Economic Vulnerability and Disaster Risk Assessment in Malawi and Mozambique

Measuring Economic Risks of Droughts and Floods

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INTRODUCTION

Highly variable climate in Malawi and Mozambique has a significant influence on the amount, timing, and frequency of precipitation events and runoff patterns, which results in frequent recurrent droughts and floods. In Malawi rainfall varies considerably both seasonally and from year to year. The country has one of the most erratic rainfall patterns in Africa. Between 1967 and 2003, the country experienced six major droughts, affecting over 21 million people in total. Floods occur in southern Malawi, particularly in the Lower Shire River valley and the lakeshore areas of Lake Malawi, Lake Malombe and Lake Chilwa, as well as in the lower reaches of the Songwe River in the northern region. Between 1967 and 2003, 18 floods were recorded killing at least 570 people, rendering 132,000 homeless, and affecting a total of 1.8 million people. Flooding also damages property and infrastructure, impeding drainage of agricultural lands and causing crop damage.

In Mozambique, drought is the most frequent natural disaster, occuring every three to four years. Mozambique has areas that are classified as semi-arid and arid where rain—even when above average—is inadequate, resulting in critical water shortage and limited agriculture productivity. It is estimated that droughts contributed to about 4,000 deaths between 1980 and 2000. A number of geographical factors cause floods in Mozambique, which give rise to high coefficients of rainfall variability. The country is situated downstream of nine major international river basins. It lies in the path of tropical cyclones formed in the Indian Ocean and is affected by three to four cyclones a year. In 2000, Mozambique experienced its worst floods in 50 years, killing about 100 people and displacing 540,000.

The economies of Malawi and Mozambique are strongly natural resource dependent, and agriculture accounts for about one-third of their GDP. Major floods and droughts in Malawi and Mozambique have a significant impact on national economic performance. Measures of fluctuations in GDP and in growth rates of agricultural and non-agricultural sector products demonstrate the sensitivity of the economies to water shocks. The expectation of variability and the unpredictability of rainfall and runoff constrain opportunities for growth by encouraging risk averse behavior and discouraging investments in land improvements, advanced technologies, and agricultural inputs. An unreliable water supply due to hydrological variability is a significant disincentive to investments in industry and services, slowing the diversification of economic activities. Frequent droughts and floods pose a systematic risk to the economies of Malawi and Mozambique and require the development of a longer-term approach for adapting to drought and flood risks and to conditions of chronic hydrological variability.

The objective of the Economic Vulnerability and Disaster Risk Assessment study was to assist the Governments of Malawi and Mozambique in determining the extent of their economic vulnerability to climate variability and in assessing the systematic economic risks associated with droughts and floods. The study results create a compelling argument for incorporating disaster risk reduction (DRR) into national economic planning and development strategies.

The study also quantified the depth and extent of hazard, vulnerability, and disaster loss associated with floods and droughts through detailed spatial risk profiling for both countries. The study results include the Atlases of Drought and Flood Risks for Malawi and Mozambique to inform various stakeholders and decision makers involved with disaster preparedness and response about the the parameters and distribution of drought and flood risks.

The study applied probabilistic risk analysis to evaluate the impacts of the natural hazards. The essential building blocks in the probabilistic risk analysis are hazard, exposure, vulnerability, and loss modules.

