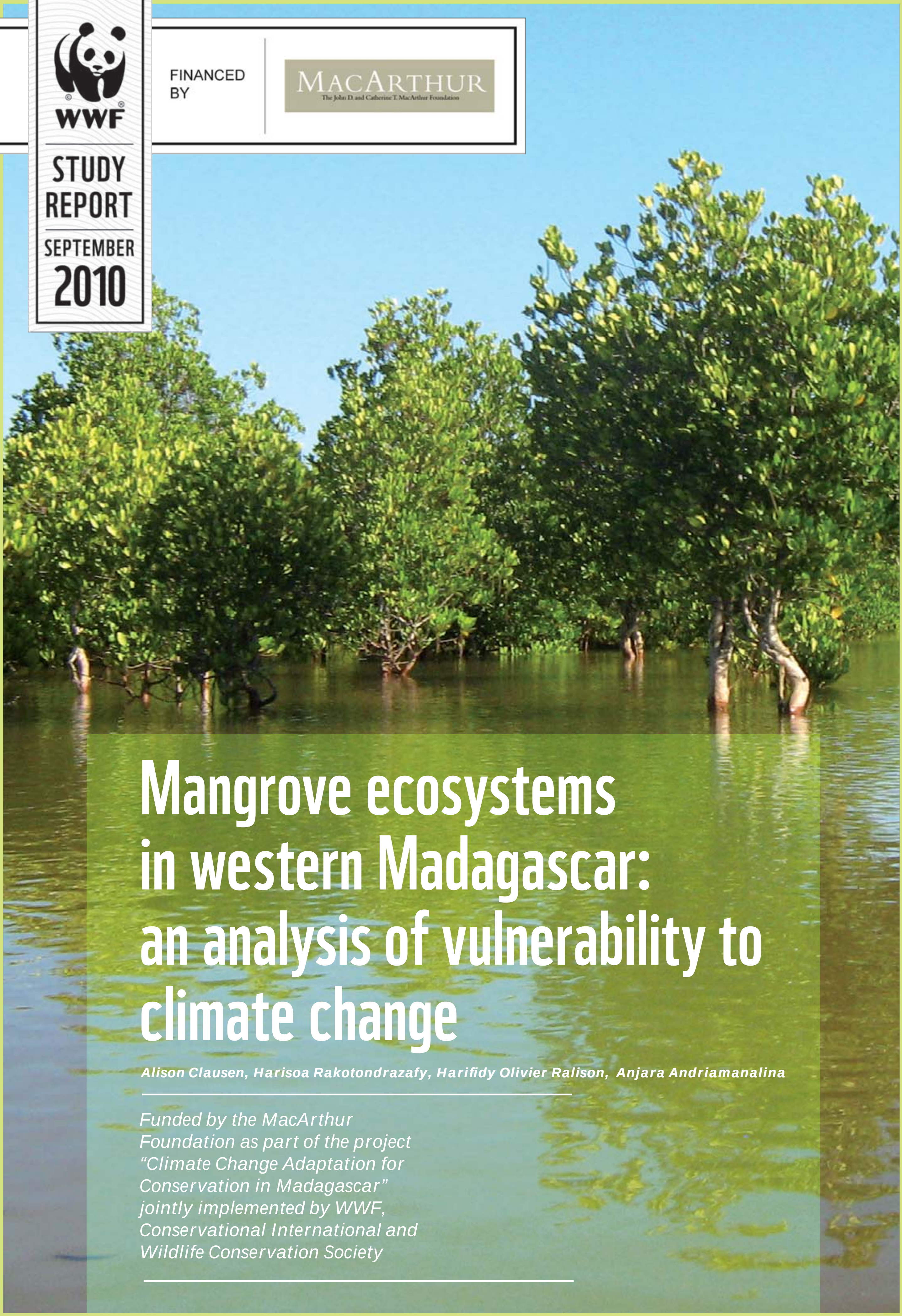

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STUDY REPORT
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Mangrove ecosystems in western Madagascar: an analysis of vulnerability to climate change

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Funded by the MacArthur Foundation as part of the project "Climate Change Adaptation for Conservation in Madagascar" jointly implemented by WWF, Conservational International and Wildlife Conservation Society

Myh Design / Ny Haja Rakotozandriny

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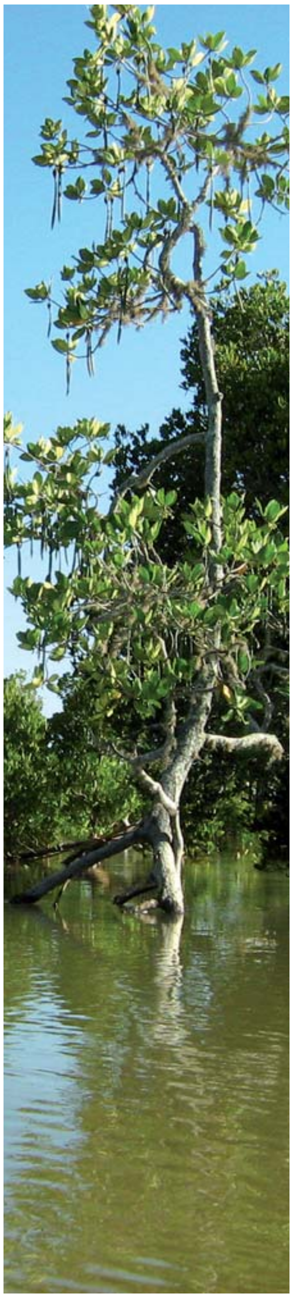
INTRODUCTION

Mangrove ecosystems are amongst the biologically productive ecosystems on earth. Covering approximately 150,000 square kilometers of the world's surface[1] , mangroves provide nursery and feeding habitat for numerous species of conservation and commercial importance. They also provide essential ecosystem goods and system for coastal communities including shoreline protection, water quality purification and provision of forest products[2] .



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The term "mangrove" refers to species of trees, shrubs or ground ferns generally exceeding more than half a meter in height, and which normally grow above mean sea level in the intertidal zones of marine coastal environments, or estuarine margins[3] . The term refers both to the individual species, and to the communities that they form. Globally, a total of 73 species and recognized hybrids of mangroves exist[4] .

However despite their social and ecological importance, mangroves are subject to a range of human pressures including clearing for coastal development, conversion for agriculture and aquaculture, and overexploitation of products[5] . 20% of the world's mangroves are estimated to have been lost in the last 30 years[6] .

Climate change is a new threat to mangroves. Rising sea levels, changes in precipitation and increased human pressures linked to growing human vulnerability to climate change, are likely to affect the productivity and conservation values of these unique ecosystems.

To increase the understanding of the potential effects of climate change on Madagascar's mangrove ecosystems, WWF Madagascar and Western Indian Ocean Programme Office (MWIOPO), with financing from the MacArthur Foundation, has undertaken an assessment of the climate change vulnerability of the second largest stand of mangroves in Madagascar in the deltas of the Manambolo and Tsiribihina Rivers on the country's west coast[7] (Figure 1).

