Evaluation of coastal squeeze and its consequences for the Caribbean island Martinique

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Abstract

Based on a spatial model, the Martinique beaches and coastal wetlands are examined to identify the risks of coastal squeeze. In many cases coastal development prevents coasts from adapting to increased erosion rates by shifting landward. Also tourism infrastructure augments the vulnerability of beach reduction and mangrove squeeze. The majority of coastal constructions and especially tourist hotels are built within the zone at risk to flooding and erosion. Spatial analysis based on a conducted GIS model is carried out that evaluates the tourist destinations most vulnerable to the impacts of sea level rise. If sea level rises and beach reduction becomes an increasing problem the attractiveness of Martinique beaches as tourist destination is likely to decline.

2.1. Introduction

2.1.1. Coastal squeeze

The likely responses of wetlands to sea level rise are: Loss of the total wetland area by coastal erosion and inundation, relocation or migration rather than overall loss, change in the mangrove forest or beach structure, and mangrove increase or new beach accretion further inland. The aim of this study is to develop a methodology to evaluate the impacts of accelerated sea level rise to the beaches and mangrove wetlands of Martinique. As described below, these wetlands are of special importance for the island's economy and ecology. This study especially considers the sensitivity of the wetlands to coastal squeeze. In general, the term "coastal squeeze" is applied to the situation where the coastal margin is squeezed between the fixed landward

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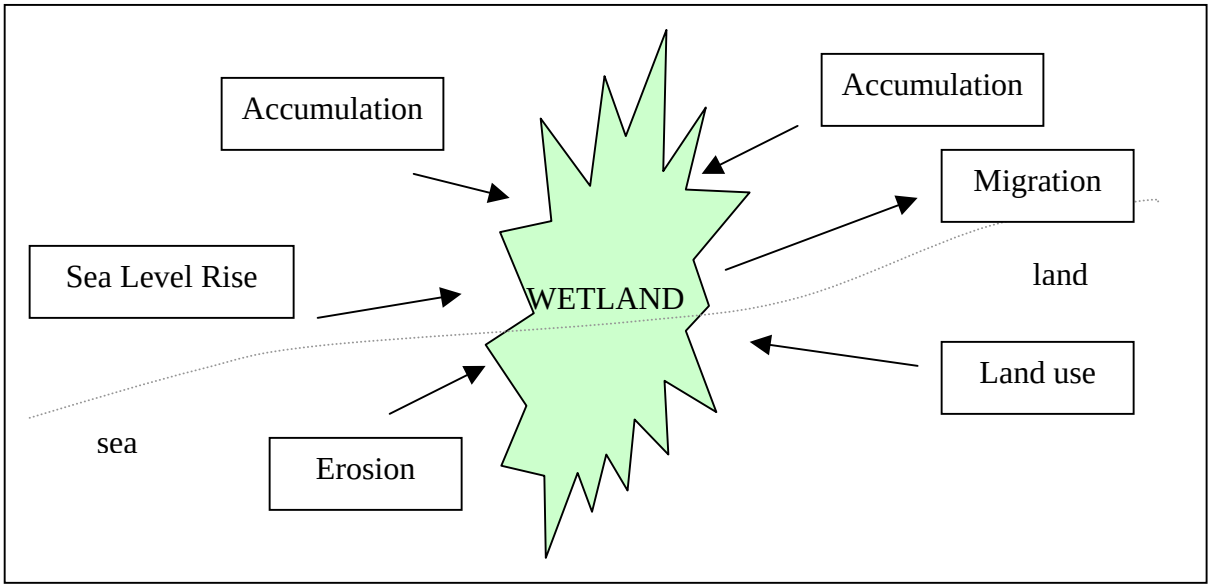
boundary (artificial or natural) and the rising sea level (ENGLISH NATURE). Most studies analyse squeeze in combination with tidal habitats (DOODY 1992; SALMAN ET AL. 2004; LEE 2001), but the term can also be used for other habitats when the landward position is fixed and erosion at the seaward margin is taking place. Numerous studies to the impacts of accelerated sea level rise exist, though only a few especially address the coastal squeeze problem (JONES 2001; DOODY 2004). Figure 1 shows a scheme representing the factors that influence coastal squeeze.

Fig 1: scheme of factors influencing coastal squeeze



2.1.2. Sea level rise in the Caribbean

Relative sea level in the Caribbean has risen of about 20 cm within the last century (MAUL 1993). Regional projections state a rise in sea level of additionally 10 to 50 cm by 2025 (MAUL 1993; UNEP 2000), respectively approximately 65 cm by 2100 (IPCC 2001). Scarce data availability within the Caribbean and high spatial variability among the islands makes concrete relative sea level rise estimates for each single island region problematic. Besides a rise in sea level further projections for the Caribbean region (UNEP 2000) expect an increasing frequency and intensity of

hurricanes and tropical storms that coincide with coastal flooding and high erosion rates at the shores, also as a cause of rising sea level.

