Limits to autonomous adaptation in response to coastal erosion in Kosrae, Micronesia

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Abstract: Small-island developing states (SIDS) are particularly vulnerable to the effects of climate change, sea level rise and extreme weather events. Sea-level rise is expected to exacerbate coastal erosion. Adaptation measures in response to this in SIDS have the potential to reduce some of the adverse impacts, yet they have limitations. This article addresses the degree to which households on the island of Kosrae, Federated States of Micronesia (FSM), are affected by coastal erosion, the autonomous adaptation measures they have implemented, the limitations thereof, and the loss and damage incurred as a result. This analysis is based on quantitative and qualitative data. We found that 70% of the 363 households we interviewed experienced adverse effects of coastal erosion. Of those suffering from impacts, 60% carried out adaptation measures. Yet, 92% of those respondents who carried out adaptation measures indicated that these measures were insufficient, resulting in loss and damage to livelihoods, housing and culture. This empirical case study contributes to the critical debate on the impacts of climate change beyond adaptation.

Keywords: loss and damage; climate change; limits to adaptation; slow-onset changes; Kosrae; Micronesia; Pacific Ocean; coastal erosion; vulnerability; small-island developing states; SIDS.

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1 Introduction

> "The storm came and broke the door and smashed the windows. The shoreline behind our house had already completely disappeared because of coastal erosion, so now the seawater quickly filled the house. Everything inside the house got wet; mattresses, clothes, and furniture. The kitchen next to the house, built of bamboo and thatch, completely washed away. The only thing left was the cement floor. Our three dogs were washed away and disappeared in the dark. Water also entered the pigpen, but fortunately, the pigs survived. We had to stay with family for 10 months while we rebuilt our home. We are building a new house in the hills, however, because the seawall and gabions we have built ourselves are no longer protecting us. The gabion nets are rusting and the waves are breaking down the seawall. The sea is almost reaching our house. Our grandson will not be able to grow old in this house." [Marston Alakoa, 55 years, male, Tafunsak, Kosrae, Federated States of Micronesia (FSM)]

Marston Alakoa's experience with the impacts of a storm on his housing and livelihood as a result of already pressing challenges of coastal erosion on Kosrae, Micronesia, is a show-case for the impacts of climate change stressors on those living on small vulnerable islands. Small-island developing states (SIDS) are already, and will be, disproportionally affected by climate change, sea-level rise and extreme weather events (Mimura et al., 2007). This is due to their social, economic and geographical characteristics – such as limited size, insular geography and remoteness, proneness to natural hazards, low-lying areas, and low adaptive capacity (Mimura et al., 2007; Nurse et al., 2001; Pelling and Uitto, 2001; Kelman, 2010; Douglas, 2006). SIDS are a grouping of 51 tropical island states which have been banded together under the United Nations to address common sustainability challenges (Mercer et al., 2012). Although SIDS produce only 0.6%[1] of global greenhouse gases, they will need to reallocate scarce resources away from economic development and poverty alleviation in order to adapt to the growing threats posed by global warming (Nurse and Moore, 2005).

SIDS are particularly vulnerable to sea-level rise, which is expected to increase in the near future and exacerbate coastal erosion, inundation, storm surges and other coastal hazards (Mimura et al., 2007). Coastal erosion is considered to be one of the most prominent climate change concerns for Pacific Ocean islands (Mimura, 1999; Mimura et al., 2007; Fletcher and Richmond, 2010). Over the past few decades, the FSM, located in the Pacific Ocean, has experienced increasing coastal erosion and an escalating rate of shoreline retreat (Mimura, 1999; Fletcher and Richmond, 2010). The sea level near the

FSM, measured by satellite altimeters since 1993, has risen more than 10 mm per year, significantly more than the global average of 3.2 mm per year [ABM and CSIRO, (2011), p.64]. It is estimated that the mean global sea level will continue to rise over the course of the 21st century, with some studies suggesting faster global rates of sea-level rise (ibid.).

In most SIDS, the majority of people live on the narrow coastal plains. On the Pacific islands SIDS, more than 50% of the population lives within 1.5 km of the coast (Mimura et al., 2007). This makes residents extremely vulnerable to sea-level rise. Moreover, the majority of infrastructure, social services, tourism facilities, airports, seaport facilities, roads and vital utilities are located in the low-lying area [UNFCCC, (2005), p.21]. Coastal erosion can, and already is, causing losses and threats to land, communities and vital infrastructure. As a result coastal erosion compromises the socio-economic wellbeing of those living on islands. Low lying islands and atolls are the most vulnerable as they can become totally inhabitable (Barnett and Adger, 2007). Nonetheless, even on islands with large areas at higher elevations, such as on the island of Kosrae in the FSM, the majority of people and infrastructure are still located in the narrow low-lying strip along the coast. The higher, uphill areas are mostly characterised by steep, unstable slopes where development is difficult (Fletcher and Richmond, 2010).