The vulnerability assessment had the dual aim of (i) identifying hotspots of climate change vulnerability to inform conservation zoning and restoration activities in the Tsiribihina and Manambolo mangroves, and (ii) developing a methodology for mangrove vulnerability assessments that can be implemented elsewhere in Madagascar.

This publication has been prepared to provide an overview of the methodology that was developed for the vulnerability assessment and a description of the assessment outcomes.

1 Spalding et al, 2010
2 Alongi, 2002; Spalding et al, 2010
3 McLeod & Salm, 2006
4 Spalding et al, 2010
5 McLeod & Salm, 2006
6 Spalding et al, 2010
7 The project was carried out as a component of the MacArthur Foundation funded project "Climate Change Adaptation for Conservation in Madagascar" which was jointly implemented by WWF, Conservational International and Wildlife Conservation Society.

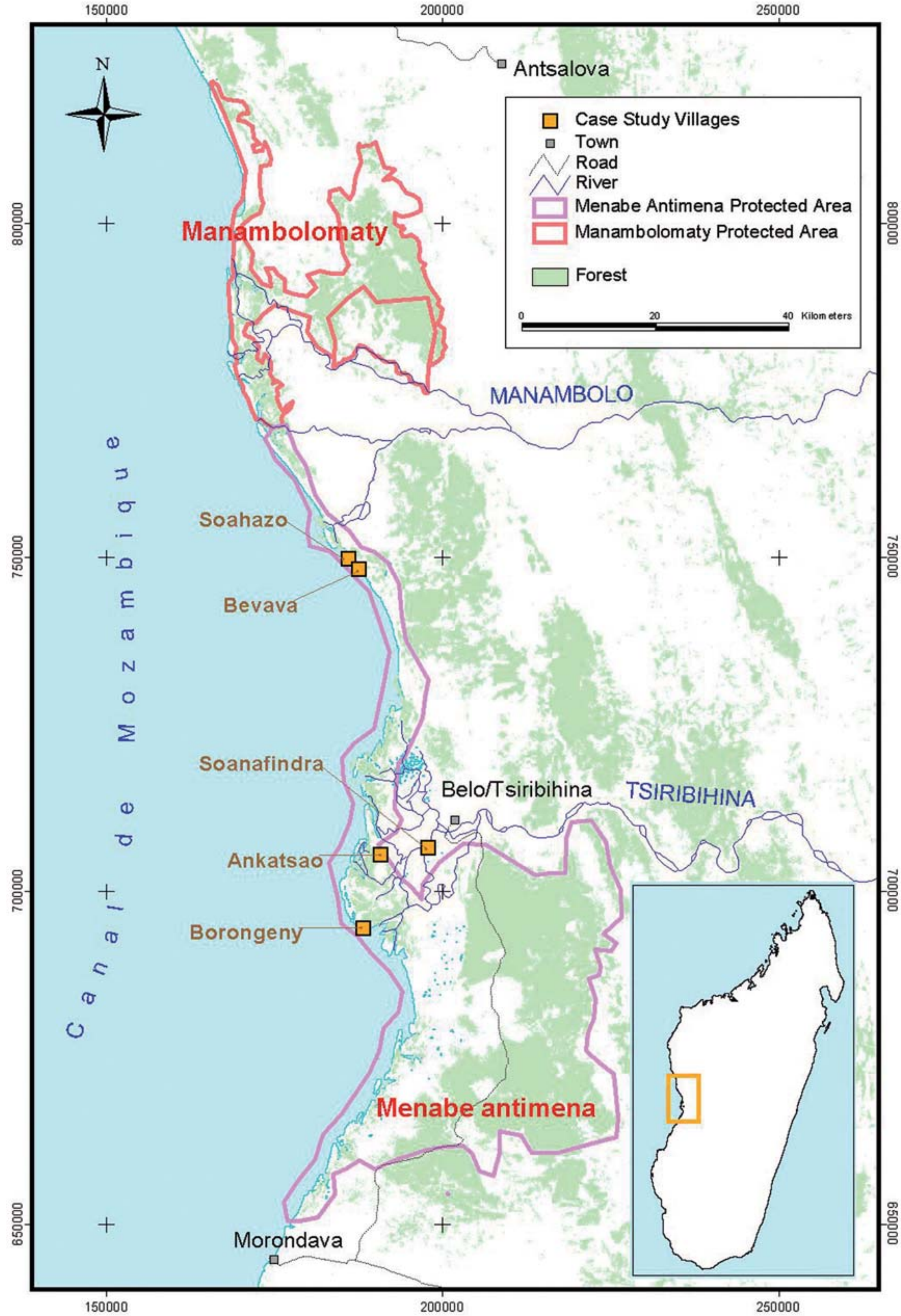

Figure 1: Location of Manambolo and Tsiribihina Mangroves

Mangrove Facts and Figures

- *Mangroves are found in 123 countries and territories globally*
- *Global mangrove coverage is equivalent to ¼ of the entire surface of Madagascar*
- *Mangroves have higher levels of primary productivity than most other tropical or temperate forests*
- *Mangroves play an important role in carbon sequestration – preliminary estimates suggest that the total aboveground biomass for the world's mangrove forests may be in excess of 3700Tg of carbon with additional sequestration in mangrove sediments*
- *Mangrove ecosystems are estimated to have an economic value of between US$2,000 and US$9,000 per hectare and play an important role in subsistence livelihoods for coastal communities*
- *Between 1980 and 2005, some 35,600 km² of mangroves were lost globally*
- *The rate of mangrove loss is three to five times greater than overall rates of global forest loss although the rate has decreased from 1.04% / year in the 1980s to 0.66% / year in the five years to 2005*
- *The greatest drivers of mangrove loss are direct conversion for agriculture and urban land uses, or overharvesting*

(Source: Spalding et al, 2010)

BACKGROUND

Mangroves are amongst the most vulnerable ecosystems to the threats of future climate change with estimates of loss of mangroves due to climate change by 2100 in the order of 10 – 15%[8] . Sea level rise is expected to be the most significant threat to mangrove ecosystems resulting from climate change[9] . It is difficult to measure the direct effects of sea level rise on mangroves because of the dynamic nature of coastal sediment elevation. However, increasing relative sea level is expected to cause die-back of mangroves through erosion that will result in weakened root structures and cause tree falls, changes in salinity and freshwater inputs, and changes in the duration, frequency and depth of inundation[10] . While to a limited degree mangroves may be able to keep up with small increases in relative sea level through accumulation of sediments and organic matter, there is increasing evidence in many areas that sea level rise is outpacing this natural adaptive mechanism[11] . Landward migration of mangroves is a complementary natural adaptive response to sea level rise. However, the success of this response depends on the availability of habitat with suitable hydrology, sediment composition, absence of competitive species, and the possibility of waterborne recruitment for mangrove species. The slope of the adjacent land and the absence of physical obstacles to migration is also important[12] .