2.1.3. Mangrove response to climate change and sea level rise in the Caribbean

Several studies about likely wetland responses to sea level changes have been conducted (e.g. IPCC 2002; ELLISON 1993; UNEP 1993; VAN DAM ET AL. 2001). However, there is still much controversy about this subject. Scenario studies of mangrove responses to sea level rise vary from little adverse impact to collapse. General statements should be treated with caution and some authors demand site-specific analyses (BACON 1994). The conclusions from these studies can be summarised as follows: The health of mangrove forests is mainly influenced by sediment supply/flux, suitable substrate, stand composition and status, tidal range and migration opportunities (VAN DAM ET AL. 2001). For this reason, the impact of sea level rise on coastal ecosystems will vary regionally and will depend on erosion processes from the sea and depositional processes from land (IPCC 2002). As the sea level rises, the surface of a coastal wetland shows increased vertical accretion due to increased sediment and organic matter input (NICHOLLS ET AL. 1999). Therefore wetlands show a dynamic and non-linear response to sea level rise. Studies of the UNEP (1993) expect mangrove forests to tolerate the anticipated sea level rise in rainfed humid areas. But the mangroves may be overstepped and abandoned in more arid areas particularly if inland retreat is not possible (UNEP 1993). Fringe mangroves, the main mangrove type on Martinique, are expected to decrease in area on mountainous islands, and to migrate inland on low lying islands (BACON 1993). River mangroves are projected to be able to migrate inland. But, in many cases on Martinique, coastal development prevents wetlands from adapting by shifting landward. Where wetlands are bounded by elevations, as is the case in many of the Caribbean islands, it is unlikely that they will shift landward as the sea level rises (UNEP 1993; ELLISON & STODDART 1991). Accretion studies of ELLISON (1993) show that mangroves of low islands are at risk from the rates of sea level rise predicted for the next 50 years. They are expected to suffer from erosion and inundation stress. Studies for mountainous islands, such as Martinique, do not exist.

2.1.4. Martinique

Martinique is an island of the Lesser Antilles in the Caribbean region. It is a French Department and EU "ultra-peripheral region". The economy is largely based on the export of agricultural goods (bananas, sugarcane, and pineapples) and tourism as major income sources. Nearly one million visitors annually arrive on the island that is inhabited by approximately 390.000 people (MARQUES 2002; CHARRIER 2003). Because the topography of the island is characterised by steep mountains, the majority of the settlements and about 77% of the population are situated along the coast below the 20 m contour line. Today, most of the Martinique population is concentrated in the extending urbanized zone of the cities Fort-de-France and Schœlcher, where houses are built almost at the level of the sea.

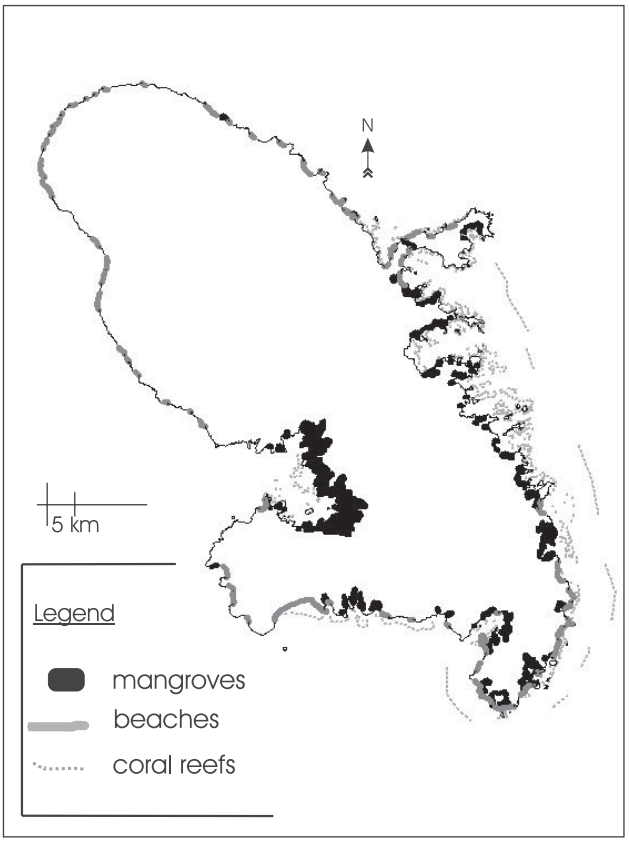
2.1.5. Beaches and mangroves on Martinique

Martinique has approximately 120 beaches, which make up 13% or 57 km of the entire coastline. The beaches on the north and south coasts of Martinique are made of fine sands. The northern beaches are situated between the foothills of the Mt. Pelée and the sea. They mainly consist of black sand that originates from the erosion of pyroclastic depositions of volcanic eruptions in the hinterland. In general these beaches are small in extent. The southern beaches consist of white sands that originate from the abrasion of bordering coral reefs along the Atlantic. They are of special importance for tourist purposes. The main endangerment for beaches is erosion. Currently eroding beaches and barriers are expected to erode further as the climate changes and sea level rises (IPCC 2002).

Along the Martinique coastline there are about 79 km (18%) of mangrove forests, which total approximately 1.850 ha of mangrove area or 6% of the total island surface (DAF-AGRESTE 1998). Mangroves are mainly found inside the bays of the south and south-eastern coast of the island (650 ha), as well as in extensive formations in Fort-de-France Bay (1.200 ha). On Martinique one can distinguish two mangrove types (DELBOND ET AL. 2003): First of all there are mangrove littorals or

submerged forests with *Rhizophora sp*. These types are situated inside the bays, mainly at Fort-de-France Bay, Francois, Robert, and Marin. Secondly, there are mangroves bordering the river mouths (Brossard et al. 1991). These types can only be found at Trinité and growths on terrestrial sediments. Figure 2 shows the distribution of beaches and mangroves on the Martinique coastline.