Sea level rise (SLR) is not the only cause of coastal erosion in the FSM, however, and coastal erosion should be seen in the light of multiple drivers. El Niño/La Niña Southern Oscillation (ENSO) climate patterns are considered to be an important factor. The predicted changes of ENSO inter-annual variability as a result of climate change differ among models and remain uncertain (Meehl et al., 2007). Anthropogenic activities such as reef dredging and sand mining are also significant sources of coastal erosion (DRC, 2000). Environmental change is thus the result of multiple drivers and has indisputable human causes (Nelson et al., 2007). Yet, the increase in sea level over the past decades and the predicted rise over the coming decade [ABM and CSIRO, (2011), p.64] are expected to exacerbate the already existing coastal erosion. The vulnerability of society to climate change stressors, with vulnerability defined here as the propensity of human and ecological systems to suffer from harm (Smit et al., 2001), thus not only relates to their increasing exposure to climatic stressors such as sea-level rise, but also to characteristics related to their sensitivity and their adaptive capacity.

Adaptation measures are actions taken throughout society, by individuals, groups and governments (Adger et al., 2005), intended to reduce the risk of climate change to things we value (Adger et al., 2009). Over the past decade there have been a growing number of studies on adaptation to climate change (e.g., Adger et al., 2003, 2005; Eakin and Patt, 2011; Moser and Ekstrom, 2010; Eriksen et al., 2010). In this article we follow the definition of adaptation by Moser and Ekstrom (2010, p.1): "Adaptation involves changes in social-ecological systems in response to actual and expected impacts of climate change in the context of interacting non-climatic changes. Adaptation strategies and actions… aim to meet more than climate change goals alone, and may or may not succeed in moderating harm or exploiting beneficial opportunities". This definition recognises that adaptation measures in response to climate stressors must be seen in the context of non-climatic developments as it is considered extremely unlikely that any type of adaptive action would be taken in response to climate change alone (Smit and Wandel, 2006; Adger et al., 2005; Eriksen et al., 2010). It can therefore at times be difficult to separate climate change adaptation decisions or actions, from actions triggered by other social, economic or ecological events. This relates to greater concerns of attributing adaptation actions to climate change (Adger et al., 2005, 2007; Eriksen et al., 2010).

Adaptations can be either *autonomous* or *planned* and depending on their timing they can be *reactive* or *anticipatory* [Smit and Wandel, (2006), p.282; Smit et al., 2001]. *Autonomous* adaptations are initiatives by private actors (e.g., individuals and households) rather than public actors (e.g., governments and NGOs) [Leary, (1999), p.308; Smit et al., 2001]. Although the roles of public and private actors are distinct, they are not unrelated. While the actions of private actors are considered to be autonomous, institutional processes such as governance structures and adaptation policies, property rights, and cultural and social norms with rules in use, both constrain and enable autonomous adaptation (Adger et al., 2005; Coulthard, 2012; Brooks et al., 2005; Tompkins and Adger, 2005; Eriksen and Kelly, 2007). *Planned* adaptation measures are actions taken by public bodies (e.g., governments, NGO) to protect citizens (Adger et al., 2005) and the result of a deliberate policy decision by a public body (Smit et al., 2001). These decisions are often embedded within broader sectoral initiatives such as water resource planning, coastal defence and disaster management planning (Adger et al., 2007). *Reactive* adaptation measures are triggered by past or current events after some impacts have been experienced (Füssel, 2007). *Anticipatory* measures are based on an assessment of future conditions and are taken before damages have occurred (Adger et al., 2005; Füssel, 2007). The latter distinction is not always definitive, however, as people base their adaptation strategies both on their experiences of the present situation and recent past as well as their expectations of the future. Adaptations can also be purposeful or unintentional, and? short-term or long-term (Smit et al., 2001; Füssel, 2007; Dow et al., 2013).

Within the adaptation debate over the past few years, increasing attention has been devoted to the limits of adaptation. Limits of adaptation refer to the point at which an actor's objective (or biophysical) needs cannot be safeguarded from intolerable risks despite adaptive actions (Dow et al., 2013). Some adaptation limits have been clearly identified, especially for ecological systems, yet much less is known about limits in social systems (Dow et al., 2013).

The debate concerning limits to adaptation relates to a growing awareness in academic and policy circles that not all climate change impacts can be addressed by current and future mitigation and adaptation efforts, and that in many cases the impacts will exceed the adaptation capabilities of individuals, communities and countries. The discourse around limits to adaptation is frequently constructed around three dimensions: physical limits, economic limits, and technical limits (Adger et al., 2007, 2009). More recently it has widened from these 'exogenous' limits to adaptation to include more endogenous factors of society including social, cultural and individual limiting factors (Adger et al., 2009).

