Financial and Economic Disaster Risk Estimation in Madagascar for the Implementation of CatSim

Summary Report

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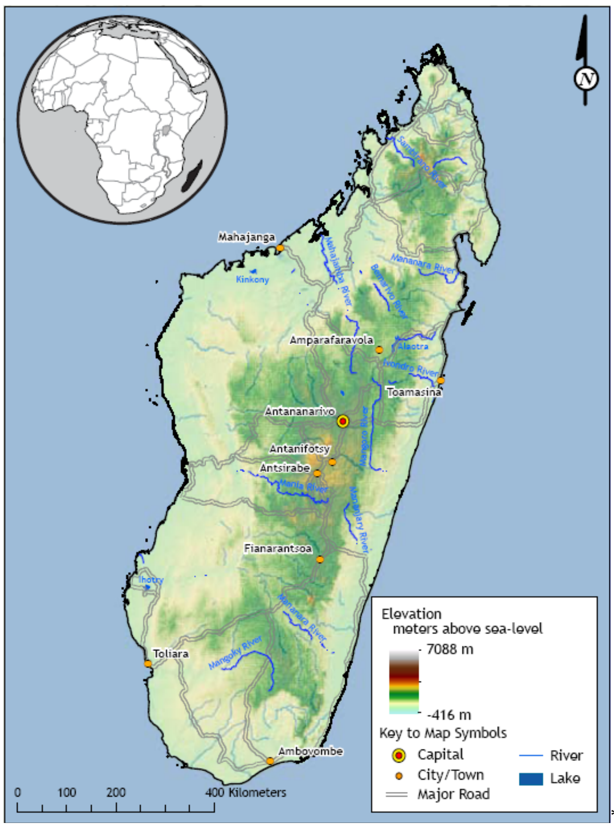

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"Mainstreaming Disaster Risk Management and Climate Change in Economic Development"
Technical Assistance to the Republic of Madagascar

Cellule De Prevention Et Gestion Des Urgences (CPGU)

* Source: GFDRR 2011

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1. Background

The purpose of this report and the exercise in the workshop is to discuss the CatSim (Catastrophe Simulation) approach to incorporate disaster risk management (DRM) into fiscal and development planning processes, as well as explore the feasibility of using disaster risk management options for reducing risk. It should support the ongoing CPGU (Cellule de prevention et gestion des urgencies) led study on "Mainstreaming Disaster Risk Management and Climate Change in Economic Development," which aims to

- quantify and model natural hazard risk for Madagascar in an objective fashion that will represent a scientific and numerical basis to inform sector-specific risk management practices
- produce solid and validated future impact scenarios that will enable stakeholders to make informed decisions on adaptive measures.
- build national capacity and coordination between the adaptation and hazard risk management institutions;
- produce a risk model for Madagascar that will inform the decisions and development of more effective risk financing options.

The report and associated modeling approach will support the overall study primarily through the assessment of the financial impacts of natural hazards on the Malagasy economy and the development of scenarios that will inform the financial strategies of the government, to manage their exposure to climate-related risk. Particular focus will be on the impacts of tropical cyclones, which tend to lead to widespread losses in the agricultural sector, and can result in severe damages to built infrastructure. The financial impacts of cyclones on the national economy is systematically assessed through a transparent modeling approach that gives the Malagasy stakeholders guidelines and a tool to better manage the financial risk arising from natural disasters now and in the future.

The two-day workshop that this document supports was intended to put the concepts into practice by allowing participants to work through a practical example of policy making in a risk based manner. The CatSim model aids in the analysis of public disaster risk management options. Furthermore, detailed descriptions of each step will be given in the appendices within the report.

Incorporating disaster risk management into fiscal and development planning requires consideration of three main issues: (i) risk reduction (preventing and loss mitigation); (ii) risk transfer; and (iii) financing the recovery. The emphasis here is on risk transfer and financing the recovery process, that is, the economic and fiscal considerations. To incorporate risk reduction into development planning would require extensive information on the human losses, which is not emphasized here. The development of a viable strategy requires policy-makers to consider their country's risk profile, development plans, as well as the government's fiscal, budget and debt situation.

Finance and planning policy makers wishing to proactively manage their country's contingent fiscal liabilities must keep in mind a number of general questions:

- Who assumes the risk – government or the commercial private sector, the rest of civil society and donors?
- What risk reduction priorities support the broader goals of development planning?
- How can risk financing instruments effectively encourage risk reduction measures?
- How can the policy process for managing contingent liabilities be mainstreamed in fiscal and budget planning, with stakeholders included?
- What might be the respective roles of the public and private sectors as well as international financial institutions and other donors in disaster risk management?

To address these and other questions, the report and the workshop aimed to discuss and put forward a disaster risk management strategy for Madagascar. The discussion does not represent the full economic and political reality. The intent is to start developing an approach to important and complex issues underlying disaster risk management in Madagascar. The report continues with a discussion of the socio-economic environment and the impacts disasters have had on Madagascar, before the systematic risk assessment and management of CatSim is utilized to analyze the potential financial and economic consequence of disasters.

The policy applications of the CatSim analysis can provide insights on the development and use of indicators of vulnerability, resilience, coping capacity and other concepts important for policy interventions with regard to disasters and other global-change phenomena. CatSim relies on quantitative indicators, e.g. risk is estimated making use of historical statistics and exposure; financial resilience is estimated with an index of observations on the financial preparedness of the government; financial vulnerability is a composite of the two and is measured in terms of the financing gap. Clearly, financial vulnerability of the public sector presents only one aspect, albeit an import one, of vulnerability to natural hazards. However, other indicators are necessary in order to complement this concept. Furthermore, participation and transparency in the design, estimation and use of vulnerability indicators is essential for their legitimacy. As there is a substantial degree of uncertainty in estimates of disasters risks and financial vulnerability, it is important that users have full participation in their design, estimation and use. Therefore, CatSim is a participatory, interactive tool for building capacity of policy makers by sensitizing them to the tradeoffs inherent in planning for disasters.

Before the in-depth discussion of economic and financial vulnerability due to cyclone risk in Madagascar in the next chapter, some general remarks about predictability, uncertainty and risk management should be kept in mind.

- Future cyclone events cannot be predicted with absolute accuracy and it is very unlikely that it will ever be possible to predict a storm's exact trajectory through a country as well as its physical strength (e.g. wind speed) beyond the immediate future. The good news is that it is possible to assess the likeliness/risk (i.e. the probability of occurrence as well as its intensity) of cyclone events and corresponding losses for specific locations/regions.

- While it is now commonly agreed that a probabilistic (or risk based) approach is the most appropriate one for managing extremes, it is highly complex and multifaceted. For example, information about past losses is usually scarce (and not very detailed) but is ultimately needed for estimation and calibration purposes. As a consequence, uncertainties of possible future losses without such information are large and only can be reduced in the future if better information is available on the different dimensions needed to assess risk. This does not only include spatially explicit gathering of additional exposure and vulnerability data but also comprises the detailed analysis of all important dimensions (including non-quantifiable ones) of future events. Hence, loss assessment and data gathering must be done on a regular basis so that uncertainties about the current and future risk level can be reduced over time.

- It should be acknowledged that instruments to reduce or spread risks come with a price and sometimes result in huge opportunity costs (probably hard to be quantified). Hence, for successful implementation of risk reduction and risk financing measures, a systems analytic approach which includes all relevant stakeholders and sectors needs to be adopted, emphasizing that additional structures and institutions have to be built to mainstream disaster risk into sustainable development planning processes. Additionally, relevant actors should recognize that different instruments to decrease or hedge risk are only successful for some risk layers and will not be able to decrease all risk to zero or the required minimum.

The issues mentioned above will be discussed thoroughly in the subsequent sections, especially in the recommendation chapter. The report itself is organized as follows: Chapter 2 provides an introduction into the current socio-economic situation in Madagascar as well as its natural disaster risk. In Chapter 3, the CatSim framework is presented and each step is discussed in detail. Chapter 4 is divided into 5 subsections, each of them looking at specific steps of the CatSim approach, including the estimation of relevant parameters and simulation runs for determining the financial risk of cyclone events to the government. Afterwards, Chapter 5 takes a closer look at possible pro-active risk reduction as well as risk financing strategies discussed during the workshop (chapter 6). Chapter 7 gives a summary of the results and recommendations for the future. The Appendix includes mostly technical notes about the estimation and simulation procedures used throughout the report. Appendix 1 presents the approaches used within catastrophe models. Appendix 2 describes the statistical estimation methods used to assess cyclone risk based on past data. Appendix 3 describes the procedural estimation of capital stock. Appendix 4 introduces the algorithm used to calculate the financial resilience of the government. Appendix 5 introduces the Solow-growth model approach used for the macroeconomic model. Afterwards, Appendix 6 describes in detail how a multi-risk assessment approach could be performed (also implemented in the CatSim model) and finally Appendix 7 provides a short summary of the workshop.

2. Introduction: Socio-economic Situation in Madagascar and Natural Disaster Risk

Madagascar has been confronted in the past with a series of economic challenges (see Thomas 2011 for a summary). Poverty remains a major challenge, with approximately 77 percent of the population living below the poverty line in 2010 (INSTAT 2011); additionally, due to a number of factors, GDP per capita has effectively been reduced over the last decades and now amounts to about half of its level in 1960 (World Bank 2012). The current political situation has contributed to the nation's economic challenges (CIA Factbook 2012).

Madagascar's economy is essentially based on subsistence-agriculture, fishery and forestry, with the primary sector employing over 80 percent of the active population and contributing about 30 percent of the total GDP. Furthermore, it accounts for 60-65 percent of the national export revenues (see Figure below).

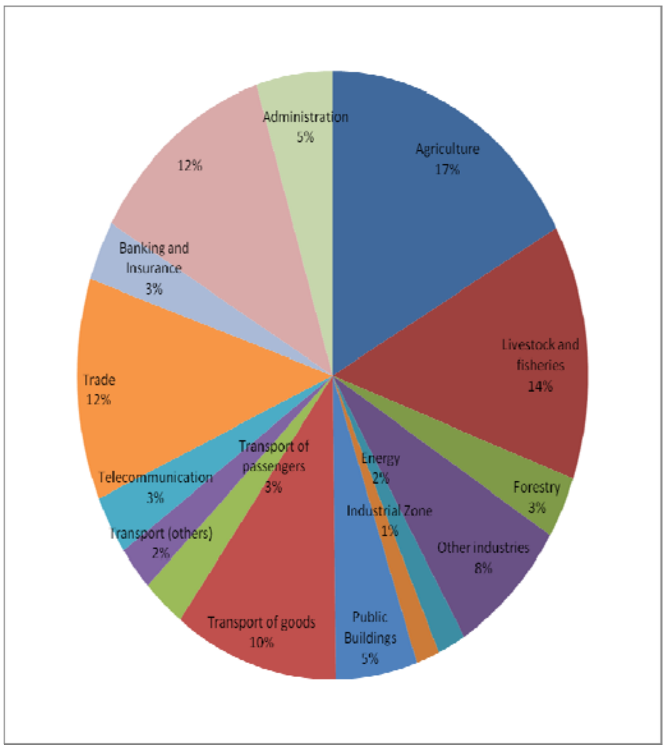

Fig. 0: Composition of real GDP. Source: Government of Madagascar 2012.

Until 2010, the export of clothing was a rising sector (the secondary sector contributed around 16 percent of total GDP), until regulatory complications abruptly halted these exports, leading to a sharp decline in production (World Bank 2012; CIA Factbook, 2012). The tertiary sector represents the largest share to GDP (with around 55 percent, see also the general macroeconomic discussion below).

Climate Baseline and Future Projections

Generally speaking, Madagascar's climate is highly varied, with two main seasons: From November to April there is a hot, rainy season (with maximum rainfall in December and January) and from May to October there is a cool, dry season (with minimum rainfall in September and October). However, during the dry season, rainfall is restricted mainly to the southern and eastern coasts. The east coast is located in the path of destructive cyclones from the Indian Ocean that occur during the rainy season, whereas the west coast is generally drier, especially between May and October, while the southwest and the extreme south are semi-desert environments (Figure 1).

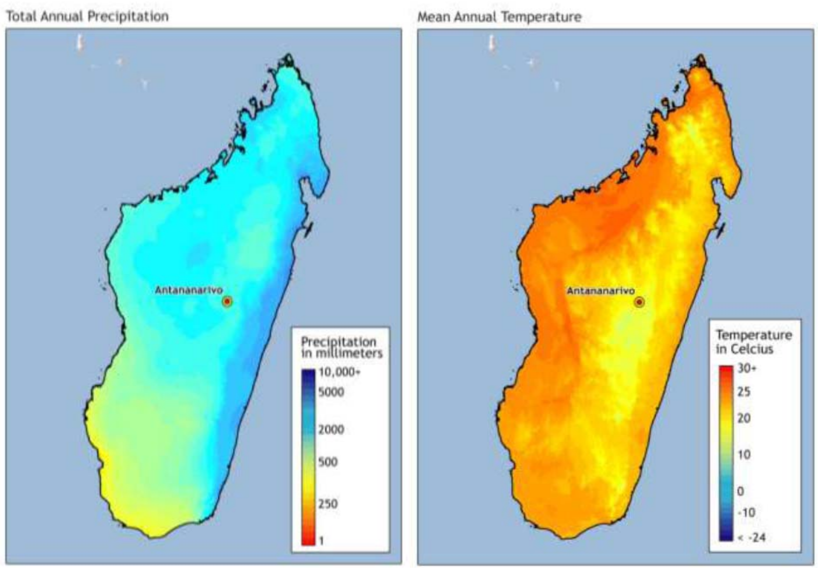

Fig. 1: Total annual precipitation and temperature across Madagascar.
Source: GFDRR, 2011

Recent analysis of past climate data revealed that temperatures have increased by 0.2 degrees in northern Madagascar and by 0.1 degrees in southern Madagascar. Furthermore, increases in daily minimum temperature – and also partially for maximum temperature – were found. Also, rainfall distribution seems to have changed over time, and a reduction in winter and spring rainfall has been detected. Additionally, in central and east coastal regions, rainfall has recently declined, accompanied by increases in the length of dry spells (Tadross et al., 2008). Regarding future climate change impacts, there are still a range uncertainties involved within the projections (see for example the Madagascar Climate Change Briefing, GFDRR 2011). However, it is expected that the frequency of cyclone events in the Indian Ocean will decrease, but cyclone intensity is projected to increase by 46 percent and shift northwards (World Bank, 2010).

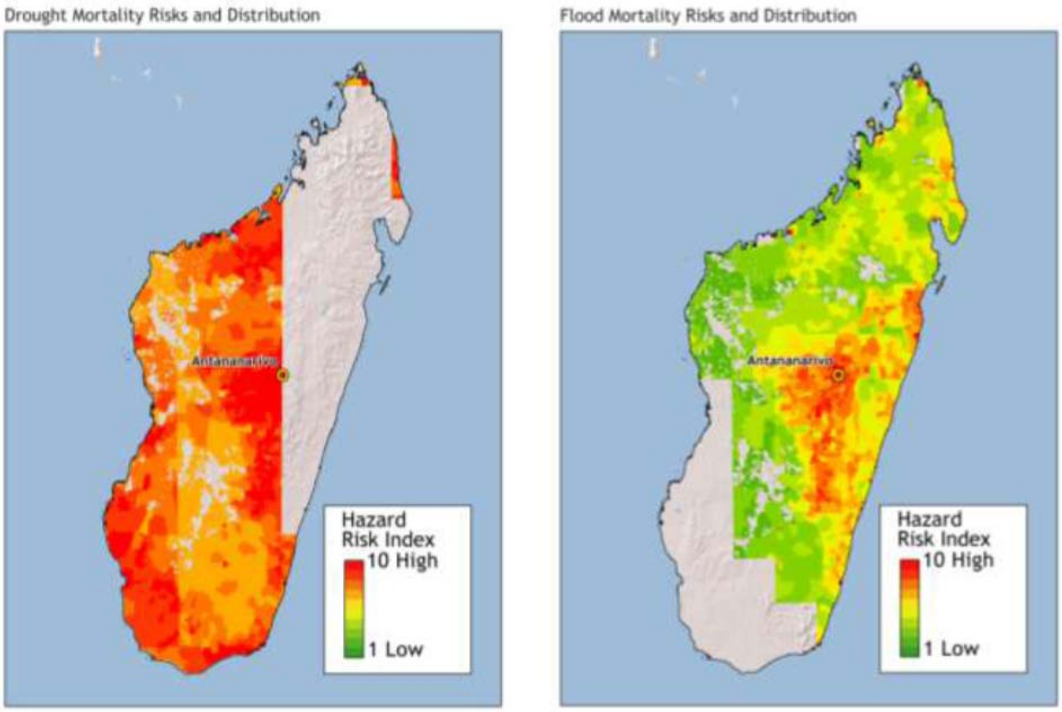

Fig. 2: Total annual precipitation and temperature across Madagascar.
Source: CHRR, 2010 (in GFDRR 2011)

As Figure 2 indicates, mortality risks are especially high for the southern and western parts of Madagascar in the case of drought, and for the northern and eastern part of Madagascar in the case of cyclone events.

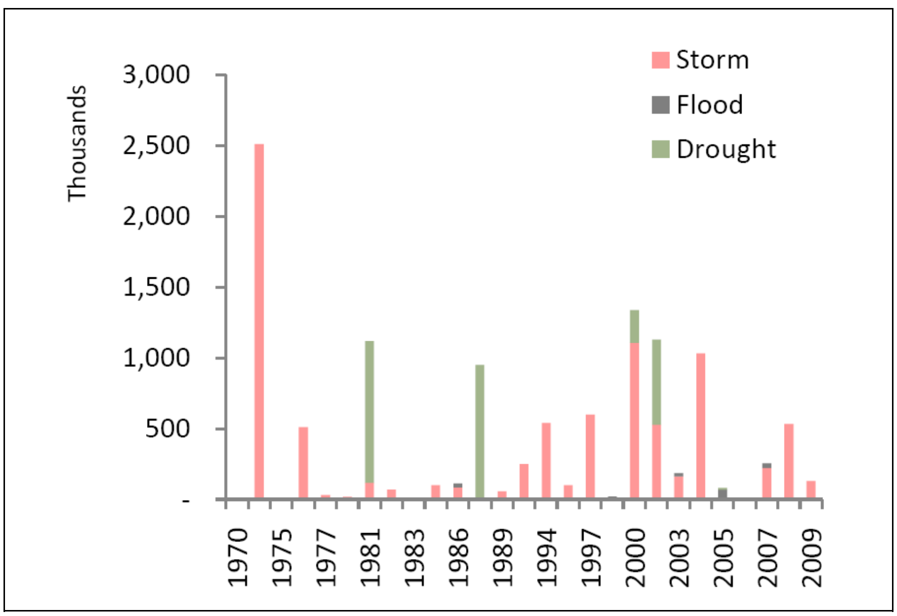

Fig. 3: Number of people affected by storms, floods and droughts (1970-2010) in Madagascar.
Source: GFDRR, 2011

Disasters are a Constant Threat

Madagascar can be subjected to different types of hazards, including cyclones, floods and droughts (see Figure 3 above). Looking back at the last 40 years to determine the top 10 natural disasters in terms of loss of life, total number of people affected and economic losses, one can see (Table 1) that cyclones pose a large threat to human life and cause the highest economic losses.

Table 1: Top 10 natural disasters in terms of killed, number affected and economic damages. Source: EM-DAT, 2012.

Top 10 Natural Disasters - number killed:

Disaster type	Date	No Killed
Epidemic	Mar-1999	860
Epidemic	Jul-2002	671
Wind Storm	Mar-2004	363
Wind Storm	Jan-1994	200
Drought	Apr-1988	200
Wind Storm	Jan-1997	140
Wind Storm	Feb-2000	130
Epidemic	Dec-1999	121
Wind Storm	Mar-2010	120
Wind Storm	`Dec-1981	107

Top 10 Natural Disasters - number affected:

Disaster type	Date	No Affected
Wind Storm	Feb-1972	2,510,056
Drought	1981	1,000,000
Wind Storm	Mar-2004	988,139
Drought	Apr-1988	950,000
Wind Storm	Feb-2000	736,937
Drought	2008	720,000
Wind Storm	Jan-1997	600,000
Drought	Nov-2002	600,000
Wind Storm	Jan-1994	540,043
Wind Storm	May-2002	526,200

Top 10 Natural Disasters - economic damage:

Disaster type	Date	Damage US* (000's)
Wind Storm	Feb-1977	350,000
Wind Storm	Dec-1981	250,000
Wind Storm	Mar-1982	250,000
Wind Storm	Apr-1984	250,000
Wind Storm	Mar-2004	250,000
Wind Storm	Mar-2007	240,000
Wind Storm	Mar-1986	150,000
Flood	Jan-2003	150,000
Wind Storm	Dec-1978	29,000
Wind Storm	Dec-1983	25,000

By comparing events occurring between 1968 and 2011, one also can see that cyclones pose the largest threat and cause the highest death toll on average (see Table 2).

Table 2: Average losses due to different types of hazards for a time period between 1968 and 2011. Source: EM-DAT, 2012.

	Number of Events	Killed	Total Affected	Damage US$ (000's)
Drought	6	200	3,515,290	-
average per event		33	585,882	-
Flood	5	52	131,210	150,000
average per event		9	26,242	30,000
Wind Storm	45	2,372	9,174,315	1,977,301
average per event		53	203,874	43,940

There is also an indication that cyclone-related mortality risk has been increasing in recent decades (see Figure 4). However, the trend is not very robust, due to the limited number of data points, necessitating further examination. Also, the causes of a possible increase can be very complex and the issue must be examined within the wider context of socio-economic development issues.

