Feasibility of Risk Financing Schemes for Climate Adaptation

The case of Malawi

Institutions for Climate Change Adaptation

DEC-Research Group, Infrastructure and Environment Unit
The World Bank

Prepared by
Pablo Suarez, Joanne Linnerooth-Bayer and Reinhard Mechler

With M. Carriquiri, J. Hansen, S. Hochrainer, A. Mishra, D.E. Osgood and G. Pflug

June 26, 2007

Risk and Vulnerability Program,
International Institute for Applied Systems Analysis (IIASA)
Laxenburg, Austria
www.iiasa.ac.at

IIASA Science for Global Insight

TABLE OF CONTENTS

---

[1] Columbia University IRI
[2] Red Cross / Red Crescent Climate Centre and IIASA
[3] Iowa University CARD
[4] IIT Kharagpur RDC
[5] IIASA

TABLE OF FIGURES

LIST OF TABLES

Executive Summary

Institutions supporting climate-change adaptation in the developing world, along with international development organizations, are closely observing the performance of recent weather-related insurance programs in vulnerable and poor regions, including especially the Malawi index-based insurance pilot program. This program offers a bundled weather insurance and loan package to subsistence farmers facing high risks of drought. If successful, innovative insurance systems of this type may provide a blueprint for reducing vulnerability to drought and other climate-related risks in highly exposed regions. They also provide opportunities for re-orienting donor assistance from after-the-fact disaster aid to pro-active support. Finally, they add an important candidate for support from existing and envisaged global adaptation funds.

There are several notable features of the Malawi scheme: joint liability of farmers' clubs, elimination of cash payments by individual farmers, index-based contracts reducing costs and eliminating moral hazard, and a bundled loan/seed package that can greatly increase farmer productivity. Greater harvests reduce poverty and render farm households less vulnerable to climate risks; however, the scheme itself does not include payments to farmers in the event of a drought. Importantly, the insurance scheme has not, to date, accounted for the relationship of drought risk with the ENSO phenomenon or with climate change. The Malawi program, which is self supporting, has been made possible by extensive technical support from the World Bank.

From the participating farmers' perspective, the first operational year of the pilot project was successful. A large majority (86%) of sampled farmers reported that they would participate again. Despite its merits, there were significant challenges in the original architecture of the program, many of which were revealed from experience gained in the first pilot year. NASFAM was critical for the system logistics, and proved adept at communications and responding to the early seed germination crisis. However, trust in this organization appears to be polarized among survey respondents (the majority place great trust, but a significant minority place low trust in the institution), which flags a potential problem of vesting responsibility largely in one organization. There were also concerns voiced about the pre-arranged agreement to sell the groundnut harvest to NASFAM. If market prices prove higher than the NASFAM price, as was the case in the first year of operation, there is a risk of side selling to outside traders, limiting NASFAM's capacity to repay the loan. Basis risk, or the risk that precipitation experienced by an individual farmer does not correspond to that measured at the weather station, has also proven to be a controversial issue. The survey of farmers revealed a worrying lack of understanding of the index-based system, and a lack of trust among many farmers in the weather station data on which the system rests. Since institutional trust is a pre-requisite for the sustainability of the scheme, the Malawi experience reveals significant challenges in scaling up operations, particularly given the already overstretched capacity of NASFAM.

Many of the revealed drawbacks have been addressed in the 2006-7 planting season, during which the scheme has expanded to an additional region and to include maize. NASFAM will continue its role in communicating with farmers and supplying seeds, but there will be more dependence on the market for selling the harvest.

Neither the Malawi microinsurance program nor others like it take account of seasonal climate forecasts in their operations and planning, rendering these systems vulnerable to adverse selection and inequitable contracts. The integration of climate predictions into innovative financial mechanisms offers interesting possibilities for promoting adaptation in the subsistence agriculture sector. This analysis shows the advantages of making use of ENSO-based predictions in the operations of the Malawi program by promoting the cultivation of larger areas with high-yield inputs when good rains are expected, and reducing the exposure to drought risk when conditions are less favorable. Results of crop simulation modeling and financial calculations show that integrating seasonal rainfall forecasts can lead to substantial increases in gross revenues during La Niña years (by a factor of about seven). Taking account of the forecasts, the cumulative gross revenue in the ENSO-adjusted scheme is more than twice that of the conventional scheme. Consequently, through wealth accumulation, such approaches can reduce the farmers' long-term vulnerability to climate variability and change. While the analysis is based on several simplifying assumptions, they are unlikely to challenge the main finding: a scheme that uses skilful seasonal forecasts to adjust the bundled loan-insurance contract according to expected rains can substantially benefit participating farmers. Risk mitigation and climate adaptation can thus be successfully integrated with risk sharing in a well-designed system, in this case, one that accounts for climate forecasts.