The concept of 'loss and damage' revolves around the question of the extent to which people in vulnerable countries are already suffering from the consequences of climate change, despite attempts to adapt (Warner and Zakieldeen, 2011). It is argued that there are limits to adaptation and that even if adaptation measures are implemented, there will still be residual loss and damage. In this study, which is part of a larger project, called the 'Loss and Damage in Vulnerable Countries Initiative'[2], 'loss and damage' is defined as "the negative effects of extreme weather events and slow-onset climatic changes that people have not been able to cope with or adapt to" [Warner et al., (2012), p.20]. This definition includes the inability to respond adequately to climate stresses and the costs associated with existing coping and adaptive strategies (cf. erosive coping strategies and mal-adaptation) (Warner et al., 2012). In this view, we use the concept of loss and

damage to go beyond purely material losses, which is still over-represented in most literature, and incorporate social and cultural losses (Adger et al., 2013).

This article addresses the degree to which households on the island of Kosrae, FSM, are affected by coastal erosion, the adaptation measures they have implemented and the limitations thereof. Although it is focused on individual households we acknowledge that adaptation and losses and damages also take place at higher levels of scale. This empirical case study contributes to the critical debate on the impacts of climate change beyond adaptation in general and within the context of vulnerability of SIDS in particular.

2 Methodology and research location

Kosrae is one of the four states of the FSM. FSM is located in the western North Pacific Ocean comprised of 607 islands with a total land area of approximately 702 sq. km. This small land area contrasts sharply with the size of the exclusive economic zone (EEZ), which totals over 2.98 million sq. km (ABM and CSIRO, 2011). FSM is plagued by persistent coastal erosion that threatens farming, housing, roads and shallow coastal aquifers (Fletcher and Richmond, 2010). As well as slow-onset coastal erosion, FSM communities are increasingly affected by storms that erode beaches and land and undercut and damage roads (Fletcher and Richmond, 2010). Kosrae is a small volcanic island of 110 km^2 lying along the equator, with mountains rising to a maximum elevation of 628 m. The large outer ring of low-lying coast is by far the most densely populated area. The majority of the 6.616 residents[3] live on land that is less than 4 m above mean sea level (DRC, 2000). Most of the island's infrastructure is on the coast and the four main villages on Kosrae are all at significant risk from coastal erosion, storms and spring tides. The main island of Kosrae is connected via a causeway to a very small island called Lelu Island.

Figure 1 Location of Kosrae, FSM (see online version for colours)

Source: Map created by Center for International Earth Science Information Network (CIESIN)

In this case study, we have investigated the autonomous adaptation of households to coastal erosion. We were particularly interested in the impacts of gradual changes in coastal erosion over time; the adaptation measures people adopted and the effectiveness thereof. For this purpose, we administered 363 household questionnaires, conducted six focus group discussions with a variety of stakeholders and 12 in-depth interviews during July 2012. Nine in-depth interviews were conducted with residents who have been affected by coastal erosion. Enumerators highlighted these people to the authors of this paper after they had conducted a survey with them or they were brought to our attention through the focus groups discussions. Three in-depth interviews were carried out with key experts (a state senator; a staff member of the Kosrae Conservation Safety Organisation NGO; a government employee working for the Kosrae Island Resource Management Authority). The research thus involved both qualitative and quantitative research methods. The survey was based on a general survey model used by all nine cases studies in the Loss and Damage project (see project website)[4] but was adapted to fit each case-study's focus.

In our survey, we first gathered basic demographic and socio-economic information of the household. Secondly, we inquired about the impacts of gradual changes in coastal erosion over time; the adaptation measures people adopted and the effectiveness of these measures. Adaptation is defined and explained to respondents as longer-term responses to more gradual changes, while coping strategies were defined as short-term responses to the impacts of sudden events and thus refer to more temporary, ad hoc, responses (Warner et al., 2012). Thirdly, we asked about impacts of more extreme events, like storms and coastal floods, over the past 20 years and people's coping strategies. Section two and three started with open-ended questions to gather people's own perception of the climate stressor as well as the potential changes, impacts and adaptation or coping strategies. This was followed by closed question gathering, *inter alia*, information on impacts on crops, livestock, fishing, trade and housing and frequent adaptation strategies, i.e. in the field of agriculture, livelihood diversification and human mobility. The closed questions enabled a quantitative analysis of results. The last section consisted of open questions about vulnerability, gender and policy options. The 363 households were chosen on the basis of a 100% target population of 374 households living within the first approximately 60 metres of the coastline and in one river-mouth area. The target population was taken from a map of Kosrae with all 1,170 households[5]. Eleven households were unavailable to participate in the questionnaire.[6] Although our main focus has been on autonomous adaptation by households, the surveys, in-depth interviews and focus groups discussions also provided information about planned adaptations measures on Kosrae.