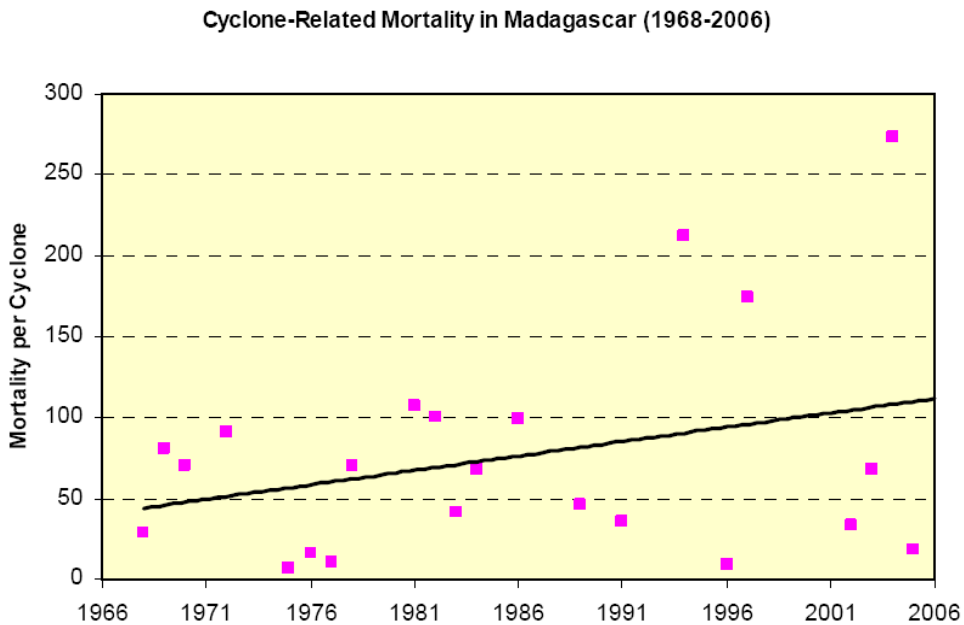

Fig. 4: Figure: Cyclone related mortality. Source: UN 2007.

Disasters are rare events and their occurrence is subject to fluctuations. As Figure 5 shows, cyclones have had the highest annual recurrence, with 0.7 events per year, over a 20-year time span. Less recurrent are droughts and floods. It should be noted that due to the limited time horizon such figures are only indicative and cannot be used for probabilistic risk assessment approaches.

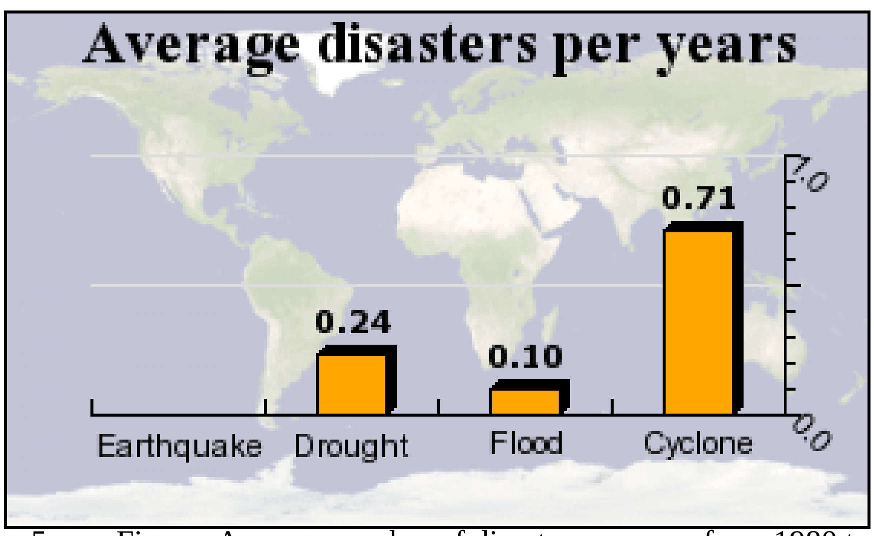

Fig. 5: Figure: Average number of disasters per year from 1980 to 2000. Source: UNDP 2003

Today, cyclones continue to pose the largest threat, both in human and economic terms. The 2006 - 2007 cyclone season was a prime example, with seven tropical cyclones making landfall, heavily influencing precipitation levels and patterns on the island. The last two cyclones alone impacted about 190,000 people and killed 150 (UN 2007). The recent 2011 - 2012 cyclone season also resulted in exceptional losses.

Financial and Economic Impacts can be Substantial

Cyclones in Madagascar have a large potential to cause substantial losses to crops and infrastructure and may eventually negatively affect economic and macroeconomic performance.

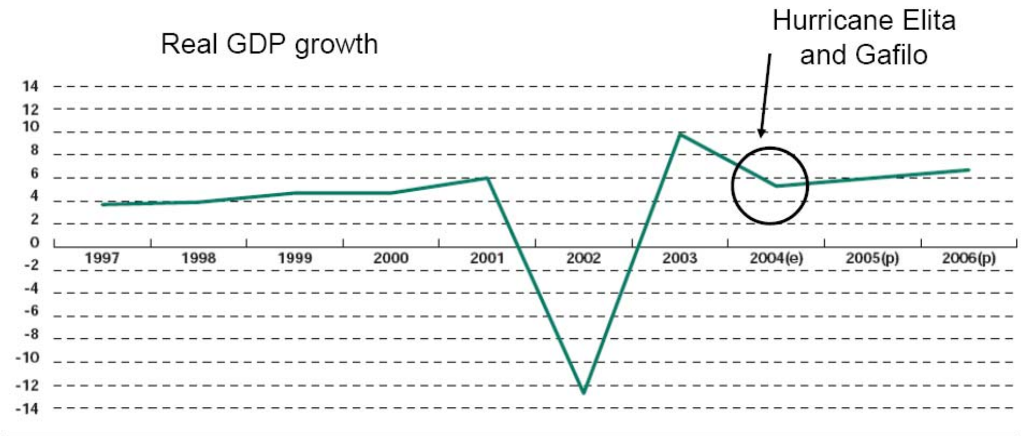

Fig. 6: Effects of tropical cyclones Elita and Gafilo on macroeconomic performance. Source: Economic Outlook 2005.

For example, Figure 6 shows that the GDP growth rate in 2004 decreased after two violent cyclones (Elita and Gafilo) that struck the country in the first quarter of the year. Also, one can see that other shocks, such as political instability in 2002, have marked and sometimes substantially larger effects on macroeconomic performance. However, it can also be acknowledged that the political crisis was transitory, while disaster impacts lasted longer (for more information on the former, see Hoftijzer and Paci, 2008).

The most detailed assessment of losses and damages for a cyclone season ever done in Madagascar was for the 2008 cyclone season with the help of the World Bank et al. (2008) and is summarized here according to different dimensions.

Disaster/Social/Economic information:

- Cyclone season from mid-November to April.
- Names and landfall dates: Fame (24.01.08); Ivan (07.02.08); Jokwe (04.03.08).
- National poverty level in Madagascar was 63.3 percent 2007.
- Damages are 52 percent of total and losses are 48 percent of around 333 million USD, losses are low because floods caused by the cyclones covered mainly rice cultivated areas, which are somewhat resistant to high water.
- Damage and losses for public sector were 22 percent of total.
- Most affected sectors of the economy were those of housing and public administration buildings (38 percent of total), agriculture, fishery and livestock (31 percent) and transport (14 percent).

- The intensity/impacts of the cyclones were different for different regions, the greatest being in Analanjirofo, experiencing 41.2 percent of total impacts.

Impact:

- Three consecutive cyclones (Fame, Ivan and Jokwe) affecting 17 of 22 regions.
- 342,000 affected (total population: 19 million), among those 191,404 lost homes and 100 died.
- Total damage and losses of about 333 million USD.
- Concentrated in the agriculture, fisheries and livestock sector (103 million USD), housing and public administration sector (127.6 million USD) and transportation sector (45.7 million).
- Mainly eastern coast affected (63 percent of total damages and losses).
- Impact about 4 percent of GDP.
- Decline of 0.3 percent of real GDP growth in 2008.
- A 38 percent decline in the account of the balance of payments (from 114.3 million to 71.3 million Standard Drawing Rights), primarily due to reduction in agriculture exports, increase on imports of goods, and reduction of tourism services income.
- Overall budget deficit increased from -4.9 to -5.0 percent of GDP in 2008.
- Loss of estimated 6.2 million working days of labor, primarily in agriculture and fisheries sector. Equivalent to a loss in earnings of 6.8 million USD.
- 2.0 percent of commerce establishments and 1.9 percent of industrial enterprises were affected.
- Loss per capita in some affected regions: 120 USD, 60 USD, 30 USD (GDP per capita is around 375 USD).
- Majority of impact (over 259.3 million USD) was on the private sector. Damages and losses to public assets amounted to about 22 percent of the total (73.6 million).

Recovery and Reconstruction Requirements:

- Financial requirements (public sector investments) of about 154.8 million USD: 18.9 million USD for immediate recovery, 135.9 million needed for middle and long term recovery and reconstruction
- By sector: social sector 52 million USD,
productivity sector 10 million USD,
infrastructure 80 million USD,
cross-sectoral 11 million USD.
- Government is expected to meet about 13 percent of total needs, e.g. 20.3 million USD, donor contributions expected to fund 28 percent (42.6 million), 23 percent are considered to be lower priority (35.9 million),
- Call for Funds to the Global Facility for Disaster Reduction and Recovery (GFDRR) would cover 28 percent (43.1 million USD), while 8 percent (12.8 million USD) would come from separate UN Funds.

Social Sectors: Education/Health/Nutrition/Housing

- 657 schools damaged, 411 completely destroyed and 246 partially, amounting to about 3.2 million USD and 0.6 million USD damages respectively.
- Total damages are 10.3 million, only public sector. 167 basic health centers (6 percent of total) and 6 hospitals.
- Increase in imports is around 1.5 million USD; impact on treasury is estimated to be around 3.4 million USD.
- Damages to 1255 community nutrition sites, around 1.8 million USD.
- Housing sector damages of 117.8 million USD and losses around 9.8 million USD, 89 percent in the private sector.

Furthermore, in 2012 the cyclone events again resulted in substantial losses. During the 2012 cyclone season, Madagascar was seriously affected by severe tropical cyclone Giovanna, which hit the island on the 14th of February, killing 26 people, affecting 663,000 and displacing 133,000 (National Bureau for Risk and Disaster Management). Tropical storm Irina, starting on the 26th of February, brought heavy rains and caused 72 deaths and resulted in the loss of homes of more than 70,000 people.

General Macroeconomic Context

Since the 1960s Madagascar experienced a relentless decline in per capita Gross Domestic Product with more or less only short periods of economic growth (Figure 7).

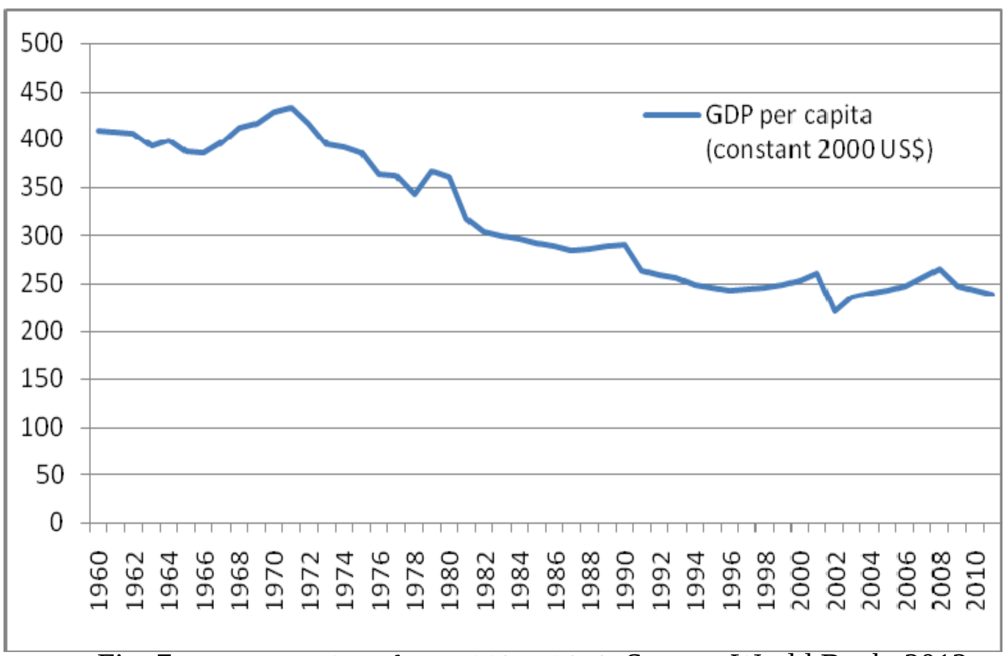

Fig. 7: Per capita GDP from 1960 to 2010. Source: World Bank, 2012

The decline and instability of growth was partly due to economic policies and high demographic growth (Pelissier and Sautter, 1994) as well as external shocks, such as cyclones and other bad weather events (Epstein et al., 2010). For a general discussion of the political and economic situation in the past see also Thomas (2012). From an overall perspective, while Madagascar is a very poor country, it has enormous potential for development, not in the least due to the high level of literacy but also as it has enormous mineral wealth, natural beauty (important for tourism), and environmental treasures (Epstein et al., 2010). However, some obstacles – such as poor transportation infrastructure – do exist, but it seems that large shocks, absent extended repercussions, can be absorbed without major long-term effects, as the 2002 crisis has shown (for a detailed analysis see Hoftijzer and Paci, 2008).

The current situation is more difficult. After years of political crisis, the fiscal situation seems to be under control. However, due to the limited option to utilize local and international financial markets, as well as limited additional fiscal revenues, the public investment program become almost marginal (Madagascar Economic Update, World Bank 2011). Continuing austerity kept the budget deficit to 1.3% of GDP in 2011 and about 1.6 percent in 2012 (Madagascar Finance Act 2012). Consumer price inflation was at 9.5% in 2011, mostly due to the increases in oil and food prices. The current account deficit decreased from 9.7% of GDP in 2010 to 3.4% in 2011 mostly because of revived goods exports and a drop in imports (which arose, however, from less economic activity). The deficit is expected to widen slightly to 4.4% in 2012 and 4.7% in 2013 with the gradual resumption of imports of goods as the political situation normalizes (African Economic Outlook, 2012). Today, the government contributes very little (5-8 percent) of total economic activities in the country through its direct expenses. International financial markets are nearly closed for Madagascar (except for some Chinese credit rating agencies, Madagascar is not rated by Moody's or Standard & Poor). Also the domestic monetary and credit market is very small and it would be very difficult and economically dangerous for the government to get money there (see the example in the Madagascar Economic Update, World Bank 2011).

Madagascar's economy grew an estimated 1.0% in 2011, much more than 2010 (0.5%). This was driven mainly by the secondary sector (up 3.4% over 2010) and also the primary sector (up to 0.7%). The tertiary sector shrank by -0.3% because of poor agricultural output resulting from sparse rainfall and several cyclone events (Finance Act 2012). In 2011, mining remained the economy's chief strength and extractive industries grew 25.9% (African Economic Outlook 2012). The secondary sector's best performers include tourism, which recovered in 2011 with a 14.8% rise in visitors. Overall investment fell to 14.9% of GDP in 2011 from 18.8% in 2010 mainly as a result of of less development aid and the end of the building and installation phases of big mining projects. The signing of a road-map agreement to end the political crisis on 17 September 2011 and the vigorous mining sector should boost growth in 2012 and 2013. Foreign aid (which funds 70% of government investment) will likely not completely resume in 2012 (African Economic Outlook, 2012).

The 2012 budget continues the policy of rigor, with tax breaks to encourage investment in renewable energy. According to the African Economic Outlook (2012) foreign aid will not have returned, except to help pay for elections, so total revenue (including grants) is estimated at 12.4% of GDP and total spending at 13.7%. The deficit will be about the same as 2011 (1.3% of GDP). Constitutional normality should be restored by 2013 and revenue increase to 13.1% of GDP and spending to 14.3%, with a budget deficit of 1.2% of GDP. The government plans to continue cautious fiscal and monetary policies that should bring inflation down to 8.3% in 2012 and 8.2% in 2013. Public debt is quite small. External debt was estimated in June 2011 at SDR 1 401.12 million (19.7% of GDP, down from 24.9% in 2010). Despite the crisis, the government has punctually paid its external debt interest, which was MGA 174.65 billion (USD 61.26 million) at the end of 2011 (African Economic Outlook, 2012).

Regarding education, with 74.3% net enrolment in 2010, the goal of universal education seems in reach, but poor quality teaching is a major problem. The primary school completion rate was 66% in 2010. Ministry budget restrictions caused pressure to the education system and increased the cost of education to families by 30%. About 400 000 children were unable to enroll for the 2011-12 school year, and urban primary schools showed a 4.6% drop in enrolment in 2009-10 (African Economic Outlook, 2012). The importance of education for economic development should not be underestimated, as recent research has shown (Crespo and Lutz 2007; Lutz et al. 2007, 2008).

3. CatSim: A Step-wise Framework for Assessing and Developing Risk Management Strategies

Given this background, this report will now lay out the methodology for systematically addressing how the government can assess and reduce the losses from cyclones, and how it can best prepare for providing relief and reconstruction in the event of a disaster. The model employed for this purpose is CatSim (Hochrainer, 2006; Mechler et al., 2006; Hochrainer-Stigler et al., 2012), which allows policy makers to interactively view their country's or region's exposure to direct asset risks and (indirect) financial, fiscal and economic impacts of disaster scenarios. The policy outcomes for reducing disaster risk are assessed by the model and expressed with indicators of interest to policy makers, such as the budget stance, debt, and economic growth. Based on an assessment of their country's or region's vulnerability and risk, the main purpose of the tool is to assess policy options related to financial risk management, including investing in risk-transfer instruments (reserve funds, insurance and catastrophe bonds). The model has a graphical user interface and is interactive (including a stand-alone application), that is, users can and should change the model parameters given different preferences and parameter uncertainty. For example, the user can adjust the amount of risk and debt the country is willing to take on, and the model will display how this changes the country's vulnerability to disasters and how it affects different policy paths (see Hochrainer et al., 2012).

We begin by examining how the government can reduce its risks of experiencing a "resource or financing gap", i.e. the inability to meet its post-disaster obligations in terms of repairing public infrastructure and providing needed relief to the private sector. For this purpose the government will need information on assessing financial and macroeconomic risks and vulnerability - Steps 1-4 of the following step-wise framework. Step 5 turns to the equally important question of how the government can *reduce or mitigate* human and economic losses, and Step 6 incorporates these considerations into a risk management framework. Figure 8 summarizes the steps to be taken in graphical format.

Provided below are short descriptions of each of the 5 steps. More details will be given in subsequent relevant sections.

- **Step 1: Assessment of risks to public sector assets**

  In developing a risk management strategy, it is important to understand the financial risks of asset losses and relief expenditure to assist households and business, and the proportion of financial losses that will be absorbed by the government. This risk depends on the frequency and intensity of cyclones, the assets exposed to the cyclone and their physical vulnerability.

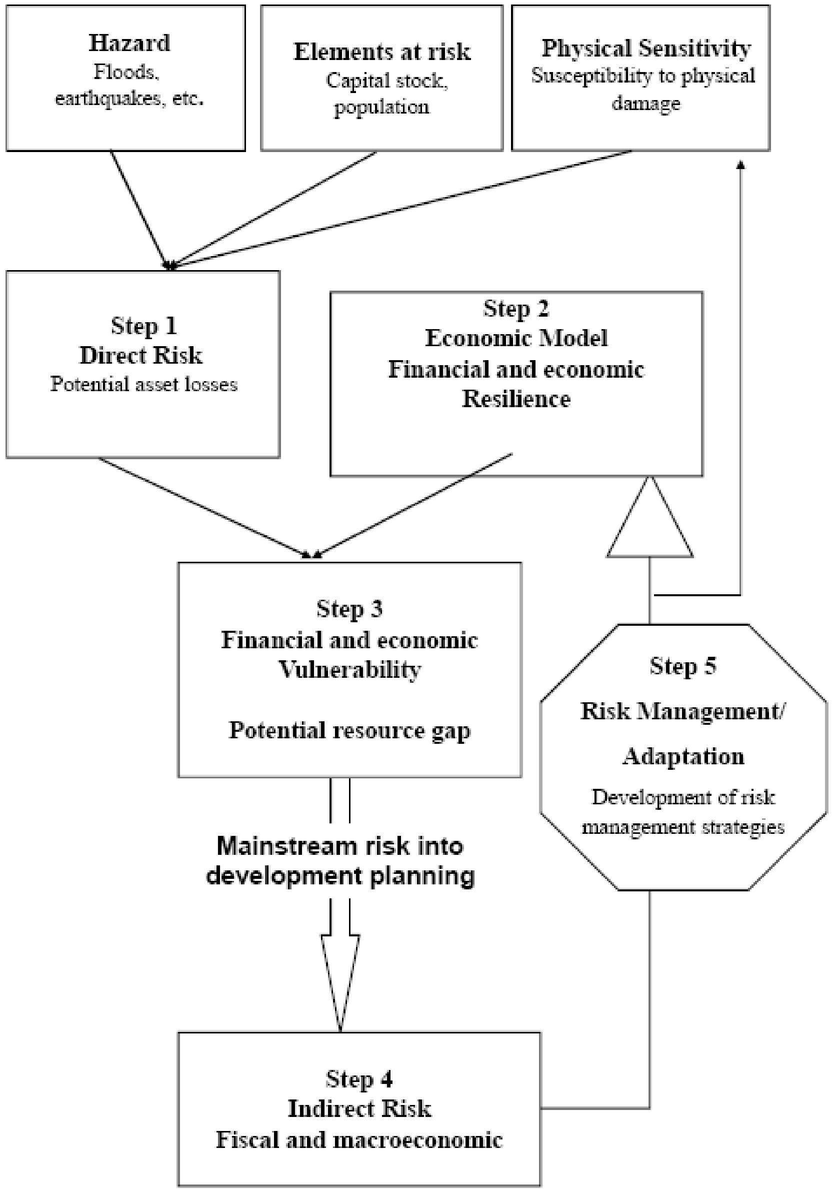

Fig. 8:CatSim framework for developing a risk management strategy.
Source: Hochrainer-Stigler et al., 2012

- **Step 2: Estimation of the financial resilience of the public sector**
  Given limited resources for reducing human and economic losses, the government must be financially resilient, or provide sufficient funds for financing reconstruction of public infrastructure and the provision of relief to households and the private sector. Financial resilience will, in turn, depend on how much the cyclone risk is reduced, thus affecting the general economic conditions of the country.