It is anticipated that rainfall in Malawi will be influenced by climate change. Through the combination of climate modeling and dynamic financial modeling, this analysis shows that climate-change induced stress will likely decrease the financial robustness of the Malawian insurance pool in the coming decade, and more significantly 50-plus years in the future. Assuming that premiums are not raised from current levels, additional back-up capital will be necessary to render the Malawi program robust. These results are limited by simplifying assumptions, as well as large uncertainties in the data and climate models on which the analysis is based. Still, by combining catastrophe insurance modeling with climate modeling, the methodology demonstrates the feasibility, albeit with large uncertainties, of estimating the effects of climate change on the near- and long-term future of microinsurance schemes serving the poor. By providing a model-based estimate of the incremental role of climate change, along with the associated uncertainties, this methodology can quantitatively demonstrate the need for financial assistance to protect insurance pools against climate-change induced insolvency. This is of great importance to insurers, and also to the climate-adaptation and international development communities.

In conclusion, experience gained from the Malawi pilot program, and insights gained from this research, show that:

- Weather insurance for low-income regions, given donor assistance, appears to be administratively and economically feasible, and shows great potential for reducing vulnerability to rainfall variability and, at the same time, promoting wealth accumulation;
- Insurance schemes that provide cover for livelihoods (beyond the loan-default risk) and for very poor regions would likely require significant donor assistance;
- Communication and marketing efforts are an important pre-requisite for successful operations. The low levels of understanding of the index-based

bundled scheme among participating farmers may threaten the continuity of the Malawi scheme, particularly if unexpected events trigger outcomes that result in irreversible loss of trust.

- As demonstrated by simulation modeling of the Malawi program, the potential for increasing farmer productivity, and thus reducing weather-related poverty and vulnerability, can be greatly enhanced by taking account of ENSO-based forecasts;
- It is possible to integrate climate and catastrophe insurance modeling for estimating the approximate additional burdens of climate change on weather insurance systems.

These results and the methodologies applied are of wide interest for scaling up the Malawi scheme as well as for informing other nascent weather insurance systems in Africa, Asia and Latin America. They can also inform development institutions and organizations supporting adaptation to climate change. The Malawi pilot program was only possible with technical assistance from the World Bank, which illustrates a potential role for development and donor organizations. Another important form of support is providing backup capital, and pooling the risks of geographically diverse catastrophe insurance systems. This will be important, even critical, for these systems as they scale up to include more clients and products adding to the systemic nature of the risks. This report concludes by offering recommendations based on the lessons learned from the first operational year.

1. INTRODUCTION

As governments, NGOs and private parties negotiate the design of the post-Kyoto climate regime, one of the most challenging and pressing issues is how much the developed world can and should support adaptation in the developing world to climate-change impacts, including droughts, floods, windstorms and other weather extremes. Adaptation to climate change has emerged on the climate agenda alongside the reduction of atmospheric greenhouse gas concentrations as an essential part of the response to climate change risks. The call for intensified support for adaptation in the developing world has been reinforced by the recent report from the International Panel on Climate Change (IPCC), which reports evidence of *current* climate impacts in the form of long-term and widespread changes in wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones (IPCC, 2007).

Insurance-related instruments that spread and pool risks are emerging as important candidates for supporting adaptation to climate-related disasters in developing countries (Linnerooth-Bayer et al., 2003). Article 4.8 of the United Nations Framework Convention on Climate Change (UNFCCC) and Article 3.14 of the Kyoto Protocol call upon developed countries to consider actions, including insurance, to meet the specific needs and concerns of developing countries in adapting to climate change. Implementation of Article 4.8 has proven arduous (Linnerooth-Bayer et al., forthcoming); yet, three recent adaptation funds administered by the Global Environment Facility (GEF) could potentially be tapped for supporting climate insurance in highly exposed and vulnerable countries. To date, however, there is little understanding or agreement within the climate community on the role that insurance and other forms of risk sharing can play in assisting developing countries adapt to climate change and reduce disaster risk.