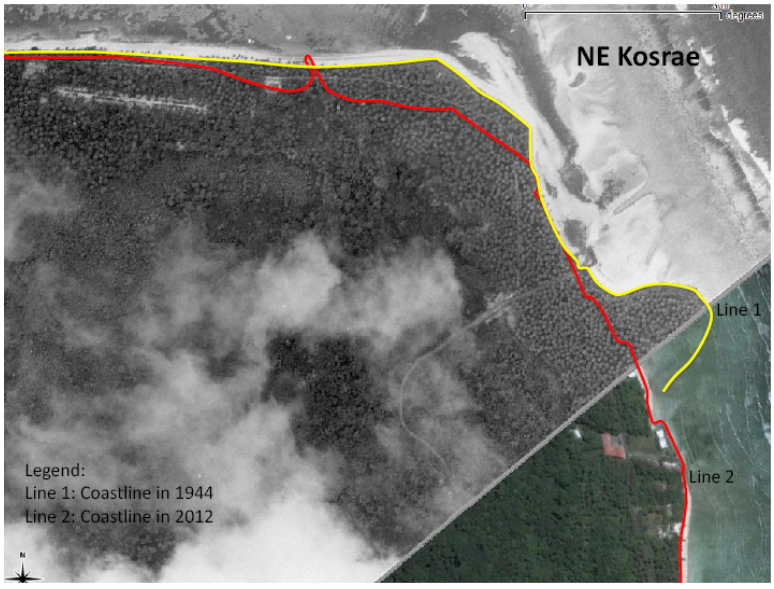
3 Results

In this section, we first discuss coastal erosion on Kosrae. This is followed by a section on the main livelihood characteristics of the households and the adaptation measures and strategies they have followed. This section concludes with the limitation of these measures and the loss and damages incurred as a result of these limitations.

3.1 Coastal erosion on Kosrae

Kosrae has experienced severe coastal erosion over the past decades (DRC, 2000; Fletcher and Richmond, 2010). The entire coastline of the island Kosrae has experienced a rapid change, primarily caused by an insufficient supply of sediments to the beaches and a reduction in the protection of waves. The resulting coastal erosion can be attributed to natural factors and anthropogenic activities. During the second half of the last century, demographic changes, development needs and changes in construction practices have significantly exacerbated coastal erosion (DRC, 2000). Dredging of the reef flat, sand mining, cutting trees and mangroves, and altering river outlets as a result of these developments have all significantly increased beach retreat. The focus group discussions and literature (DRC, 2000) indicated that the removal of coral rubble from the outer reef flat for building roads as well as the development of three different airstrips have been a major cause of coastal erosion. The volume of coastal aggregate necessary to build an airstrip or other constructions can be easily extracted within a few months or years, yet replacement of this material in natural carbonate systems will take hundreds of years (Maharaj, 1998). Storms can cause flooding and inundation therefore further aggravating coastal erosion. The current and expected intensification of sea-level rise in Micronesia will further increase the island's vulnerability to coastal erosion. Figure 2 shows the significant loss of coastline between 1944 and 2012 on the northeast side of the island. The photo is an overlay of two images, one an aerial photograph taken in 1944, the second a satellite image of the same area from 2012. Line 1 shows the coastline in 1944, line 2 the current coastline in July 2012. The difference clearly shows the significant coastal land loss in this area on Kosrae.

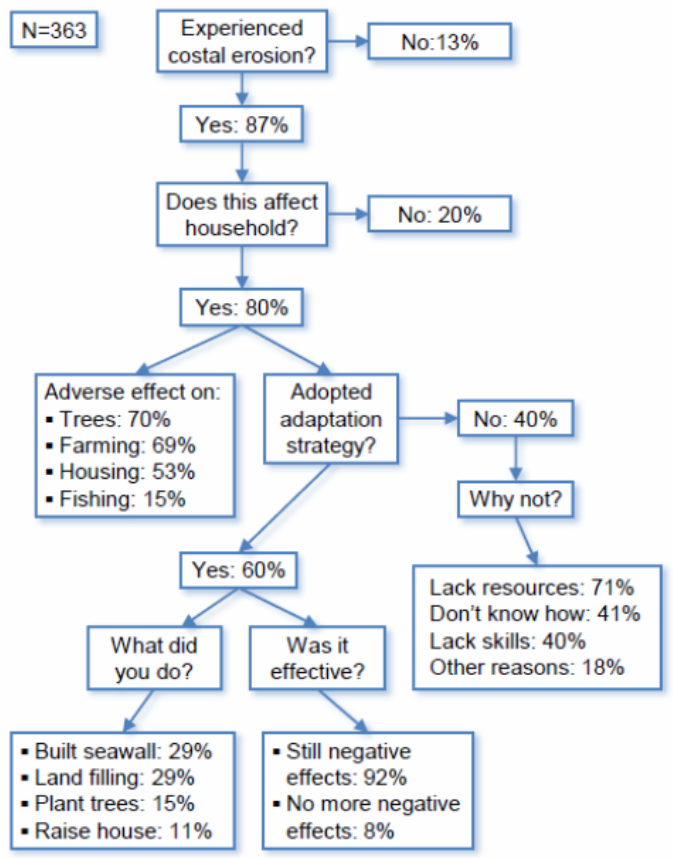
Figure 2 Change in coastline on the north-east corner of Kosrae between 1944 and 2012 (see online version for colours)