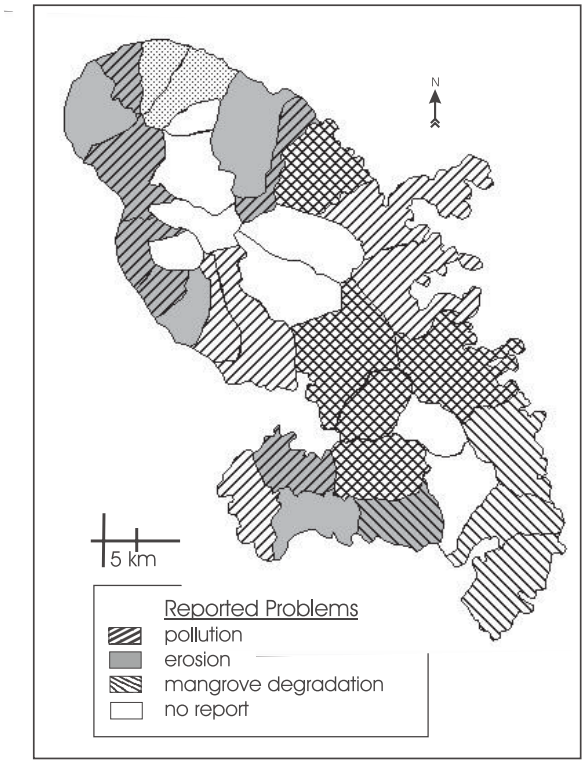
Fig 2: Distribution of beaches and mangroves on Martinique.(Based on IGN 1996; HINNEWINKEL & PETIT 1975)



Mangroves serve as main nursery areas to commercially important fish stocks. They are also home for a large variety of birds, reptiles and mammals. The wetlands at Fort-de-France Bay are internationally important for migratory birds (UNEP 1989), and the Martinique mangroves are rich in molluscs and crabs. Despite its (biological) value (see also COSTANZA ET AL. 1997), Martinique mangrove swamps are often regarded as marginal land and are therefore systematically degraded and destroyed (GABRIE ET AL. 2004). Often they have been selected as dump sites or for housing or

other urban structures to accommodate coastal development (LEWSEY ET AL. 2004). In the past, mangroves have been cleared especially for the construction of tourism and residential developments, due to urbanisation pressure, unsustainable wood use, or industrial pollution. GABRIE ET AL. (2004) report that about 30 % of the mangroves on Martinique were lost between 1972 and 1992. Even though there are now measures to prevent mangrove destruction which also include the construction of purification plants and the treatment of industrial sewage at an European norm, most of the mangroves still suffer from degradation (IFRECOR; ASSAUPAMAR 2002) and loss (FAO) (see Figure 3).

Fig 3. Reported environmental problems of the coastal zone. Data adapted from ASSAUPAMAR 2002.



2.1.6. Tourism on Martinique

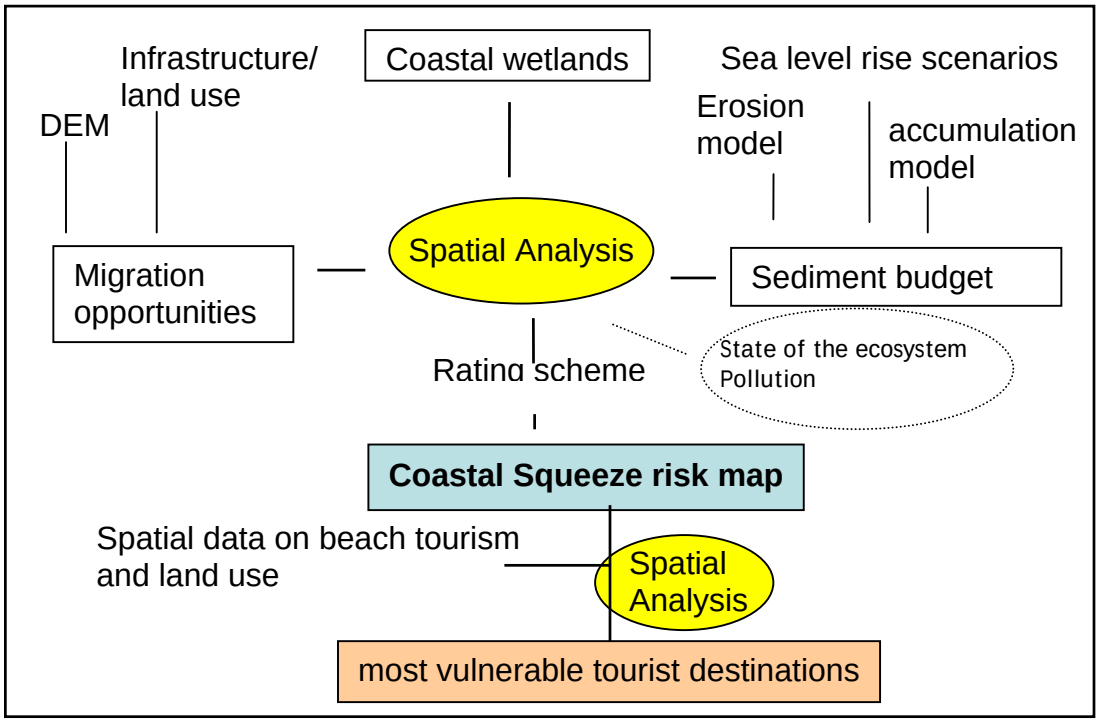
Tourism is, besides the export of agricultural goods, the most important income source on Martinique providing 6.4 % of the GDP (CARIBBEAN TOURISM ORGANIZATION 2004). Especially the beaches along the Martinique south coast are famous among tourists. Here the majority of tourist accommodation facilities, mainly