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Within the Western Indian Ocean region, the most extensive stands of mangroves are found in Madagascar, which in total supports approximately 327,000 ha of mangroves. Mangroves are widespread along the entire west coast of the country facing the Mozambique Channel, with the largest stands located in the northern and central parts of the west coast where the climate is more humid. At least eight species of mangroves are found in Madagascar and human uses of mangroves are widespread. Madagascar's mangroves form part of the Indo-Pacific domain, but like

8 Alongi, 2007
9 Gilman et al, 2008
10 McLeod and Salm, 2006
11 Gilman et al, 2008 ; Spalding et al, 2010
12 Gilman et al, 2008

other African mangroves they exhibit less floral and faunal diversity than those of Southeast Asia[13] .

The Manambolo and Tsiribihina Rivers have their sources in the Bongolava Massif. The Manambolo and Tsiribihina deltas contain the second largest expanse of mangrove ecosystems in Madagascar covering an area of approximately 28,000ha. All eight species of mangroves that are found in the country are present in the area (Table 1).

Table 1: Mangrove Species found in the Manambolo and Tsiribihina Deltas

Species Name	Local Name in Project Area
Rhizophora mucronata	Tangandahy
Bruguiera gymnorhiza	Tangampoly
Ceriops tagal	Tangambavy
Avicennia marina	Afiafy
Sonneratia alba	Songery
Lumnitzera racemosa	Moromony
Heritiera littoralis	Lognony
Xylocarpus granatum	Fobo

The mangroves in this area have a critical importance for numerous endemic species that are listed as threatened on the IUCN Red List. These include the bird species that use the mangroves for nesting and roosting: Bernier's Teal (*Anas bernieri*) listed as Endangered; Madagascar Fish Eagle (*Haliaeetus vociferoides*) listed as Critically Endangered; Humblot's Heron (*Ardea humbloti*) listed as Endangered; and Malagasy Sacred Ibis (*Threskiornis bernieri*) listed as Endangered. The mangrove ecosystems also provide important habitat for the frugivore bat species, the Madagascar Fruit Bat (*Pteropus rufus*), which is listed as Vulnerable and subject to high hunting pressures. The mangrove ecosystems have important ecological functions and act as a production site for aquatic resources such as crabs, shrimps and fish; more than twenty species of fish, including four endemic species exist in the mangroves. The mangroves are contained in the Manambolomaty and Menabe Antimena protected areas, both of which have temporary protection status.

The project area is traditionally home to the Sakalava and Vezo ethnic groups. A population of approximately 50,000 lives in the area. In recent years immigration to the area has become more pronounced and has resulted in overexploitation of fisheries and mangrove resources and increased clearing of mangroves for rice production. The literacy rate of the local population is low and access to markets, health and education services are very limited. The population relies on fishing, agriculture, notably rice production, and animal husbandry. Mangrove resources are used for house and fencing construction, fuel wood and traditional medicines.

The area experiences a tropical, sub-humid climate with four distinct seasons throughout the year. The majority of the rainfall is experienced between October and March. The average monthly temperature ranges between 22°C in June and 29°C in March. The region is characterized by the *tsioka tsimo* winds which blow from south to north from May to July. These winds agitate the sea and make fishing activities impossible during this period. The area suffers cyclones and tropical storms on average twice a year which can cause flooding and other damages. Between 1969 and 2004, nine tropical storms or cyclones affected the area.

Modeling of future climate change for temperature and rainfall patterns in Madagascar has been carried out for 2050 using the A2 SRES scenario[14]. This modeling indicates a possible increase in annual mean temperature of between 1.1°C to 2.6°C, with the highest warming in the arid south-west region and the lowest in the north and on the coasts. While precipitation trends are harder to project, modeling data shows that by 2050, rainfall is likely increase in summer (January to April) throughout most of the country although projections are inconclusive over

13 Roger & Andrianasolo, 2003
14 Direction Générale de la Météorologie, 2008

the northwestern region. The winter (July-September) is likely to be drier in the south-east and east while the rest of the country is likely to be wetter.

Vulnerability to Climate Change

Human communities and ecosystems will be affected in different ways by climate change. Vulnerability is a measure of the type and scale of potential future effects, and can be defined as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.
Sensitivity is defined as the degree to which a system is affected by a climate stimulus, and adaptive capacity is defined as the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.
(Source: adapted from IPCC, 2007)

METHODOLOGY

The overall aim of the study was the development and implementation of a methodology to assess mangrove ecosystem vulnerability. In simple terms, the vulnerability is the climate risk, less the resilience of a system. For the purposes of the analyses undertaken during the study, the vulnerability of a system has been defined as the function of the exposure to climate change, the sensitivity of the system and the resilience of the system.


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Vulnerability = (Exposure + Sensitivity) – Resilience

Given the strong relationship between the mangroves and the human communities that exploit and depend on the resulting ecosystem goods and services, the overall vulnerability is influenced by the ecological vulnerability – linked to the biological and ecosystem characteristics of the mangrove themselves – and the social vulnerability – linked to the characteristics of the human communities that depend on and influence the mangrove ecosystems. The methodology that was employed for the project thus investigated these dual influences on vulnerability.

Step 1: Determine climate change exposure of system

↓

Step 2: Determine ecological vulnerability: data on sensitivity and resilience

↓

Step 3: Determine vulnerability of human communities

↓

Step 4: Conclusions on overall vulnerability of mangrove ecosystems

Step 1: Determine the climate change exposure

Climate change exposure can be defined as the degree to which the study area is exposed to the various manifestations of climate change. Such manifestations can take the form of increased temperature, changes in precipitation patterns, increased intensity and/or frequency of extreme events such as cyclones, and sea level rise. When assessing vulnerability it is not possible to analyze the effects of all manifestations of climate change and thus a decision has to be made as to which manifestations are dominant, or likely to have the most significant impacts.

In the case of ecological vulnerability of mangroves, sea level rise is the dominant manifestation of climate change and has the most potential to cause adverse effects[15]. The analyses of ecological vulnerability thus focused on the effects of sea level rise on the ecological characteristics of the mangroves.

Various methods exist for calculating the likely exposure of a study area to sea level rise. If regional or local modeling projections are available they can be used; while an alternative method involves development of a range of sea level rise scenarios for the study area, and the use of detailed topographic data to calculate possible inundation patterns. Neither of these methodologies was suitable for use in the study area because of a lack of available projections of sea level rise, and a lack of digital elevation data. The methodology that was used involved the digital analysis of historic satellite images from 1973 to 2005 in the project area to determine the past trends in flooding and thus extrapolate data on future inundation probabilities. The objective of this methodology was to identify those zones that will be most at risk of sea level rise due to lower elevation. The project area was categorized into six zones based on the probability of future inundation and four exposure categories were developed based on these zones[16] .

In the case of the vulnerability of human communities to climate change, the dominant manifestations were not known at the outset of the study and were investigated through surveys and discussions in local communities. National level climate change projection modeling carried out by the Direction Générale de la Météorologie in 2008 was used to investigate the different manifestations of climate change that influence social vulnerability as regional level projections are not available.