STUDY METHODOLOGY

The study applied probabilistic risk analysis to evaluate the impacts of the natural hazards. The essential building blocks in the probabilistic risk analysis are hazard, exposure, vulnerability, and loss modules. Hazard represents the occurrence and severity of adverse events. Exposure characterizes the asset(s) at risk. Vulnerability describes the potential damage to the exposure, corresponding to varying degrees of hazard severity. Risk is expressed in terms of the probability of exceeding specific levels of direct losses (in physical and monetary terms). Figure 1 illustrates the methodological framework adopted in this study.
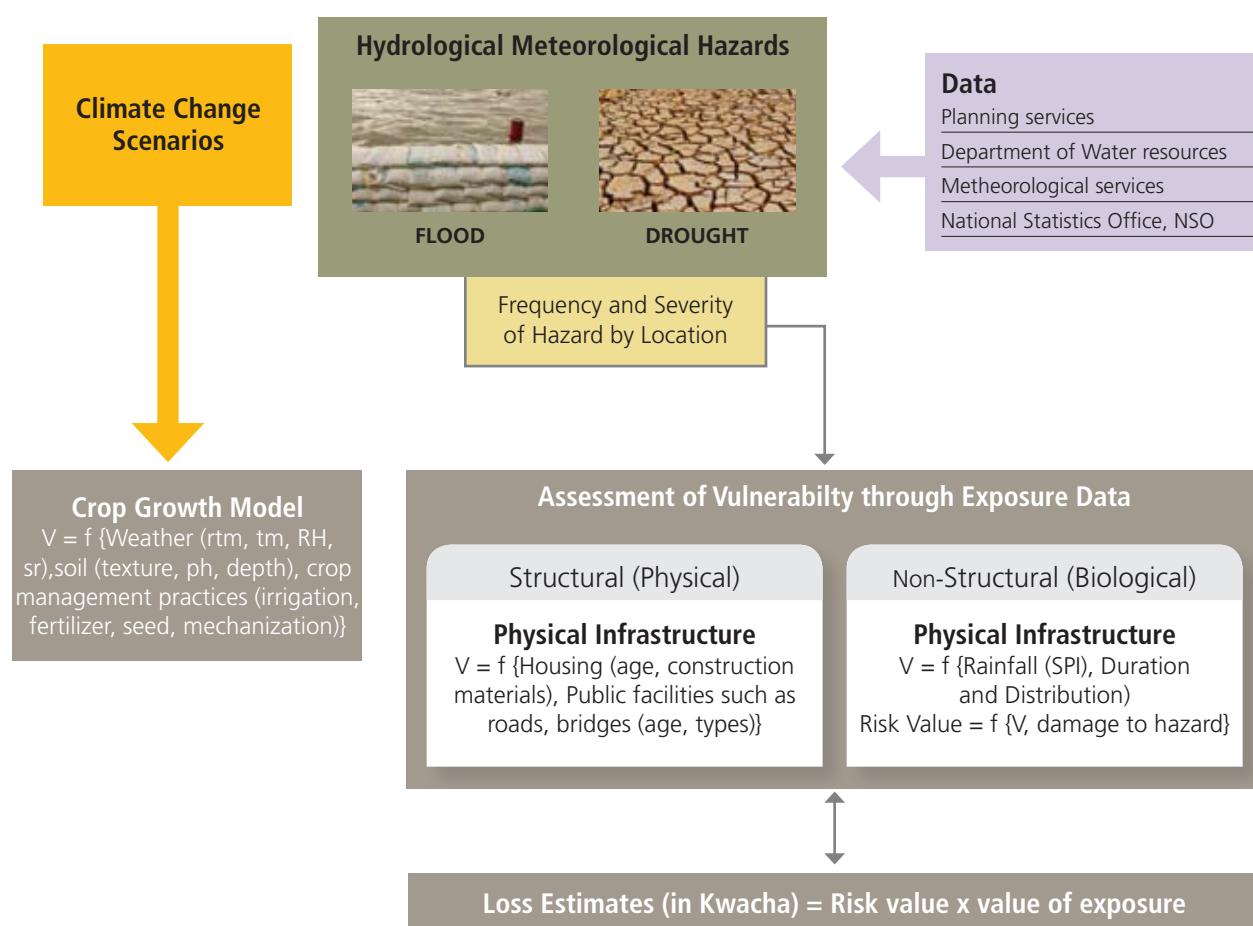

Figure 1. Drought and Flood Risk Modeling Framework

The implementation of the methodology was subdivided into six modules:

- **Stochastic Weather Module** generates a set of stochastic events derived from the characteristics of historical weather events. Each stochastic weather event is quantified in terms of its location, severity, and rate of occurrence.

- **Drought and Flood Hazard Module** estimates the geographic impact of an event in terms of its severity, frequency, (drought duration and intensity, flood depth and extent), and probability of future occurrence. In the case of floods, for each event in the stochastic set, a "footprint" is generated that quantifies the severity distribution over the area affected. The probability of the event occurrence within a given year is measured by an event's "return period" (RP), which is the expected length of time between the reoccurrence of two events with similar characteristics. In this analysis, weather events were evaluated across the full spectrum of return periods.

- **Exposure Module** defines the spatial distribution of the asset(s)-at-risk and classifies them based on the entailed potential damage to the relevant levels of hazards. In drought risk modeling, the principal assets at risk for Malawi are maize and tobacco and for Mozambique are maize and sorghum. The exposure parameters include the crop area and its production. In addition to the agricultural exposure, the residential (population and households) and infrastructural (roads and railways) exposures are considered in the study.

- **Vulnerability Module** quantifies the vulnerability of the assets subjected to the hazard. In the case of droughts, biological vulnerability is assessed by modeling the potential losses in the crop yields due to droughts at different phenological stages of their crop cycle. The risk is expressed in terms of production losses. The study also developed drought indices, using statistical and deterministic agro-meteorological models to simulate responses to probabilistic crop losses. In the case of floods, the crop production losses are estimated by relating the crop area and production with seasonal maximum flows at various gauge sites. The physical vulnerability of the infrastructure—roads and household dwellings—is computed using flood depth and extent with corresponding MDR (mean damage ratio).

- **Direct Loss Computation Module** calculates the total direct loss in monetary terms by combining the vulnerability with the value of the affected assets into financial loss costs.

- **Macroeconomic Module** estimates economy-wide impacts of droughts and floods in Malawi by imposing estimated direct crop production losses on an economy-wide general equilibrium model (CGE). By integrating information from a wide range of sources, including national accounts, foreign trade data, and a 2004-2005 household survey, the model estimated macro impacts on agricultural and national GDP and micro impacts on employment and household poverty.