- **Step 3: Assessment of the "resource gap"**

  The resource gap is the difference between the contingent post-disaster liabilities of the government (for repairing infrastructure and providing relief to the private sector) and the sources of funding available to the government. It can be assessed by simulating the risks to public assets and estimating the government's ability to cover these risks as well as provide private sector assistance.

- **Step 4: Mainstreaming disaster risk into development planning.**

  Disaster risk is mainstreamed into national development planning by incorporating financial disaster risk and potential financing gaps for funding these losses into macroeconomic projections of the country. These consequences can be analyzed on variables such as economic growth or the country's external debt situation. These indicators represent impacts on economic flows as compared to impacts on stocks addressed by the financial asset risk estimation.

Risk management: evaluating pro-active strategies

- **Step 5: Assessment of government programs to reduce risks**

  Naturally, the government is concerned primarily about loss of life from cyclones, and also about loss of livelihood and productive assets. As an important step in any risk management plan, it should consider the cost effectiveness of government programs to reduce human and economic losses.

- **Step 6: Assessment of pre-disaster insurance and other risk financing options**

  There are several options the government can consider in proactively reducing its risk of a resource gap, including insurance, using catastrophe bonds, a reserve fund or contingent credit arrangements. It is important to examine the cost effectiveness of these instruments in reducing the resource gap risk.

Strategies can be developed and illustrated that reduce the risks of disasters and build the financial resilience of the public sector. The development of risk financing strategies has to be understood as an adaptive process, where measures are continuously revised after their impact on reducing financial vulnerability and risk has been assessed.

With the exception of Step 5 (which is highly stylized in the model), the information needed will be consolidated by the CatSim model to give an overall picture of Madagascar's cyclone risk, the options for mitigating this risk, the vulnerability of the government to a post-disaster resource gaps and its effects on macroeconomic indicators. In addition, the model will provide alternatives for reducing the government's fiscal vulnerability to the cyclone risk.

4. Estimating the Potential Resource Gap and Macroeconomic Risk

4.1 Step 1: Assessment of risks to public sector assets

A single hazard analysis for cyclones is performed, based on the experience of the past losses due to this hazard (for an overall technical description how to estimate direct risk we refer to Appendix A1, detailed technical information on the approach used here is given in Appendix A2). Generally speaking, tropical cyclones are more frequent in the northern hemisphere (75 percent of the global total) than in the southern hemisphere (Gray, 1968). In the southern hemisphere, cyclones occur in three principal regions:

- The Indian Ocean near Madagascar, where over 10% of the global total cyclones occur;
- The oceanic area to the north-east and north-west of Australia; and,
- The Gulf of Carpentaria.

Figure 9 shows world cyclone tracks from 1842 - 2009. As one can see Madagascar is in one of the more active regions.

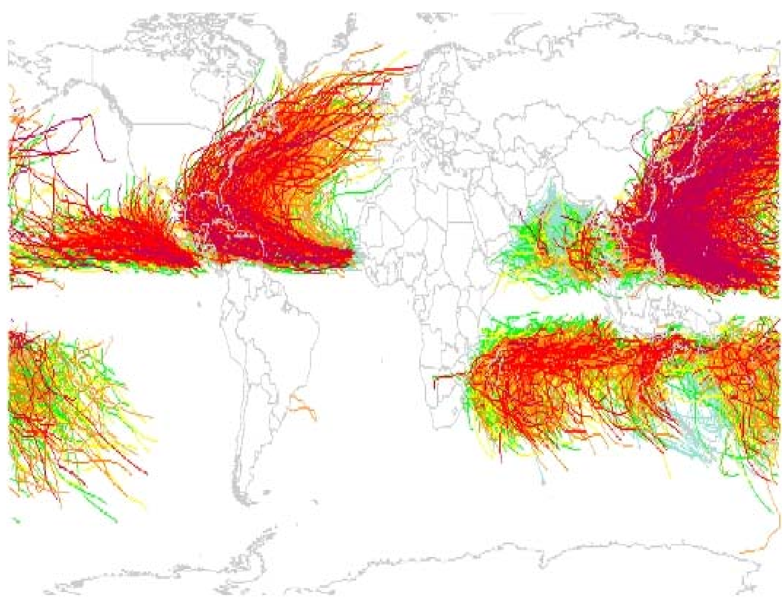

Fig. 9: Cyclone tracks from 1849 to 2010 worldwide.
Source: NOAA 2012

To estimate the damage potential of cyclones, different techniques can be used, e.g. stochastic or engineering approaches for estimating physical vulnerability of the assets exposed (see Appendix A1 for a discussion how such an approach can be applied). However, as this kind of detailed information is not yet available, historical losses are used here for the direct risk assessment (see Appendix A2). There are two databases available that can be used for this analysis. One is the open-source EMDAT disaster database (EM-DAT, 2012) maintained by the Centre for Research on the Epidemiology of Disasters at the Université Catholique de Louvain. EMDAT currently lists information on people killed, made homeless, and affected as well as overall financial losses for more than 16,000 sudden-onset (such as floods, storms, earthquakes) and slow-onset (drought) events from 1900 to present. Data are compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies.

The second one is the newly produced time-series loss data by Malagasy officials based on the "Damage and losses assessment methodology" (from now on called MLoss 2012). It consists of past public sector loss estimates for the Analanjirofo region from 1980 to 2012 separated into different sectorial impacts. Furthermore, the results for the Analanjirofo were upscaled to the national level by assuming the same exposure and vulnerability levels in other areas. Hence, one can expect in both datasets large uncertainties and therefore both will be used for the analysis to provide confidence intervals for the direct risk portion of analysis.

We start with an explanation of the EMDAT dataset. Details on historic losses due to cyclones are presented in the following table.

Table 3: Historical losses due to cyclones for Madagascar between 1960 to 2011. Source: EMDAT 2012.

Year	Name	Fatalities	Total Affected	Total Damage (1000s) (current USD)
1968	Georgette	29	75000	3100
1969	Dany	81	43040	5000
1970	Jane	70	10000	11400
1972	Eugenie	91	2510056	12420
1975	Deborah & Ines	7	10050	0
1976		16	508876	17000
1977	Emilie	10	30000	350000
1978	Angele	70	18000	29000
1981		107	118000	250000
1982	Benedic, Electre, Frida, Justine	100	117000	250000
1983		42	13560	25000
1984	Kamisy	68	100215	250000
1986	Honorinina	99	84309	150000
1989	Alibera	46	55346	0
1991	Cynthia	36	250000	0
1994	Daisy, Geralda	200	540043	10000
1994	Nadya	12	8	200
1994	Litanne	0	0	0
1996	Bonita	9	100000	0
1997	Gretelle	140	600000	50000
1997	Josie	34	0	0
2000	Eline, Gloria	130	736937	9000
2000	Hudah	23	369272	0

2002	Cyprien	2	1900	181
2002	Hary	1	0	0
2002	Kesiny	20	526200	0
2003	Fari	0	500	0
2003	Manou	89	162086	0
2003	Cela	0	164	0
2004	Elita	32	44290	0
2004	Galifo	363	988139	250000
2005	Ernest	78	7985	0
2006	Boloetse	3	6212	0
2006	Bondo	1	304	0
2007	Clovis	0	1460	0
2007	Indhala	80	215198	240000
2007	Jaya	3		0
2008	Fame	12	8613	0
2008	Ivan	93	524153	60000
2008	Jokwe		400	0
2009	Eric and Fanele	12	62505	0
2009	Izilda		3376	0
2009	Jade	15	64918	5000
2010	Hubert	120	192132	0
2011	Bingiza	35	115215	0

These losses are recalculated to constant 2000 prices and it is assumed that vulnerability (for example, crops or infrastructure susceptible to damage due to the hazard) remained constant over time (see Figure 10).

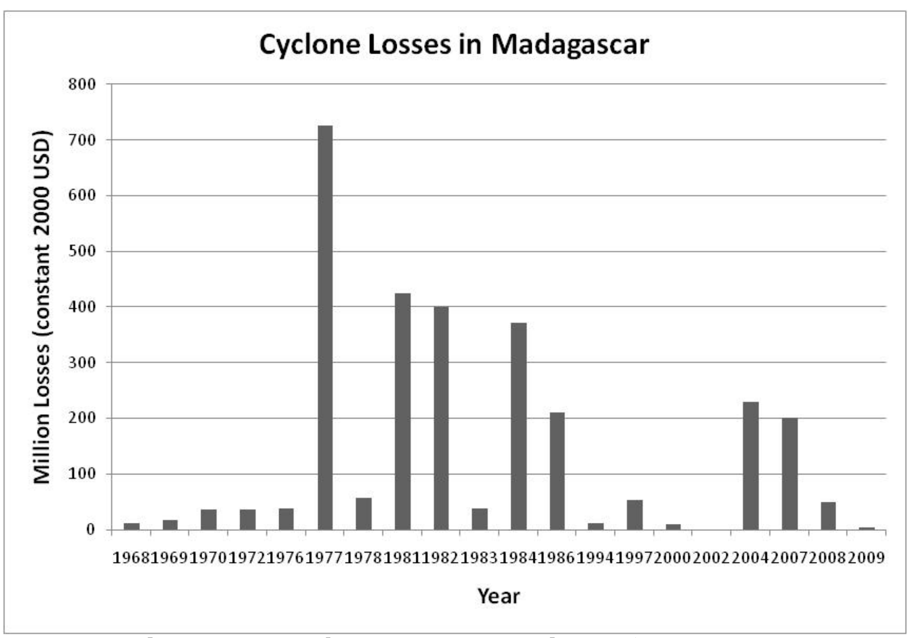

Fig. 10: Cylone events in the past: Economic losses (1000' USD, constant 2000)
Source: Calculations based on EMDAT 2012 and World Bank 2012.

Assuming a stationary process for vulnerability and exposure over time is a strong assumption, which merits more attention and analysis. For example, cyclone intensity may change as shown in Figure 11 (see also the comments in the introductory section). Also, other variables, such as socio-economic and exposure changes would ideally be included so that the direct losses can be compared on the same scale. However, due to a limited amount of data, this was not possible (for a discussion of these issues and ways to avoid them see Appendix A2).

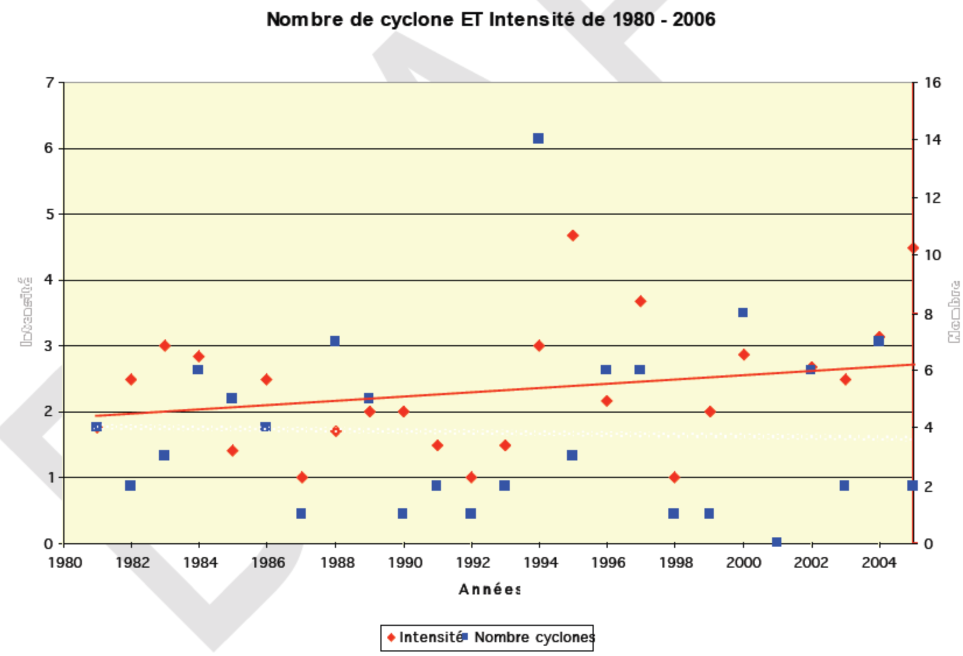

Fig. 11: Intensities of cyclones from 1980 to 2006.
Source: UN 2007.

From a financial/fiscal perspective, total losses in a given year are important and thus in CatSim, annual losses are used as input parameters.

The time series from 1960 to 2011 forms the basis for estimating a national level loss distribution function. In more detail, it is assumed that the losses belong to the maximum domain of attraction of an extreme value distribution and as losses are always a downside risk, we select the Frechet type distribution as the basic loss distribution. For estimating the shape as well as the location parameter, a non-linear optimization model was built, which best fits the curve with the data at hand (see Appendix A2). Furthermore, to increase the robustness of the results, other models - such as the Generalized Pareto model - were tested and improved in a step-based manner to satisfactory levels (based on graphical tests such as P-P plots and Q-Q plots, see Embrechts et al. 1997 for more information on these techniques). The parameters obtained with this method are used to calculate annual loss return periods.

The same approach was used for the MLoss dataset. This dataset includes losses of the public sector, which are separated into different dimensions including damages to schools, hospitals, the telecommunications system, the environment, and transportation from 1980 to 2012 (see Figure 12).

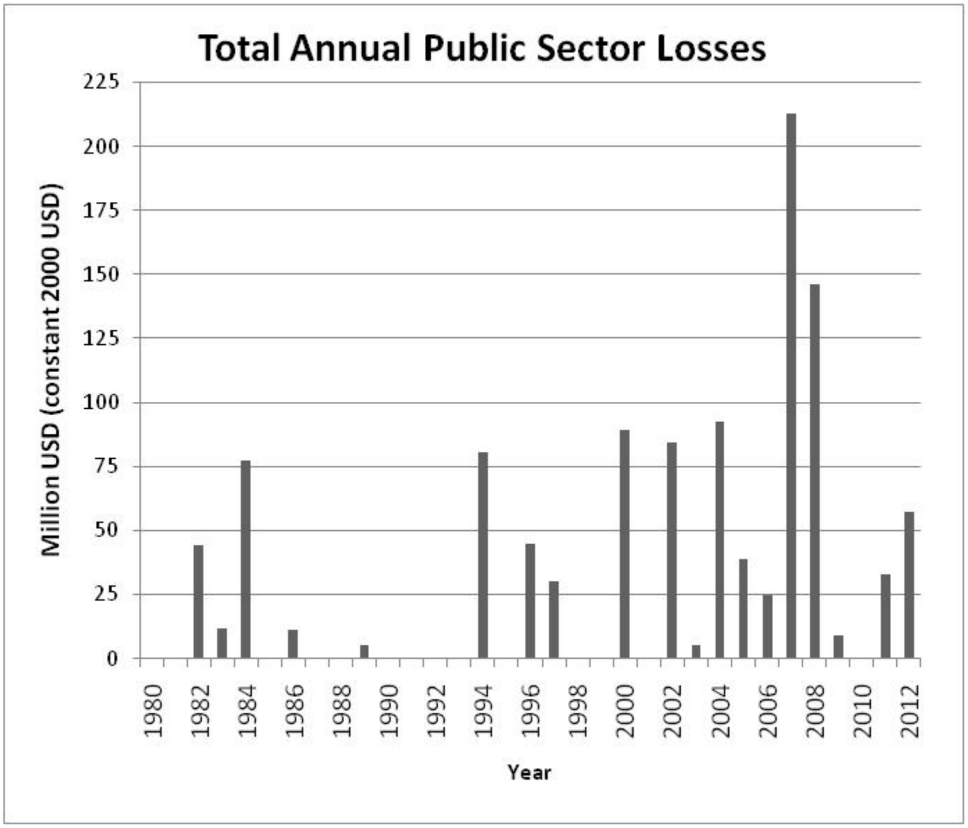

Fig. 12: Public Sector Losses due to Cyclone events 1980-2012.
Source: MLoss 2012.

Unfortunately, comparison with the EM-DAT data revealed a small correlation between the two datasets (loss events) and it is unclear which one estimates the past losses more accurately. Hence, both will be used in the analysis. However, in one regard the MLoss data is superior compared to the EMDAT dataset, as it also shows the distribution of damages to different sections, which is important information for the policy-making process as it can be used to tackle specific loss financing questions. The next pie chart shows the average percentage of sectorial losses.

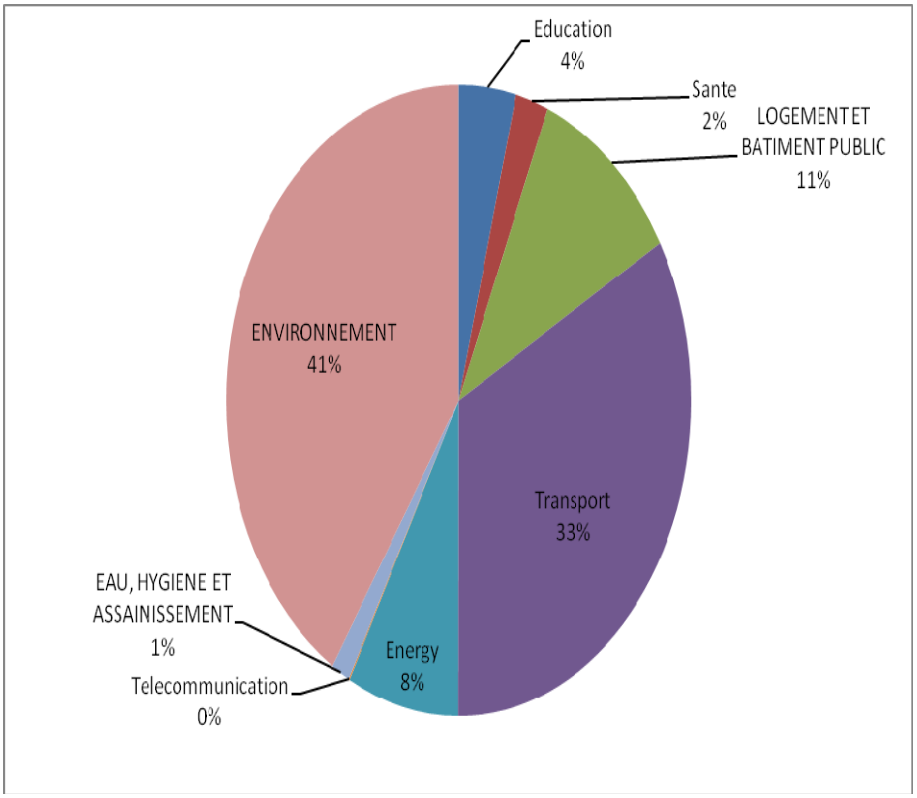

Fig. 13: Percentage of total public sector losses according to different dimensions. Source: MLoss 2012.

As one can see, transportation and environmental losses as well as losses in buildings represent the largest share (more than 80 percent). However, important long-term growth related dimensions such as education (schools) might be substantially affected as well. Appendix 2 summarizes the different datasets available and also presents all the results found with the estimation procedure already explained. After careful analysis and comparisons with single hazard occurrences (e.g. based on the World Bank 2008 study) the following direct risk estimates were used. First, for the (current) public sector risk a Generalized Pareto (GP) distribution is estimated based on the MLoss dataset. Table 4 shows the losses for selected return periods.

Table 4: Estimated loss return periods for public sector cyclone risk.

Annual Return Periods	Losses (constant 2000) million USD, public sector only
20	149.0
50	204.2
80	232.5
100	245.9
150	270.4
200	287.7
250	301.1
300	312.1
400	329.4
500	342.9

Source: Own calculations

The probability of first loss was estimated to be around 0.406, meaning that the public sector has a 40 percent probability of experiencing a loss every year (translating to an expected loss every 2 to 3 years). For the macroeconomic risk assessment step, private sector losses are needed, necessitating the use of the EMDAT database as well as other constructed datasets (see Appendix 2). Table 5 provides the results.

Table 5: Estimated loss return periods for total (private and public) cyclone risk based on different estimation methods.