Step 2: Calculate the ecological vulnerability

A literature review and extensive field based study of the mangrove ecosystems was undertaken to allow analysis of the ecological vulnerability. The first step involved the categorization of existing mangroves based on their condition, regeneration potential and levels of disturbance. Six categories of mangroves were identified:

i. Dense mangroves: intact mangroves with a canopy height of 6 – 12 m
ii. Clear mangroves: widely spaced individuals with a number of dead individuals caused by the passage of a cyclone
iii. Recent / regenerating mangroves: young plants that are regenerating
iv. Degraded mangroves: widely spaced older plants that show evidence of cutting or clearing
v. Stunted mangroves: low density, stunted plants less than 2 meters in height that are influenced by the highly saline conditions
vi. Salt pans: arid, highly saline zones with little or no vegetation

15 Gilman et al, 2008
16 Andriamoraniaina, 2010

An inventory of the distribution and condition of the mangroves ecosystems was carried out and mapping prepared based on the above categorization.

Indicators for the resilience and sensitivity of the mangrove ecosystems were then selected. The rate of regeneration was identified as the most relevant indicator of resilience. The regeneration rate was calculated using the following formula:

$$TR = Nr / Ns \times 100$$

Where TR = rate of regeneration, Nr = number of regenerated individuals and Ns = number of seedlings

The rate of regeneration was determined for each category of mangrove and a resilience value attributed to each category based on the following scale:

TR Value	Resilience Value
0– 99	Low
100– 999	Medium
>1000	High

The sensitivity of the mangroves was determined for each mangrove category based on a consideration of the sensitivity of individual species to an increase in salinity, flooding, drying or siltation, and the proportion of each species found in each of the mangrove ecosystem categories. The following equation was used:

$$S = \sum s_m \times n_i / N_i$$

Where S = sensitivity of the category, sm = the average sensitivity of a species to the sensitivity factors, ni = the abundance of a species and Ni = population of the mangrove category

The following scale was used to categorize the sensitivity values:

S Value	Sensitivity Value
$1 \leq S \leq 1.75$	Low
$1.75 < S < 2.25$	Medium
$2.25 \leq S \leq 3$	High

GIS mapping of the resilience and sensitivity of the mangrove ecosystems was carried out and combined with climate change exposure mapping to illustrate the spatial distribution of zones of high, medium and low vulnerability.

Step 3: Calculate the vulnerability of human communities

The evaluation of social vulnerability in the project area was carried out at two levels. A commune level analysis was undertaken for the regions of Menabe and Melaky and more detailed analyses were undertaken in five villages that were selected as case studies in the project area.

Commune Level Analysis

The primary data source that was used for the commune level analysis was the 2001 commune census that was carried out by ILO and Cornell University in 1385 communes throughout Madagascar. Despite the fact that this database is several years old, it is a readily available source of data that contains 107 indicators on a wide range of commune characteristics. Reference was made to the IUCN guideline on social vulnerability to determine the relevant vulnerability indicators for use in the analysis[17] . The indicators that were selected are identified in Table 2.

Table 2: Social Vulnerability Indicators for Commune Level Analysis

Indicator Name	Explanation
Distance index	This indicator categorizes communes in terms of their distance from essential services and infrastructure and is a comprehensive measure of the isolation of the commune.
Presence of primary school	Access to basic education is a strong influence on the ability of a commune to adapt and reorganize the face of a climate shock.
Daily market	Access to markets is a measure of the ability to have a diverse food intake, as well as the ability to sell and purchase products.
Running water	Access to running water is an influence on hygiene and health.
Sales point for agricultural products	Access to agricultural products is a measure of the ability of framers to use improved seeds and products.
% of farmers that use chemical fertilizers	Use of fertilizers is a measure of the proportion of farmers that implement improved products in their agricultural activities.
% of population in agriculture, fishing or husbandry activities	The proportion of the population engaged in these sectors is an indicator of the importance of natural resources for livelihoods.
% of impoverished households	This indicator identifies the proportion of households who are food insecure throughout the year.
Duration of lean period	This indicator identifies the period during which a majority of the population reduce the number of meals or the quantity of food intake in response to lack of food.
Presence of farmer / fisher association	This is a measure of the organization and social capital of the commune.

For each indicator a vulnerability scale was developed and a resulting vulnerability score calculated for each commune. The scores were totaled and the communes were categorized as being of of high, medium or low social vulnerability.

Case Studies in Selected Villages

Five villages in the project were selected for more detailed vulnerability analyses both to investigate the links between commune level and village level vulnerability, and to illustrate the local specificities of socio-economic vulnerability (Figure 2). These villages were selected based on criteria related to the vulnerability of the commune where the village was located, condition of mangroves present in the vicinity of the village, the dominant economic activity of the village (i.e. agriculture or fisheries) and additional specific socio-economic characteristics such as high rates of exploitation of mangroves or high rates of immigration to the village[18] .

The qualitative analyses that were undertaken in the case study villages had the aim of identifying the dominant manifestations of climate change on local villages,