Assessing Drought Risks

Drought occurs when the precipitation or soil moisture levels are sufficiently below the long-run mean. In this study the Standard Precipitation Index (SPI), which is based on precipitation data, is used for drought identification. This index permits the measurement of drought intensity, magnitude, or severity, as well as its duration. The probability of an event occurring within a certain year is estimated on the basis of historical data. The measured SPI is adjusted to control for when the event took place during the growing cycle (i.e., November to March). Regression models are used to identify whether a statistical, non-linear relationship exists between historical drought events of different severities (i.e., as measured by their SPIs) and the associated crop production losses for different crops observed during those years. Production losses are calculated as the difference between observed production and expected production where the latter reflects the production level achieved during the closest "normal" or non-drought year.

The regression coefficients are then used in a stochastic model that randomly generates a large number of possible drought events across the full range of return periods (RPs). The relationship between different drought events and their associated production losses is defined and represented by a "loss exceedance curve" (LEC). In the context of agricultural risk, a LEC gives the likelihood or probability that a certain level of crop loss will be exceeded during a particular drought event.
The "average annual loss" (AAL) and the "probable maximum loss" (PML) describe the expected long-term loss (Box 1).

Box 1. Risk Metrics

Loss Exceedance Curve (LEC): Using a probabilistic model, the probability for a certain level of loss to be exceeded during a particular (drought or flood) event is determined and represented by a LEC. The LECs allow attachment of a precise probability of occurrence to each possible weather event.

Average Annual Loss (AAL): While future weather patterns are uncertain, expected long-term losses can be predicted with greater certainty. This expected long-term loss is the average annual loss (AAL), which is obtained by multiplying the probability of an event by its expected loss and summing over all possible events (i.e., integration of the LEC).

Probable Maximum Loss (PML): This represents the largest possible loss that may occur in regard to the risk of the event. In this study, PML is defined as the loss that occurs in case of a flood or drought event of 100-year return period.

The drought hazard and exposure (crop area and production) maps were simulated, highlighting the areas that have a 1-in-5, 10, 20, 50 and 100 year return period frequency. The generated risk maps spatially portray the drought impacts on crop area and production across the countries (Figure 2).