	Losses (constant 2000) million USD, total losses		
Dataset	Menages	EMDAT	PP
Model	GEV	GEV	GP
	Maximum	Baseline	Minimum
PFL	0.406	0.607	0.406
20	5311.5	228.6	745.2
50	7982.7	819.9	1021.1
80	9547.7	1550.6	1162.7
100	10344.0	2093.8	1229.9
150	11886.4	3604.8	1352.0
200	13061.1	5292.8	1438.6
250	14021.4	7125.7	1505.8
300	14839.4	9082.6	1560.7
400	16195.0	13314.9	1647.4
500	17303.6	17908.9	1714.6

Source: Own calculations

As can be seen, the losses increase sharply with higher return periods. All of the estimates in Table 5 show larger values compared to the MLoss estimates. In fact, (see Appendix 2) the public sector loss estimates do not show fat tail behavior and therefore likely underestimate the risk. The probability of first loss using the EMDAT data is estimated to be 0.607, which means that Madagascar could expect monetary losses due to cyclone events more than every second year. The magnitude of losses is characterized by the Exceedance Probability curve that the return periods are based on (see Appendix A2). Given this probability-loss relationship, the next task is to estimate how much of the losses the government is responsible to finance, i.e. its contingent liabilities.

<u>Government exposure: Contingent public liabilities</u>

To set the stage, the table below introduces the concept of explicit and implicit as well as direct and contingent liabilities (see Schick and Polackova 2004). In the case of cyclone risk, obligations will only occur if the event causes damages, hence the liabilities are contingent. The proportion of damages the government is responsible to finance depends not only on its own public assets but also can depend on implicit obligations.

Liabilities	**Direct** Obligation in *any* event	**Contingent** Obligation if a *particular* event occurs
Explicit Government liability recognized by law or contract	Foreign and domestic sovereign borrowing, expenditure by budget law	State guarantees for non-sovereign borrowing and public and private sector entities, r**econstruction of public infrastructure and assets**
Implicit A moral obligation of the government	Future recurrent costs of public investment projects, pension and health care expenditure	Default of subnational government and public or private entities, **disaster relief to affected households and business**

Source: Schick and Polackova 2004

For example, in many cases market forces are unlikely to generate an adequate adaptation to disaster risks, broadly because of uncertainty and imperfect information, missing and misaligned markets but also financial constraints (Stern 2011). In case of a disaster event, consequently, there may be substantial contingent liabilities as identified above.

We start with the following assumptions. If a disaster strikes, the government of Madagascar will take responsibility for the following:

- Reconstruction of public assets: roads, bridges, schools, hospitals, etc;
- Support to private households and businesses for relief and reconstruction;
- Provision of relief to the poor;

As shown in Table 6, the values at risk for which the government is liable (contingent liabilities) are approximated at 27.3 billion USD. The calculation is made as follows: Because little information is available on public sector capital stock in Madagascar, it is assumed that approximately 30% of the total stock is public (this is in line with global averages). Since 77 percent of the population of Madagascar is poor, the government is assumed to absorb a large extra burden in the case of a cyclone (INSTAT 2011). Consistent with average figures (see Freeman et al. 2002; Hochrainer and Mechler 2012) it is further assumed that the government will have to spend an amount equivalent to another 20% of the total stock losses to provide relief. For an estimated total capital stock of USD 54.8 billion (see Appendix A3) the maximum contingent liabilities of the government of Madagascar is therefore around 27.3 billion USD if both public assets as well as private sector relief is assumed.

Table 6: Value of elements exposed to risk

Type	*USD billion (constant 2000 prices)*
Private capital	38.4
Public capital	16.4
Total capital	54.8
Relief spending	10.9
Government contingent liabilities (public assets and assistance to private sector and households)	27.3

If the government decides to exclude any implicit liabilities then this number (27.3 billion USD) would go down to 16.4 billion USD. Different assumptions about what kind of liabilities the government is responsible for can be tested within CatSim (see also the CatSim Guidelines)

Financial risk in probabilistic terms

Based on the information above, the probabilistic losses due to cyclones in terms of percent of capital stock loss are estimated for Madagascar. The following table shows four data points on the probability distribution for cyclone risk. Combined with assets at risk (exposure), the probabilistic absolute losses to the government are calculated and shown in Table 7 (only baseline case shown here).

Table 7: Potential cyclone losses

	Total financial losses in % of GDP	*Government financial losses million USD*
20-year event loss	4.54 %	114.3
50-year event loss	16.31 %	409.95
100-year event loss	41.65 %	1046.7

Total potential losses for the government, with an annual probability of five percent of being exceeded (a 20 year event), is assessed at currently approximately USD 114.3 million. The 50-, 100- and 500-year events would cause losses of about USD 409, 1047 and 8954 million, respectively. This information can be expressed in terms of an exceedance loss distribution (EP) (see Appendix A2) as shown in Figure 14 (see also Appendix 6 for the case of multi risk situations).

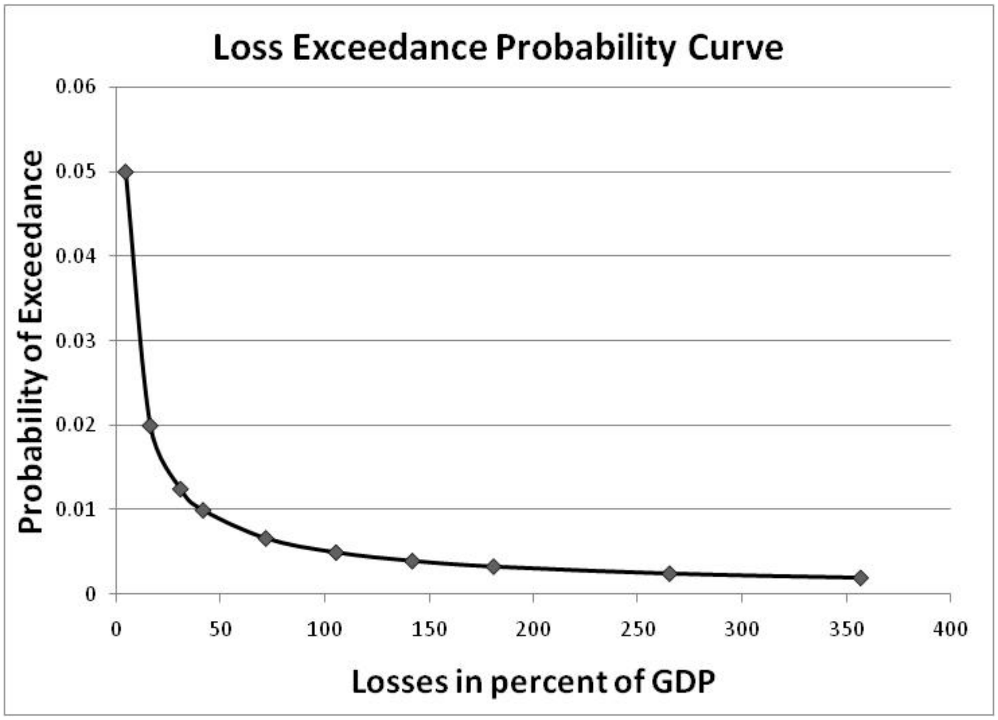

Fig. 14: Loss exceedance distribution

An important summary measure of this probability distribution is the annual expected losses, or the losses to be expected on average every year. The annual expected loss is the sum of all losses weighted by the probability of occurrence. Graphically, the expected losses are represented by the area below the exceedance distribution. For the public sector only, modeled annual losses are on average around 10.48 million USD with a standard deviation of 39 million USD. For the baseline model annual average losses are around 55 million with a standard deviation of 253 million USD. The minimum baseline case gives annual expected losses of around 26 million USD with a standard deviation of 98 million USD. Integrating the curve for the maximum case, losses are very high, with average annual losses estimated to be around 213 million USD and a standard deviation of about 787 million USD. Table 8 summarizes the results.

Table 8: Annual expected losses and corresponding standard deviations for selected models

Model	*Annual expected loss (million USD)*	*Standard deviation*
Public sector only	10.48	39
Baseline case	55	253
Minimum case	26	98
Maximum case	213	787

As said, the public sector only model gives the lowest number and is calculated to be around 10 million USD, or in other words, the government of Madagascar could expect to be responsible for cyclone loss financing of around 10 million USD every year. Bear in mind that disasters are not average, but extreme events occurring very rarely. Over a longer time period, like 100 or 500 years, catastrophe losses suffered will be close to the sum of annual expected losses over these years, but large shocks could occur anytime and therefore necessitate the modeling of potential consequences of these shocks.

4.2 Step 2: Estimation of the financial resilience of the public sector

After identifying and assessing financial disaster risks, the next step is to determine the government's ability to finance the potential losses should the disaster occur in the current period. In general, governments can make use of the following ex ante (before the event) and ex post (after the event) financing sources.

Ex post financing sources

The government can raise funds after a disaster by:

- accessing international assistance,
- diverting funds from other budget items,
- imposing or raising taxes,
- taking a credit from the Central Bank (which either prints money or depletes its foreign currency reserves),
- borrowing by issuing domestic bonds, and
- borrowing from multilateral finance institutions (MFIs) and issuing bonds on the international market.

Each of these sources of financing is characterized by costs to the government as well as factors that constrain its availability. A methodology was developed for estimating the costs and availability of these sources, and these data serve as inputs to CatSim (Hochrainer, 2006; Mechler et al. 2006). More detail on the calculation of these sources can be found in the guidelines (see also Appendix A4)

Ex ante financing sources

The government can arrange for financing before a disaster occurs. Ex-ante options comprise insurance (traditional or alternative, e.g. catastrophe bonds), reserve funds or arranging a contingent credit (the payment of an annual fee for the option of securing a loan with pre-arranged conditions after a disaster). Ex ante financing may also include premiums paid into an insurance pool. These ex-ante options involve annual payments or opportunity costs that can be substantial. Furthermore, benefits in terms of claim payments arise only if an event happens.

Assessment of feasible financing sources for Madagascar

An understanding of the sources for financing a disaster in Madagascar, including the costs and constraints, is crucial for planning a disaster risk management strategy.

Concerning ex-post sources, Madagascar is constrained by its fiscal inflexibility and low revenue base: it is assumed that domestic credit is available up to approximately USD 50 million (a very optimistic assumption, see also Madagascar Economic Update 2011). Diversion from the budget is not feasible to a large extent; however, we assume 0.1% of the budget can be diverted. Furthermore, we assume 10.4 percent of the total losses will be financed by outside assistance; this is based on some past loss financing assistance estimations in other countries (see Freeman et al. 2002ab).

Table 9: Sources for financing of disaster losses

Source	***Parameter value used***
International donor assistance	10.4 %
Diversion from budget	0.1%
Domestic bonds and credit	50 million USD
Multilateral borrowing	20 million USD
Reserve fund	0 million USD
International borrowing	20 million USD

Alternatively, due to low debt, borrowing from multilateral and international sources is assumed to be possible (in a worst case scenario, there are some Chinese Banks who actually give a credit rating for Madagascar). We estimate post-disaster loans to be possible to approximately USD 40 million with an equal split from multilateral and international sources but at different interest rates and conditions. The sources are summarized in Table 9 above (these parameters form the baseline for discussion and were discussed and assessed during the workshop). It should be also noted that these are very optimistic assumptions and therefore should treated with caution (however, the options were assessed at the workshop and generally accepted; if they should be changed in the future within CatSim, the manual from Hochrainer 2012 should be consulted).

4.3 Step 3: Estimating the government's "financing gap"

Summarizing all potential sources, CatSim can provide an estimate of the government's financing gap for its cyclone exposure. Given the assumptions and data as described above, the cyclone risk financing gap for Madagascar's government using the baseline case is shown in Figure 14.

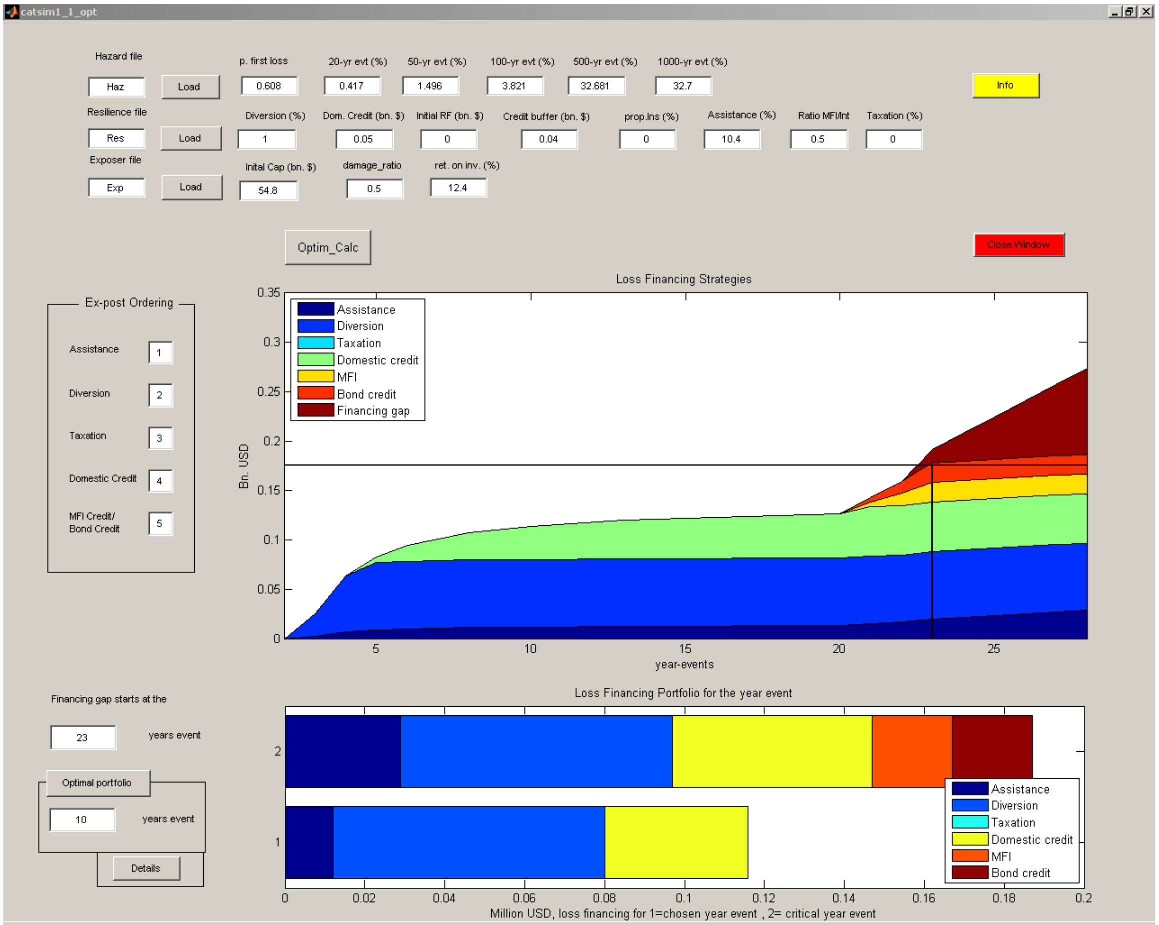

Fig. 15: Financial vulnerability and resource gap

Note, that Madagascar experiences difficulties in raising sufficient funding for the 23-year event. The chart in Figure 14 shows total financing needs and financing available for different year events. Keeping in mind the data limitations and restrictive assumptions, this analysis shows that the government of Madagascar has sufficient financing available up to the 23 year cyclone-related loss event. However, for less frequent and more severe events a gap would occur, e.g. for a 100 year event, this gap would amount to US$ 0.95 billion. What this means for long term consequences is assessed in the next section.

In Table 10, the financing gap year event as well as the corresponding gap for a 100 year event loss is shown.

Table 10: Financing Gap return period and 100 year gap (billion USD).

	Model			
	Maximum	Baseline	Minimum	Public
Financing Gap Year Event	1	23	4	24
100 year gap	5.71	0.95	0.547	0.09

Source: Own calculations

The financing gap year event is similar for the “public sector only” as well as the “baseline” model runs. However, as the former does not have a fat tail (it actually does not increase very steeply), losses for more extreme events are significantly lower as can be seen if compared to the 100 year event gap. Even with very optimistic loss financing assumptions one can expect higher losses for more extreme events. On the other hand, using the maximum and minimum bounds losses are estimated to be very high and nearly always causing financing problems and a 100 year event gap of about 5.71 billion. It also should be noted that while the minimum model here has lower values than the baseline, this is not the case for the higher year events (see Table 11).

Summarizing, in the baseline case scenario it was found that a financing gap year event would start around the 23-24 year event. Losses from more extreme events such as the 100 year event loss will be very difficult to be financed and could cause gaps around the 1 billion USD threshold. It should be noted that confidence bounds around these estimates are large. In one of the models, the financing gap year event would actually approach 1, meaning that the government of Madagascar cannot finance any losses whatsoever and extremes can cause heavy damages where a large portion cannot be financed. It should also be noted that if the financing resources were less optimistic than used here, the baseline results would decrease vastly. For example, without the option to divert funding from the budget, the financing gap would start at the 7 year event. Additional tests (see the calibration chapter 7 in Hochrainer 2012) can be performed for sensitivity analysis but the financing gap would remain in an area around the 10 to 20 year event.

4.4 Step 4: Mainstreaming disaster risk into macroeconomic and development planning

Information on the financial losses from cyclones and the resource/financing gap is helpful, but ultimately the implications of this gap on economic development and other “flow variables” are of major interest when mainstreaming disaster risks into development planning and macroeconomic management. For that matter, financial risk, financial vulnerability and the prevalent economic conditions in Madagascar are combined in order to derive an estimate of potential fiscal and macroeconomic impacts. As disaster events are probabilistic events, the full information contained in the probabilistic loss curve can be used for simulating economic growth trajectories. Figure 16 and 17 show a selection of trajectories for fiscal and macroeconomic impacts for Madagascar. In Figure 16, potential trajectories for the discretionary portion of the budget are outlined. This indicator may be useful as it represents budget flexibility after mainstreaming disaster losses and government relief requirements. The graph shows that while on average, budget flexibility should increase, there is some potential for disasters seriously affecting budget flexibility.

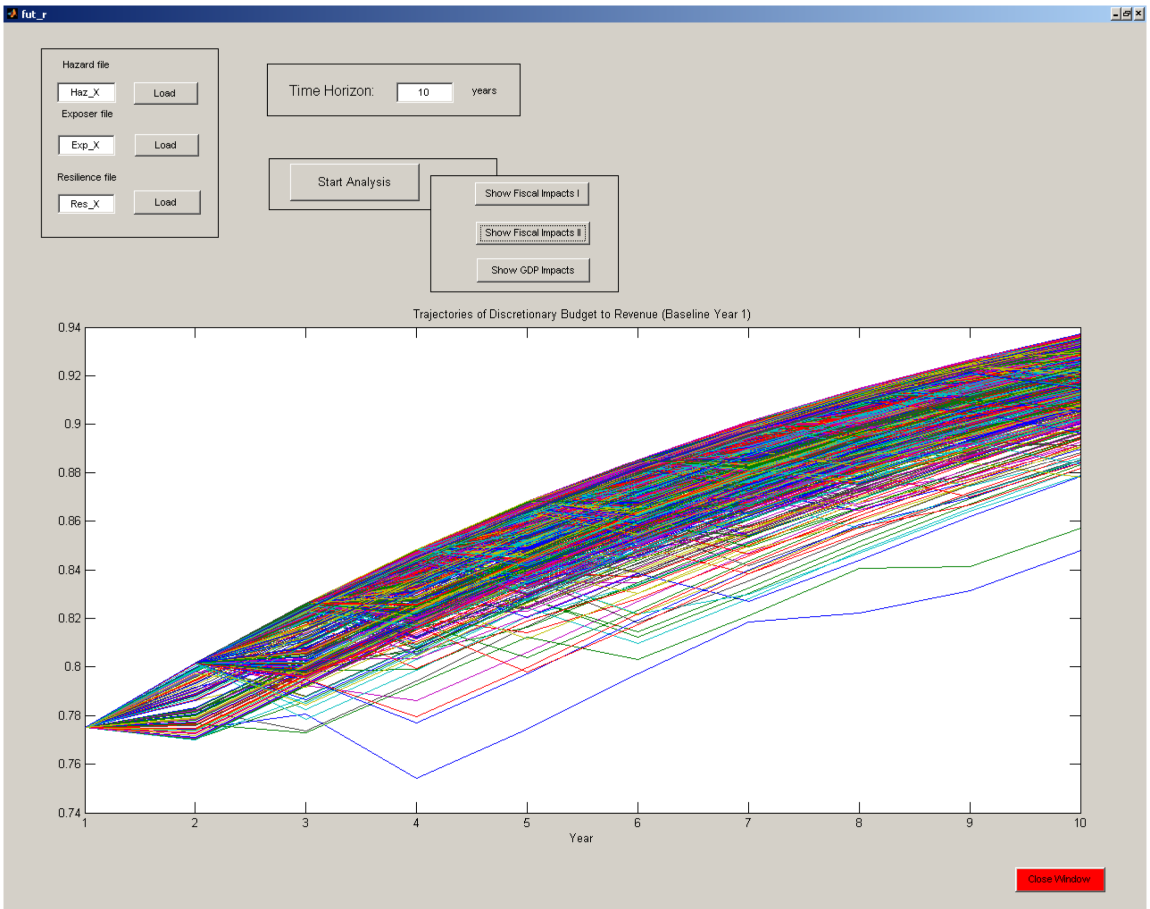

Fig. 16: Potential fiscal impacts due to disaster impacts

Similarly, macroeconomic performance may be affected. In Figure 17 the economy grows over time as investment adds to the capital stock. However, in a number of cases disasters cause a loss of assets and income. Given the financial resilience of the government, these events put the economy on a lower trajectory. In some cases, there is a dramatic decrease in economic activity.