bigger hotel complexes are situated because of the favourite climatic and coastal conditions. Every year thousands of tourists visit the island just to spend some time (14 days on average) on these beaches. Main tourist season is during the dry months between December and March. From 1960 to 1998 the number of visitors has multiplied by about 50 (OFFICE DÉPARTEMENTAL DU TOURISME). Most visitors come to Martinique for its “sun, sea, surf and sand” image. More than three quarters of the visitors are of French origin (2003: 79 %), whereas most of them come from the Départements d’Outre-Mer - Territoires d’Outre-Mer (DOM-TOM) (MARQUES 2002).

2.2. Methodology: evaluation of coastal squeeze and its consequences

The methodology is divided into two main parts: the first one is the evaluation of the coastal squeeze risk of beaches, mangrove forests, deltaic and estuarine areas, as well as coastal swamps resulting in a map and the second one is the detection and location of the most vulnerable tourist destinations to squeeze impacts on Martinique. Figure 4 illustrates the applied methodology in more detail. Additionally, Table 1 gives an overview of the used data and its sources to examine the risk of coastal squeeze and area reduction.

Fig 4. Overview of the methodology.



Data	**Sources**
coastal elevation	HINNEWINKEL ET AL. 1975, IGN 1996, LANDSAT ETM+ SATELLITE DATA
coastal sensitivity to erosion and inundation during hurricanes	SCHLEUPNER 2007
land use	IGN 1996, LANDSAT ETM+ SATELLITE DATA,
wetland distribution	IGN 1996, LANDSAT ETM+ SATELLITE DATA,
sedimentation	ELLISON 1993, IFREMER.FR, SAFFACHE ET AL. 1999, SAFFACHE 2000

Table 1: data and their sources for the evaluation of coastal squeeze.

To evaluate coastal squeeze a spatial GIS-based model has been developed. Two parameters are selected that reflect the sensitivity of beaches and coastal wetlands to coastal squeeze and area reduction most: migration opportunities inland and sediment budget. These parameters were added to the spatial model that also gives geo-information about the coastal wetlands. The parameter “migration opportunities” rely on the variables human infrastructure and land use and a digital elevation model of

which the inclination has been computed. The parameter sediment budget on the other hand refers to sea level rise scenarios of 25, 50 and 100 cm (IPCC 2001). It is conducted in an erosion model and an accumulation model. The erosion model is based on historical erosion rates as well as results from a sensitivity evaluation (SCHLEUPNER 2007). In addition, the Bruun-Rule has been applied to the spatial model (BRUUN 1962). "Accumulation" as a weighted spatial submodel on the other hand takes the size of the shelf area, currents as well as sediment supply of rivers into consideration. Due to lack of detailed information data from studies that determine accretion rates for mangrove swamps on other Caribbean islands are used. Such rates seem to be similar on different Caribbean islands. This makes it possible to utilise the data also for Martinique even if there is a high range of uncertainty because of its mountainous topography. For example, the accumulation rates from Bermuda, Tonga and Cayman average from 8 to 10.6 cm/century (ELLISON 1993). That is less than the rate of sea level rise of 14.3 cm/century over the last few centuries, and the average rate of expected sea level rise of 28 cm/century during this century. Even if the hinterland is steep or developed there may be no wetland change at all due to high accretion rates. SAFFACHE (1999) examined sedimentation rates in bays of Martinique and found that hyper-sedimentation takes place that leads to enormous accretion rates inside the bays. Measurements of the Direction Départementale de l'Equipement reveal that the river Lézarde deposits on average 100.000 m³ of sediments into the Fort-de-France Bay every year, the river Monsieur 45.000m³ and the river Salée 90.000 m³ (cit. in SAFFACHE 1999). The reasons are high erosion rates in the intensified used watershed areas. Due to improved management techniques the erosion and with it the hyper-sedimentation in the bays is going to be minimized to normal level in the next years. Additionally, these sediments are often polluted and vegetation stocks are stunted because of this.

The squeeze model also contains the parameter "state of the ecosystem". At the moment there is a lack of detailed information to this. Therefore, the state of the ecosystem has not been included into the model so far but it is highly recommended to do this if data are available. Below this problem is discussed with the results. For

evaluation of coastal squeeze the parameters were analysed within the GIS-based model with help of a rating scheme that is described in more detail in Table 2.