This is not the case in the development community, which is placing increasing emphasis on disaster prevention and sees insurance as part of an effective *ex ante* risk-management strategy (Linnerooth-Bayer, Mechler and Pflug, 2005; World Bank, 2005a; Gurenko, 2005). The Hyogo Framework for Action calls for the development of risk sharing mechanisms, particularly insurance and reinsurance against disasters (UNISDR, 2005). International financial institutions, as well as some bi-lateral donor organizations, are already providing assistance for catastrophe insurance schemes in Latin America, Asia and Africa, and the World Bank is exploring the idea of a global facility for hedging developing country risk (World Bank 2005a). Both development organizations and agencies responsible for climate-change adaptation are thus closely observing recent experience with micro-insurance schemes to ascertain their long-term viability and potential for providing security to the most vulnerable.

Several micro-insurance schemes have emerged in recent years to address drought risk among smallholder farmers (Linnerooth et al., 2006). Of particular interest is a pilot insurance scheme in Malawi. First implemented in 2005, the Malawi scheme offers index-based weather insurance to smallholder groundnut farmers. While conventional crop insurance is written against actual losses, index-based weather insurance is written against a physical trigger, such as cumulative rainfall during a certain period of time.

The mechanism of the pilot scheme could be briefly described as follows: before the rainy season, participating farmers receive improved agricultural inputs through a contract that specifies (i) an index-based weather insurance component, in which the premium is calculated based on the probability of a payout, and (ii) a loan component. At the end of the season the farmer will owe the lending institutions an amount equal to the cost of agricultural inputs plus insurance premium plus interest and taxes. If rains are good (as measured in a nearby weather station operated by the meteorological service), then the insurance company keeps the premium and farmers pay back the loan with proceeds from the (presumably good) harvest. If measured rains are below certain trigger values (based on critical stages of the groundnut growing season), then the insurance company pays part or all of the loan to the bank. For a more detailed description of the contract design, see UNDESA (2007).

The Malawi insurance scheme improves farmers' creditworthiness and therefore their ability to access credit for investing in higher yield/higher return crops. Banks generally consider that lending to rainfed farmers with no collateral is excessively risky, mostly due to high systemic risk of loan default in the aftermath of droughts. By coupling bank loans with index-based weather insurance, farmers can receive the requisite credit for seeds and other agricultural inputs, and they can expect a net gain after repayment of the coupled loan-insurance contract.

Figure 1: Malawian farmer showing a groundnut plant affected by water stress (photo: P. Suarez).

The Malawi insurance program serves a region that is vulnerable to climate change and to climate variability associated with El Niño – Southern Oscillation (ENSO) (Dilley, 2000; Glantz, 2001). Droughts, which are strongly related to ENSO, are expected to become more frequent and intense in many areas within the Southern African region under a changing climate (Hewitson and Crane, 2006, IPCC, 2007). This poses a major risk for the subsistence agriculture sector, which is the main source of livelihood for vast sectors of the population in this region. While development initiatives can certainly help farmers cope with droughts, the increased risk of disasters associated with climate change needs to be integrated into more robust development planning initiatives (van Aalst, 2006). A major challenge in Malawi, and throughout the world, is not just preparing for the foreseeable climate, but also modifying decision-making processes in order to incorporate the availability of new information (Stern and Easterling, 1999).

To date, neither the Malawi scheme nor (to our knowledge) other disaster insurance schemes operating in developing countries have taken account of climate-change predictions or seasonal precipitation forecasts based on ENSO and other data. The integration of climate-change modeling and ENSO-based seasonal forecasts into the Malawi insurance scheme may help address threats to the scheme's long-term viability. Additionally, using forecasts in risk sharing schemes may help devise ways to reduce risk by assisting farmers make better decisions to improve their productivity. Such an approach, if successful, would constitute an important step in harmonizing the fields of disaster risk reduction and regional development.

The Malawi pilot project is a result of the initiative of dedicated local persons, as well as the Commodity Risk Management Group at the World Bank, which provided technical and other assistance. The initiators view the program as a significant step forward in reducing farmer vulnerability and rural poverty in Malawi and potentially world wide (Hess and Syroka, 2005). Whether the Malawi pilot program and others operating in Asia and Latin America fulfill the expectations of their initiators is a question of keen interest to the development and climate-change communities. If successful, the Malawi program (especially if reformulated to take account of climate change and ENSO phenomena) can serve as one blueprint for development and donor organizations in their support of pre-disaster risk pooling schemes in poor and vulnerable regions. It can also be a blueprint for assisting adaptation to climate change.

