international community make it difficult for local people to understand the impacts of climate change that they may face. Thus, local people, local and national authorities, and the international community confuse negative anthropogenic impacts on the social-ecological system of Anjouan with climate change and the impacts of sea level rise.

Understanding the conflicts between coastal user groups is a first step toward remedying the situation, but in itself is not enough to stop the ongoing coastal erosion in Anjouan. To resolve the confusion between local anthropogenic impacts and wider climate change impacts on the coastal environment, authorities need to take a series of steps. Before addressing sea level rise in a top-down manner, they first need to acknowledge local people's perceptions of the coast and the values they ascribe to them. This means acknowledging the motivation that drives people's use of the coast—a key factor in fostering non-destructive, alternative ways of using the coast, instead of for sand mining. One way to achieve this is to place coastal resource management at the heart of an island's strategy aimed at sustainable development. Effective solutions to coastal problems can only be found if local authorities and the international community focus on understanding the social-political-ecological system. Understanding the prevailing mental constructs of the coast, as well as the resulting destruction of the beaches, can also help in supporting bottom-up collective action for sustainable adaptation to climate change on the island, which will be among those most affected by further sea level rise.

The case study of Anjouan demonstrates how important it is to consider the local causes and conditions in designing development interventions. Although it might be difficult to generalize for all SIDS countries, this research implies that to differentiate between constructive and destructive practices on the coast both from a mental and technical perspective is necessarily acknowledged and considered in any climate change adaptation strategy. Attributing beach erosion to climate change seems too narrowly focused, and constructing sea walls is insufficient in combating coastal problems. This holds true not only for the island of Anjouan, but for others as well.

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