IDENTIFICATION OF AREAS AT RISK OF FLOODING AND LANDSLIDES FOR FOOD PREPOSITIONING – A CASE STUDY: MADAGASCAR

Carlo Pandolfi, Filippo Pongelli, Lara Prades, Giorgio Sartori

ABSTRACT:

With the advent of a myriad of freely available remote sensing products and analyses at a global scale it becomes technically feasible and very cost-effective to use this 'data-at-hand' to delineate spatial patterns of vulnerability at sub-national levels.
In many instances, *particularly for developing countries*, detailed field studies, updated census data and accurate data in general are not available and these are main constraints in disaster risk assessment. These constraints are further compounded by the prohibitive cost and limited coverage of high resolution satellite imagery as well as by the time delay and bureaucratic impediments inherent in such analysis.
While quick and cost-effective risk assessments using readily available information might not provide a high degree of precision, a functional analysis together with ground-level inputs could present a basis for reliable predictive models and forecasting useful to field-level decision making. WFP is quite well positioned in most locations for the ground-level support.

1. CASE STUDY: MADAGASCAR

In the last four decades, over 50 cyclones hit Madagascar. This number of events and their intensity compounded with the accelerated environmental forest and vegetation cover destruction produced an increase of the food insecure areas, spreading vulnerability to areas that historically have always been able to cope.

A study for pre-positioning the existing food stocks for 2010 was necessary because these stocks were not anymore in strategic positions that could ensure a prompt response in case of an emergency. The aim of this analysis was to support a programme review and formulation support mission for the PRRO and CP in August 2009.

The key question that we tried to answer was : is it possible to identify the best suited locations for the pre-positioning of food in areas plagued by heavy deforestation and therefore exposed to the effects of the seasonal cyclone activities (floods and landslides) ? These locations should also provide opportunity for 'Food-for-Work' type programs in the event of no cyclone activity in a particular year.

2. COUNTRY OVERVIEW

Madagascar (587,000 square kilometres), is the fourth-largest island in the world, and is home to 5% of the world's plant and animal species, of which more than 80% are endemic to Madagascar. This so called "eighth continent" is incredibly varied in terms of and land cover and vegetation. The eastern, or windward side of the island is home to tropical rainforests where a a steep escarpment leads from the central highlands (747 to 1,341 m) down into a ribbon of rain forest with a narrow coastal further east, where the descent from the central highlands toward the west is more gradual. The western and southern sides, which lie in the rain shadow of the central highlands, are home to tropical dry forests, thorn forests, and deserts and xeric shrublands.

In Madagascar there are two seasons: a hot, rainy season from November to April, and a cooler, dry season from May to October. South-eastern trade winds predominate, and the island experiences cyclones and massive rains. (Source : Wikipedia)

3. SOCIO ECONOMICS

Fishing and forestry are the mainstay of the economy. Two thirds of the population lives below the international poverty line. Rural areas are very poor and poverty levels remained stubbornly high through time. (Source: Wikipedia)

4. DATA COLLECTION

Elevation	Source: SRTM – NASA Availability: Free Type of Data: Raster Resolution: 90 meters Vertical Accuracy: Max Error 16m
Basin: Sub-Level Catchments	Source: USGS Availability: Free Type of Data: Vector Level: Basin
Population Density	Source: Landscan Oak Ridge Laboratory Availability: Free Type of Data: Raster Resolution: 900 meters Level: Country (extracted from Global Dataset)
Deforestation	Source: FAO Availability: Available for free upon request Type of Data: Table Level: District Time frame: 1900 – 2005

Table 1: Data Collection

5. ANALYSIS CONCEPT

This analysis is based on the assumption that a rainfall event will be more disruptive in areas characterized by strong slopes (landslides, flash floods). The water will eventually gather in the flatter areas of the catchment basin, possibly provoking floods.

The negative effects of the rainfall events will probably be even more disruptive if the basin has been subjected to land degradation and deforestation.

The negative economic and human impact of landslides and floods will be felt more where the areas at risk are also densely populated.

Keeping in mind that this analysis was done in order to support programming objectives, is important to highlight that has been conducted at water catchment basin level for two main reasons:

1. Planning with watershed approach: having a watershed approach makes the planning efforts easier and more effective because it brings the community together with a participatory watershed joint effort to harmonize and consolidate planning procedures at the household level. Through a participatory watershed approach is possible to understand what has to be done at various levels to sustain the watershed ecosystem while improving coping strategies.
2. Environmental reasons: following the catchment definition, for hydrological reasons all flooding models/analysis should be conducted at a watershed level as all the runoff will be collected and drained at a common point and will affect therefore the people, farming systems, land resources and coping strategies within that watershed.