1. migration opportunities depending on morphology and development **(M)**
 a. landward margin steep or coastline developed = **High**; migration impossible **(3)**
 b. landward margin of reclaimed land = **Medium**; migration under restriction possible **(2)**
 c. landward margin an adjoining wetland = **Low**; migration possible **(1)**

2. sediment budget **(S)**
a. sedimentation < sea level rise = **High (3)**
b. sedimentation and erosion offset = **Medium (2)**
c. sedimentation > sea level rise = **Low Sensitivity (1)**
(adapted from BACON 1994; altered)

Table 2. Rating scheme of the parameter migration opportunities and sediment budget

The results of the squeeze model are illustrated in a map that serves as base for the second part of this study, namely the detection of the most vulnerable tourist places to squeeze. Beaches are the main tourist destinations on Martinique. And also the mangrove forests serve as visiting places for tourists giving them the imagination of an adventurous day trip into "untouched nature". Spatial data on beach tourism (MARQUES 2002; DAF-AGRESTE 1998; OFFICE DÉPARTEMENTAL DU TOURISME; ARDTM; PARA ET AL. 2002; MARQUES 2003; ESPACES; INSEE; UYARRA ET AL. 2005) and infrastructure/land use were combined with the results of the squeeze risk analysis. Spatial analysis is carried out that evaluates the tourist destinations most vulnerable to the impacts of coastal squeeze.

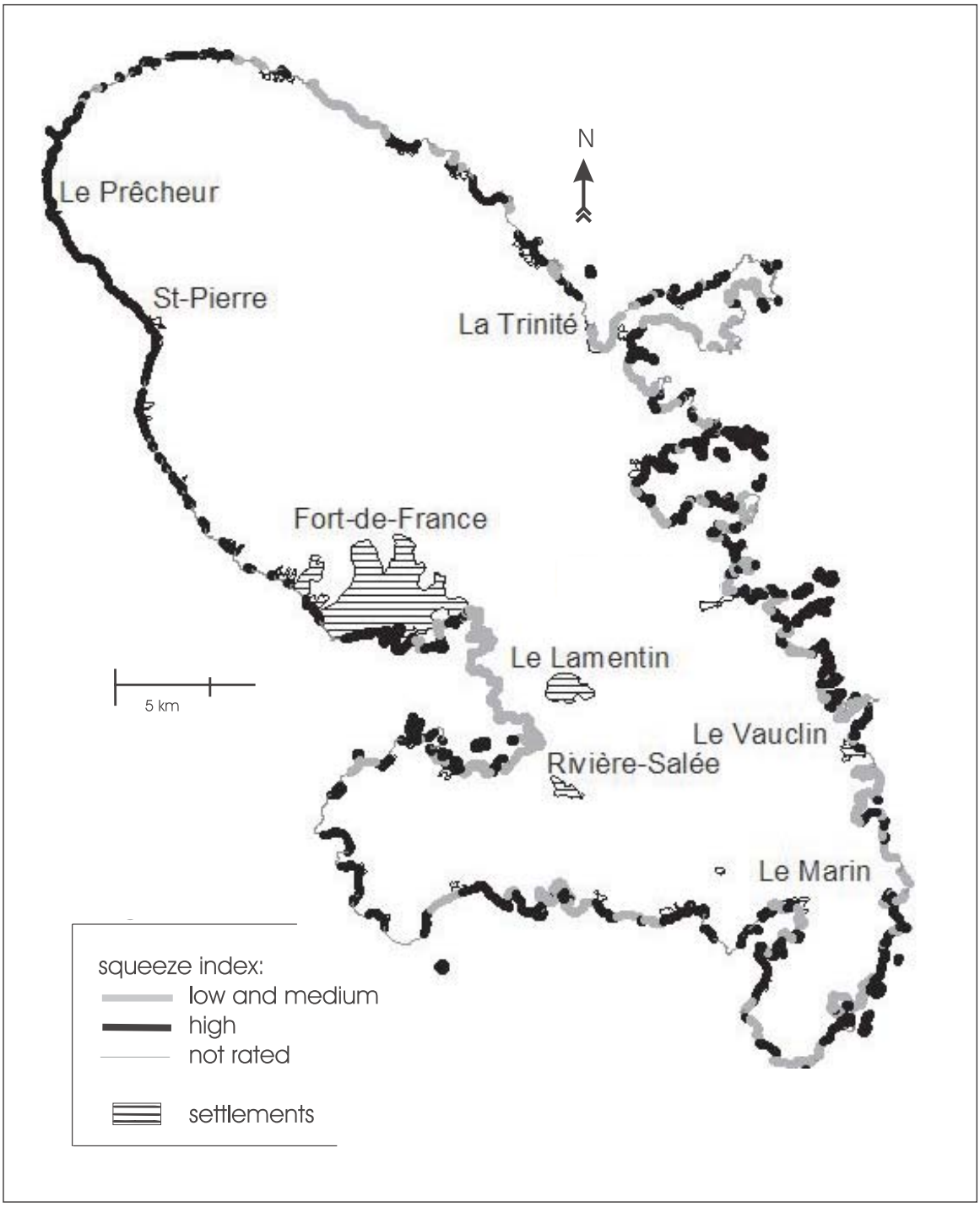
2.3. Results

2.3.1. Sensitivity of Martinique wetlands and beaches to coastal squeeze

In many areas of Martinique, beaches, mangroves and other wetlands provide significant coastal protection (DELBOND ET AL. 2003). The ecosystems serve as natural shock absorbers and protect coastal infrastructure and land use against