Source: Created by Webb (2012), SOPAC Pacific Island Applied Geoscience Commission

In line with the findings of reports on coastal erosion on Kosrae (DCR, 2000; Fletcher and Richmond, 2010) the majority of survey respondents (87%) indicated that they have experienced adverse effects of coastal erosion over the past 20 years. They indicated that the coastline has retreated and beaches have disappeared. Besides the more gradual changes, 62% of the surveyed households have also suffered from the adverse effects of extreme weather events such as storms (Figure 3). These short-term events have caused short-term (e.g., damage to housing by floods) and long term impacts (e.g., salinisation of cropland and timber?) on households. Of those who had experienced gradual coastal erosion, 80% said it had directly affected their household economy, mostly as a result of loss and damage to their crops, timber? and homes.

Figure 3 Experience of coastal erosion, impacts and adaptation measures (see online version for colours)



Of those who reported negative impacts on their household economy, 53% said there had been damage to their homes. Respondents indicated for example "the shoreline has gotten closer to our house which increases the risk of water intrusion and flood"[7], "my farm and garden were eroded and I can't do any farming anymore"[8], and "a large portion of our private land is lost and several of our tree crops are gone"[9]. A Kosraen resident of the small island Lelu next to Kosrae describes his experience of coastal erosion over the past decades:

> "I have seen the changes on the coast very well (...) here on Lelu Island (...). There used to be a little island in front of our house, called Rabbit Island. As long as the island was there it was protecting our backyard. Over the last ten years the island has been disappearing slowly and now the sea just slams into our yard. When the tide is high the water comes right up to the road. We have built seawalls to protect us but it's getting worse." (Edward Saimon, male, 33 years, Lelu, 26 July 2012).

A US hotel-owner moved to Kosrae 17 years ago. She and her husband built ten beachside cabins made of natural material.

> "Only six years ago I finally accepted coastal erosion was really destroying our place. At first I was in denial, I just didn't want to see it. When a scientist was here eight years ago I would keep on showing him places where new sand had been deposited as I just didn't want to see what was happening to my home. But six years ago I couldn't deny it any longer. The log of the tree you can see in the water now is the tree we used to sit on in the evening after a day's work. Now more than ten metres of our beach have been destroyed since we moved here and the cabins we have for our hotel in the front have washed away entirely." (Angela Simms, female, 64, Lelu, 18 July 2012)

Coastal erosion is thus a widespread phenomenon on Kosrae. The following section explores the adaptation measures households have carried out to face the challenges of increasing coastal erosion over the past decades.

3.2 Adaptation measures

Kosrae households engage actively in agricultural activities, such as cultivating crops (71%), growing fruit trees (74%), fishing (70%) and raising livestock (71%) (see Table 1). The produce of these activities are mainly used for household purposes, however, and do not comprise more than 3% in terms of income generation. The main sources of income on Kosrae thus come from non-farm activities (59%), including white collar work, blue collar work and petty trade (see Table 1). The second most common sources of household income are remittances (both money and goods): 64% of respondents indicated their household received remittances, mostly sent by family members living in the USA. Due to the fact that FSM has a constitutional government in free association with the USA, Kosraeans are able to freely work, study and live in the USA.

Table 1 Main sources of income and livelihood opportunities of respondents

Category	*Percentage of households*	*N =*	*Percentage of income*
Non-farm activities	68	247	59.1
Remittances (money and goods)	64	234	21
Other sources	23	85	9.2
Crop cultivation	71	256	3.1
Tree crops	74	269	2.5
Fishing	70	252	2.1
Livestock	71	256	1.6
Farm labour	4	15	1.5

Nearly all households own their land and the house they live in (91% and 88% respectively). Houses are commonly built with iron sheet roofs and cement walls, although the cement walls are commonly only up to the first metre, with the remainder made of wood. Coastal erosion has severely affected households living on the coast in Kosrae and resulted in loss and damage to their livelihood, housing, land and culture. Over 60% of those who indicated they were affected by coastal erosion said they had carried out adaptation measures. The most popular measures were: building seawalls and gabions (29%); land filling (29%); tree planting along the coastline (15%); and elevation of housing (11%) (Figure 3). Seawalls are constructions made of rocks, logs, car tires, or any other material to build small walls to protect their houses from inundation and coastal erosion. Gabions are 'cages' of net or metal wire and filled with rocks and any other type of material (including for instance fuel or paint drums filled with cement). Gabions are used to stabilise shorelines and slopes against erosion. Landfilling is carried out by building a small wall (e.g., of cement) or dam and filling this with dirt, rocks and earth to create more land or reclaim lost land. Material resources needed for all these activities are scarce on Kosrae and households have had to make do with the material available to them. Respondents described their efforts in the following ways: "I build a 5-foot high 80 cm-thick sea wall"[10]; "I planted coconut trees near the shoreline to hold the soil"[11]; "I usedlogs, rocks and other debris to fill in the eroded areas"[12] or "I filled the land with rocks, and then poured cement on top of the rocks"[13]. Their attempts have been based on trial and error at the individual level and they have not received any institutional funding (e.g., from NGO or government).