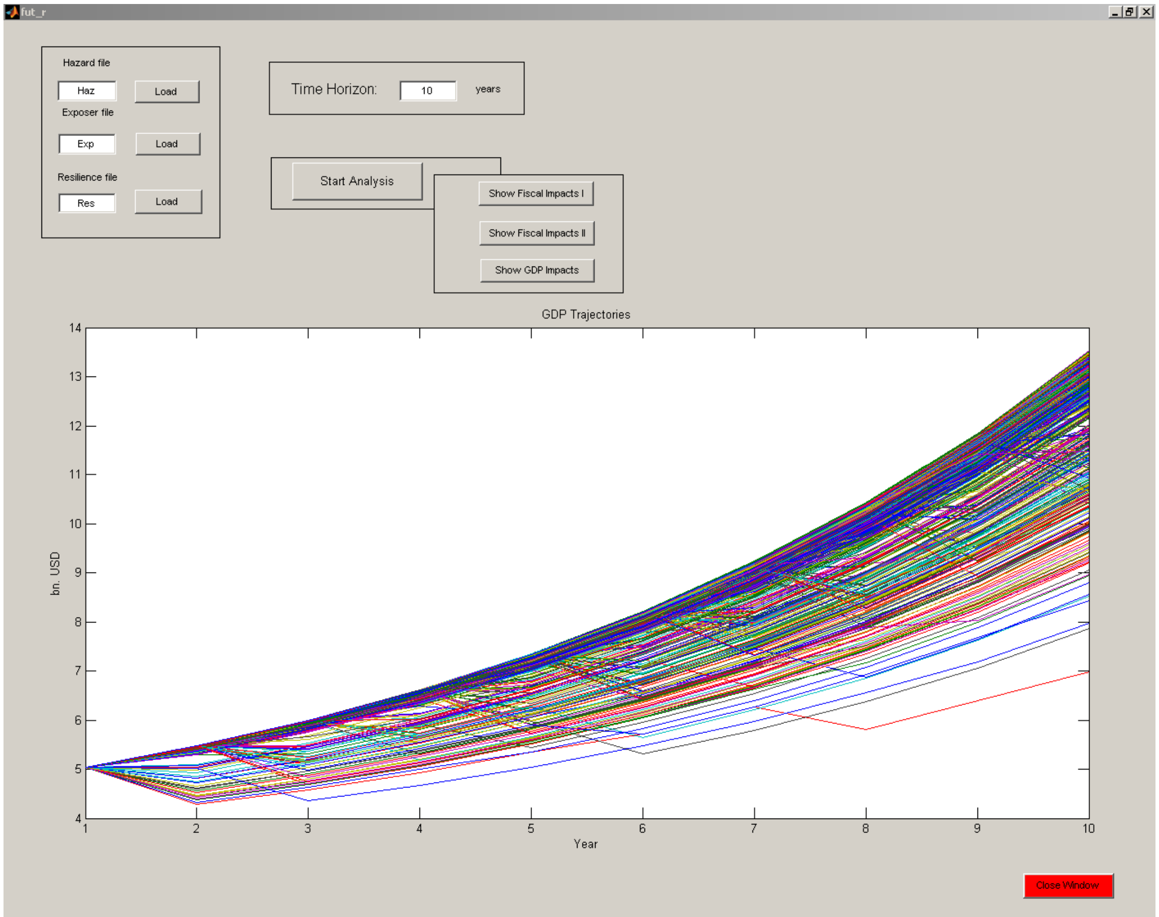

Fig. 17: Potential GDP impacts due to disaster impacts

The occurrence of such trajectories is stochastic and depends on the probability distribution of financial losses. Normally, 5,000 or 10,000 trajectories are calculated, but in this chart only 2000 are summarized for illustration purposes. These trajectories do not have equal probability: the cases with economic growth proceeding as planned (the trajectories in the upper part) have a higher probability than the catastrophic cases at the bottom. Such an assessment illustrates the worst outcomes compared to the planned business-as-usual cases of economic development. Table 11 presents the financing gap probability for the next 5 years as well as the credit buffer drop for the baseline, maximum and minimum models (the public sector only model can no longer be used, as private sector losses need to be incorporated). The credit buffer drop is defined as the average drop over the next 5 years from the starting level (here defined to be 40 million USD). A decrease of the credit buffer indicates high indebtedness and no possibilities to borrow in the future.

Table 11: Financing Gap probability and credit buffer drop (million USD).

	Model		
	Maximum	Baseline	Minimum
Probability of Financing Gap (%)	93	48	89
Credit buffer drop million USD	39	32	36

Source: Own calculations

For the baseline model, the probability of having a financing gap in the next 5 years is 48 percent. For the other two models it is between 89 and 93 percent, i.e. financing problems will emerge in the future with near certainty. Additionally, indebtedness will likely increase as well; while it is estimated that around 40 million USD of credits could currently be taken from international markets, this amount would decrease to less than 8 million (baseline case) or near zero. Hence, even in the case that losses can be financed sporadically in the short term via credits, this kind of option is decreasing over the long term, making it difficult in the future to have creditworthiness. It is now the question what kind of instruments or options could be chosen to decrease this kind of risk, which is discussed in the next section.

5. Risk Management: Evaluating Proactive Risk Reduction and Risk Financing Strategies

After identifying and assessing risks and the financing gap, the next step in a risk management process is to evaluate the state of risk reduction and risk transfer measures. As shown in Figure 18, risk reduction, mitigation and preparedness reduce losses, whereas risk financing transfers and shares [residual] risks. The capacity of a government to proactively manage its risks with mitigation and financing options depends to a large degree on its risk management and governance institutions.

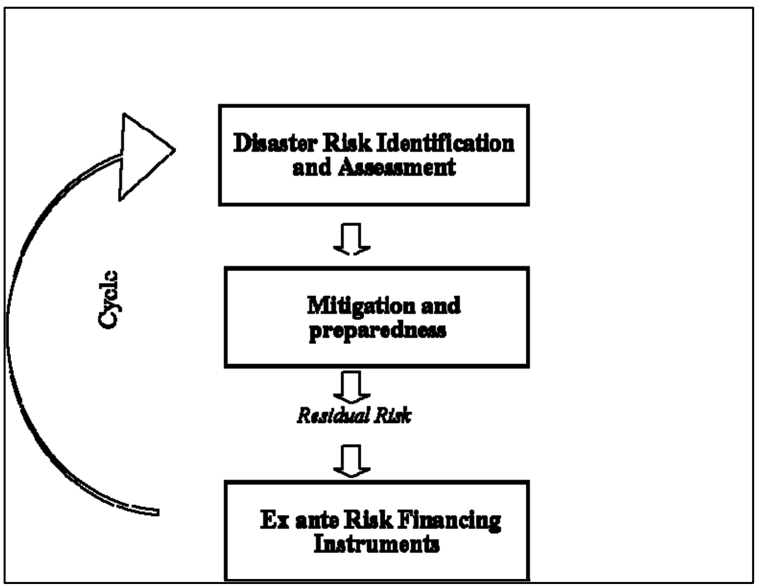

Fig. 18: Disaster risk management cycle

Possible risk financing instruments could include insurance-type arrangements (such as insurance, reserve funds or contingent credit arrangements), shortly discussed below.

- Insurance and other forms of risk transfer provide indemnification against losses in exchange for a premium payment. The most common forms of risk transfer are insurance or reinsurance. Alternatively, catastrophe bonds can be used to access capital of the international financial markets.
- A reserve fund holds liquid capital to be used in the event of a disaster. Normally, the fund is financed on an annual basis, so that capital can accumulate. A fund accumulates in years without catastrophes and can be used in the case of an event to finance the losses.
- Contingent credit arrangements do not transfer risk, but spread it intertemporally. In exchange for an annual fee, the right is obtained to take out a specific loan amount post-event that has to be repaid at contractually fixed conditions. Contingent credit options are commonly grouped under alternative risk transfer instruments.

All of these instruments have its pros and cons summarized in Table 12 below.

Table 12: Pros and cons of ex-ante financing instruments

	Insurance	Reserve fund	Contingent credit
Cost before event	Premium multiplied by number of years before event	Payment into fund multiplied by number of years before event	Holding fee multiplied by number of years before event
Benefit after event	• Loss indemnification for elements insured • Increased capital inflows from abroad to affected economy	• Reserve funds and interest available • Funds will not be lost in case of no event	• Funds available immediately • Increased capital inflows from abroad to affected economy
Cost after event	None	None to the extent that enough reserve has been accumulated	Additional debt service, reduction in ability to take out future debt
Incentive for mitigation?	Yes	Only if risk is known	No
Risks	Risk of (re)insurer insolvency	▪ Risk of depletion before disaster events due to political pressures ▪ Risk of insufficient funds	• Risk of insufficient funds • Risk of financial entity insolvency

Source: Mechler, 2004.

Figure 19 presents a flow diagram as a summary of how each of the steps could be performed in a practical way over time. The first step is to identify hazards the country is exposed to. Then, risks are evaluated to determine if they are acceptable.

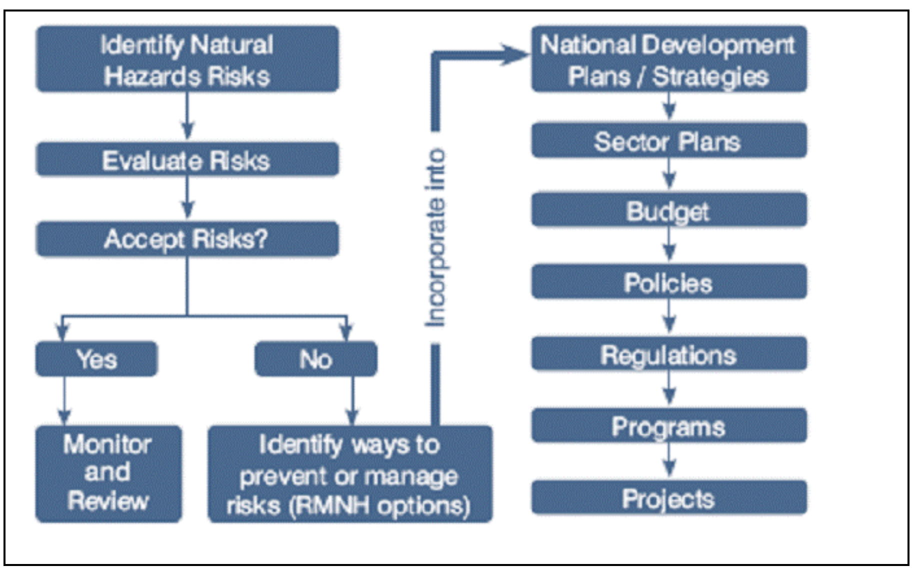

Fig. 19: Planning for disaster risks. Source: Bettencourt et al., 2006

If not, one has to think about possible risk management strategies including top-down as well as bottom-up approaches. At the end, programs and projects should be started (on various levels) to decrease the risk to an acceptable level. Afterwards, monitoring should be undertaken on a continuous (annual) basis

Summarizing, disaster risk management consists of measures taken before, during and after the disaster event to either reduce the extent of the hazard, exposure of the elements at risk and/or vulnerability (Lindell and Perry 2004). These measures can usefully be divided into risk-reduction (mitigation) instruments and risk-financing instruments. The former, such as levees to protect against floods or strengthening roofs against cyclone events, reduce direct hazard impacts, and the latter reduces the financial impacts. In addition, or alternatively, one can invest in insurance and other types of risk-financing measures to assure that sufficient resources are available after the event for timely relief and reconstruction. This reduces indirect "downstream" losses.

However, the choice between how much should be invested in risk reduction versus risk financing is not straightforward. Such a selection will depend primarily on the occurrence probability of the hazard, the associated size of impacts, the costs and benefits of both types of instruments, as well as on their interaction. Risk-reduction measures against direct losses are usually more cost effective for frequent events (say 10 to 100-year loss return period) with low to medium-sized losses than for high impact/less frequent events. For lower impact events substantial reduction in damage can typically be achieved at relatively little expenditure, but it becomes increasingly costly to achieve further reductions in risk (Rescher 1983).

Concerning risk financing, risk bearers (individuals, businesses, governments) are generally better able to finance lower consequence events from their own means, including savings, reserve funds or credit arrangements. Risk financing is thus generally more appropriate for medium sized to extreme losses (say 100- to 500-year loss events) to smoothen the *variability* of financial losses. Finally, some events (say above the 500-year loss event) can be too costly to be reduced or insured. Hence, outside assistance may be needed (e.g. from the government, international financial institutions such as the World Bank, donations, etc.).

If investments in risk reduction are more cost effective for low-consequence events, and investments in insurance more cost effective for high-consequence events, how would this translate into cyclone adaptation measures? Below (Figure 20) we present a hypothetical illustrative example of how a *risk layering* approach can provide insights on adaptation investments Madagascar.

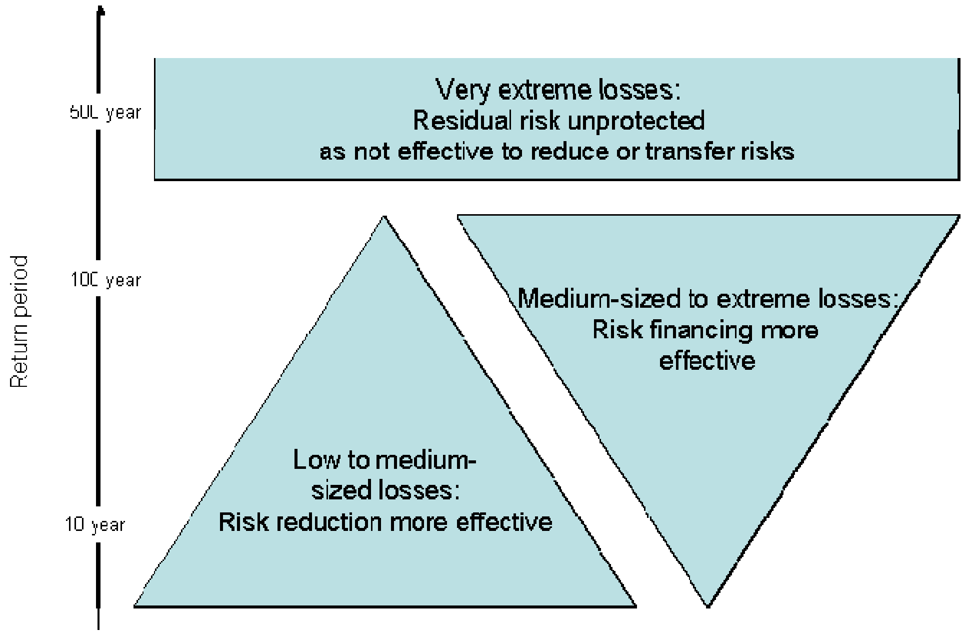

Fig. 20: Efficiency of risk management instruments and occurrence probability. Source: Hochrainer-Stigler and Pflug, 2012.

The financing gap year event was estimated to be between the 10 to 23 year events, so according to Figure 20 risk reduction should be the primary focus. On the other hand, financial pressure to the fiscal system and indebtedness level can be expected in the future as the probability of a financing gap was between 50 and 90 percent, with a drop in credit availability of nearly 80 to 100 percent. Hence, a range of financial instruments should also be contemplated. Unfortunately, the macroeconomic situation is very difficult currently; draining resources from other development and growth projects may result in important opportunity costs. These tradeoffs could affect transportation, usually seen as not the engine but the wheels of economic growth, and education, with an importance for development that cannot be overestimated (World Bank 2003, Lutz et al. 2012).

Figure 21 shows the resulting decrease in the probability of a financing gap for the next 5 years, given implementation of different options. While the expenditure as percent of available budget is shown from 0 to 80 percent (x-axis) one should recognize that only 1 to 2 percent could be actually used in the most optimistic setting.

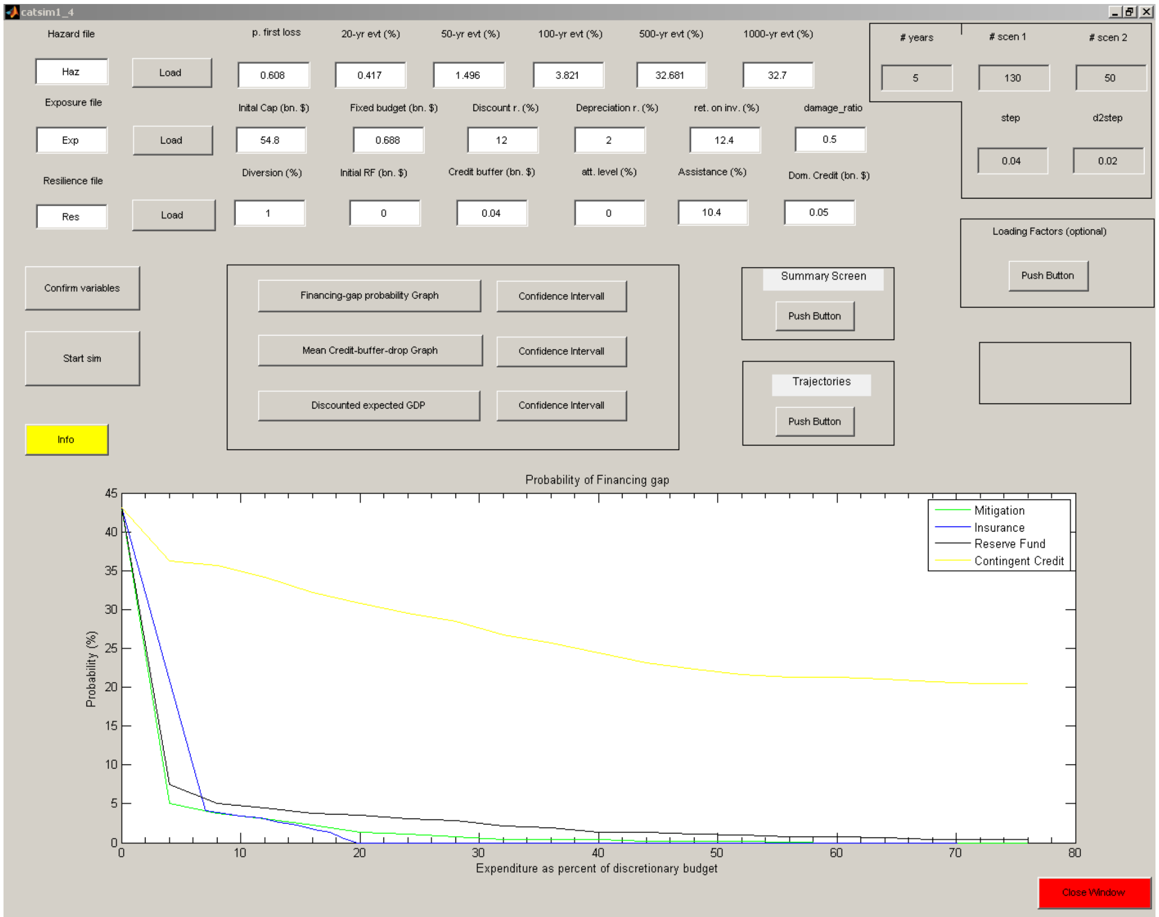

Fig. 21: Decrease of the financing gap probability using different instruments

For example, using 2 percent of the discretionary budget over the next 5 years would decrease the probability of a gap from 43 to around 22 and 31 percent. However, looking at the credit buffer drop, values did not change significantly, which indicates that most of the losses would have to be financed through credits. This is further reflected in the yellow line, which represents the contingent credit option. While it is beneficial to obtain easy and cheap credits after a disaster event, one still has to repay the loan and therefore is more financially vulnerable during this period than with other options. Furthermore, one should not forget the trade-off between stability and growth. Investing 2 percent of the discretionary budget into risk management options would decrease GDP by half a billion over the next 5 years due to less possibilities to invest in growth.

6. Group Exercise during Workshop and Training Day

Your task is to evaluate options for reducing and transferring disaster risk based on available information on your country's disaster risk profile, its fiscal position, development plans, institutional capacity and development agenda/plans. You are charged thus with giving guidance to your government on strategy and public investments in pro-active disaster risk management. Specifically, your group is asked to:

1. **Develop an integrated risk management and financing strategy** that includes judgments on what losses the public sector will bear; of this, define how much will be absorbed, where/how much you will invest to reduce risk, and select mechanisms for financing remaining contingent liability for ex-post reconstruction (savings/funds, reorienting budget and existing credit; contingent debt, insurance, etc.).

2. **Identify next steps (action plan)** to implement the integrated risk management and financing strategy: budget instructions (debt, budget caps, capital investments, allocations to ministries/sectors and subnationals etc.); tools for identifying and reducing risk in the annual public investment program; necessary steps to improve the prudent use of private insurance; any additional risk evaluations needed, such as identification of critical facilities, infrastructure and populations at high risk.

Please use the information available above in combination with CatSim, which provides you with information on the following themes:

- Background information on Madagascar and its exposure to natural hazards, including its public investment program and development agenda,
- The government's contingent liabilities, including relief to victims and reconstruction of private assets,
- The government's fiscal profile (budget, debt, etc.),
- The macroeconomic and fiscal risk to the country,
- Options for physical risk reduction (loss mitigation) measures, including their benefits and costs,
- Options for transferring risk from the public sector and thus better enabling the government to meet its post-disaster liabilities.

7. Summary, Conclusion and Recommendation

Madagascar has one of the highest cyclone risks worldwide, especially the east coast, which is located in the path of destructive cyclones coming from the Indian Ocean. Furthermore, it is projected that climate change will increase the intensity of cyclones in the future, while decreasing their frequency. The purpose of this report and the exercise in the workshop was to discuss and apply the CatSim (Catastrophe Simulation) approach to incorporate disaster risk management (DRM) into fiscal and development planning processes, as well as exploring the feasibility of using disaster risk management options for reducing risk. Additionally, it should support the ongoing CPGU (Cellule de prevention et gestion des urgencies) led-study on "Mainstreaming Disaster Risk Management and Climate Change in Economic Development".