tropical storms and hurricanes. They also provide critical storage capacities for storm surges and flood waters (COSTANZA 1997). Beaches serve as attractions for tourists and are of economic value. All together, in 2002 6.537 people were involved in the tourist business on Martinique, 4.534 of them are directly employed in hotels and restaurants, 1.390 indirectly through other services, agro-industry, agriculture or transport, for example (PARA ET AL. 2002). Loss of the coastal systems would therefore have great impacts on human life on Martinique. The following analysis examines the adaptive capacity of wetlands and beaches to sea level rise on Martinique. Altogether, 78 % of the mangroves, 98 % of all Martinique beaches, and 86 % of other coastal wetlands are at risk to erosion and inundation if sea level rises. Often inland migration is impossible because of topography reasons but also because of urbanisation. Even if the majority of the coastline is natural space, 32 % (916 ha) of the coastal zone, the so called “50 pas”, are urbanised. Figure 5 visualises the sensitivity of coastal segments to area reduction and coastal squeeze for a sea level rise of 25 cm. About 45.6 % of the coastline is very sensitive to coastal squeeze.

Fig 5. Sensitivity of coastal segments to area reduction and coastal squeeze with accelerated sea level rise

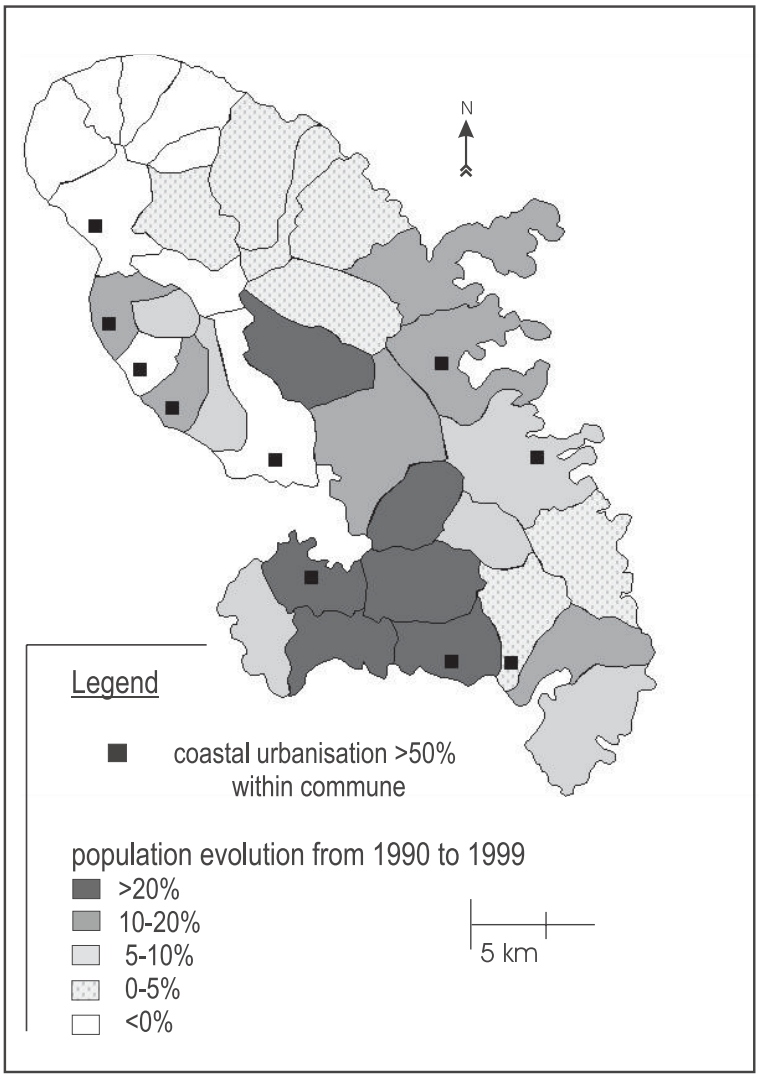

N
Le Prêcheur
St-Pierre
La Trinité
Fort-de-France
Le Lamentin
Le Vauclin
Rivière-Salée
Le Marin
5 km
squeeze index:
low and medium
high
not rated
settlements

The endangered segments are distributed all over the island, and especially the north-western part of the island is at high risk. Here the anthropogenic developments are situated right between the sea and the steep slopes of Mt. Pelée. Without their high sedimentation rates bays at the southern and eastern coast and the Fort-de-France Bay would also have greater sensitivity indexes than evaluated. 28.8 % (=124.6 km) have a medium squeeze index, only 0.8 % (3.4 km) got the "low sensitivity" index. 24.8 % (107.5 km) have not been included in the analysis because of their morphology (e.g. steep coast etc.).