17 Marshall et al, 2009

18 Information on accessibility and security were also used in the selection of villages for the case studies

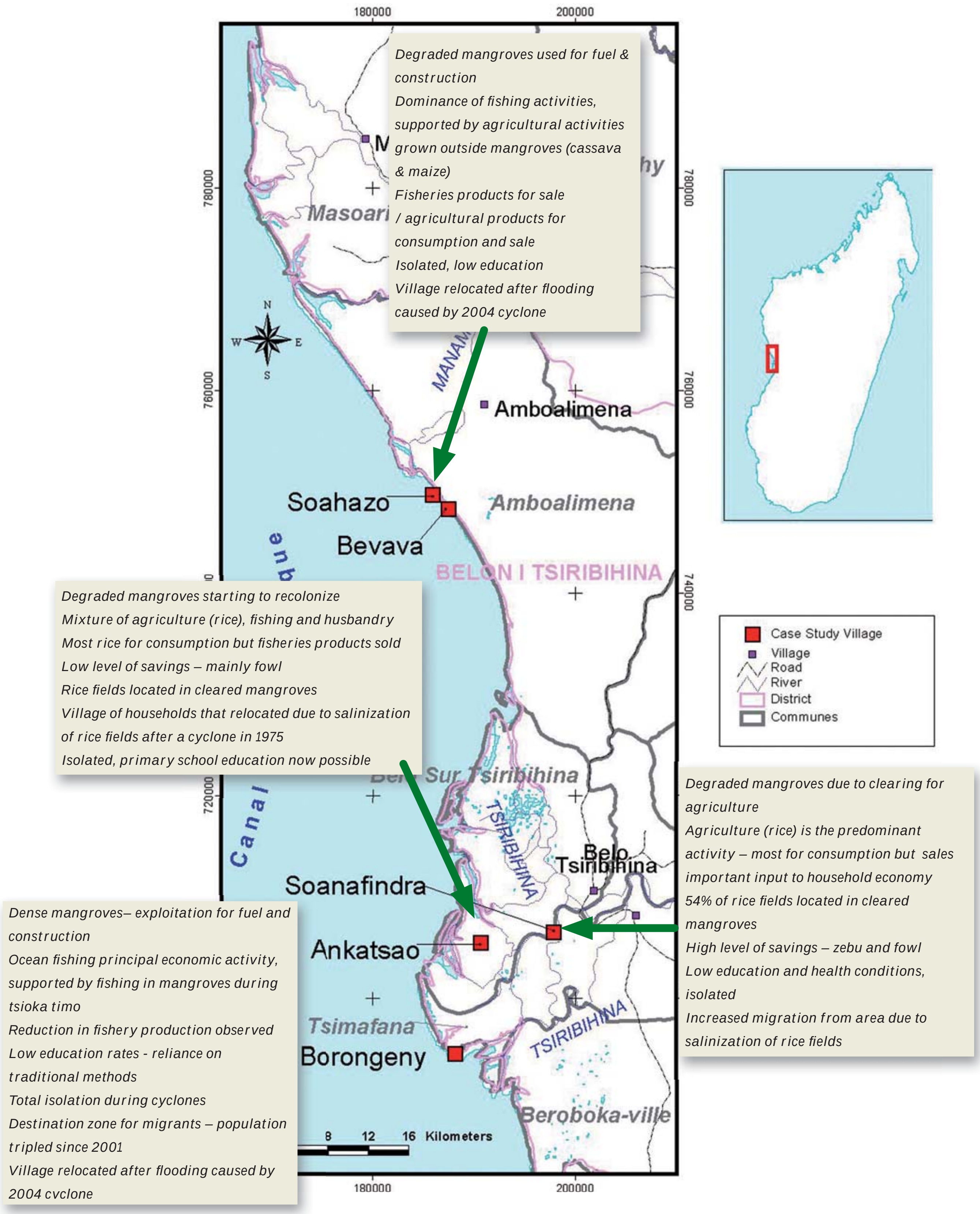

Figure 2: Description of Villages Selected for Case Studies

the characteristics of current vulnerability to climate change, and the likely trends in future vulnerability and resilience. In each village, household surveys and participatory research questions with focus groups were conducted. WWF's Climate Witness approach, a participatory social research tool that aims to both understand community adaptive capacity and raise awareness in communities about future climate change, was utilized as an important analysis tool in the villages[19] .

Step 4: Conclusions on the overall vulnerability

Conclusions on the overall vulnerability of the study area were developed from a qualitative analysis of the ecological and social vulnerability in the study area.

Project Methodology: Lessons Learnt

There is very little documented practical experience in developing countries related to vulnerability assessments in mangrove ecosystems. The methodology that was applied during the study was thus developed in an iterative manner to suit the local context and had to take account of a range of issues relating to difficulties in security and access to project sites, challenges of communication with and involvement of local communities in project related analyses and lack of baseline data sources. Key lessons that were learnt during the development and implementation of the methodology that will assist in its application in other areas in Madagascar or in other developing country contexts included the following :

- *The social vulnerability analyses at the commune level utilized data from a 2001 census. This database was selected as it was a comprehensive, freely available database that is easy to manipulate. To improve the accuracy of the commune level analyses, more recent data could be generated or purchased.*
- *Research tools that were used in the local community need to be adapted to the local context. In the case of the current study, the communities were nearly entirely illiterate and several of the tools employed such as seasonal calendar creation or village mapping were difficult for some less-educated participants and as such, they did not have the same ability to express themselves during the analyses.*
- *The method that was utilized to generate climate change exposure data relied on incomplete historic datasets as a proxy for future conditions. If topographic data had been available or able to be generated at an appropriate scale, it would have allowed a range of different future scenarios to be tested and analyzed.*
- *The uncertainties and data gaps inherent in the analyses highlight the need for monitoring and adaptive management processes to form an important part of future work in the project area, both to validate predictions and to allow ongoing refinement of developed responses.*

19 WWF South Pacific Programme, undated

RESULTS

Ecological Vulnerability

Each category of mangrove ecosystems differs in the level of resilience to climate change. Table 3 summarizes the resilience of each category of mangroves in the two delta areas.

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Table 3: Resilience of mangroves in Manambolo and Tsiribihina Deltas

Manambolo Delta	Resilience Category
Clear Mangroves	Medium
Dense Mangroves	High
Degraded Mangroves	High
Stunted Mangroves	Low
Tsiribihina Delta	
Clear Mangroves	Low
Dense Mangroves	High
Degraded Mangroves	Low
Stunted Mangroves	Low

Analysis of the sensitivity of the mangroves requires an understanding of the ecology and climatic tolerances of individual species. Despite their adapted root structures, the majority of species in the Rhizophoraceae family do not support prolonged periods without being inundated. *Rhizophora mucronata* and *Bruguiera racemosa* are stenohaline species that do not have a high tolerance to changes in salinity levels. *R. mucronata* requires large inputs of fresh water and *B. racemosa* only supports long periods of exposure to air if the substrate is moist. While of the same family, *Ceriops tagal* is the exception to the general rule and can tolerate high salinity levels and sandy substrates.

Species in the Avicennia family, *Avicennia marina*, are more tolerant, not only to sand intrusion but also to long periods of exposure or inundation. Within the Sonneratiaceae family, *Sonneratia alba* supports high salinity levels and prolonged periods of inundation. *Xylocarpus granatum* in the Meliaceae family requires low salinity levels and prefers habitats on the banks in inland canals. Similarly *Heritiera littoralis* and *Lumnitzera racemosa* require water with low salinity levels.

The ecological vulnerability is illustrated in Figures 3a and 3b.

In the Manambolo Delta, there are no areas of mangroves that are classified as having high or very high ecological vulnerability. Areas of mangroves of medium ecological vulnerability are located in this zone adjacent to the coast and along inland waterways, while the majority of the delta's mangroves are classified as being of low ecological vulnerability. In the Tsiribihina Delta, areas of mangroves with very high ecological vulnerability are found in the northern part of the zone and in isolated patches throughout the Delta. There are large expanses of mangroves with medium ecological vulnerability throughout the remainder of the delta and in general this delta exhibits a higher ecological vulnerability than the Manambolo delta to the north. Table 4 identifies the areas of mangroves in the project area in each of the vulnerability classes.

Table 4: Area of Mangrove by Ecological Vulnerability

Vulnerability Class	Manambolo		Tsiribihina		Total	
	Ha	%	Ha	%	Ha	%
Low *(Vulnerability category 0-2)*	6,413	77	6,001	30	12,414	44
Medium *(Vulnerability category 3-4)*	1,727	21	9,902	50	11,629	41
High *(Vulnerability category 5-6)*	201	2	3,386	19	4,037	14