Drought vulnerability is expressed in terms of mean damage ratio (MDR), which represents the ratio of the loss in crop production to the total crop production under the "normal" weather conditions. The MDR maps were generated corresponding to 1-in-5, 10, 20, and 50 year droughts (Figure 3). Risk is expressed as the probability of exceeding specific levels of physical and direct financial losses. In the present context, drought risk is presented as production losses (tonnage) and equivalent monetary losses (US$). These are generated corresponding to 1-in-5, 10, 20, and 50 year droughts along with AAL (annual recurrence) and PML (1-in-100 year).
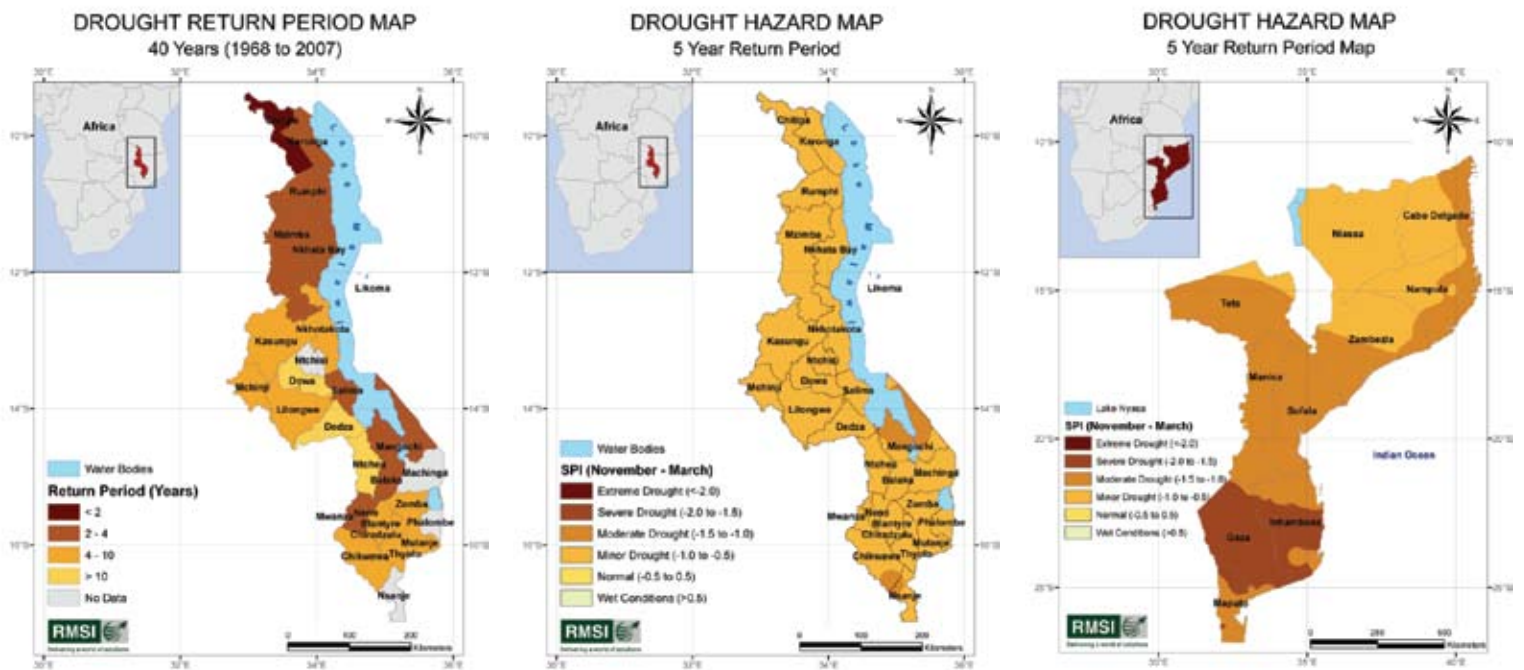
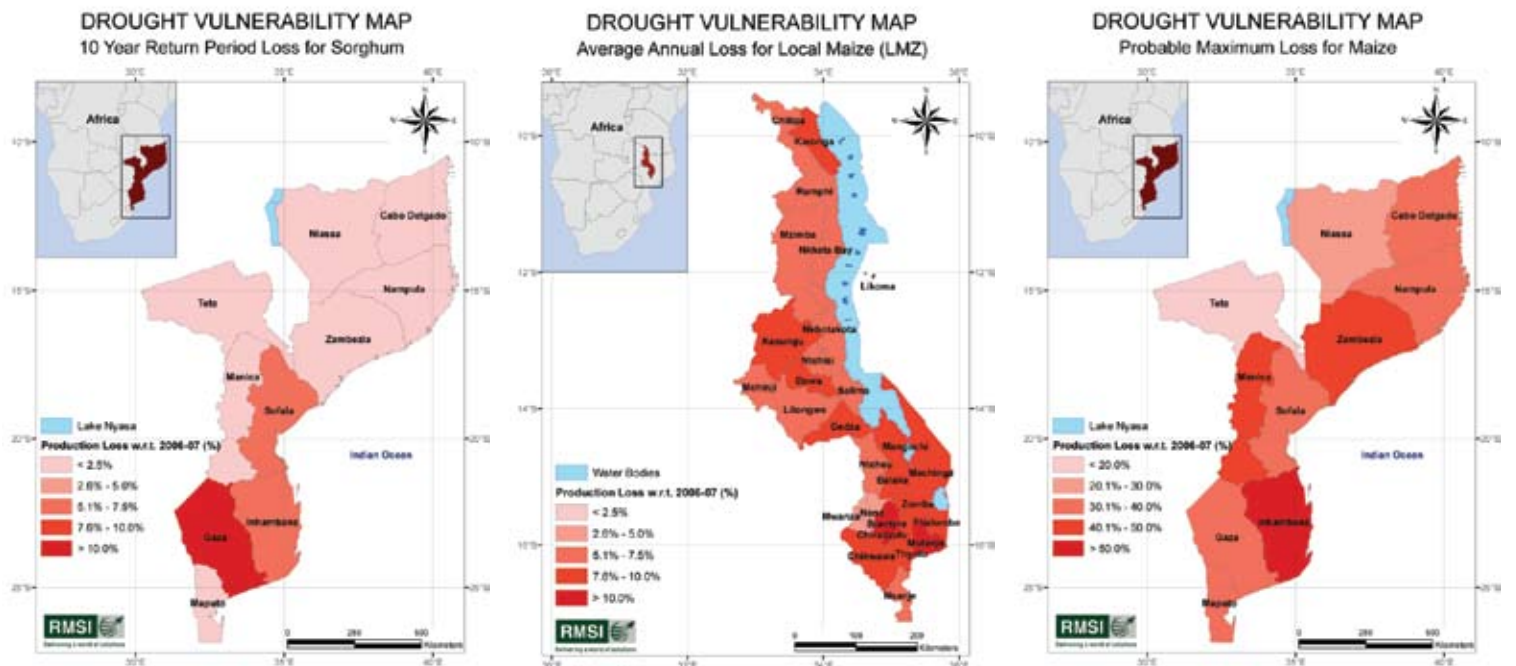**Figure 2.** Drought Hazard Maps for Malawi and Mozambique for a 1-in-5 Year Return Period (RP).

Figure 3. Mapping Drought Vulnerability for Malawi and Mozambique

Assessing Flood Risks

The flood risk model adopts a similar approach to the drought model in that hazard is assessed using estimates of the probability of occurrence for floods of different severities. The probabilistic risk model is based on runoff, which means that observed flood discharges are used to identify floods and to estimate their probability of occurrence. Stochastically generated discharges are then routed through a Digital Elevation Model of the affected floodplain to determine flood extents and depths at a detailed 90 meter resolution.