Besides the autonomous measures that households have carried out there have also been several planned adaptation measures carried out on Kosrae. The planned measures on Kosrae were mostly carried out between 2002 and 2005. The state of Kosrae organised and paid for the building of seawalls, mostly of armoured rock, on occasion supported by external agencies. Tree planting along the shoreline is considered to be another viable option to protect the coast and either stop or prevent coastal erosion. Respondents indicated they plant trees in their back yards autonomously to protect their land but at times the state has also provided state funding for seedlings.

Alek Alokoa describes the development of the construction of a seawall in his village:

> "In 1971 we built the first seawall made from coral reef rocks. Only 15 years later we had to build a new seawall as the water just kept on rising. We built these two walls as a community with groups of men. In 2004 the last seawall was built by the government. Large trucks delivered the rocks. But the seawall changed the current and we lost all of our beaches. We used to have a very large beach – this has now disappeared. The seawall we have is not enough and when it floods the water still comes right up to the house. Our bakery floods every year and it wasn't like that in the past. To improve the situation, my wife and I decided to use our own money to make the seawall in our backyard higher. I bought 150 bags of cement. Not all at once – every month I would buy a few bags and cement the area in the back. It cost 500 US dollars – as much as we make in the bakery in three months. But now we feel safe for a while." (Alek Alokoa, male, 64 years, Malem, 18 Jul 2012)

This example illustrates that an adaption measure can be autonomous and planned, and reactive as well as precautionary. The first two walls were built collectively by residents, the third was built by the state and the fourth adaptation measure (raising up and fortifying a small part of the existing seawall) – was an individual initiative. It is both

reactive and precautionary as it aims to protect from current coastal erosion as well as from future erosion and flooding.

3.3 Limits to autonomous adaptation

The previous section has shown that the majority of respondents affected by coastal erosion carried out adaptation measures. Yet, 92% of those who had carried out adaptation measures indicated that these measures were insufficient (Figure 3). Household-level adaptation measures (seawalls, gabions, tree planting and landfilling) were limited by ecological physical limits, economic limits, and technical limits of adaptation They are often only temporarily effective and protect only the segment of coastline behind the structure. If one household along the coastline builds a seawall but the neighbours fail to do so, the seawall will only have a limited effect. This limitation is thus not only a physical and financial one but also a social limitation. The island is very remote and the material used often inadequate to build adequate protection. The majority of households (56%) indicated the main solution to coastal erosion would be large-scale seawalls supported by the state as well as communal action in the form of landfilling (11%), moving to higher grounds (7%) and tree-planting (6%). Yet, building seawalls, both autonomous as well as planned, requires large-scale financial inputs that cannot be met easily by residents or their governments. In line with these findings, survey respondents who did not carry out any adaptation measures at household level indicated that this was mostly due to lack of financial means (71%), lack of the necessary knowledge (41%) or skills (40%), or lack of other resources (18%) (Figure 3). Our data clearly revealed that lack of the necessary knowledge on materials to use and the lack of technical capacity to know how to build adequate adaptation measures was a significant limitation in carrying out adaptation measures. Coastal erosion is perceived to be a very serious threat by many on the island, and only 3% of the affected respondents indicated that they did not adopt any adaptation measures because they did not consider it a priority.

At state level there have also been limitations to adaptation. The state has acknowledged the increasing negative impacts of climate change and various recent policy documents highlight this, most notably the Nationwide Climate Change Policy (NCCP) in 2009, the National Energy Policy and State Action Plans (NEP) in 2010, the National Action Plan to Combat Land Degradation (NAP) in 2011, and the UNFCCC FSM National Communication in 2012. The state has declared policies to reduce the human causes of coastal erosion, such as the prohibition of sand mining and climate change awareness programs. The state of Kosrae is the only state in the FSM that has passed the Climate Change Bill, implying that all new activities to be carried out on Kosrae would have to be climate-proof (e.g., when a new road is built it has to be at a higher elevation to withstand SLR).[14] However, this Bill has not implemented due to lack of material and financial resources, and has to be incorporated in the environmental impact assessment regulation currently in process.

Adaptation measures can also cause environmental externalities (Eriksen et al., 2010). The autonomous adaptation measures residents have carried out only provide temporary relief at best. Gabions filled with paint drums and other waste can cause environmental hazards. Planned sea walls have also had unforeseen and undesired environmental consequences. They have caused changes in currents and beach loss, and caused coastal

erosion at the edges of the wall (Maharaj, 1998). Data from our in-depth interviews and focus group discussions showed that in the majority of planned sea walls, erosion was actually intensified at the edges of the construction.