This report presents the results of a research project commissioned by the World Bank's Development Economics Research Group, funded by the Bank Netherlands Partnership Program, and carried out by the International Institute for Applied Systems Analysis (IIASA). The research is based on extensive interviews with Malawi farmers and other stakeholders in the pilot insurance program, as well as on a questionnaire administered to 168 participating farmers. In addition to eliciting stakeholder views, the project utilized various modeling approaches to analyze the extent to which the scheme may be affected by climate change and ENSO phenomena. This is important for the planning horizon of the farmers, bank, insurers and other stakeholders, as well as to GEF and donor organizations considering additional support.

We begin in the next section by presenting background information on climate change, adaptation and micro-insurance. In Section 3 we describe the Malawi scheme: its context, logistics, economics, key features and challenges. In Section 4, we report on interviews and a questionnaire eliciting stakeholder views on the performance and future viability of the project. In the fifth section, we explore the integration of ENSO-based seasonal rainfall forecasts into the 2006-07 Malawi weather insurance scheme, and show the potential for increasing farmer productivity and reducing risk. Section 6 integrates climate modeling with dynamic insurance modeling, and shows the potential effects of climate change on the viability of the Malawi program. Section 7 summarizes and draws conclusions.

2. BACKGROUND: CLIMATE CHANGE, ADAPTATION AND MICRO-INSURANCE

2.1. Climate change and adaptation

The United Nations Intergovernmental Panel on Climate Change (IPCC) has warned that shifts in *average* weather conditions due to climate change may be less disruptive than increased weather *variability,* which takes the form of droughts, windstorms, floods and other weather-related extremes (IPCC, 2001a, b). The IPCC recently reported observations of long-term and widespread changes in wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones (IPCC, 2007). There is, in fact, mounting evidence of a significant climate-change signal in the frequency and severity of some climate-related hazards (Schönwiese et al., 2003; Emanuel, 2005).

Although a diversity of mechanisms, approaches and rules for funding adaptation has been adopted by implementing agencies and governments in the context of the United Nations Framework Convention on Climate Change (UNFCCC), adaptation still remains an underdeveloped part of the climate regime. Early efforts have aimed at funding activities strictly related to climate *change*, but there are increasing calls that adaptation should be driven by vulnerability and poverty, and that it should be mainstreamed into the development process (Kartha et al., 2006; Klein et al., forthcoming).

Developing countries are strongly affected by climate variability and climate extremes. In the past quarter century over 95 percent of disaster deaths occurred in developing countries, and direct economic losses (averaging US$ 54 billion per annum) as a share of national income were more than double in low-income versus high-income countries (Arnold and Kreimer, 2004). Disasters exacerbate poverty as victims take out high-interest loans, sell assets and livestock, or engage in low-risk, low-yield farming to lessen exposure to extreme events. Without a post-disaster infusion of capital for reconstruction, disasters can also exacerbate poverty by their long-term adverse effects on economic development.

The reduction of escalating losses from weather extremes is viewed thus as essential to eradicating poverty and achieving the Millennium Development Goals (Arnold and Kreimer, 2004). The specter of worsening risk due to climate change has given added emphasis and momentum to the development agenda, and disaster risk management is becoming an important component of international development and aid strategies. Since most hazard-related aid is triggered by specific events and the need for rapid post-disaster humanitarian response, only limited resources have been available to achieve disaster risk reduction *ex ante*. *Ex post* disaster aid is essential for humanitarian purposes, but experts emphasize the greater potential of ex ante risk reduction and risk transfer as a way of reducing lives lost and expediting recovery. The Hyogo Framework of 2005 (UNISDR, 2005) concludes that natural hazard risk reduction should be a core component of economic development assistance, and that attention should be directed to financial strategies that hold promise for reducing the burdens on the poor.

In contrast to the development/donor community, there has been little attention to financial strategies for disaster risk management by the climate change community.

Negotiating a concrete commitment to implementing Article 4.8 of the UNFCCC, which calls for the consideration of insurance for purposes of adaptation, has proven arduous (Linnerooth-Bayer et al., forthcoming); yet, three recently created adaptation funds managed by the Global Environment Facility (GEF) could, in principle, support insurance instruments. As candidates for GEF support, two proposals have recently been put forward for the creation of a global facility (or regional facilities) for the purpose of supporting climate insurance: The first would indemnify public infrastructure damage from climate extremes in least developed countries (Bals et al., 2006) and the second would provide technical support and reinsurance to nascent weather insurance systems in the developing world (Linnerooth-Bayer and Mechler, 2006). Yet, providing support on this scale would require funding beyond what is currently envisaged in the GEF adaptation funds. Moreover, a controversial stipulation underlying disbursement of the adaptation funds is the so-called "additivity" clause. The GEF can fund only the *incremental* cost of adaptation activities, and only if these activities generate global environmental benefits or are identified as high priorities by national communications. Constraints on funding adaptation activities underline the potential for merging the agendas of the development and climate-change communities. For this reason, both communities are closely observing recent experience with climate micro-insurance pilot programs in vulnerable countries.