The stochastic results from this model were validated using satellite images of historical flood events. Agricultural losses are determined on the basis of information about farmers' exposure to flood events. This depends on the portion of cultivated land in geographic areas likely to be inundated during floods of different severities. As with the drought analysis, regression models are used to estimate the relationship between production levels and historical flood events. The physical vulnerability of the infrastructure—roads and household dwellings—is computed using flood depth and extent with corresponding MDR (mean damage ratio).

Data from the regression models were incorporated into a stochastic flood model in order to generate production losses under the complete distribution of flood events (i.e., for all RPs). Detailed spatial information on flood hazard and vulnerability is necessary for flood risk assessment and is extremely important for the preparedness and prevention strategies of governments, as well as for individual stakeholders, such as communities, enterprises, and house owners.

The hazard module generates hazard intensities (in terms of flood depth) at the district-level resolution for each stochastic event. The vulnerability module relates flood depths with damage susceptibility to houses, infrastructures, and agricultural areas. The exposure module describes the inventory of different types of dwellings, roads, rail network, and agricultural areas at a district-level resolution. Figures 4 and 5 map illustrate some of the modeling results for Malawi and Mozambique.
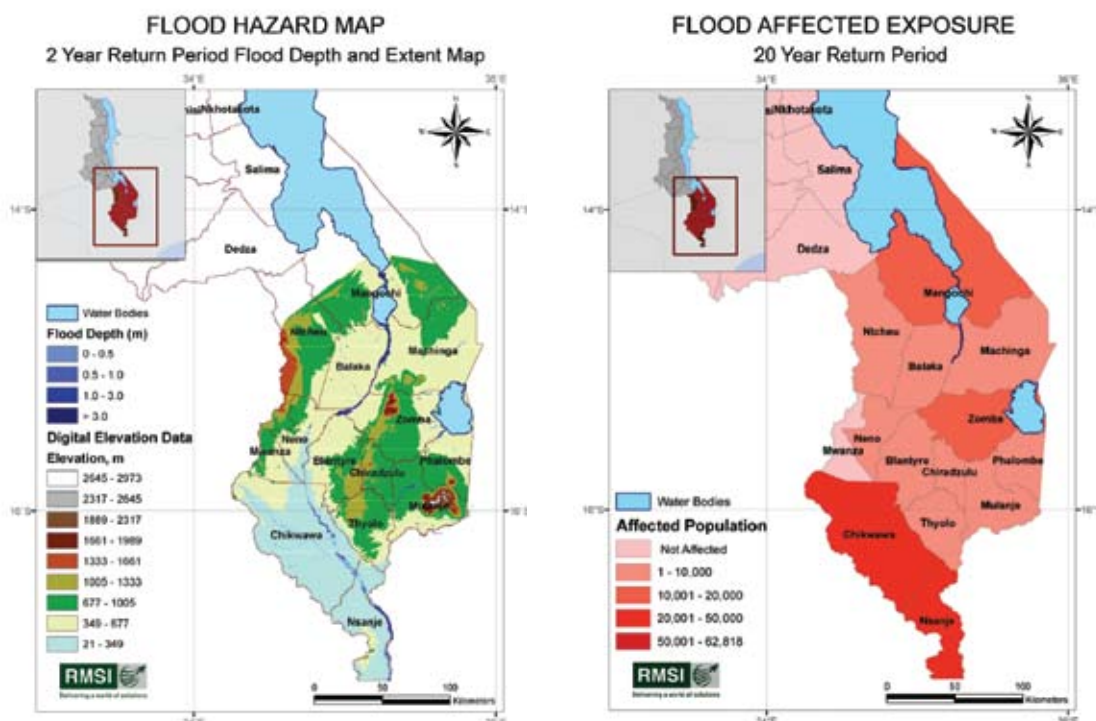