Limits to adaptation were also found in endogenous factors of society including social, cultural limiting factors (Adger et al., 2009). These limitations on Kosrae can for instance be found in relocation to higher grounds and the cultural practice of burying loved ones in the close vicinity of their house and thus often by the sea. Low-lying reef islands in the Pacific Ocean are perceived to be particularly vulnerable to the impacts of sea-level rise. On a number of low-lying atoll islands there are no uphill areas for residents to turn to for migration. Kosrae has steep, uphill areas yet, only two respondents indicated they had moved to higher grounds. This does not necessarily mean that moving to uphill areas has not been used as an adaptation measure. This results partly from our sampling method. We interviewed all households living within 60 metres from the coastline. However, when asked about solutions to coastal erosion, 'moving uphill' was only mentioned by 7% of respondents. Not only is access to the area difficult, there is also lack of access to drinking water, electricity and telecommunications. Moving uphill requires money to buy new land from the owners. Alternatively the state can buy land in uphill areas and redistribute it to those most affected and willing to move. Land distribution could change social relations and create potential conflict. Residents would also have to change their culture of living very close to the sea.

Coastal erosion is also affecting burial culture on Kosrae. In Micronesian culture, burial plays a major role (Spennemann, 2006). While burial patterns have changed with the arrival of Christianity, the land claims derived from burials remain strong (Spennemann, 2006). Many loved ones are still buried next to present day houses and family property. As most residents live right along the coastline, these graves are often close to the sea. With increasing loss of beach front, traditional burial practices are now being threatened, as one respondent explained:

> "We bury our loved ones right next to our house. We want to have our loved ones close to us. But now sea level rise and floods cause problems with the burial of our loved ones while we want our loved ones to rest in peace. We can't go on burying them like this and maybe we have to think of other ways to bury them." (Ismael George, male, 67, Lelu, 24 July 2012)

On Lelu island, resources to build seawalls and fill land are particularly limited as there are no large hills and rocks. In former times it was used as the residence of chiefs, while the main island Kosrae was for commoners. In the six centuries before European contact, the people erected an island city on Lelu island consisting of more than 100 compounds, paved roads and buildings with high walls up to 7 metres high (Morgan, 1988). Residents have used the basalt rocks from their ancient heritage site to build seawalls. Although it is presently illegal to use the ancient stones, a residents recalls the loss of cultural heritage:

> "The sea keeps on rising and the people need to protect themselves. They have used the stones from the ancient ruins on Lelu Island to build walls and fill the lands. For centuries the commoners built a complete city for the chiefs with paved roads and large houses made of rocks coming from Kosrae. Huge rocks, weighing tonnes, had to be shipped from the main island of Kosrae to Lelu island by wooden canoe over the open ocean. Now, when I visit the ruins most of the walls that used to be there when I was young have disappeared." (Moses Ittu, male, 67 years, Lelu, 27 July 2012)

4 Discussion and conclusions

In this paper we have examined the impact of coastal erosion on Kosrae, the various adaptation measures carried out by households and the limitations thereof. Studies suggest that rising sea level, particularly in the Pacific Ocean, can lead to a reduction in island size. Coastal erosion is considered one of the most prominent concerns on Kosrae (Mimura, 1999; Fletcher and Richmond, 2010). This study has demonstrated that, in line with other reports, a large percentage of households in the survey have experienced coastal erosion. The coastline has retreated, beaches have disappeared, and coastal roads and other infrastructure are at risk of being washed away. For the large majority this impacted their household, for example by impacts on housing or crop cultivation. Of those households impacted 60% indicated they had carried out autonomous adaptation measures such as building seawalls, reinforcing their homes, and planting trees. In line with Adger et al. (2007), Füssel (2007) and Klein and Smith (2003) our findings show that the theoretical distinction between reactive and proactive adaptation measures is fuzzy in reality. Household decisions to adopt adaptation measures were often triggered by an extreme weather event, but were largely made in anticipation of future risk changes.

Adaptation measures on Kosrae have shown the resilience of people and their aspiration to protect their housing and culture. As the island is very remote, residents have used rocks, coral and sand to build seawalls and fill gabions with whatever material they could find. This study argues that the adaptation measures adopted by most households are only partly successful in avoiding adverse effects of coastal erosion and that there are limits to adaptation. This study reveals that the limits faced by households to adaptation have physical, economic, and technical dimensions as well as social and cultural (Adger et al., 2007, 2009, 2013). The ability of an individual household to build a seawall and halt coastal erosion is limited both by their financial means, the physical limitations of small seawalls constructed by one household but perhaps not by his or her neighbours, and the lack of technical material and knowledge they have available to build adequate adaptation measures. In addition to the autonomous adaptation measures at the household level, there have also been several planned adaptation measures carried out. These mostly relate to the building of seawalls funded by the state. Sometimes, adaptation measure can be effective at reducing climate change impacts locally and in the present, but have adverse effects in other locations or in the longer term. Adaptation measures can thus create social and environmental externalities (Eriksen et al., 2010; Moser and Ekstrom, 2010; Adger et al., 2007). Our study found that although the planned adaptation measures were partly effective they also caused negative environmental externalities. The seawalls were effective at reducing the impacts of coastal erosion in the particular location where the seawall was built, but created negative environmental consequences at the outer edges of the seawall. Building more, and/or, improper seawalls could negatively affect the coral reefs around the island, impacting both biodiversity and fishing activities.