2.2. Micro-insurance for disasters

Micro-insurance is attracting wide interest as a growing body of evidence demonstrates its potential for low-income households and businesses that are traditionally excluded from conventional insurance services. The intent of micro-insurance is to provide easily accessible insurance cover for small-scale assets and livestock at affordable premiums by keeping transaction and other costs low. Often with donor support such pilot schemes are being offered in Asia, Latin America and Africa and, if they can be scaled up to create a sufficiently diversified pool, hold considerable promise for the more than 40% of farmers in developing countries, who face threats to their livelihoods from adverse weather (World Bank, 2005b). The Malawi microinsurance scheme is highly innovative, and if proven successful, it could serve as a blueprint for scaling up within Malawi and across borders in Africa and beyond.

Yet, micro-insurance schemes that offer widespread cover for disaster risks face substantial challenges. If insurers with limited capital reserves choose to indemnify large covariant and recurring risks, they must guard against insolvency by diversifying their portfolios geographically, limiting exposure and/or transferring their risks to the global reinsurance and financial markets. A recent review of micro-insurance throughout Asia and Latin America showed little transparency or commonalities in the financial backup arrangements of private market providers (Mechler et al., 2006). Diversification and reinsurance can prove expensive, which raises the challenge of assuring the financial sustainability of microinsurance providers and at the same time providing affordable premiums to poor and high-risk communities. Many support subsidies to meet this challenge and caution against shifting full responsibility to the poor (especially in light of Northern responsibility for climate change), while others warn against the negative incentives promoted by subsidies and favor limiting support to starting up microinsurance operations. Another important option is the provision of affordable reinsurance, possibly through a global or regional re-insurance facility that would pool the risks of geographically diverse micro-insurance programs.

Climate change, along with ENSO-related climate variability, will likely put additional stress on the people targeted by many microinsurance schemes. For example, in Malawi, a large part of the farmland already today is marginal due to a lack of adequate rainfall, and in the future the situation may become more precarious with climate change potentially shifting rainfall patterns. This poses a major risk for the subsistence agriculture sector, which is the main source of livelihood for vast sectors of the population in this region.

It is important to note that catastrophe insurance has become feasible largely as a result of advances in modeling that make it possible to better estimate and price low-probability extreme event risks for which there are limited historical data. Catastrophe models typically generate probabilistic losses by simulating stochastic events based on the geophysical characteristics of the hazard and combining the hazard data with analyses of exposure in terms of values at risk and vulnerability of assets. In addition, there has been important progress in the mathematics of extreme value theory, and in the convergence of the theories of finance and insurance, rendering possible the pricing of exotic risk-transfer instruments, such as weather derivatives and catastrophe bonds (Embrechts et al., 1997; Geman, 1999). Climate-change presents a major challenge to catastrophe modeling, and, here again, analysts can build on recent progress. Global circulation models have moved from accounting for land surface and cryosphere to assessing biosphere, carbon cycle and atmospheric chemistry with a resolution of several hundred kilometers (Met Office, 2007). Regional climate models with a higher resolution (typically 50 km) have been developed in order to study local effects, such as from mountains, on climate. For example, the Hadley Centre has developed a PC version of such a model for any world region, the PRECIS model.

Yet, insurance modeling (*dynamic financial analysis*) and climate change modeling has rarely been carried out in an integrated way. As Mills (2005) points out, insurance modeling is essentially backward-looking with a focus on historical trends in order to price and offer short-term contracts. Alternatively, climate-change modeling is forward-looking, by taking account of long future time horizons.

Scaling up microinsurance schemes (with the ensuing additional costs of ensuring their sustainability), and buffering the systems against increased weather variability from climate-change and ENSO phenomena, are thus major challenges. As such, they offer unique opportunities to the research community involved in development and climate-adaptation.