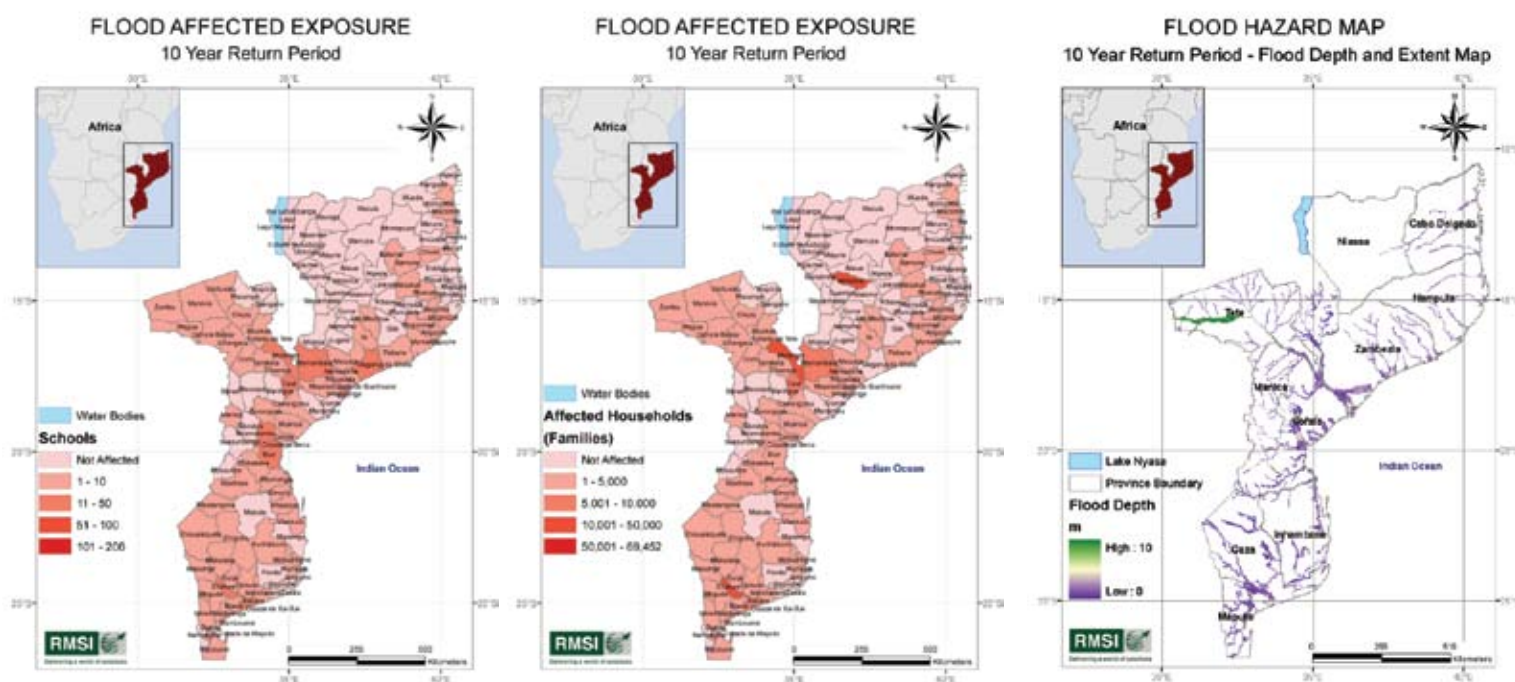**Figure 4.** Flood Hazard and Exposure in the Shire Basin, Malawi

Figure 5. Flood Hazard and Exposure (Schools and Households) for 1-in-10 year flood in Mozambique

Long-Term Losses

The loss module quantifies the losses incurred by the assets as defined by the exposure module. Uncertainty over when droughts and floods will occur is a serious problem for short-term risk management. However, the Annual Average Loss (AAL) calculated based on the drought and flood LECs is an important characteristic of the systematic losses due droughts and floods in the long term. These calculations show that, for example, Malawi loses, on average, 4.6 percent of its maize production each year due to droughts (based on today's adoption of different varieties). Similarly, about 12 percent of maize production is lost each year to flooding in the southern region where about one-third of Malawi's maize is grown. Droughts and floods are, therefore, a major obstacle for agriculture and food security in the country. Figures 6 and 7 summarize some results of the assessment of direct losses for Malawi and Mozambique.
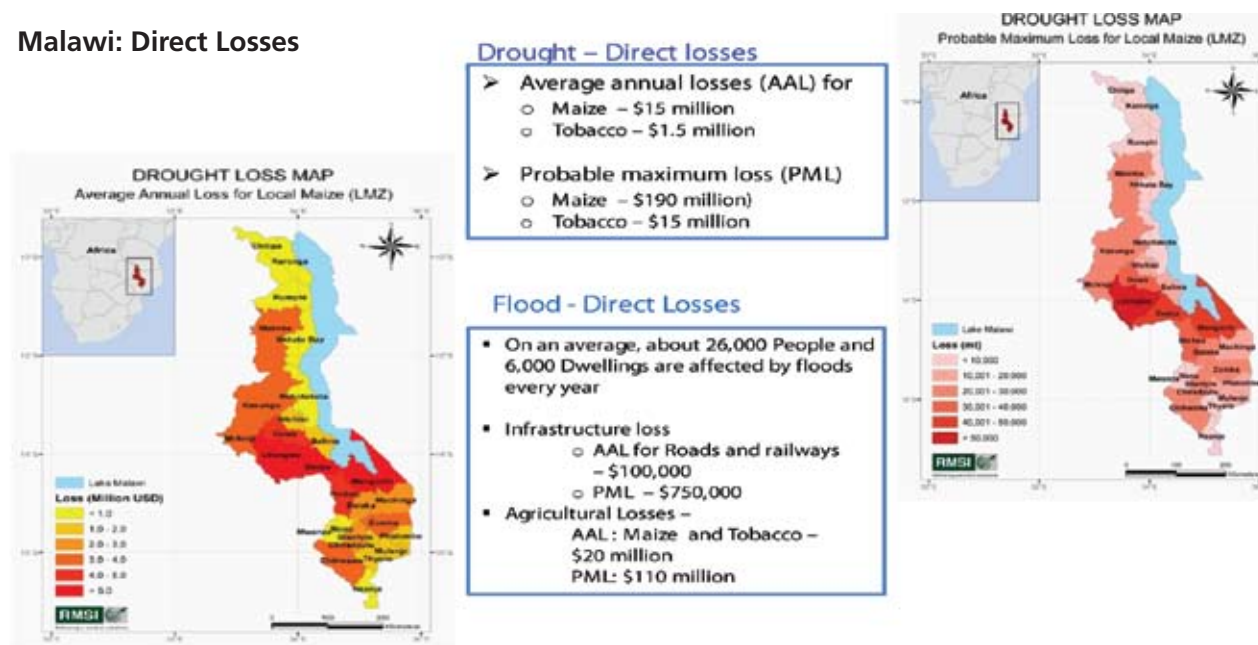
Malawi: Direct Losses