Based on two datasets, ie. EMDAT and MLoss, different estimates of direct risk were estimated. Dependent on the model used, average annual losses the government is responsible for were estimated to be between 10 million USD and 55 million USD. Corresponding standard deviations were found to be large and therefore should not be neglected. For example, using the public sector loss estimates from MLoss, average annual losses were found to be 10.48 million with a standard deviation of 39 million USD; for loss estimates based on the EMDAT database average annual losses were about 55 million USD with a standard deviation of 253 million USD.

Including the financial resources of the government to finance losses due to cyclone events, it was found that the government would experience difficulties in raising sufficient funding after a 23-year loss event. For less frequent and more severe events, a financing gap would occur, e.g. for a 100 year event, this gap would amount to US$ 0.95 billion. Hence, losses from more extreme events such as the 100 year event loss would be very difficult to finance and could cause gaps around the 1 billion USD threshold level. It should be noted that confidence bounds around these estimates are large, especially if financing resources are less optimistic than used here. Additional sensitivity tests were performed and it was concluded that the financing gap would be between the 10 to 25 year loss events.

Regarding long-term consequences, for the baseline model the probability of having a financing gap in the next 5 years was 48 percent. For the other two models it was between 89 and 93 percent, i.e. financing problems will emerge in the future with near certainty. Additionally, indebtedness will likely increase; while currently it is estimated that around 40 million USD of credits could be taken from international markets, this amount would decrease to less than 8 million (baseline case) or near zero. Hence, even in the case that losses can be financed sporadically in the short term via credits, this kind of option is decreasing over the long term, making it difficult in the future to have creditworthiness.

This raised the question of what kind of instruments or options could be chosen to decrease this kind of risk. Unfortunately, the macroeconomic situation in Madagascar is very difficult currently and draining resources from other development and growth projects may cause important opportunity costs. For example, using 2 percent of the discretionary budget over the next 5 years would decrease the probability of a financing gap from 43 to around 22 and 31 percent. However, indebtedness levels would remain high, which indicates that most of the losses need to be financed through credits. Furthermore, one must not forget the trade-off between stability and growth. Investing 2 percent of the discretionary budget into risk management options would decrease GDP by half a billion over the next 5 years due to less investment in growth projects.

It was discussed via the risk layer approach that for frequent events, risk reduction is more appropriate and for less frequent events risk financing (such as an insurance or a contingency fund) is more effective. As the financing gap is still at least below the 50 year return level, it therefore seems better to focus on risk reduction options first (such as the GFDRR supported development of cyclone-resistant national building codes). Afterwards, risk financing options should be contemplated. As said, infrastructure is usually seen as “if not the engine then the wheels of economic activity” (World Bank 1993) and education and its importance for development cannot be overestimated (Lutz et al. 2008). Hence, focus on such dimensions seems superior. Two possible instruments which showed some success in the past in this regard will be discussed briefly next, e.g. the Mexican FONDEN and the Caribbean insurance initiative.

The 1985 earthquake in Mexico City sensitized Mexican authorities to the benefits of proactively engaging in prevention and financial disaster risk management. Nearly 9,000 people lost their lives, and direct economic losses from this disaster were estimated at $7 billion (in 2006 $) or 2.7% of the GDP in the year of the event (Cardenas et al., 2007). Colossal expenses on rehabilitation and reconstruction resulted in an increase in the fiscal deficit of $1.9 billion over the next four years. Despite inflows from private sector (business and households) insurance and foreign donations, the earthquake is estimated to have had a negative effect of $8.6 billion on Mexico’s balance of payments over this period (Jovel, 1989). In 1996 the national government created a budgetary program called FONDEN (Fund For Natural Disasters) to enhance the country’s financial preparedness for natural disaster losses. As a budgetary item FONDEN is established at the start of each fiscal year by the Mexican parliament as part of the federal government budget plan. FONDEN provides last-resort funding for uninsurable losses, such as emergency response and disaster relief. In addition to the budgetary program, in 1999 a reserve trust fund was created, which is filled by the surplus of the previous year budget item. FONDEN’s objective is to prevent imbalances in the federal government finances derived from outlays caused by natural catastrophes. The fund does not support reconstruction of private infrastructure, nor does it act as insurer of last resort. It grants financial support only to those private individuals that, due to their poverty status, require government assistance. Figure 22 shows FONDEN’s budgeted and spent funds for natural disasters over the last decade, including the average balance and one standard deviation around this mean.

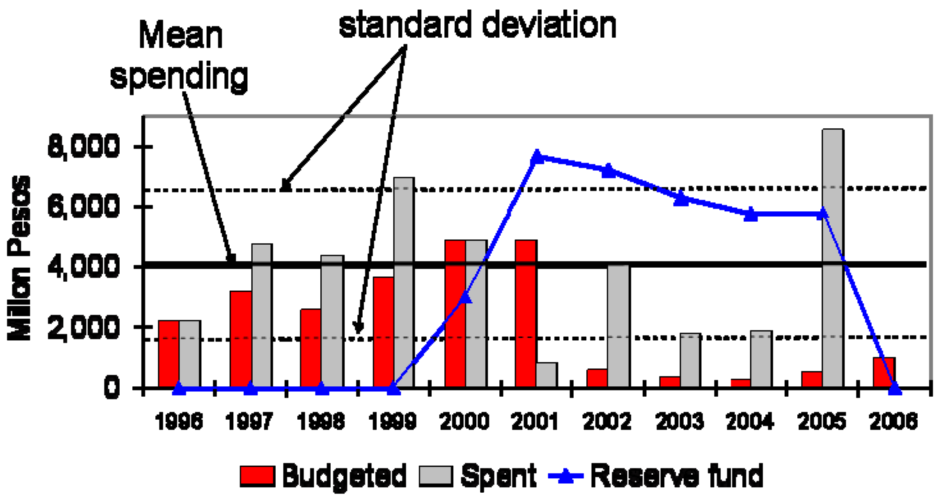

Fig. 22: Budget and resources of FONDEN. Source: Ministry of Finance and Public Credit of Mexico, Cardenas et al. 2007

As shown in Figure 22, budgeted FONDEN resources have been declining over the last few years. Moreover, demands on FONDEN's resources are volatile, and outlays have often exceeded budgeted funds. As a consequence the reserve fund has diminished, and finally in 2005, after the severe hurricane season affecting large parts of coastal Mexico, the fund was exhausted. The uncertainty associated with FONDEN to provide sufficient post-disaster finance led officials of the Ministry of Finance and Public Credit (hereafter referred to as the Finance Ministry) to consider hedging against natural disaster shocks (see Cardenas et al. 2007). A similar contingency fund could be also a possibility for Madagascar. However, as said, the opportunity costs of such instruments should not be neglected. As seen with the Mexican disaster fund, in the due course of its development over time (Figure 22), the necessary kind of financing needs and capital requirements became clearer.

Pooling extreme risk deserves special attention. If insurers with limited capital reserves choose to indemnify large covariant risks (losses occurring at the same place/time), they must guard against insolvency by diversifying their portfolios, limiting exposure and/or transferring their risks to the global reinsurance and financial markets. Yet, due to lack of access to the reinsurance markets and the high cost, many insurers are operating with little financial backup arrangements. This is not a problem for small pilot schemes, but raises a question of viability when scaling up. Similarly, developing country governments, particularly those of small states, pay international prices that are subject to fluctuations caused elsewhere. For example, Barbados, which is one of few countries insuring public infrastructure, experienced a ten-fold increase in insurance premium after Hurricane Andrew in 1992 despite the fact that Barbados is not in a major hurricane path. A promising strategy to more effectively diversify risks is through intergovernmental risk pooling arrangements.

Caribbean island states in 2007 formed the world's first multi-country catastrophe insurance pool to provide governments with immediate liquidity in the aftermath of hurricanes or earthquakes. The Caribbean Catastrophe Risk Insurance Facility (CCRIF) went into operation in June 2007 with the participation of 16 Caribbean countries, whose governments contributed resources ranging from US$200 thousand to US$4 million depending on the exposure of their specific country to earthquakes and hurricanes. This pool is expected to result in a substantial reduction in premium cost of about 45 – 50% for the participating countries. The fund covers up to 20% of the estimated infrastructure loss, and claims will be paid depending on an index for hurricanes (wind speed) and earthquakes (ground shaking). Initial funding by donor organizations provided support for start-up costs and helped capitalize the pool. The facility will transfer the risks it cannot retain to the international financial markets through reinsurance or through other financial instruments (for example, catastrophe bonds). The accumulation of reserves over time should lessen the facility's dependence on outside risk transfer. Should the total insured losses exceed its claims-paying capacity, payouts will be pro-rated based on the total amount of expected claims compared to the remaining available funds. In addition, donors are adding to the reserves. The governments of Bermuda, Canada, France, the United Kingdom, as well as the Caribbean Development Bank and the World Bank recently pledged a total of US $47 million to the CCRIF reserve fund. Part of this funding is used to help low-income island states, such as Haiti, pay the requisite premium (Ghesquiere et al., 2006).

There were clear advantages of pooling their risks, and thus diversifying across island states. Together governments can negotiate re-insurance terms for their pool at a significantly lower cost than if they were to purchase insurance separately in the financial markets. Early cash claim payment received after an event will help to overcome the typical post-disaster liquidity gap. Such an option to pool risk together with other African states could be also a possibility for Madagascar. Again, due to the tight financial situation in Madagascar it is likely the case that opportunity costs will be high and therefore such options have to be assessed in the general context of economic development strategies for future economic growth.

Apart from this more technical assessment of possible options it should also be emphasized that additional structures and institutions have to be built to mainstream disaster risk into sustainable development planning processes. This includes:

- Catastrophe models (see Appendix 1) need detailed exposure and vulnerability data, which are not yet at hand. Hence, spatial assessments of critical infrastructures and other elements at risk as well as corresponding vulnerabilities have to be gathered in the future.

- Frequent updates between different government ministries about the different information they have (for example in regards to the different steps of the CatSim approach) would be beneficial for the risk assessment and risk management process. For example, while the meteorological office could provide details about cyclone-exposed areas, other ministries could additionally provide their input to create vulnerability hotspots, i.e. where attention should be prioritized.

- As there is a substantial degree of uncertainty in estimates of disasters risks and financial vulnerability, it is important that other potential users have full participation in the design, estimation and use in the future. The stand alone application of CatSim with the accompanied manual should help in that regard.

- Clearly, financial vulnerability of the public sector presents only one aspect, albeit an import one, of vulnerability to natural hazards. However, other indicators are necessary in order to complement this concept. Hence, disaster risk management has to be understood within a general integrated concept to enhance socio-economic development. It is especially important to also include qualitative data and objectives which are at hand, e.g. increase in school enrolment and quality of teaching etc.

- It important to measure future cyclone events and its effects on society in as much detail as possible (such as the study of the Cyclone 2007/2008 season, World Bank 2008). This is not only needed for estimating the direct risk as discussed in this report but also will be very important in the future to calibrate catastrophe models. Additionally, it will be clearer what kind of emergency steps have to be taken first and what kind of recovery processes are most needed.

- Finally, cyclone risks pose only one of the many challenges ahead. Hence, integrated approaches where other dimensions come into play should be considered as an appropriate way to derive sustainable decisions. Clearly, cyclone risk is only one part of the puzzle and needs to be integrated within a systems analysis.

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9. Appendix: Technical Notes

Appendix A1: Assessing Disaster Risk: Approaches

Common practice in catastrophe models is to conceptually model the direct damage calculations via three components, i.e. the "hazard", "exposure" and "vulnerability" module. A fourth "loss" module summarizes the results from these modules with the help of risk metrics or loss distributions (see Figure 1).

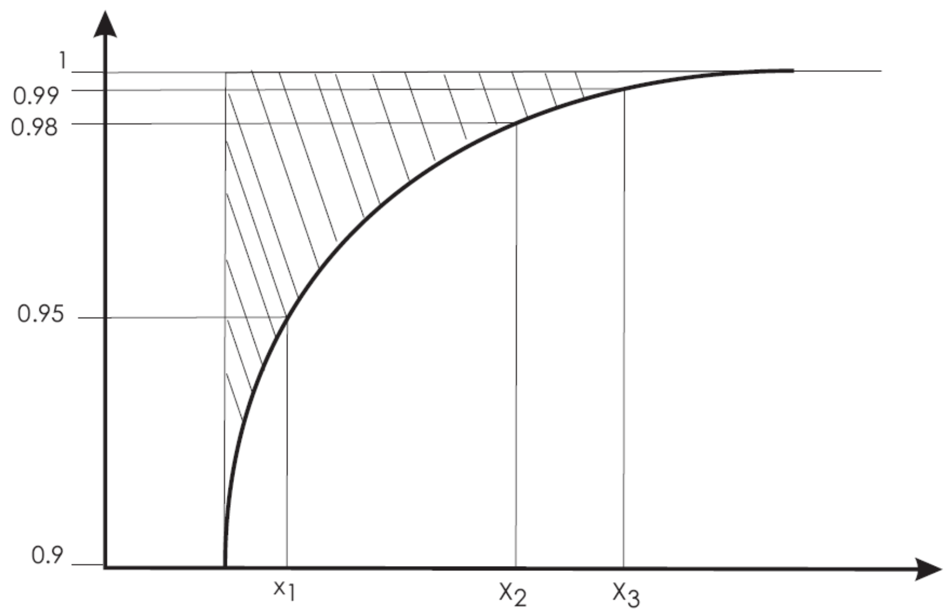


Fig. 1: Loss distribution. Source: Hochrainer, 2006.

Loss distributions are cumulative distribution functions where the x-axis represents the losses, e.g. monetary losses, annual losses in terms of GDP, or capital stock losses. The y-axis represents the probability that losses do not exceed a given level of damage. It therefore can be called the "event axis". For example, in Figure 1, a value of 0.98 on the event axis means that with a probability of 98 percent the losses do not exceed a given level of damage, say x2. In other words, with a probability of 2 percent the losses will exceed this level of damage. Note that a 2 percent probability can be interpreted as a (1/0.02=) 50 year event, e.g. an event that happens on average once every 50 years. The same principle can be used for all other events. This means that the higher the return period, the lower the probability of the event, but the higher the losses. The loss distribution function itself is very useful for risk management purposes because various risk measures can be calculated from it (see Pflug and Römisch). For example,

- the average annual loss, which is the area above the loss distribution
- the Value at Risk (VaR) which is defined as $VaR(p)=F^{-1}(1-p)$, where F^{-1} is the quantile function defined as the inverse of the loss distribution function, or
- the Probable Maximum Loss (PML) which is associated with a given probability of exceedance (see also Grossi and Kunreuther 2005).

Generally speaking, two approaches are available to estimate loss distributions, either via catastrophe modeling approaches or by using past events. Conceptually, as indicated above, four different modules in catastrophe models can be distinguished: Hazard, Exposure, Vulnerability and Loss (Figure 2).

Fig. 2: Catastrophe Modeling Approach for Risk Assessment of Natural Hazards. Source: Based on Grossi and Kunreuther, 2005.

The hazard model must incorporate at least three variables regarding the source parameters of the hazard: the location of future events, their frequency of occurrence and their severity. This information is based on either historical and/or engineering information, e.g. by simulating potential hurricane tracks to increase the number observations. The probability of a given event has to be determined either by time-series analysis or by assuming suitable stochastic models, e.g. a non-homogeneous Poisson distribution of the probability of a hurricane event. Furthermore, the intensity needs to be determined. For example, in the case of cyclones the wind speed at location z could have the following functional form:

$$W_z = f(dp, r, s, l, a, t)$$

W_z = Wind speed at location z
dp =Ambient pressure minus central pressure
r =Radius of maximum winds
s =Forward speed of the storm
l =Landfall location (longitude, latitude)
a =Angle of incidence at landfall
t =Terrain or roughness coefficient at location z

One starting point for getting this kind of data is to use past landfall events of cyclone hazards. Figure 3 below, for example, shows the number of cyclone entry points in Madagascar. From an institutional point of view the Meteorological Office within the Government should collect and analyze the data, which afterwards need to be included in the other modules.

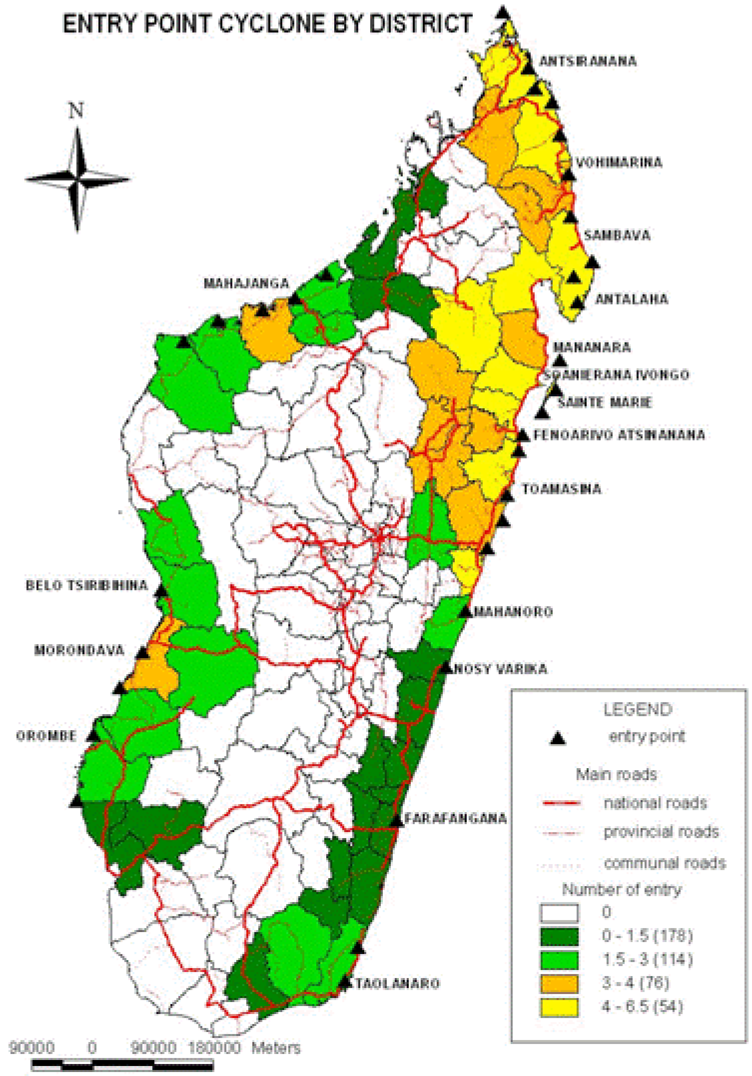


Fig. 3: Cyclone entry points by districts in Madagascar.
Source: Bettencourt, 2007.

The elements at risk module is the building inventory. Here, it is important to capture the spatial distribution of the assets exposed. However, this can be done on various levels. At best, the inventory should also reflect regional differences in construction practice and building codes. Insurance companies usually require spatial resolution of the exposure data in the following increasing order: Storms, earthquake, flooding, man-made hazards. The process of inventory development can be a tedious, expensive and time-consuming task. However, it is a crucial part within the risk assessment process. Satellite images and tier classification or dasymetric mapping could be used to make the process more affordable.

The physical vulnerability model quantifies the physical impact of the hazard on the exposed elements. For example, it gives the relationship between the intensity of the hazard and the percentage of house damage, e.g. damage ratio. Because the intensity and the level of damage are uncertain, the damage itself is an uncertain quantity as well. Underlying each damage function is a frequency component and a severity component. The former determines the probability that an exposed element is damaged and the latter determines the percentage of property damaged, assuming damage has occurred. For example the relationship between damage and wind speed is dependent on the construction of the building, the age of the building and so on:

$$P_z, c, a, s, v = f(W_z, c, a, s, v)$$

$P_z, c, a, s, v =$	Percent damage at location z for risk characterized by c, a, s and v
c =	Construction of building
a =	Age of building
s =	Number of stories
v =	Coverage (e.g. building, contents, time element)

The physical loss module translates the damages into monetary losses. Various risk metrics can be investigated then, e.g. Value at risk, exceedance probabilities, hazard maps or loss distribution functions. Again, a possible function for the total damage in monetary terms could be according to the following formula:

$$D_z, c, a, s, v = E_z, c, a, s, v \text{ x } P_z, c, a, s, v$$

$D_z, c, a, s, v =$	\$ damage at location z for risk characterized by c,a,s,v
$E_z, c, a, s, v =$	\$ exposure at location z for risks characterized by c,a,s,v

In this manner, loss distribution functions or risk maps are calculated. Furthermore, if possible future changes also have to be incorporated within the model approach, each of the above modules have to be modeled in a dynamic setting, for example, change of the hazard intensity and/or frequency, changes in the vulnerability due to economic and social development, or change in the risk exposure.

Appendix A2: Method used in this report to assess cyclone risk

In the case of Madagascar, detailed information that could be used within catastrophe models was not available and therefore one had to rely on an approach (ii) primarily utilizing past data and extreme value theory. For that reason, total annual cyclone losses (in constant 2000 USD) are used and an optimization algorithm for selecting the best fit under the assumption of an Extreme value distribution as well as generalized Pareto distribution was built. In more detail, a sequence of parameter fits were obtained based on a weighted average function of those data points between projected return periods, which subsequently were used as the next starting point iteratively over the process.