2.3.2. Human impacts on mangrove squeeze and beach reduction

On Martinique tourism infrastructure, road networks and major settlements are usually all located along the coast giving locals and visitors an easy access to the coastal and marine natural resources and hindering the wetlands to migrate further inland. The vulnerability of beach reduction is also augmented. An evaluation of infrastructure and constructions situated within the impact zone reveals that settlements are seldom found below an elevation of 5 m along the southern coast whereas at the northern coast they reach further down to sea level because here is often the only flat land available. On average, the majority of coastal constructions are built at heights between 5 and 10m above the present sea level and therefore also within the zone at risk of flooding and erosion. Especially the tourist hotels are mainly found very close to the sea and below the 5 m level. Additionally, many coastal districts in the south experienced massive population increases during the last decade: Le Diamant +40 %, Trois Ilets +38 %, Sainte-Luce +30 %, Rivière-Salée +30 %, and Saint-Joseph +25 %, for example (CONSEIL REGIONAL). Figure 6 shows the districts with more than 50 % coastal urbanisation as well as the population evolution per district over time. Especially in the north-western coastal part urbanisation rates are quite high because of the mountainous topography. But also southern districts, at the moment considered as the most attractive living space, show high urbanisation rates.

Fig 6. Evolution of district population and coastal urbanisation rates.
(Sources: GABRIE ET AL. 2004; ASSAUPAMAR 2002)



Massive hotel construction programmes led also to a profound transformation of the coastal zone. In the past, the majority of tourism development has taken place without prior environmental assessments. As a result, hotels have been constructed in areas of valuable natural habitat. Latest trends have even led towards high-density, mass-market tourism sites close to the water's edge. But also smaller holiday and weekend homes are found along the south and south-eastern coast mainly between Trois-Ilets and Trinité. It is therefore a quite logical consequence that the majority of southern districts experience mangrove degradation (see Figure 3). This may accentuate the

coastal squeeze and would give way to the sea to reach further inland than with land protecting mangrove forests. Also coastal pollution adversely affects the health of mangrove forests and its ability to keep pace with rising sea levels. A clear example is the Fort-de-France Bay where pollution is a severe problem (SAFFACHE 1999; PUJOS ET AL. 2000).

2.3.3. Consequences of coastal squeeze and beach reduction for Martinique tourism

Local inhabitants depend on the diverse system of coastal and marine resources. The projected loss of beaches as a consequence of sea level rise may cause severe economic impacts on the tourism industry. A study on the beach-oriented island of Barbados showed that income from tourism is predicted to decline by 62% if the beach areas were significantly reduced (UYARRA ET AL. 2005). During questionnaires tourists indicated a reduced probability of selecting the island destinations if climate change significantly altered features such as beach structure or coral reef health (UYARRA ET AL. 2005). The same may also happen on Martinique: about 85 % of the beaches on Martinique are economically used for tourist recreation. That is a total length of nearly 42 km sandy beaches. Of these 27 % are associated with a village, a sightseeing-road, or a harbour. The remaining majority are the lonely beaches that Martinique is famous for. GIS-analysis revealed that the additional supply of suitable beaches that are tourism unused till now is nearly exhausted. A total of 6 km of the beaches, especially along the northern coast, are out of reach, and the remaining are not attractive for beach tourism. In total 83 % of the tourist used beaches are at risk to coastal squeeze. If sea level rises and beach reduction will become an increasing problem for the attractiveness of Martinique beaches as a tourist destination, because in general the Martinique tourist looks for the classic beach environment combined with warm climate, sandy beaches, an exotic picture, as well as relaxation opportunities. About 87 % of the visitors of 2002 came to the island to relax on the beach (MARQUES 2003), for example. With rising sea levels the consequences might be similar to those of Barbados (UYARRA ET AL. 2005).

In addition to the consequences of beach reduction, infrastructure found up to 300 m landward of the beach and within an area below 5-10 m along the coast is vulnerable to accelerated sea level rise. That is an area of about 11-14 % of the total island surface, where more than 62 % of the infrastructure and about 53 % of the total population is situated.

2.4. Summary

Spatial evaluation of the adaptive capacity of wetlands and beaches to sea level rise on Martinique shows that the regional wetland system is unlikely to collapse completely. Of the 79 km mangrove forests along the coast, only a total of 23 km is rated as highly sensitive to coastal squeeze, the majority of 55 km is of medium sensitivity, mainly due to high sedimentation rates. Furthermore, besides the migration opportunities and sediment budget the state of the ecosystem (degraded, stressed or in good condition) also needs to be taken into consideration. The marine and coastal ecosystems are stressed by agricultural pollution, hyper-sedimentation of bays, urban and industrial pollution, especially due to sugar and rum production, as well as oil and petrol pollution (SAFFACHE 1999). Studies about the coastal pollution of Martinique were available by SAFFACHE (1999; et al. 1999; 2000). Degraded and stressed ecosystems may not be able to adapt to sea level rise impacts even if coastal squeeze is not a problem. Degradation makes the ecosystems more vulnerable to extreme events. Many Martinique wetlands, particularly the mangrove forests are overexploited and polluted. Figure 3 shows those districts of Martinique reporting coastal pollution and wetland degradation. Most of the districts are reporting severe coastal pollution. It is important to note that six districts at the south coast do not seem to have any pollution problems. These districts are the main beach tourist destinations. They depend on their untouched, natural image of white Caribbean beaches. Nevertheless, most of these districts report high mangrove degradation. Nearly all districts with mangrove-stands report degradation, except for Le Robert and La Trinité, where the nature park of “Caravelle Peninsula” protects the remaining mangroves from human destruction.