Figure 6. Malawi: Long-term Direct Losses Due to Floods and Droughts
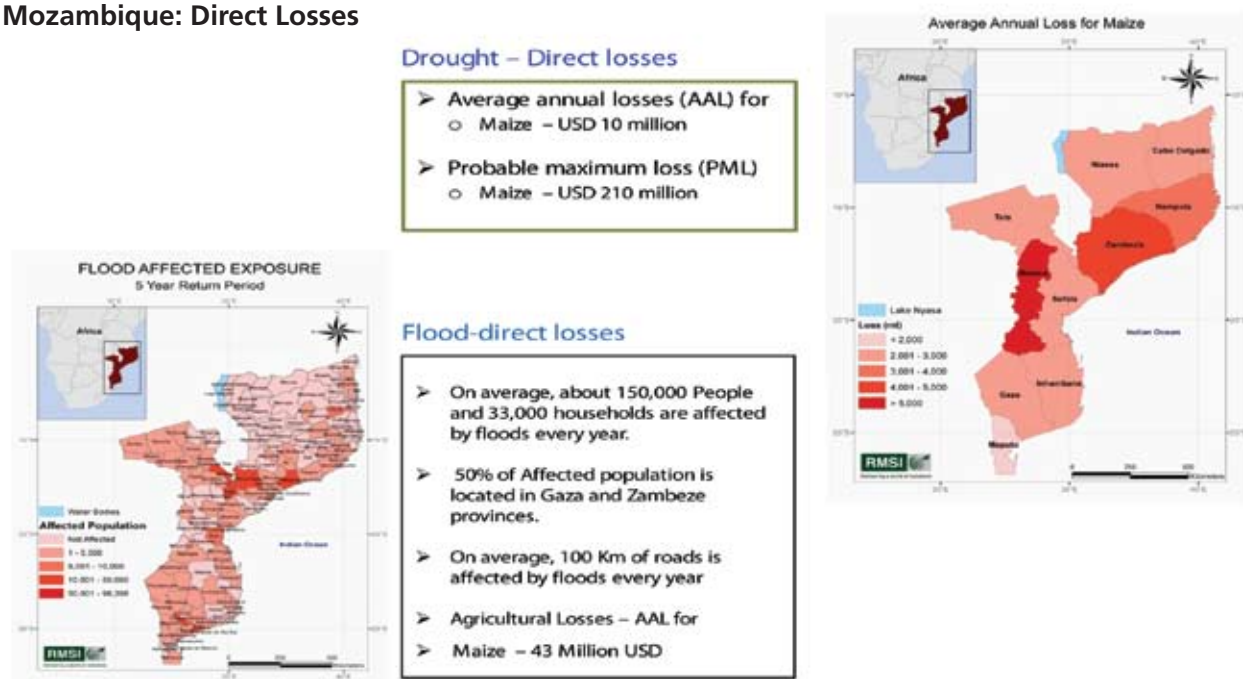
Mozambique: Direct Losses

Figure 7. Mozambique: Long-term Direct Losses Due to Floods and Droughts

Results for Malawi indicate that, on average, droughts and floods together reduce total GDP by about 1.7 percent per year. Damages, however, vary considerably across weather events with total GDP declining by at least 9 percent during a severe 1-in-20 year drought.

Economy-wide Impacts of Droughts and Floods

The study imposed estimated crop production losses on an economy-wide general equilibrium model of Malawi that captures farm and nonfarm sectors and households in different parts of the country. The model is based on information from a wide range of sources, including national accounts, foreign trade data, and a 2004-05 household survey. By integrating this information, the model estimated macro impacts on agricultural and national gross domestic product (GDP) and micro impacts on employment and household poverty.