6. KEY CONCEPT

- <u>Difference between catchment</u> and <u>watershed</u>: A drainage basin or catchment is the area of land that drains water, sediment, dissolved materials, and biota to a common outlet at some point along a stream channel. If the area is large (hundreds of square miles) it is a drainage basin, if it is small (acres to square miles) it is a catchment. We define a watershed as the area of land that drains water, sediment, dissolved materials, heat, biota, etc., to a common outlet at some point along a stream channel (watershed outlet). A watershed is a naturally delineated unit of land. Watersheds are the basic land unit of the hydrologic cycle, just as pastures are the basic land unit of a ranch. All of the land on Earth is in a watershed." (Source: California University)
- <u>Slope</u> is the change in height of the terrain expressed in percent rise over distance.
- <u>Deforestation</u>: cleared portions of forests.

7. ANALYSIS STEPS

A. We searched for reliable and updated second level administrative boundaries to be utilized in the population analysis (following step).

B. Population density data from various sources was compared with a table of estimated population by district obtained through our country office. We found that Landscan, version 2005, provided the most accurate distribution, compared to the 2006 version and CIESIN. We utilized Landscan 05 population distribution in the following steps. (Figure 1)

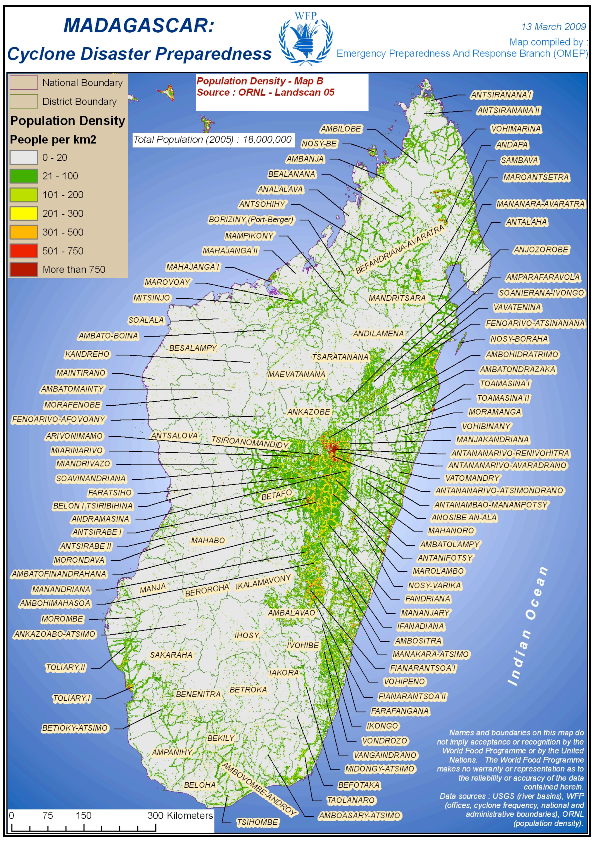

Figure 1: Population Density

C. SRTM 90 m digital elevation data was prepared, mosaicing and clipping all the necessary tiles. (Figure 2)

D. We searched for reliable river basins and watersheds to be used in the subsequent steps

E. From the digital elevation model we calculated the slope of the terrain as % rise and classified it initially following FAO's guidelines for soil description 2006. We superimposed to the slope analysis the main watersheds, the river basins, rivers and lakes. (Figure 3)