Losses of wetlands impact many sectors and functions of coastal areas including food production (loss of nursery areas for fisheries), flood and storm protection (storm surges will penetrate further inland), waste treatment and nutrient cycling, and the capacity to serve as a habitat for wildlife (NICHOLLS ET AL. 1999). The mangroves may be able to adapt to the changing conditions: *Rhizophora* mangle, the main mangrove species on Martinique, occurs in markedly different geographic habitats, under brackish, marine, and hypersaline conditions, as well as in developed estuarine fringe forest down to lower scrub (BACON 1993). A problem is the coastal and marine pollution that threatens the mangrove habitats and makes them more vulnerable to sea level rise impacts.

In addition to the probable mangrove losses, 45% of other coastal wetlands and more than 70% (40 km out of 57 km total) of the beaches are highly sensitive to coastal squeeze. In particular the fine sands beaches along the southern coast that serve as main tourist destinations are the most vulnerable to coastal erosion. Theoretically, shoreline migration will create new areas of economic benefit as new beaches are built, but because of the mountainous island character, steep shores, and anthropogenic constructions very close to the sea sedimentation processes that might lead to beach evolution are unrealistic on Martinique. Therefore, the protection, replenishment and stabilisation of existing beaches, at least until major existing tourist investments are amortised, represents a principal socioeconomic impact (UNEP 1993). Against progressive coastal erosion it had become necessary for the regional council to work out defence strategies to protect the settlements and other infrastructure. Besides longitudinal and transversal buildings found along the coast at some settlements, breakwaters are built in front of hotel complexes in the south. Often the use of structural solutions interferes with sediment transport along the coastline and, with that, the shoreline stability of adjacent properties (UNFCCC 2000). Another aspect is that these measures are often not set in the right place to keep the view to the open sea for tourists. As a result protection for coastal erosion does not take place. In all, the protection buildings are not suitable for managing and protecting the coast permanent (UNEP 1989). Furthermore, no additional

considerations and strategies for a potential rise of sea level and its consequences do yet exist for Martinique beaches and wetlands.

However, Martinique has more to offer to tourists than just sandy beaches: Since 1999 the island also promotes ecotourism as alternative to its «sea, sand, sun »-slogan. Ecotourism on the island includes nature and culture activities like mangrove excursions, bird watching, museums, a garden route and rum circle that shall make the inland island and mangrove forests more attractive for tourists. Between 1990 and 1998 the booking of rural accommodations by tourists has doubled. In 1999 already 3 % of the Martinique visitors have been categorised as ecotourists. About 1.000 rural overnight accommodations have been counted in 1998 and future perspectives aim at 1.800 rural accomodations in 2006 and 2.800 accomodations in 2011 (NOSEL 2000).

Considering population developments on the island the northern districts might suffer from additional population loss, if coastal squeeze is going to continue further. The southern districts, however, are not going to decline in population, even if valuable beaches would get lost. The main population growth factor is here the proximity to the urbanization zone of Fort-de-France. Moreover, population growth would increasingly happen in the hinterland that is agriculturally used to date. Taking this scenario together with growing ecotourism into account, land use would change from agricultural fields for exports to suburban living spaces and rural tourist destinations. But the danger for the Martinique economy is still that the island may no longer be as attractive a destination as they is now and will lose visitors to competing destinations if environmental degradation, coastal squeeze, and beach reduction further continues as is projected here.

2.5. Conclusion

This study showed that spatial analysis is quite useful to locate and evaluate coastal parts sensitive to coastal squeeze and area reduction. On the basis of several spatial datasets, Martinique beaches, mangrove forests, deltaic and estuarine areas, as well as coastal swamps, are examined with regard to the risk of coastal squeeze and area reduction. The spatial evaluation of the adaptive capacity of wetlands and beaches to sea level rise on Martinique revealed that the majority of the beaches are highly

vulnerable to area reduction, whereas only 29 % of the mangrove forests are rated as highly sensitive to coastal squeeze. The majority is of medium sensitivity, mainly due to high sedimentation rates. But many Martinique wetlands are also overexploited and polluted. The state of the ecosystem is a factor that affects coastal squeeze and should be included into the sensitivity modelling as soon as appropriate data are available not to underestimate the results.

This study also tried to address the correlation between human impacts and wetland reductions. Often not only topography prevents the wetlands to shift inland, but also anthropogenic infrastructure. Especially the tourism industry often occupies areas very close to the sea. On the other hand the same is also dependent on the existence of wide natural beaches. The key aspects of the popularity of Martinique as a tourist destination are its fine sandy beaches, clear water and pristine habitats. If accelerated sea level rise further continues, Martinique is endangered to loose not only the majority of its famous beaches and its valuable mangrove habitats but also its prestige as beach tourist destination.

The data situation on Martinique is quite poor regarding coastal squeeze. It is therefore important to undertake more detailed studies to improve this littoral vulnerability assessment. Nevertheless, this study is a suitable attempt to emphasise that not only low lying islands are exposed to the consequences of accelerated sea level rise, but that also mountainous islands are vulnerable.

Acknowledgements

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Figure Captions

Tables