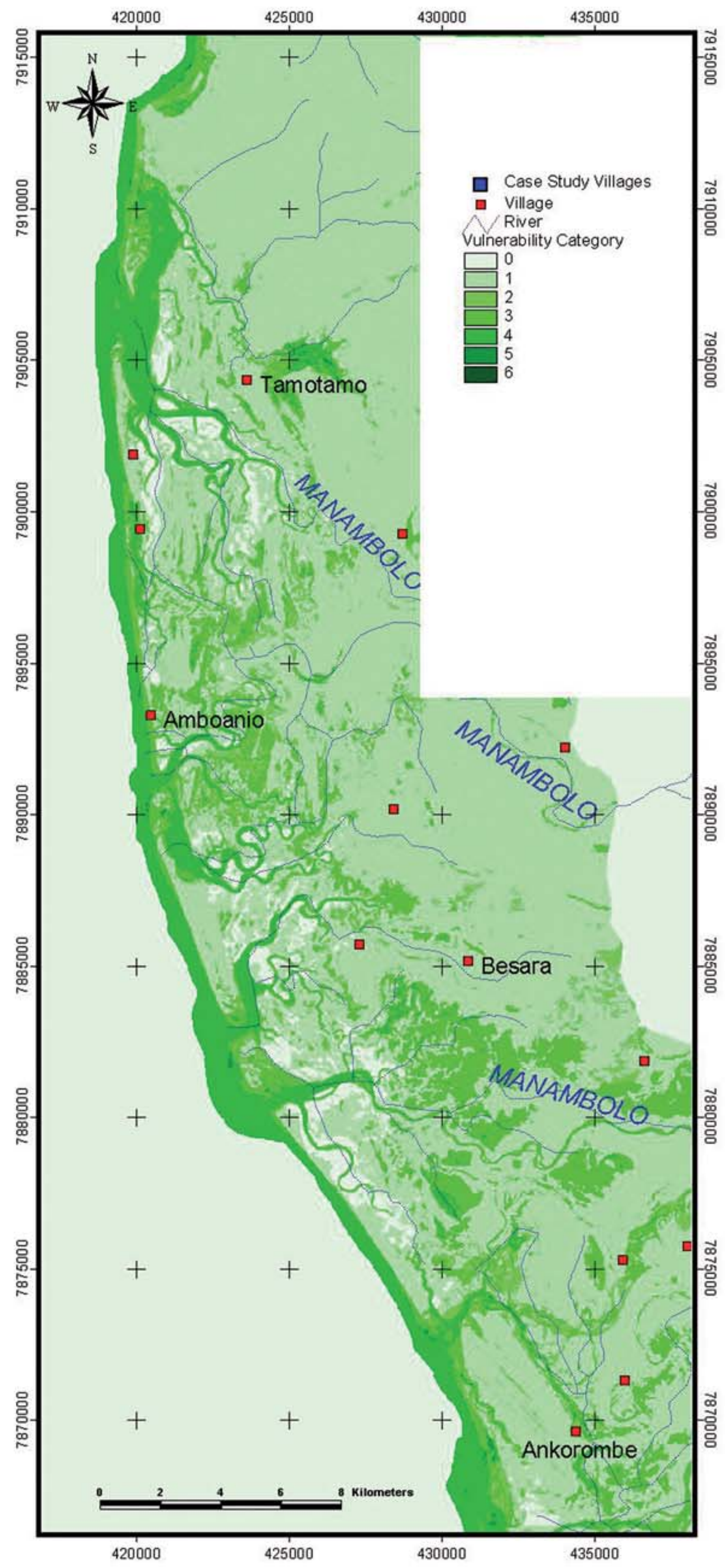

Figure 3a: Ecological Vulnerability: Manambolo Delta

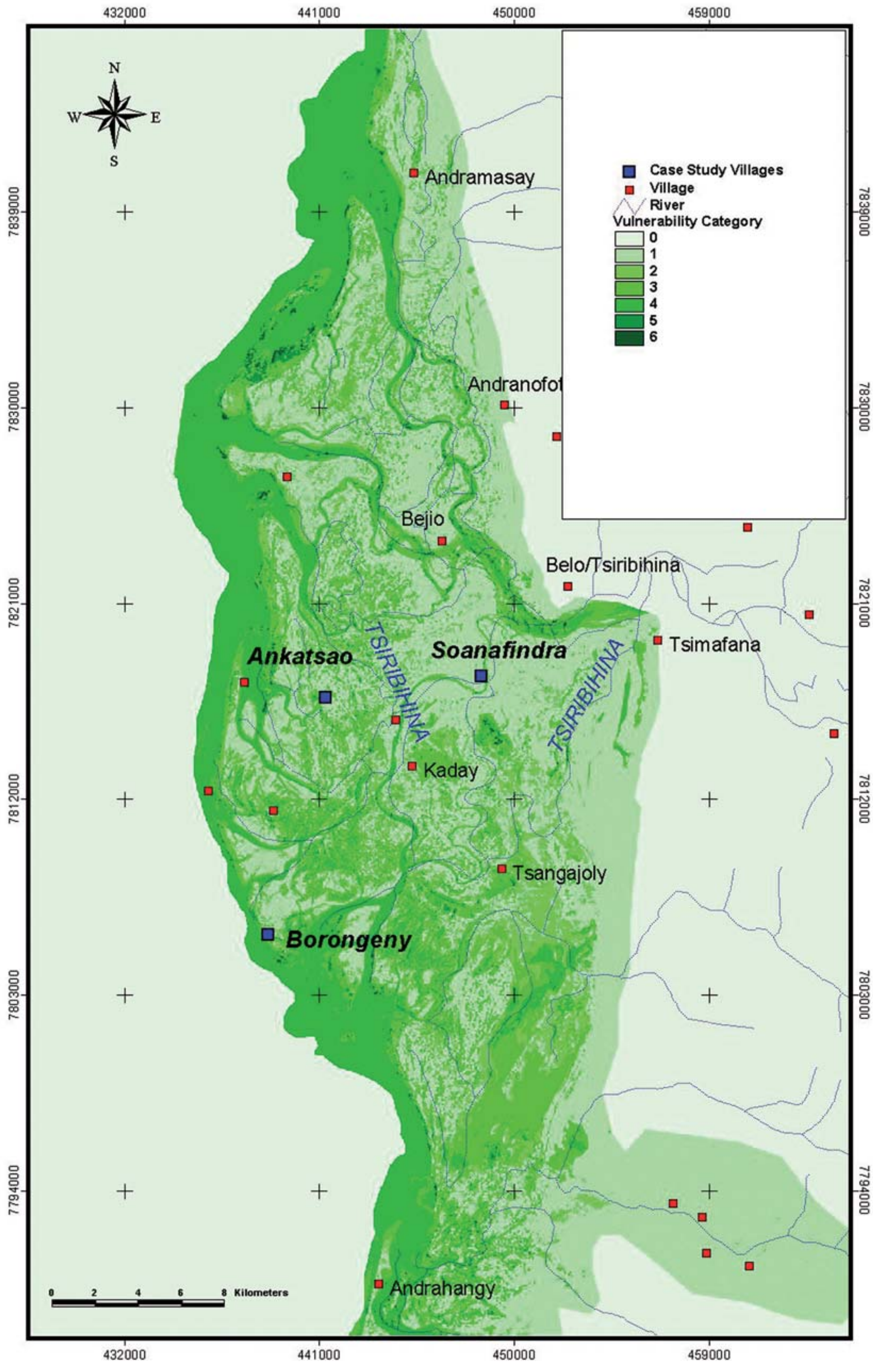

Figure 3b: Ecological Vulnerability: Tsiribihina Delta


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Social Vulnerability

Within both Menabe and Melaky regions, the vulnerability indicators that had the strongest influence on the overall vulnerability ranking were the distance index and the proportion of poor households in the commune. Those communes with a higher distance index, i.e. that were located further from a urban centre, and those with a higher proportion of poor households i.e. households less likely to have reserves to rely on after a climate shock, were the most vulnerable.