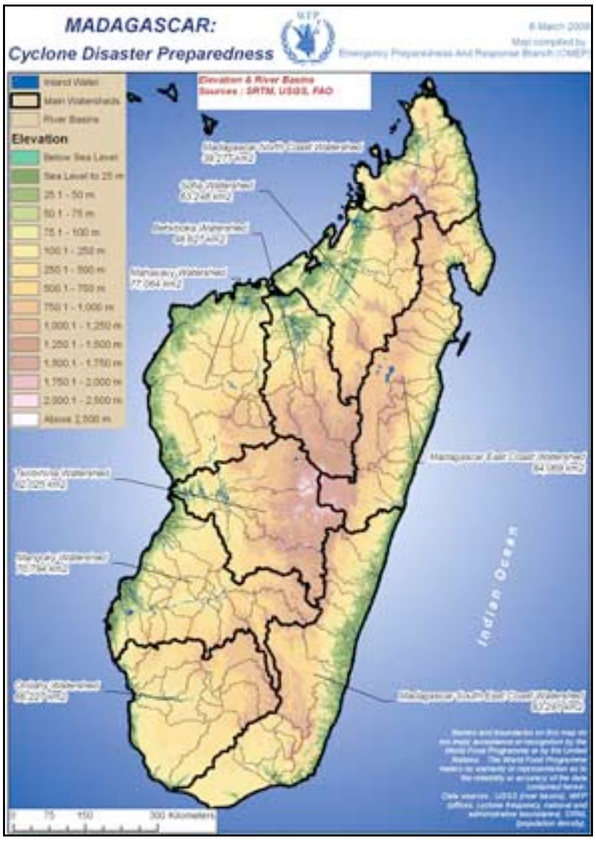

Figure 2: Digital Elevation Data

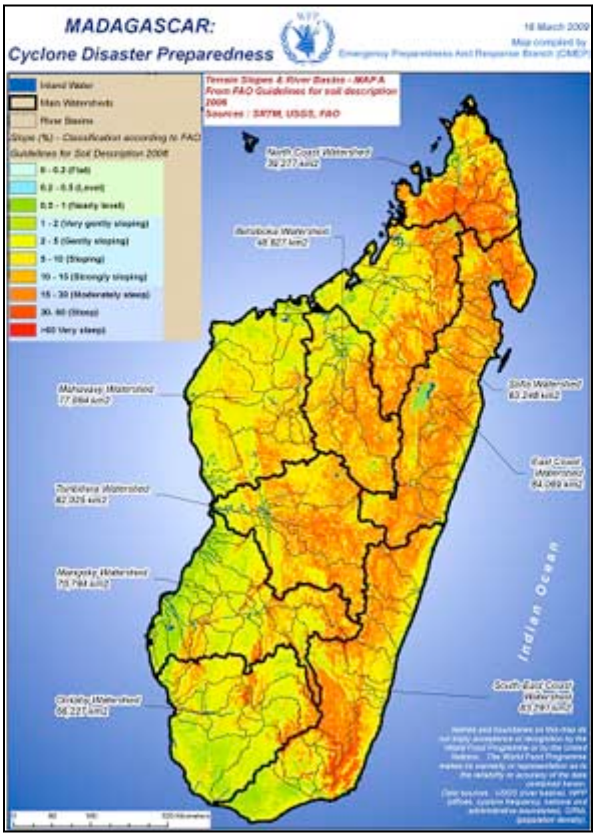

Figure 3: Slope of the terrain

F. We considered that the areas most at risk in the event of cyclone or heavy rainfall would be :

   a. Terrains characterized by strong slopes (risk of landslides and flash floods); referring to FAO's classification, we took 15% as the lower limit for the steepest, most at risk areas.

   b. Flat areas (risk of flooding); always referring to FAO's classification, we took 2% as the upper limit for the flattest areas.

G. We produced a new map with a simplified slope classification, where the areas most at risk are the dark red (more than 15% slope) and dark green (up to 2% slope). (Figure 4)