As indicated in the report, there are two databases available which can be used for the analysis. One is the open-source EMDAT disaster database (EM_DAT, 2012) maintained by the Centre for Research on the Epidemiology of Disasters at the Université Catholique de Louvain. The second one is the newly produced time-series loss data by Malagasy officials based on the "Damage and losses assessment methodology" (from now on called MLoss 2012). It consists of past public sector loss estimates for the Analanjirofo region from 1980 to 2012 separated into different sectorial impacts. The figure's related estimation procedures for all data sources can be found on the next pages. Menages, Public and PP are based on loss estimates from Madagascar colleagues from 1980 – 2012. EMDAT data is based on CRED 2012 from 1960 - 2011. A summary of estimated loss return periods for all respective models can be found in the next Table.

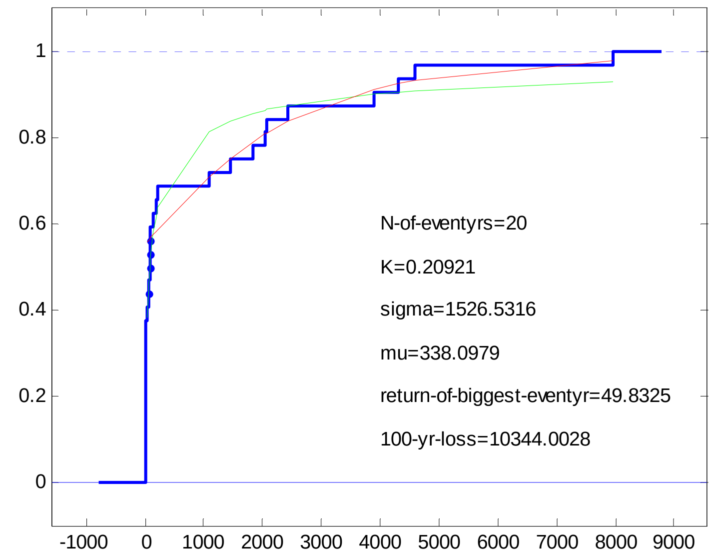
Table 1: Return period loss estimates as well as probability of first loss for all selected models. Losses in million USD.

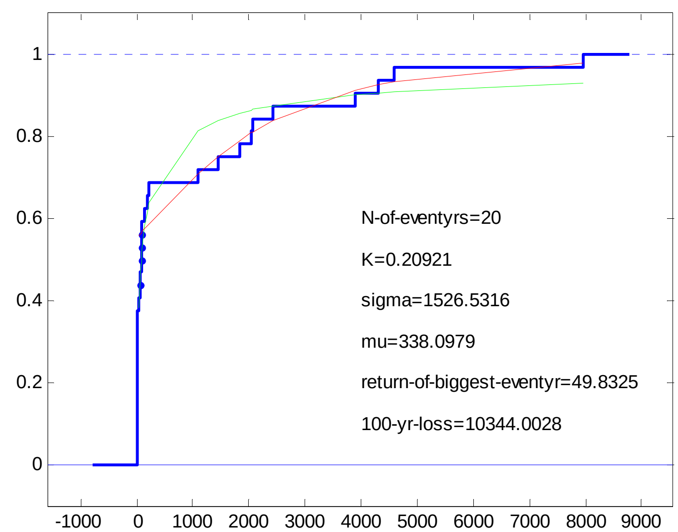
Return Period	Menages		EMDAT		Public		PP	
	GEV	GP	GEV	GP	GEV	GP	GEV	GP
PFL	0.4063	0.4063	0.6078	0.6078	0.4063	0.4063	0.4063	0.4063
20	5312	24595	229	223	137	149	686	745
30	6437	58366	406	388	160	173	798	867
40	7289	107650	604	570	176	191	882	954
50	7983	173020	820	766	190	204	949	1021
80	9548	469866	1551	1419	219	233	1096	1163
100	10344	754953	2094	1898	234	246	1169	1230
150	11886	1786881	3605	3215	262	270	1309	1352
200	13061	3292843	5293	4667	282	288	1412	1439
250	14021	5290321	7126	6230	299	301	1496	1506
300	14839	7792978	9083	7887	313	312	1566	1561
400	16195	14360940	13315	11440	336	329	1681	1647
500	17304	23072224	17909	15262	355	343	1773	1715

Note: GEV means Generalized Extreme Value distribution and GP means Pareto Distribution.

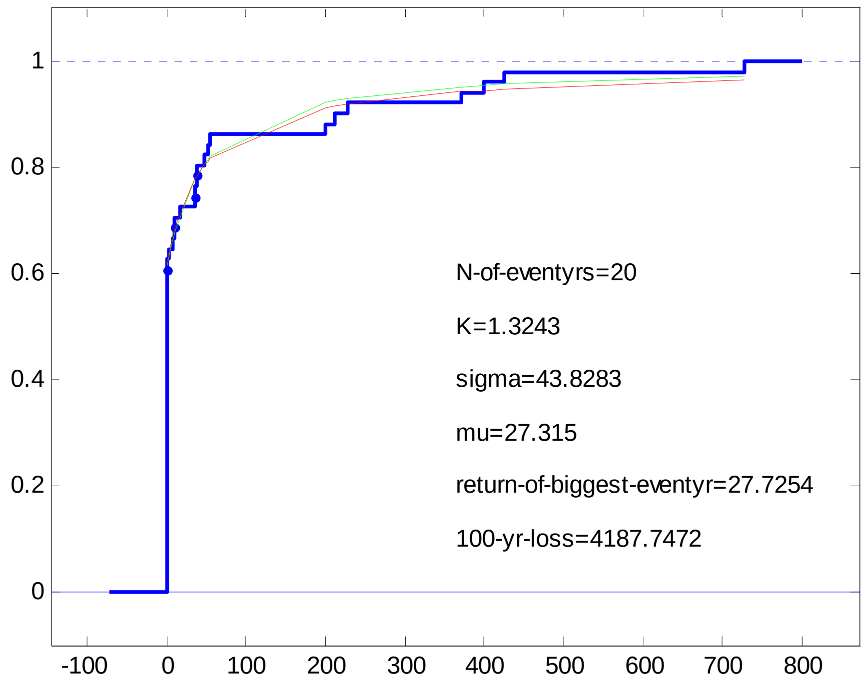
The graphs below can be interpreted in the following way. Number of events provides the number of events for the whole time period. K is the shape parameter, which if above 0 indicates a heavy tail. Sigma and mu are location parameters needed for estimating the return periods (see Embrechts et al. 1997 for a discussion). Based on the empirical distribution (blue line) a Generalized Pareto or Extreme value distribution is calculated. Furthermore, the return period of the biggest event is also calculated as well as the 100 year event loss.

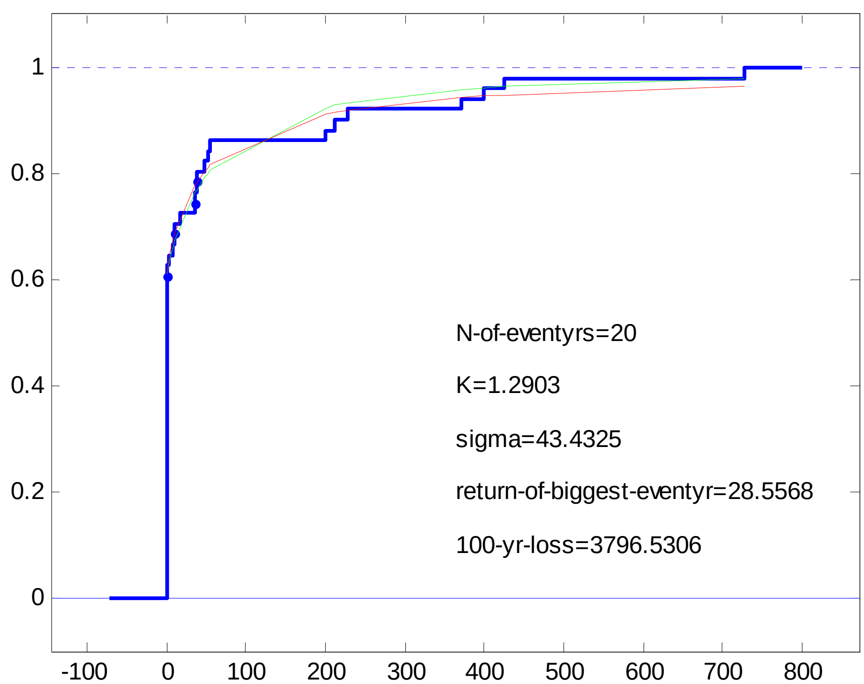
Menages Dataset:



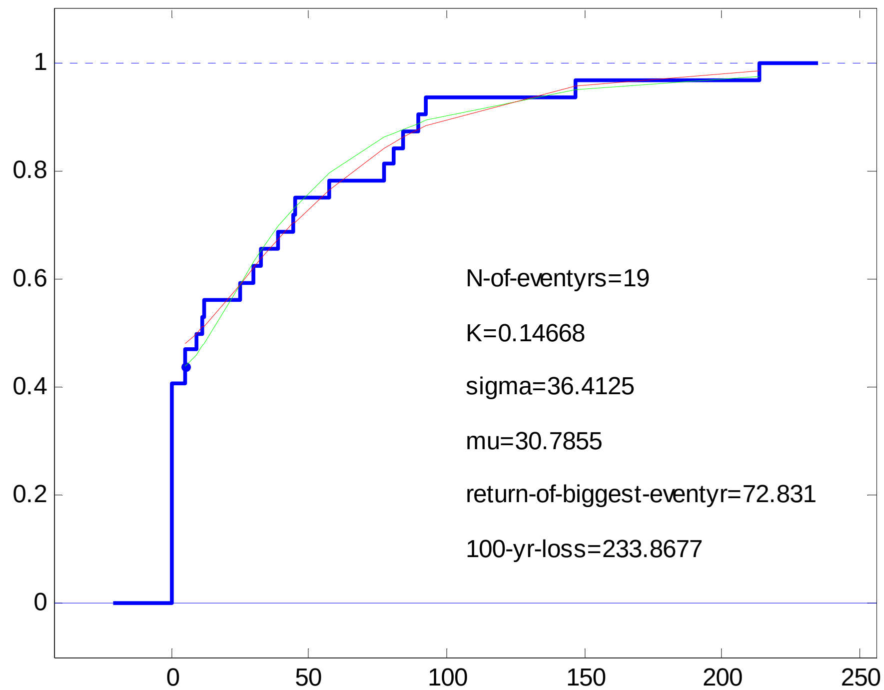


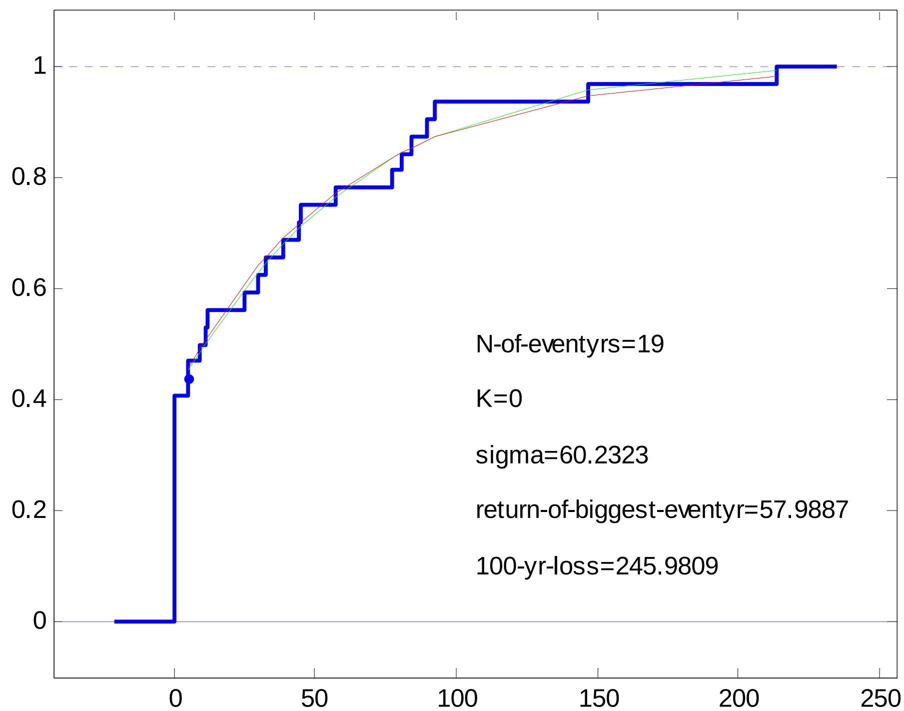
EMDAT (2012):


N-of-eventyrs=20
K=1.3243
sigma=43.8283
mu=27.315
return-of-biggest-eventyr=27.7254
100-yr-loss=4187.7472

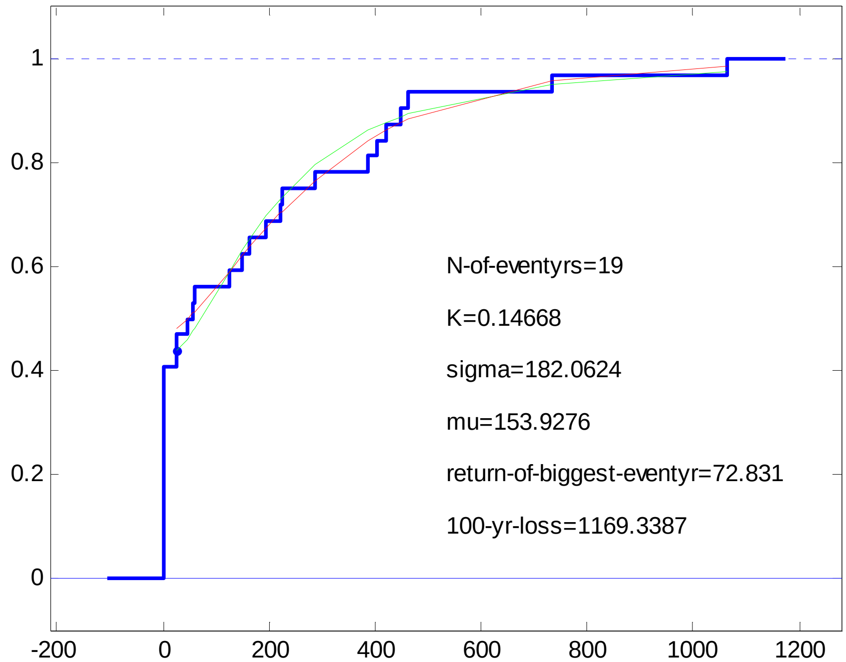

N-of-eventyrs=20
K=1.2903
sigma=43.4325
return-of-biggest-eventyr=28.5568
100-yr-loss=3796.5306

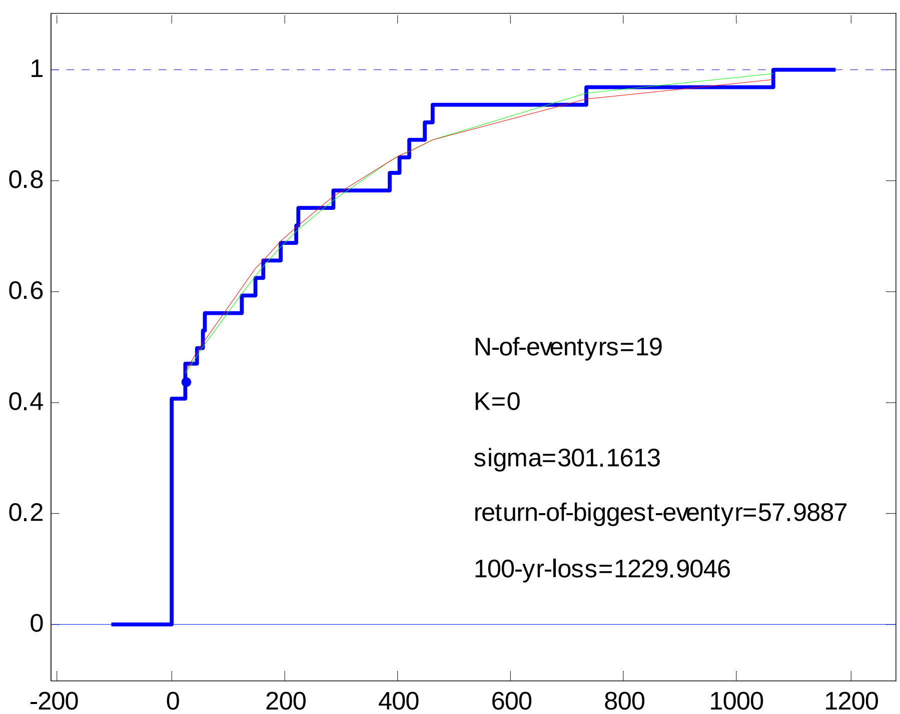
Public sector loss (MLoss):





PP: assuming public losses are 20 percent of total losses





Appendix A3: Assessing Capital Stock and GDP

Capital stock estimates based on the method by Sanderson and Striessnig (2009) are used within the report. In more detail, using the Penn World tables from 2012 the average of the first five years of the country's investment series are used to back-project investment until 1900, assuming an annual growth rate of 4 percent in investment. The sum of all previous investments, discounted by the number of years since they were made, was taken as the initial year's capital stock. Applying the perpetual inventory method, a rate of depreciation of 4 percent was assumed, which allowed for aggregating regional physical capital stocks for the entire period. This was compared to GDP rates from the World Bank and averages over the maximum time period was calculated afterwards. GDP to Capital Stock ratios were found to range between 8 and 10, with an average of 9.5 in the last 20 years (see Table 1 below).

Table 1: Capital Stock and Capital Stock to GDP ratios. Source: Own Calculations based on Penn World Tables and Sanderson and Striessnig 2009.

Year	Capital Stock, bn. USD, (constant 2000)	GDP, bn. USD, (constant 2000)	K to GDP Ratio
1980	16.9181	3.098664	5.459805
1981	17.91717	2.798131	6.403263
1982	18.61357	2.747479	6.774782
1983	19.18217	2.772264	6.919316
1984	19.74615	2.819523	7.003368
1985	20.33853	2.852113	7.131039
1986	20.93924	2.907989	7.200591
1987	21.57163	2.942247	7.331686
1988	22.30922	3.042384	7.332809
1989	23.29629	3.16648	7.357158
1990	24.33079	3.265592	7.450654
1991	25.65518	3.059548	8.385284
1992	26.22951	3.095839	8.472505
1993	27.06453	3.160745	8.562706
1994	27.97239	3.158482	8.856276
1995	28.75026	3.212562	8.949326
1996	29.54067	3.281597	9.00192
1997	30.42926	3.402802	8.942413
1998	31.36879	3.536612	8.86973
1999	32.48021	3.701387	8.775147
2000	33.60704	3.877575	8.667025
2001	34.90154	4.110921	8.489957
2002	36.48899	3.589911	10.16431
2003	37.4812	3.94118	9.510145
2004	38.9583	4.148368	9.391236
2005	40.84781	4.339313	9.413429
2006	42.71272	4.557259	9.372459
2007	44.93726	4.841664	9.281367
2008	47.62543	5.186794	9.182055
2009	51.73387	4.949331	10.4527
2010	54.76953	5.026822	10.89546

Appendix A4: Estimating the financial resilience of the government

Financial resilience parameters are split into two categories, *ex-ante*, which are put into place before a disaster event, and *ex-post* sources, which require no planning to access after a disaster occurs. A short summary of the relevant ex-ante and ex-post sources can be found in Table 1, and the following section describes select parameters for Madagascar in greater depth.

Table 1: Calculation of ex-ante and ex-post sources

Type of source	**Method**	**Variable in CATSIM Model**
Ex-ante		
Insurance	Claim defined by attachment and exit point	prop. Ins (%)
Reserve fund	Reserve fund is depleted to the extent necessary up to full depletion	Initial RF (bn. $)
Contingent credit	Triggered to the extent necessary and "reserved in advance" due to payment of a fee for the contingent credit, involves more debt as credit instrument	Contingent credit *(on the Resilience input form only)*
Mitigation	Damages are reduced to zero, if threshold exceeded full loss occurs and accumulated mitigation investment is lost	Efficiency of Mitigation *(on the Resilience input form only)*
Ex-post		
Budget diversion	Maximum diversion is a fixed percentage of revenue	Diversion (%)
Aid	Fixed portion of physical loss, assumed to be 10.4% of the damage according to a regression analysis done with historic data (see Freeman et al 2002a)	Assistance (%)
Domestic credit	Maximum domestic credit available is a fixed fraction of the revenue	Dom. Credit
Foreign credit	Constrained by external debt sustainability indicator credit buffer. It is assumed that half of the needed sum comes from multilateral sources and half from issuing international bonds	Credit buffer (bn. $) and Ratio MFI/Int

Insurance

This ex-ante parameter refers to both traditional and/or alternative insurance mechanisms, such as catastrophe bonds. While private sector uptake of insurance is substantial, insurance of government contingent liabilities is set to zero percent in the model.

The parameter may be changed via the *“prop. Ins (%)”* variable in the Resilience file.

Reserve Fund

A reserve fund is a stock of money the central government has set aside for use in recovery from a disaster event. The input is formatted in Millions of constant 2000 US Dollars. The government of Madagascar has a reserve fund of approximately 20million USD, which is used as input for the model.

To manipulate this parameter, input a new estimate into the variable titled *“Initial RF (bn. $)”* in the Resilience file.

Contingent credit

Contingent credit is an ex-ante risk financing measure where a central government arranges for guaranteed loans to be made available post-disaster event at lower rates than would be found in normal markets. However, a country has to pay a stipend each year where the loan is not accessed, and only receives a benefit if there is a disaster event, which triggers payout of the loan. The benefit of this type of mechanism is guaranteeing financing which can be made available rather quickly after a disaster, contrasted to normal borrowing, and is at slightly better rates than normal.

For Madagascar, no such credit agreement is in place, so the variable is set to zero.