Melaky region in the north of the study area is more vulnerable to climate change than Menabe Region. In Melaky region, nearly two thirds of the communes are ranked as highly vulnerable to climate change, while in Menabe Region, less than half the communes are ranked as highly vulnerable. Within Melaky district, the coastal communes are generally more vulnerable than those located further inland, while in Menabe district the vulnerability of coastal communes is less due to the proximity to the provincial town of Morandava. The results of the commune level analyses of social vulnerability of the study area are illustrated in Figure 4.

The qualitative analyses carried out in the five case study villages revealed numerous common characteristics as well as highly localized differences that influenced village level vulnerability.

Changes in precipitation, both in terms of amount of precipitation and the timing of precipitation, were the most influential climate change manifestations in all of the case study villages. All villages indicated that in the last decade changes in the patterns and amount of rainfall had been observed. A reduction in the length of the rainy season from seven months (October to April) to five months (November to March) has resulted in later onset of rains and an earlier end to the season. All villages noted that this change in the seasonal calendar has had effects on agricultural and fishing activities. However, agricultural activities have been more severely affected than fishing activities.

Cyclones were also observed to have caused disruption to village life. For example in Borongeny and Soahazo villages Cyclone Gafilo in 2004 triggered the relocation of both villages following flooding and destruction of houses. Similarly in 1975 a cyclone blocked the freshwater supply to Kaday village which forced the relocation of that village to its new location at Soanafindra.

A review of vulnerability characteristics of the villages was based on the indicators described in Table 2 (although data was not available for each indicator) and indicated that all villages share high vulnerability in terms of the distance index, absence of markets and sales points, absence of running water and sanitation and low levels of use of improved agricultural or fishing techniques.

In all villages, pirogues are the main form of transport. Soanafindra village has a rural track that leads to Belo sur Tsiribihina but it is rarely used, while Borongeny and Soahazo villages also use boats to move up and down the coast. In the dry season navigation by pirogue is very difficult, and during cyclones and the period of the *tsioka timo* winds, boat navigation on the ocean is not possible. This reduced accessibility impacts on the ability of villagers to access markets to buy supplies and sell their products. None of the villages had improved water or sanitation facilities and all experience domestic water shortages in the dry season. The education levels in all villages were very low with nearly total illiteracy amongst adult populations. As a result of these low education levels the adoption of new, improved agricultural or fishing techniques is very low. In Soanafindra village, there is a primary school and attendance rates are high which may improve the education situation there for future generations.

The key differences between the villages relate to the types of economic activities they undertake. This characteristic, which plays an important role in determining the rate of poverty in the village and the duration of the lean period, was thus the key determinant of relative vulnerability amongst the villages.

Ankatsao village with a high dependence on agriculture, and with virtually no alternative sources of revenue, was identified as the most vulnerable because the sole means of existence for the 98% of the population depends on freshwater availability. The vulnerability of this village is offset somewhat by the high rate savings in the form of zebus and fowl, these animals are sold when required to provide an additional source of revenue.

Soanafindra village was identified as somewhat less vulnerable due to the higher diversity of income sources. Fishing in rivers and mangroves is carried out for sale in this village to complement the agricultural activities that are undertaken for consumption. This mix of activities confers a greater social resilience to this village.

The villages of Soahazo/Bevava and Borongeny were identified as the least vulnerable villages due to their reliance on fishing and the high economic gains from these activities which are less reliant on rainfall. Even though the length of the fishing season has been reduced due to a reduction in the length of the rainy season these villages are expect to respond better to future climate conditions. Borongeny fared better than Soahazo/Bevava in terms of social vulnerability due to the better condition of mangroves and the higher productivity of shrimp and crabs. However, if increasing cyclone frequency or duration in this area were to occur as a result of climate change, the vulnerability of these villages would increase due to the effects on the fishing season and the accessibility to markets for sale of fisheries products.

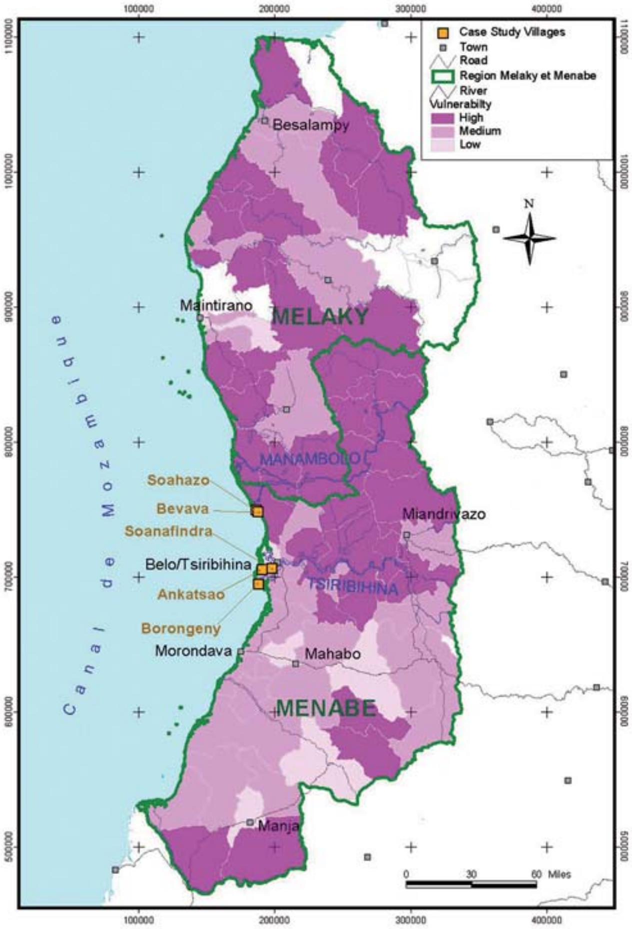
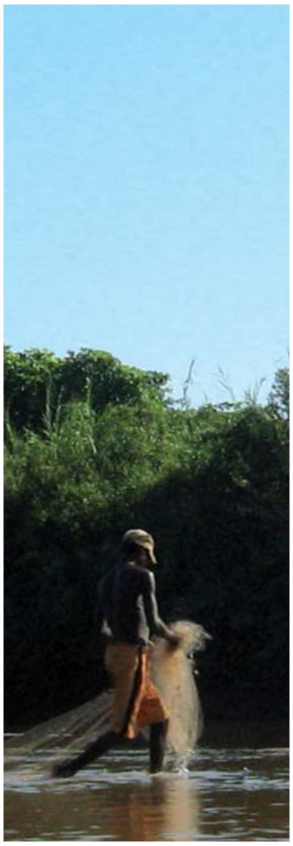


Figure 4: Social Vulnerability of the Project Area

CONCLUSIONS

From an ecological point of view, the highest vulnerability ecosystems are found in the southern part of the study area in the Tsiribihina delta. In this zone, 19% of mangroves are of high vulnerability and 50% are of medium vulnerability. The ecological vulnerability of mangroves in this area is influenced by large areas of mangroves with low resilience and the presence of numerous zones with a high probability of flooding that are distributed throughout the area, despite the absence of significant areas of highly sensitive mangroves.