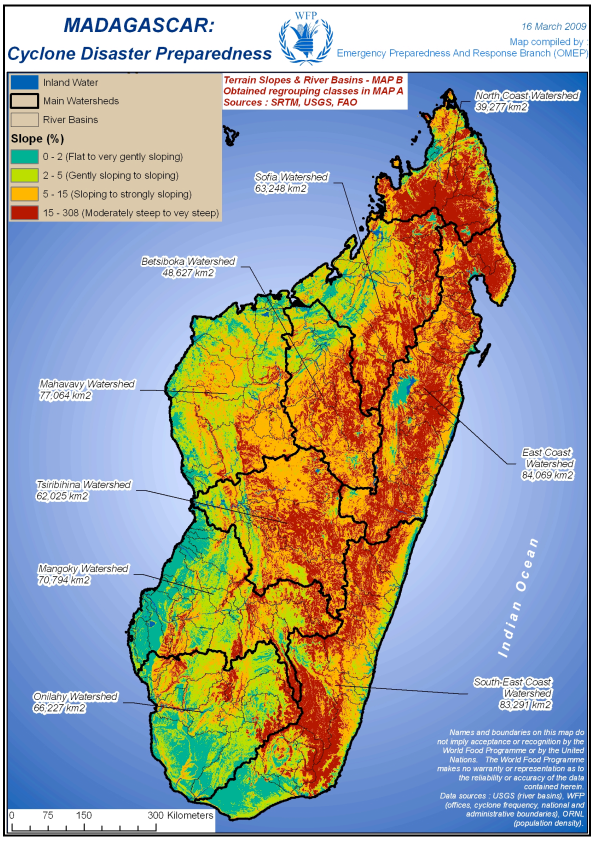

Figure 4: Slope classification

H. For each river basin we now calculated the percentage of its area with a slope bigger than 15%. Considering that slopes bigger than 15% are very steep, river basins with a bigger percentage of their surface above 15% slope could be more subject to flash floods, erosion and mud slides. In the map below the pink and green basins are most at risk (in this classification the pink basins have 30 to 40 % of their area sloping more than 15%, green basins have more than 40% of their area sloping more than 15%). We also show on the map the population living in the basin (derived from the population density data, Landscan 05), the basin's area and the actual percentage of the area with strong slopes as support information (Figure 5).

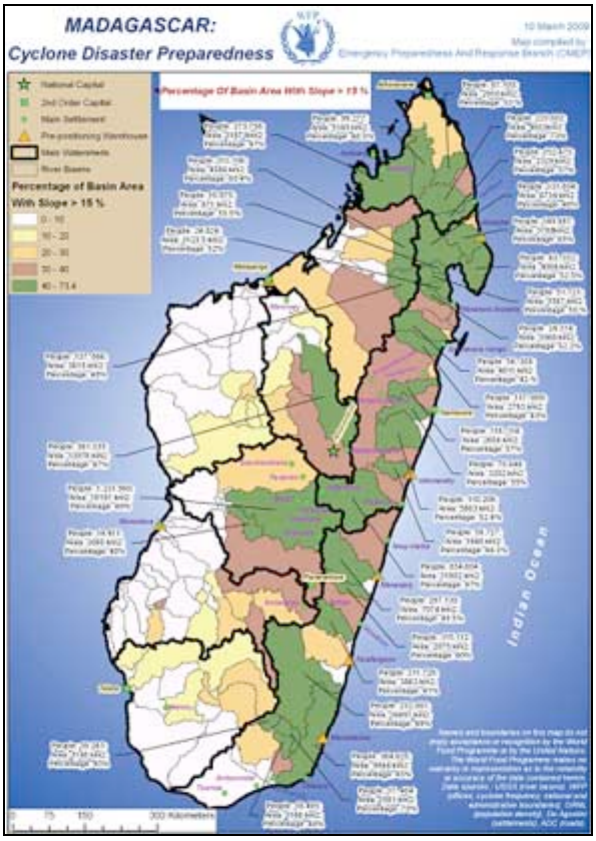

Figure 5: Risk classification

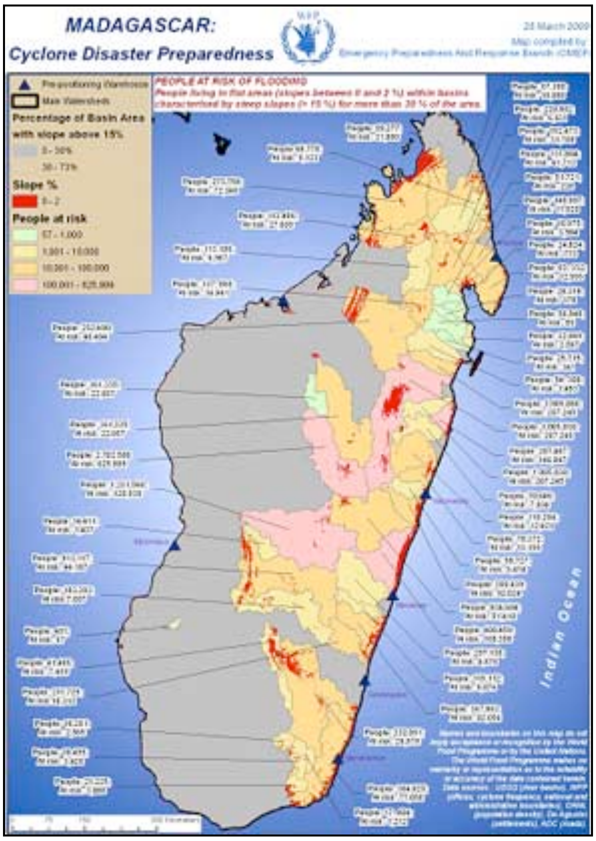

Figure 6: People at risk of flooding

I. In the map on the right only those river basins with steep slopes covering more than 30% of their surface were considered. Flatter areas (slopes below 2%) were extracted (in red on the map). These should be the portions of the basins more subject to flooding. We calculated the population living in the flat areas and this represents the population at risk. River basins were then color-coded according to the amount of population at risk (Figure 6).