To change the parameters associated with contingent credit, the applicable variables are located on the Resilience page of the CATSIM model, in the section for Risk Financing, labeled as *“Contingent credit”*.

International Aid

International aid is the amount of money made available to a country after a disaster event in the form of donations from other countries and aid organizations. In Freeman et al (2002a), the average amount of funding made available is estimated (via regression analysis of historic data) to be 10.4% of the direct damages from a disaster. For the estimates of the case of Madagascar, 10.4% is kept as a default parameter, resulting in 10.4% of government liabilities being covered by international aid funding.

This is used as a default first estimate as input to the CATSIM model as the variable *“Aid”* in the Resilience file.

Budget Diversion

Diversion represents the amount of funding from the central government’s budget available to be re-directed and focused towards disaster recovery. As a first order estimate, the parameter is calculated in a two step process (see Figure 1). The first step is to determine whether the government has a deficit or surplus in its budget. This is estimated by comparing revenues and expenditures. CATSIM estimates use the latest year data available from the World Bank's World Development Indicators, in the case of Madagascar, from the year 2010. If expenditures exceed revenue by more than 5%, it is assumed that the government will be unable to divert funding into recovery. However, if there is a surplus or a smaller deficit, it is assumed that the government will be able to divert a portion, estimated here at 10% of total revenue, towards relief.

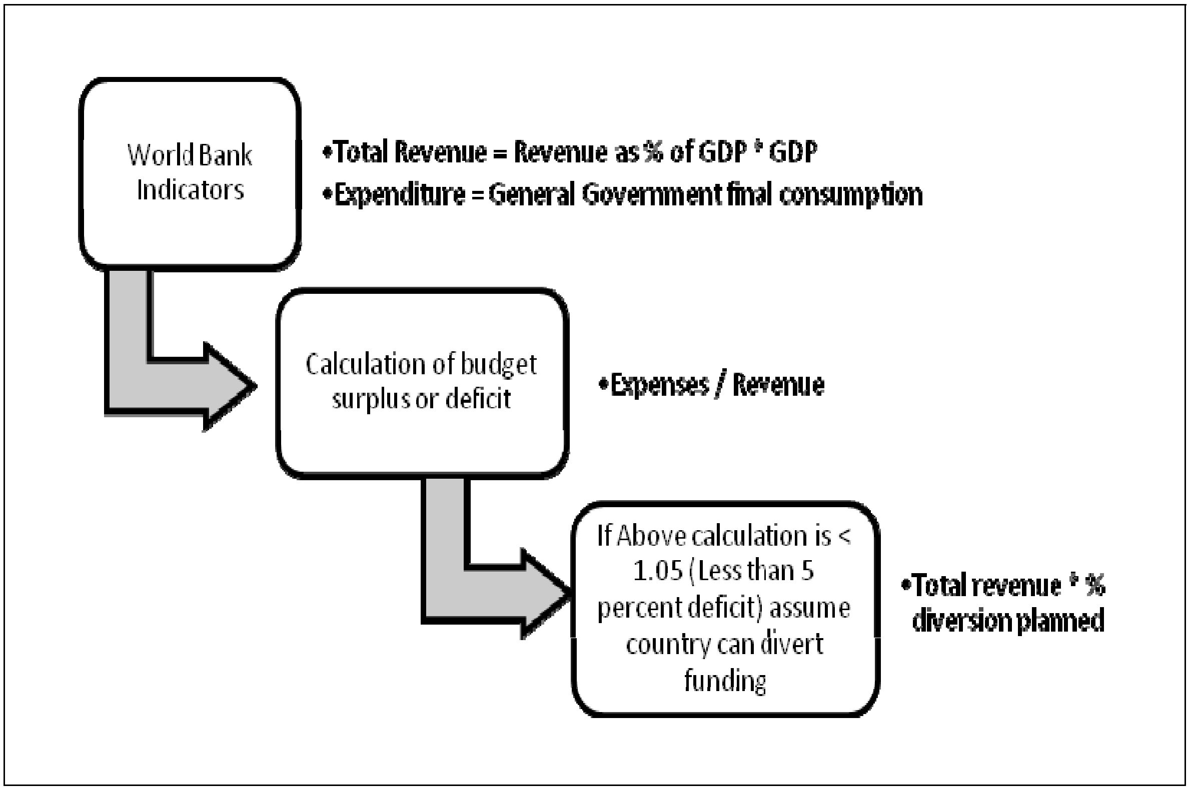


Fig. 1: Calculation of budget diversion

To change the amount of diversion in the model, edit the variable labeled *"Diversion"* in the Resilience file.

International / MFI Borrowing

This parameter is an estimate of how much a central government would be able to borrow on international markets and from multi-lateral financing institutions (MFIs). Calculation of this value is based on numerous factors, which affect total funding available.

An initial assumption is that a country cannot finance disaster losses past a point at which its present value of debt as a percentage of exports reaches a value higher than 150%. This value represents the point at which the country would be classified as a highly-indebted poor country (HIPC) and finding additional funding would be regarded as extremely difficult on the open markets, due to the extremely high perceived risk to borrowers.

Other determinants to this value include the country's classification as eligible for an International Development Association (**IDA**) or International Bank for Reconstruction and Development (**IBRD**) loan, guaranteed by the World Bank, which may allow them to receive loans at concessional rates. For international borrowing, the country's debt rating has a high influence on the conditions of financing, and affects total funding available. This rating is a major determinant for loan interest, amortization, and grace periods for repaying interest and principal.

For exact calculation of the first order estimate of this parameter (see Figure 2), a "loan package" is created which divides funding needs evenly between MFI and international borrowing rates, determined by national debt rating, whether the country is IDA or IBRD, as well as current interest rates. After determining the average properties for the loan package (mean of the two interest rates, amortization times, and grace periods) we calculate how much the country can borrow and remain under the initial assumption of 150% PV debt to export ratio.

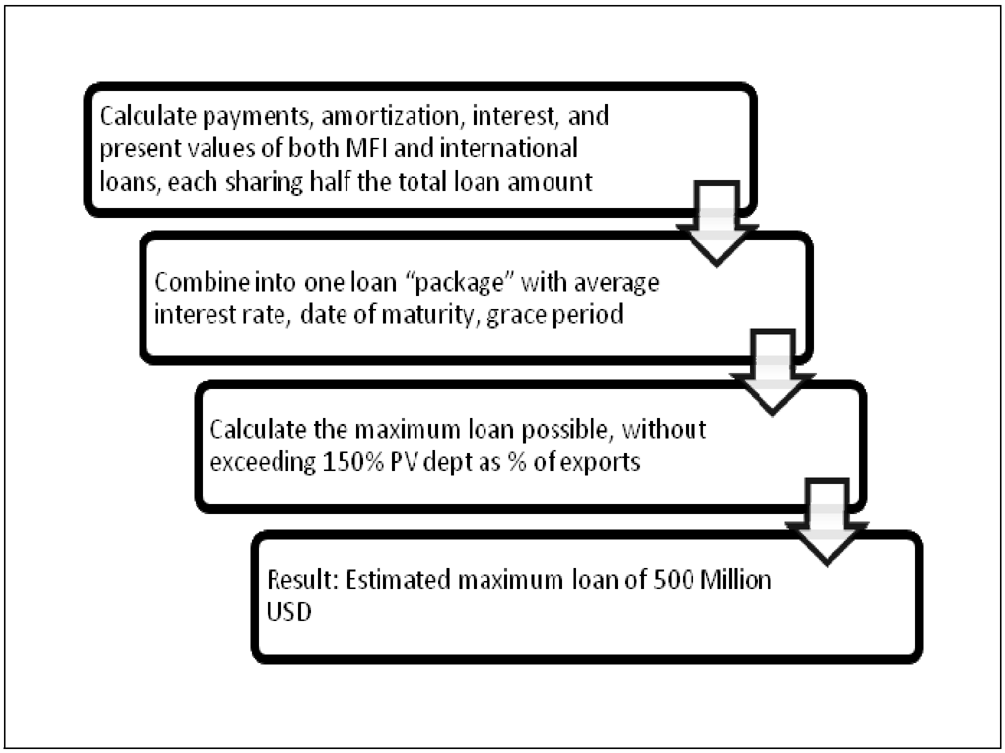


Fig. 2: Calculation steps for determining borrowing limits

In the case of Madagascar, theoretically, post-disaster borrowing from international and MFI sources would be possible, as the country has a very low debt to export ratio. In the CATSIM model, we estimate that it is possible to borrow approximately 500 million USD from these sources, with an equal split between the two.

However, it should be noted that obtaining a loan on the international market may prove difficult, as credit rating agencies issue no estimates of Madagascar's credit rating, which results in a lack of visibility and creditworthiness. However, IDA and IBRD credits are available to the government, and development indicators show that the country has received a substantial amount of these credits in the recent past.

To change the amount of international and MFI credit available to the country in the model, the variable *"Credit buffer (bn. $)"* is used to indicate the amount, and *"Ratio MFI/Int"* indicates the division of the total amount between the two funding sources.

Domestic credit

After a disaster event, a nation has the option of trying to finance recovery via domestic credits, either by printing money, issuing bonds, or borrowing from domestic sources. This parameter must be estimated on a country-by-country basis, as it is very specific to individual conditions.

For the case of Madagascar, we estimate that, the government will not be able to finance much recovery via this method. The World Bank Madagascar Economic Update (2011) illustrates that this assumption is probable, explaining that:

> If the government were to borrow 100 million USD, financing a deficit of 1.5% of GDP, the total stock of domestic credit would rise by 10%, crowding out private sector credit, leading to more monetary expansion, and lead to an increase of inflation. (WB, 2011)

Given the above, it is assumed in the model that the government will be limited to 50 million USD, financing a deficit of 0.75% of GDP. It is still possible to assess the affect of different amounts of domestic credit on the model results, by inputting new data into the field *"Dom. Credit"* in the Resilience file.

Taxation

The national government could also hypothetically finance some recovery via an increase in the tax rate. The CATSIM parameter for this value is an input of percent increase in taxes. While it is an option available to the government, we assume it is not used, as it could result in negative effects, which outpace the added funding for reconstruction, namely that the additional tax burden is being placed on an already over-stressed population that is trying to recover. For Madagascar, we assume that this option is not available, and set the variable to 0%. The amount of taxation can be manipulated via the variable *"Taxation (%)"* in the Resilience file.

Appendix A5: Macroeconomic model

The following simple **exogenous growth model** is used.

- Supply: CD $Y^S = A\ K^a\ L^b$

- Demand side: Y^d=C+I+G+X-M=C+S+T

- Investment: I=S=sY

- Capital accumulation: DK=sY-DK_{dep}-DK_{Cat}+I_{recon}

  - DK_{Cat}: stochastic disaster shock to K, random Monte Carlo draw from distribution
  - I_{recon}
    - Algorithm for finding additional savings for reconstruction to continue growth
    - Based on resource gap concept: lack of financial resources for achieving growth targets (Chenery and Strout 1966)

- Caveats: no learning or technological progress

The Resource gap estimation within the macroeconomic model is described below

The physical damage translates into a financial loss for the government after subtracting all ex ante and ex post sources. The existing options are used to the extent necessary. If all of the physical damage can be covered by ex-ante and ex-post options the financial loss is zero. Otherwise if after exhausting all ex-ante and ex-post sources, there still is a net loss, i.e. a resource gap, part of lost capital stock will remain unreplaced, affecting GDP and leading to lowering revenue in the next period. Table 4 shows how the ex-ante and ex-post instruments resources are determined.

Table 1: Calculation of ex-ante and ex-post sources

Type of source	Method
Ex-ante	
Insurance	Claim defined by attachment and exit point
Reserve fund	Reserve fund is depleted to the extent necessary up to full depletion
Contingent credit	Triggered to the extent necessary and "reserved in advance" due to payment of a fee for the contingent credit, involves more debt as credit instrument
Mitigation	Damages are reduced to zero, if threshold exceeded full loss occurs and accumulated mitigation investment is lost
Ex-post	
Budget diversion	Maximum diversion is fixed percentage of revenue
Aid	Fixed portion of physical loss, assumed to be 10.4% of the damage according to a regression analysis done with historic data (see Freeman et al 2002a)
Domestic credit	Maximum domestic credit available is a fixed fraction of the revenue
Foreign credit	Constrained by external debt sustainability indicator credit buffer. It is assumed that half of the needed sum comes from multilateral sources and half from issuing international bonds

In more detail, let the (monetary) loss distribution for the government be called F. Furthermore, assume that the government has "k" instruments (either ex-post and/or ex-ante) available to finance the losses. In case of a disaster event some or all of the instruments are used to a given amount to finance the losses. In the easiest case, there is a strict preference order between the financing instruments, represented by the resource vector $\vec{x} = (x_1,...,x_k)'$ in the following way: the first instrument (with monetary resources x_1) is preferred before all others until depletion, afterwards the second instrument (with resources x_2) is preferred before all others until depletion, and so on. Let $\vec{x}_m = (x_{m1},...,x_{mk})'$ be the maximal (monetary) amount available for each instrument for a given loss event. Then the loss financing scheme for a given event with return period $1/y$ (e.g. for a 100 year event y would be 0.01) is the solution of depleting resources in the respective order till the losses ($F^{-1}(y)$) are fully financed. In the case that $\sum_{i=1}^{k} x_{mi} \le F^{-1}(y)$, one says that a resource gap occurred, and the return period of the event where this happens for the first time (i.e. all events with lower return periods satisfies equation $\sum_{i=1}^{k} x_{mi} = F^{-1}(y)$) is called *the critical return period*. As indicated, resource gaps will have (possible long-term) economic consequences which are assessed by the economic module.

Appendix A6: Multi Risk Assessment

Regarding multi risk assessment, an elegant way of combining losses could be via the notion of dependent and independent risk (see Hochrainer and Pflug 2012). Assume for the moment that one has estimated a loss distribution for two independent hazards, i.e. we assume to have two random variables *X* and *Y*, with cumulative distribution functions F_X and F_Y. Our goal is to observe the distribution of *Z*, which is defined to be the sum of the two random variables, i.e. $Z=X+Y$. If *X* and *Y* are comonotonic, i.e. $F_X(X)$ is always equal to $F_Y(Y)$, then the value of *Z* corresponding to a given probability *p* is simply the sum of the values of *X* and *Y* corresponding to the same *p*, i.e.

$$F_Z^{-1}(p) = F_X^{-1}(p) + F_Y^{-1}(p), \qquad 0 \le p \le 1 \tag{1}$$

On the other hand, if *X* and *Y* are independent, then F_Z equals the convolution of both distributions using the Stieltjes integral:

$$F_Z(t) = \int_{-\infty}^{\infty} F_X(t-x)dF_Y(x), \qquad -\infty < t < \infty \tag{2}$$

Now, let's assume that up to a given probability level, say p_thresh the variables *X* and *Y* are independent and afterwards comonotonic. This premise can be made more precise as follows. Suppose that $X \ge F_X^{-1}(p\_thresh)$ occurs if and only if $Y \ge F_Y^{-1}(p\_thresh)$, and in that case $F_X(X) = F_Y(Y)$ holds. In the case $X < F_X^{-1}(p\_thresh)$ (equivalently $Y < F_Y^{-1}(p\_thresh)$) the two variables are independent. Then, the distribution of *Z* is given by separate formulae over the comonotonic part and over the independent part. For the comonotonic part we would have

$$F_Z^{-1}(p) = F_X^{-1}(p) + F_Y^{-1}(p), \qquad p\_thresh \le p \le 1 \tag{3}$$

and for the independent part

$$F_Z(t) = \int_{-\infty}^{F_Z^{-1}(p\_thresh)} F_X(t-x)dF_Y(x), \qquad -\infty < t < F_Z^{-1}(p\_thresh), \tag{4}$$

with $F_Z^{-1}(p\_thresh)$ given by (3).

One overarching advantage of such an approach is not only the analysis of the total risk within a coherent manner but also that well developed risk metrics (or functionals) could be applied to them, making decisions about frequent events (using averages) and extremes (using fat tail metrics) simultaneously possible. Furthermore, if loss reduction measures and risk financial measures beneficial for multi risk are analyzed in the single case scenario it is also directly possible with the approach suggested to analyze the total benefits in a comprehensive way.

Appendix A7: Workshop Details

Workshop

Financial and Economic Disaster Risks in Madagascar Implementation and use of the CatSim Approach

30 April – 04 May 2012
Antananarivo, Madagascar

Participants

Madagascar

- Representatives/technicians of Ministry of Finance and Budget: 13
- Representatives/technicians of Ministry of Economy and Industry: 4
- Representatives of the "CERED" (Centre d'Etudes et de Recherches Economiques pour le Développement) / Université d'Antananarivo FACDEGS : 3
- Representatives of the DGM (Direction Générale de la Météorologie) : 2
- Representative of the World Bank : 1
- Representatives of the CPGU and Track II Project : 7
- Representative of the "BNGRC" (Bureau National de Gestion des Risques et des catastrophes): 1

IIASA

- Stefan Hochrainer-Stigler
- Keith Williges

Topics

- Risk assessment and analysis of extremes
- Economic risk assessment: macro, micro, sectoral
- Risk modelling using CATSIM
- Discussion of risk management options
- Discussion of uncertainty and variability: Climate change, exposure dynamics etc.
- Training

Objective

The workshop will familiarize the participants with catastrophe modelling approaches, incl. a discussion of the basics of catastrophe modelling, direct vs. indirect risk assessment and risk management strategies on local, regional and country levels. The participants will learn about the obstacles and difficulties in catastrophe modeling and how to avoid them. Focus will be on the CatSim approach as well as understanding the framework and possible uses. Furthermore, they will be trained with the help of a stand-alone software package. To a large extent, the workshop will provide hands on training using the IIASA CatSim methodology and running and installing the software package. The workshop should provide participants with the necessary know-how to conduct similar analyses, which will feed into the economic risk assessment element for mainstreaming natural disaster risk into development planning processes.

AGENDA

Monday, 30 April and Tuesday 1 May:
Pre-Workshop meetings (Only consultants, including preparation work for Wednesday):

- *General discussion*
- *Setting up CatSim software*
- *Discussion of input parameters and data formats*
- *Revising numbers and additional estimations (done by consultants on 1. May)*

Wednesday, 2 May – Workshop Day 1: at Hotel "Louvre" Antaninarenina

9.00 Arrival
9.15-11.00 (Presenter: Madagascar government officials, Hochrainer-Stigler, Williges)

- *Welcome, Introduction to the workshop and overview*
- *Status of and update on the study on assessing risk with the following items to be discussed*
- *Introduction to risk modelling* (Hochrainer-Stigler, Keith Williges*)*
    - *Risk modelling: the basic paradigm*
    - *Assessing economic impacts of disasters: Direct vs. indirect risk*
    - *Risk management: Budget planning process and economic modeling*

11.00-11.15 Coffee break
11.15-12.30

- *Catastrophe modelling approaches: Key elements* (Hochrainer-Stigler)

12.30-13.30 Lunch
13.30-15.00

- *Catastrophe modelling: The CATSIM approach* (Hochrainer-Stigler)

15.00-15.30 Coffee

15.30-17.45

- *CatSim methodology: Overview of CatSim parameters used to run the model for Madagascar*
- *Wrap up and discussion* (All)

17.45 End of Day 1

Thursday, 3 May – Workshop Day 2: at Hotel "Louvre" Antaninarenina

9.00 Arrival
9.15-10.30

- *Revisiting of issues* (All)
- *Update on CATSIM model and approach used* (Hochrainer-Stigler)
- *Questions addressed*

10.30-10.45 Coffee
10.45-12:30

- *CatSim demonstration continued based on Madagascar pre-estimates (to be brought by participants)*

12.30-13.30 Lunch
13.30-15.00

- *Risk management strategies on the local and country level* (Hochrainer-Stigler)
- *Continuation of working groups and discussion of approach including risk management options*

15.00-15.30 Coffee
15.30-17.00

- *Final discussion including possible scope and ambition of the economic risk assessment and identification of roles of participants* (Officials, Hochrainer-Stigler, Williges)

17.45 End of Day 2

Friday, 4 May – Training:

9.00 Arrival
9.15-10.30 Training

- *Revisiting of issues (All)*

10.30-10.45 Coffee

- *Training*

12.30-13.30 Lunch
13.30-15.00

- *Continuation of training including risk management options assessment* (All)

15.00-15.30 Coffee

- *Final discussion* (All)

16.30 End of Day 3

Material Presented: Summary

A total of 11 sessions thematic were covered and 300 slides presented. Power point presentations were made available to the participants beforehand and can also be found under http://www.iiasa.ac.at/~hochrain/Madagascar/.

- Presentation Day 1 Madagascar Session 1 Introduction: 34 slides
- Presentation Day 1 Madagascar Session 2 Policy Examples: 32 slides
- Presentation Day 1 Madagascar Session 3 The case of Madagascar: 24 slides
- Presentation Day 1 Madagascar Session 4 Direct Indirect Risk: 16 slides
- Presentation Day 1 Madagascar Session 5 Government risk and risk management: 40 slides
- Presentation Day 1 Madagascar Session 6 CatSim Methodology: 27 slides
- Presentation Day 2 Madagascar Session 1 Introduction: 11 slides
- Presentation Day 2 Madagascar Session 2 Cat Modelling: 25 slides
- Presentation Day 2 Madagascar Session 3 Exemplary CatSim run: 30 slides
- Presentation Day 2 Madagascar Session 4 Step by step analysis based on report: 25 slides
- Presentation Day 3 Madagascar Session Training CatSim run: 31 slides

Programming Code: Summary

More than 40 000 programming lines were produced for the new CatSim version for Madagascar, including the new multi risk assessment module.

CatSim manual:

Total of 59 pages.