3. THE MALAWI WEATHER INSURANCE PILOT PROJECT

3.1 Context

Malawi is one of the more food-insecure countries in the Southern African region. In addition to droughts, an AIDS pandemic, declining soil fertility, shortages of land (most farmers have small holdings, from 0.5 to 3 hectares) and inadequate agricultural policies contribute to the country's vulnerability. Life expectancy in Malawi is approximately 38 years, and about 7 million Malawians (60% of its 12 million population) live below the poverty line, the majority in rural areas with more than 80% relying on rain-fed subsistence farming to survive (Action Aid, 2005; Osgood and Warren, 2007). As reported by the UN Food and Agriculture Organization, four percent of Malawians were undernourished in 2003, down from 4.8 percent in 1992 (Skoet and Stamoulis, 2006). Food insecurity is widespread, and evidence suggests that increased droughts and floods may be exacerbating poverty levels, leaving many rural farmers trapped in a cycle of poverty and vulnerability (Action Aid, 2005). UN scientists reported in 2005 that one in six countries is facing a food shortage because of severe droughts that could become semi-permanent (Vidal and Radford, 2005).

As shown in Figure 2, the number of flood and drought disasters in Malawi have increased dramatically since 1970, marked especially by the 1991-92 southern Africa drought that affected over 6 million people and the drought and flood in 2002 that resulted in a severe food crisis. While weather disasters are becoming more frequent, the number of people affected has declined since the 1991-92 drought.

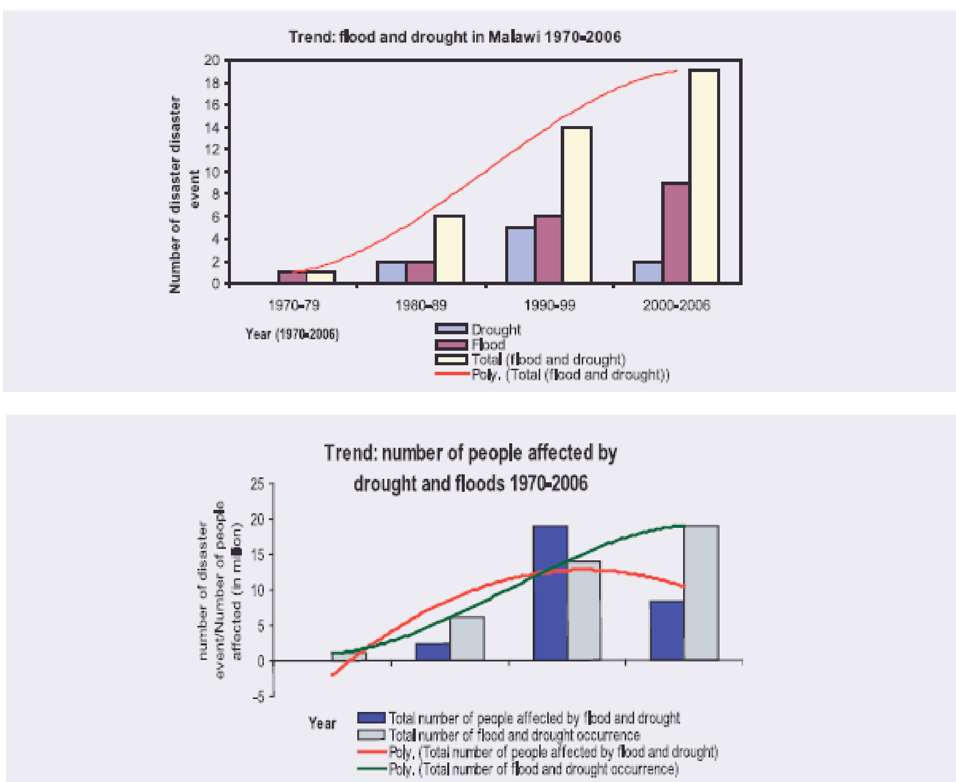

Figure 2: Flood and drought in Malawi 1970-2005. Source: Action Aid (2005)

According to Action Aid (2005, p. 7), "changing rainfall patterns and higher temperatures have forced farmers to shorten the growing season and switch to more expensive hybrid crops. Frequent droughts and floods are eroding assets and knowledge, leaving people more vulnerable to disaster. An upsurge in malaria and cholera requires women to spend more time tending to the sick and less time working their fields." As the weather becomes more variable, adaptation is complicated by increasing uncertainty. Farmers are more uncertain of when and what to plant, and they face limitations in adapting to climate change because of their lack of knowledge, skills and money.

Increasing insecurity with regards to weather is complicated still further by government policies. The staple food in Malawi is maize, and hybrid maize has been supported through a credit scheme that offered subsidized inputs to farmers. When this collapsed in 1994, the share of land allocated to maize fell from 30% to 18% (Simtowe and Zeller, 2006). The removal of subsidies and the privatization of seed companies caused an escalation in prices beyond the reach of smallholder farmers (Action Aid, 2005). According to Action Aid, farmers need skills, knowledge and access to credit for addressing short and long-term needs of diversifying from maize into other crops.