Results for Malawi indicate that, on average, droughts and floods together reduce total GDP by about 1.7 percent per year. Damages, however, vary considerably across weather events with total GDP declining by at least 9 percent during a severe 1-in-20 year drought (Table 1). Such severe outcomes place a significant constraint on Malawi's development prospects. Smaller-scale farmers in the southern regions of the country are especially vulnerable to declining agricultural revenues and rising poverty during drought and flood years (Box 2). Urban households also experience increased poverty due to higher food prices and declining nonfarm wages.

Table 1. Malawi: Estimated changes in production (GDP)

| Droughts	RP5	RP10	RP15	RP25	AAL
Total GDP	**−0.5**	**−3.5**	**−7.2**	**−10.4**	**−1.0**
Agriculture	−1.1	−7.3	−14.9	−21.5	−2.0
Industry	0.0	0.0	0.3	0.7	0.0
Services	−0.2	−1.3	−2.8	−4.4	−0.4
Floods*	RP5	RP10	RP20	RP50	AAL
Total GDP	**−1.7**	**−2.5**	**−3.2**	**−4.0**	**−0.7**
Agriculture	−3.5	−5.1	−6.5	−8.2	−1.4
Industry	−0.6	−0.9	−1.2	−1.6	−0.2
Services	−0.5	−0.7	−0.9	−1.2	−0.2

* National results, although flood shock only applied to southern region.

Box 2. Malawi: estimated changes in poverty rate

- Droughts
  - Declining household income <u>and</u> rising prices raise poverty

Percentage point increase poverty (from 52.4% in the base)		
RP5	RP25	'AAL drought'
0.7	16.9	1.3 (154,000 people)

- Floods
  - Poverty increases 0.9 percentage points during 'AAL floods'
  - Impact is more severe in the Southern region (2 percentage point increase)
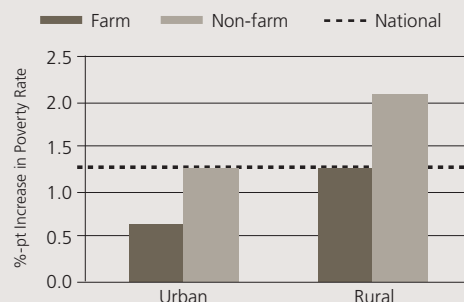
Model results estimate that droughts, on average, cause GDP losses of almost 1 percent every year. Economic losses are much higher during extreme droughts; for example, during a 1-in-25 year drought (RP25) similar to that experienced in 1991/92 in Malawi, GDP contracts by as much as 10.4 percent. Droughts also exacerbate Malawi's already high levels of income poverty. On average, droughts cause a 1.3 percentage point increase in poverty, but this rises to almost 17 percentage points during an RP25 drought (this is equivalent to an additional 2.1 million people falling below the poverty line). Importantly when droughts do occur, their impacts vary considerably across regions and population groups with smaller-scale farmers most vulnerable to drought-induced economic losses. Nonfarm and urban households are also vulnerable, especially the poor who spend a large proportion of their income on food.

The impact of floods in the southern region of Malawi was also estimated. The average annual GDP loss due to floods is about 0.7 percent, thus making the average impact of floods slightly less than that of droughts. However, considering that this is the national-level impact of an event that is highly localized, i.e., one that only affects production levels in the southern region directly, the economy-wide effects are in reality quite severe. These national-level losses occur despite the fact that agricultural production in the central and northern regions may increase during floods. These benefits arise from higher national food prices during southern floods. The implications for farming households in the southern region, however, are severe. Average annual crop and livestock losses range from 4 percent in Blantyre to 6.8 percent in Machinga. Floods are further found to mainly affect small- and medium-scale farmers.

Concluding Remarks

The impacts of droughts and floods are often discounted or ignored in the long-tem national development planning and sectoral strategies development. Drought and floods, however, have considerable negative impacts on the economies of Malawi and Mozambique each year in terms of direct losses in assets, reduction of GDP, and poverty increase. The results of the study also demonstrate that droughts and floods are major obstacles for agriculture and food security in both countries. Indications suggest that drought and flood events are becoming more frequent in Malawi and Mozambique, and thus the average annual impact might become even greater in the future. It is, therefore, crucial that policymakers take heed of the severe implications of climate variability, especially for the most vulnerable in society, such as resource-poor, small-scale farmers and poorer urban households. It is clear from this analysis that climate variability risks are important; they need to be considered and addressed explicitly in designing and evaluating national development policies and strategies in Malawi and Mozambique.

The assessment's findings and recommendations serve as a means to prepare disaster risk adaptation strategies or to expand existing national and sectoral policy and strategies. The study has laid the groundwork for discussions and analysis of the effectiveness and viability of various measures to decrease economic vulnerability of the countries to the risks of droughts and floods. Preparation of detailed sectoral strategies to address the risks of droughts and floods will be undertaken through follow-up disaster risk management activities in both countries.

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