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In the northern part of the project area, only 2% of mangroves are of high vulnerability and 21% of medium vulnerability. In this area, despite the presence of large expanses of mangroves with high sensitivity, there are large expanses of mangroves with high resilience and very few areas with a high probability of flooding.

The communes with the lowest vulnerability due largely to their proximity to an urban centre are located in the southern part of the study area where the ecological vulnerability is the highest. This trend would appear to be a positive sign – i.e. that the lowest vulnerability communities are located in the highest vulnerability mangroves and vice versa.

Nevertheless there appears to be little correlation between the commune level social vulnerability and the village level vulnerability, with highly localized characteristics an important influence on social vulnerability. The highest vulnerability village, Ankatsao, is located in the commune with the lowest vulnerability categorization. Similarly, Soahazo village which is amongst the villages with the lowest vulnerability, is located in the commune with the highest vulnerability score. Thus in the project area, the commune level vulnerability scores are not necessarily a good guide to an identification of localized hotspots of vulnerability. Local level knowledge is thus essential to the development of local scale adaptation measures.

Villages in the study area have exhibited a significant autonomous adaptation response to past extreme climate events, notably cyclones. In all of the case study villages past cyclones have triggered migration of individual households or entire villages. Direct effects (e.g. flooding, destruction of houses) and indirect effects (e.g. blockage of freshwater supplies) of cyclones were responsible for such migrations. Very few other adaptive responses were identified by communities in relation to past events. Common examples from other areas of Madagascar such as changes in planting patterns or calendars, or adoption of new products or techniques for fishing and agriculture have not been utilized in the project area. This indicates that communities have independently developed only a narrow range of responses and generally exhibit a low adaptive capacity. Low education levels and the high level of isolation of villages are possible causes of this low adaptive capacity.

The study highlighted the fact that analyses of vulnerability need to take into account both local community knowledge and scientific data. While traditional knowledge is essential to understanding the local context, a distinction should be made between community perceptions and community observations validated with research findings. For example, in the project area communities stated that a reduction in rainfall was responsible for a reduction in ocean fisheries production. Research into this issue in other parts of the country indicates that there is little scientific basis for such a claim and that overfishing is a more likely cause of reduction in fish productivity.

Despite the threats posed by climate change, globally research indicates that rates of deforestation and human pressures on mangroves currently outweigh the risks of climate variability[20]. It is estimated that if current deforestation rates continue, the majority of mangrove ecosystems will disappear before the most significant climate change impacts are experienced[21]. This is equally true in the project area where demand from urban centers for mangrove wood is increasing, together with the scale of industrial fishing. The development of adaptation strategies for mangrove ecosystems should focus on no-regrets measures that counter current anthropogenic pressures as well as increasing the resilience of mangrove ecosystems to face the climate related challenges that lie ahead.

20 Gilman et al, 2008 ; Alongi, 2002

21 Alongi, 2007

NEXT STEPS

Understanding vulnerability to climate change is the precursor to developing strategies that allow human communities and ecosystems to adapt to climate change. The current study has identified the overall relative vulnerability of mangrove ecosystems in the Tsiribihina and Manambolo deltas and investigated the types of effects that climate change is likely to have on human communities that depend on mangrove ecosystems.

WWF MWIOPO has secured a grant from the MacArthur Foundation to ensure that the data generated during the vulnerability assessment is used to make a difference to the lives of local communities and in the conservation of these important ecosystems. Use of the vulnerability assessment data to develop climate change adaptation strategies that build on local knowledge and practices to increase the resilience of local communities and the continued provision of ecosystem goods and services will commence in late 2010.

Adaptation to Climate Change for Mangrove Ecosystems

*The objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to ensure **'…stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system … (and) … allow ecosystems to adapt naturally to climate change'**. However, given recent modeling that has shown that even with immediate and dramatic cuts in greenhouse gas emissions the world's climate is already committed to long term change, there is now general consensus amongst the scientific community that proactive responses to climate change will be required for human communities and ecosystems. Adaptation can be defined as the process of developing and implementing measures to reinforce the resilience and adaptive capacity of systems, to assist them to adjust to the effects of climate change, to moderate potential damages, take advantages of opportunities or cope with consequences.*

Adaptation responses for mangrove ecosystems can be categorized as follows:

1. *'No-regrets' options that involve reduction of human stresses or restoration of degraded mangrove ecosystems*
2. *Catchment management strategies to manage activities that affect mangrove sediment elevation*
3. *Managed landward retreat of mangrove ecosystems*
4. *Representation and replication of mangrove ecosystems in protected area networks*
5. *Creation and protection of climate refugia containing resilient mangrove ecosystems*
6. *Monitoring and evaluation activities*
7. *Awareness raising and education activities*

(Source: Adapted from IPCC, 2007, Gilman et al, 2008 and McLeod and Salm, 2006)

Further information on the vulnerability assessment or WWF MWIOPO's climate change adaptation work can be found at *www.wwf.mg*
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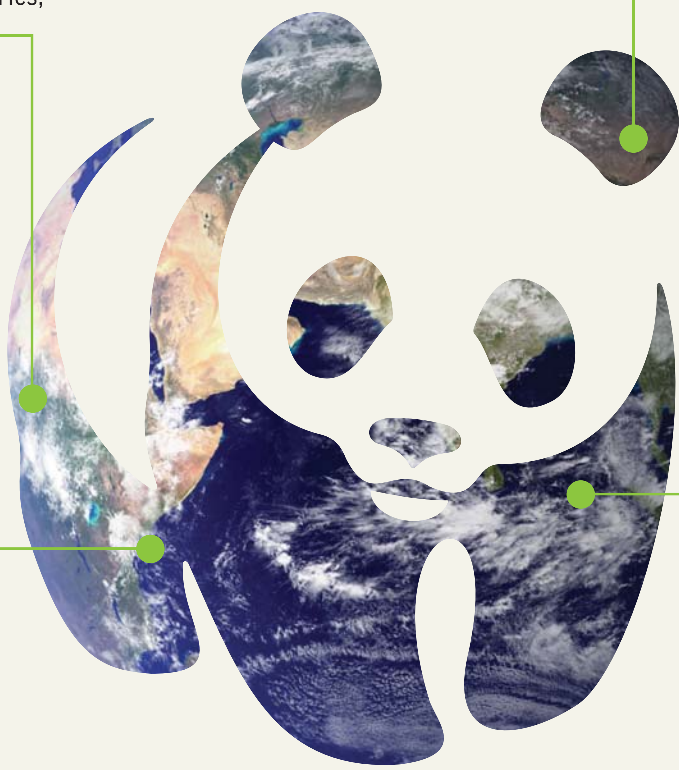

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To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony and nature.

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