Outside of these more ‘exogenous’ limits to adaptation we have also found a number of more endogenous factors that relate to social and cultural limiting factors (Adger et al., 2009). Relocation to uphill areas comes with social consequences and limitations as it would affect current land tenure systems. Traditionally, nearly all infrastructure and

population are located in the narrow strip bordering the sea. Moving to the uphill areas not only requires a new set of infrastructure and access to basic facilities in these areas; it also necessitates a cultural change to move away from the sea. Kosraeans are also culturally accustomed to living close to where their loved ones are buried. Increased coastal erosion is affecting the burial practices of residents. The loss of culture as people have to change burial practices and the on-going loss of land and homes have far-reaching consequences that cannot be reversed and adaptation measures need to incorporate these cultural values.

This study showed that the existing measures households carried out to deal with impacts of coastal erosion are not enough to avoid loss and damage due to limits in their adaptive capacity. As a consequence these measures have costs (economic, social, and cultural) that are not regained. Despite adaptation measures, households still incur residual loss and damage; 92% of respondents indicated they still suffered from negative effects of coastal erosion and were unable to counter its effects. In the working definition used in this study, loss and damage refers to the "negative effects of extreme weather events and slow-onset climatic changes that people have not been able to cope with or adapt to" [Warner et al., (2012), p.20]. This research links 'loss and damage' explicitly with the literature about 'limits to adaptation' and non-economic losses (Adger et al., 2005, 2007; Warner et al., 2012). We have seen losses and damages that go beyond material losses, and that touch upon people's culture and identity values that contribute to the functioning of society as a whole. Implementation of new adaptation strategies requires significant institutional and political reform, technical support, social changes and financial support from donors. In order to improve future adaptation measures, collective collaboration and planned adaptation measures are necessary, for example relocation and advanced technological coastal defences adapted to local circumstances. These adaptation measures, however, need to be 'sustainable adaptation' measures (Eriksen et al., 2010) and thus contribute to socially and environmentally sustainable development pathways.

This case study can serve as a good example of many other islands facing similar challenges and the limitations and constraints SIDS face in dealing with climate change. Although Kosrae is an island that in comparison with low-lying atolls in the Pacific Island region has a larger area of uphill areas, it still faces similar challenges. This study can provide an example of limits to adaptation and the loss and damage that incur which other island in the region will face equally or even worse. The island's vulnerability is characterised by predicted severe impacts of climate change, SLR and extreme events; its relative isolation; the concentration of population, socio-economic activities and infrastructure along the low-lying coastal zone; and its insufficient financial, technical and institutional capacities. This extreme vulnerability seriously limits the capacity of Kosrae, and SIDS in general, to adapt to adverse impacts of climate change. Enhancing adaptive capacity is thus critical for SIDS if they are to meet the challenges of projected climate change and sea-level rise. Yet, climate change is just one of the pressing problems that most SIDS face. Other socio-economic concerns, such as poverty alleviation, high unemployment, improving housing and education all compete for scant resources. Adaptation measures must therefore be framed within the larger development goals of SIDS.

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Notes

1 This percentage is based on our calculations of SIDS' carbon production in 2009 from the Carbon Dioxide Information Analysis Center. See http://cdiac.ornl.gov/trends/emis/meth_reg.html (accessed 23 July 2013). All SIDS are included in this analysis except for: American Samoa; Guam; Puerto Rico; Tuvalu; and the US Virgin Islands.

2 See for more information on the Loss and Damage project http://www.lossanddamage.net/.

3 Kosrae state census 2010.

4 For further details and questionnaire template of project see http://www.lossanddamage.net/empirical-research.

5 Kosrae state census 2010.

6 The total number of households on Kosrae is1,170, with a total population of 6,616, according to the 2010 census.

7 Alek Alokoa, male, 63, Malem, 8 July 2012.

8 Sadako Sanney, female, 36, Tafunsak, 13 July 2012.

9 Jacob Palik, male, 63, Walung, 25 July 2012.

10 Julius Sigrah, male, 66 years, Malem, 15 July 2012.

11 Rucila Skilling, female, 59, Lelu, 18 July 2012.

12 Katie Allen, female, 42 years, Walung, 27 July 2012.

13 Kenson Thomson, male, 66 years, Lelu, 11 July 2012.

14 See, e.g., http://www.kpress.info/index.php/climate-change/576-kosrae-pacc-a-shining-example-of-climate-change-adaptation-measures.