A similar but broader view is expressed by experts from the World Bank (Hess and Syroka, 2005), who point out the strong linkage between food security and weather risk management. According to the authors, the management of drought risk in Malawi involves adapting production, making markets function, establishing effective social safety nets and preparing for food emergencies through ex ante emergency risk management. They claim that Malawi should be a net exporter of food since agro-climatic conditions are relatively good, despite the volatility in rainfall patterns. With incomplete or failed markets (exacerbated by food aid that undermines local markets), remote areas tend to be underserved by traders, especially if traders can expect the government or donors to intervene with free or under priced food supplies. In the past, the government has responded to recurrent drought-induced food crises by providing ad hoc food relief. Functioning markets for storage and financial services are therefore crucial, especially in remote areas. In addition, markets fail in rural areas because of lack of farmers' access to financial services, including loans and agricultural insurance enabling the purchase of needed agricultural inputs.

Droughts not only are a source of risk of food shortage, but also inhibit farmers from planting higher yield hybrid seeds. Smallholder farmers lack traditional collateral and often have a limited credit history, and therefore loan recovery and creditworthiness are directly linked to farmers' seasonal revenues. Because rural banks are reluctant to issue credit to the heavily exposed agricultural sector, farmers cannot obtain the capital to purchase high-yield seeds. Not only is there a high risk of default due to droughts, but banks seeking to diversify their lending portfolio into the agricultural sector are constrained by their inability to manage co-variant drought risk (World Bank, 2005a).

3. 2 Description of the Malawi microinsurance scheme

To address market failures, the Commodity Risk Management Group (CRMG) at the World Bank in collaboration with local stakeholders, and assisted by the International Research Institute for Climate and Society (IRI), piloted a weather insurance scheme in central Malawi for the 2005-06 crop season. The purpose of the Malawi pilot project is to enhance groundnut farmers' ability to manage drought risk and, in turn, access credit (Hess and Syroka, 2005). Bundled loan and insurance contracts were designed to address issues associated with the risk of deficit rainfall during the growing season, and were offered in four pilot areas: Nkhotakota, Kasungu, Lilongwe and Chitedze (see Figure 3). In November 2005, 982 smallholder farmers through their farmer clubs (10-20 members each) bought the weather insurance that allowed their respective clubs to access a loan package for hybrid groundnut seed.

Figure 3: The pilot regions in Malawi: (1) Kasungu, (2) Nkhotakota, (3) Lilongwe and (4) Chitedze, depicted on a map of missing food entitlements in Malawi during the first pilot season (MVAC, 2006).

Malawi's drought insurance project began with a stakeholders' meeting organized by the World Bank in July 2005. According to an account by two of its founders, Daniel Osgood and Duncan Warren (2006), stakeholders realized the potential of the new concept and expressed a great deal of enthusiasm in participating. Groundnut was chosen for the pilot phase of the insurance scheme based on a number of criteria: drought sensitivity; the level and cost of needed inputs; the existence of an organized marketing system; the value of the crop (which needed to be profitable enough to allow farmers to pay off the loan and retain a surplus); and suitability for smallholder farmers (not involving intensive management, complicated processing, or rapid perishability).

Table 1 shows the ratings assigned to groundnut versus other candidate crops. According to Osgood and Warren, the only doubt about the choice of groundnut was the existence of an outside market enabling farmers to sell their harvests to outside traders instead of through NASFAM, thereby jeopardizing loan repayment. NASFAM thus agreed to offer higher prices than other traders. The variety chosen was Chalimbana 2000, a new hybrid that combines high yields with drought resistance.

Table 1: Selection criteria for crops covered by Malawi's weather insurance project (Source: Osgood and Warren, 2007)

Crop	Selection criteria (1=not suitable 5=highly suitable)				
	Sensitivity to drought	Input usage	Marketing system	High value	Suitability for smallholders
Chillies	1	1	4	5	5
Cotton	2	5	3	2	5
Groundnut	5	3	4	4	5
Maize (grain)	5	4	1	1	5
Maize (seed)	5	4	5	5	1
Paprika	3	5	4	4	3
Rainfed rice	Not applicable	3	3	3	4
Irrigated rice	Not applicable	4	4	3	4
Soya	4	2	1	2	4
Tobacco	4	5	5	5	4

The founders of the pilot project were optimistic that the scheme would contribute to reducing poverty of rural farmers. In the words of the local NASFA representative: "With this insurance product, we are creating among farmers the possibility to dream" (Mapfumo, 2006). Or, as the proponent from the World Bank expressed:

> "This is a breakthrough. We want farmers to adopt high return technologies that allow them finally to make the leap and accumulate earnings over time. Correlated risk is **the** factor impeding this ... This Malawi transaction shows that there is a sustainable way to take the big rocks out of the way - drought risks – and clear the path to development!" (Hess, 2005).