J. In the final map we also added the deforestation percentage from 1990 to 2005 calculated from FAO Forestry data by district. For the purpose of this study, only the steepest basins were considered. As mentioned above, deforestation is another element that exposes the population to the risks of flooding and landslides. The map shows again also flat areas and population at risk.

This last map (Figure 7) clearly shows that naturally steep areas within basins around the capital city have been extensively deforested within a 15 year time period, and that there are 5 districts that contain a percentage of deforestation rate above 30% and slopes less than 2 %: Ambatolampy, Antanifosy, Betafo, Antsirabe I and Antsirabe II. For reference, the map shows also the position of the food pre-positioning warehouses at the time of the study.

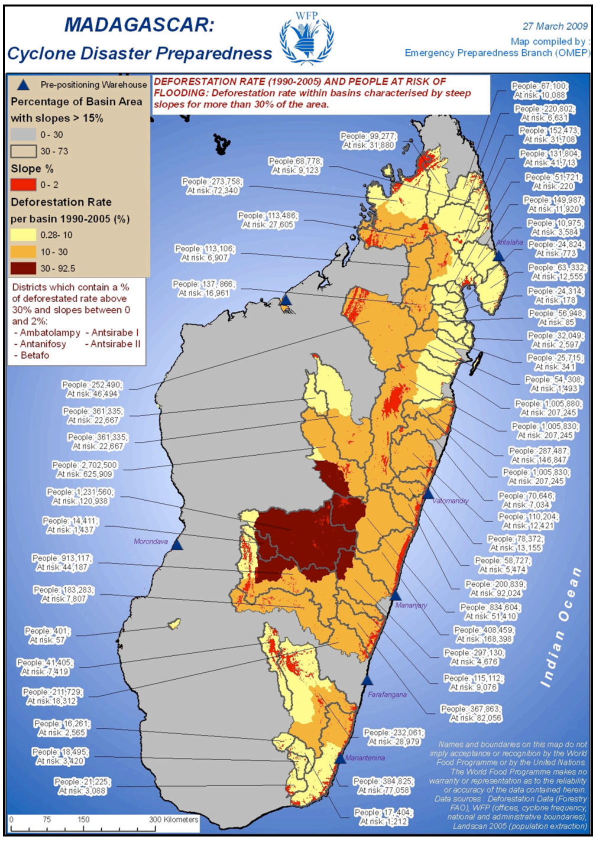

Figure 7: Deforestation rate and people at risk of flooding

8. CONCLUSIONS

It is important to highlight some limitations of this study :

- It was conducted at a very large scale (1:5,800,000) and is necessarily a first approximation : upon receiving detailed feedback from the country office, some areas could be followed up more in depth. Roads, bridges and towns can be shown on the resulting maps, thus highlighting more in detail population and connections most at risk.
- A more detailed digital elevation model could be utilized today, with 30m cell size (ASTER-GDEM); this would increase the precision of most of the analysis.
- The various datasets utilized have very different precisions and details, thus affecting the precision of the final output (population data has cells size of approximately one km, elevation cell size is 90 m, deforestation data is by district and admin and basin boundaries derived from VMAP-0). Nevertheless we believe that this can constitute a good first approach : eventual feedback from the country office can help validate or discard some of the results and can help us fine-tune the procedure.
- We did not have some datasets that could have helped us improve the model, such as a detailed soil map, an updated and reliable land cover, a geological dataset. We also found several studies on the deforestation in Madagascar, but very few or no datasets were freely and quickly available.
- The short time span available for the study represented a strong limitation that dictated some of the choices that we made as well as the depth of the analysis.

Despite all the problems and shortcomings mentioned above, this study on Madagascar has proven useful because it helped the country office prepare the Country Programme. We hope that the study started a process of dialogue and support among units at headquarters and country offices that can be highly beneficial to all.

ANNEX I - FAO's guidelines for soil description 2006