Figure 4: Groundnut field in the Kasungu district of central Malawi. The Chalimbana 2000 hybrid variety often yields twice as much output as the traditional variety (photo: P. Suarez).

There are several notable features of the Malawi scheme:

- *Structure and logistics:* The structure of the bundled loan-insurance scheme was designed in collaboration with a multiplicity of stakeholders in a way that engages different players in a sequence of steps aimed at facilitating accountability and clarity. Another important logistical feature is the elimination of cash handling and payments on the part of farmers.
- *Index-based contracts:* In contrast to traditional indemnity-based crop insurance, the contracts are index based, which means that the insurer will pay the contractual claim if rainfall falls below a specified level regardless of crop damage. In other words, index-based insurance is against *events* that cause loss, not against the loss itself (Turvey 2001). Index-based contracts as an alternative to traditional crop insurance have the advantages of greatly limiting transaction costs (from reduced claims handling) and eliminating moral hazard (claims are independent of the farmers' practices). A disadvantage is their potential of a mismatch between yield and payout, or basis risk.
- *Increased productivity:* By enabling farmers to engage in higher productivity agriculture, the insurance program can operate independently of subsidies, and appears thus to be a win-win proposition for all the stakeholders. The farmers expect a substantial net gain, and the market actors foresee a lucrative new market.
- *Donor support:* Although direct premium subsidies are not necessary, the scheme does need assistance for starting up operations. This was provided by World Bank, which sets an important precedent and opportunity for financial and development organizations to reorient from reactive post-drought assistance to pro-active programs that increase resilience;
- *Security against food shortage:* The Malawi scheme does *not* fully protect insured farmers against food insecurity since they receive no cash payouts during

droughts. This is not the case with a similar pilot scheme launched by the rural microfinance organization BASIX in the Indian state of Andhra Pradesh, which provides cash payouts – albeit to higher-income farmers who insure their cash crops and (Hess and Syroka, 2005; Mechler et al., 2006).

These features are discussed in more detail below.

3.2.1. Structure and logistics

The Malawi pilot scheme is a partnership of Malawian and international institutions, including

- *Micro-finance institutions:* Two micro-finance institutions are participating as loan providers: the Malawi Rural Finance Company (MRFC), which was already lending to the smallholder sector, and Opportunity International Banking Malawi (OIBM), a newcomer to the sector. Both expressed interest in drought insurance as a way of safeguarding repayment of their loans. In fact, for OIBM the insurance was the key component that secured its willingness to lend to smallholders.
- *Insurer:* the Insurance Association of Malawi, a consortium of Malawi's leading insurance companies.
- *NASFAM:* the National Smallholder Farmers Association of Malawi is an umbrella association embracing 40 or more local farmers' associations throughout the country. NASFAM aims to develop the commercial capacity of its members and delivers programs that enhance their productivity. All farmers that participated in the pilot insurance scheme are members of a NASFAM club.

According to the scheme's initiators, the Malawi government helped facilitate the project through the active participation of the national meteorological service, which is the source of the climate- and weather-related data and expertise essential for the design and implementation of the insurance scheme (Osgood and Warren, 2007). The data needed for design include historical rainfall and evapotranspiration, together with soil characteristics and agronomic information. Reliable monitoring and timely reporting of rainfall are essential for determining payouts.

Figure 5 illustrates the following overview of the logistics of the Malawi insurance scheme. Once the farmers and their respective clubs agree to join the scheme (step 1), they enter into a loan agreement with the local bank (step 2). When farmers join the scheme, they commit to sell their harvest to NASFAM at the end of the season, thus ensuring a market for their harvest, but more strategically ensuring repayment of the loan. In addition to the loan interest rate, the loan contract incorporates the weather insurance premium, which means that the weather insurance product is "bundled" with the agricultural input loan. The insurance is purchase on behalf of NASFAM clubs (step 3). Farmers then sign a form authorizing the bank to pay NASFAM for the seeds (step 4). NASFAM distributes the groundnut seed to participating clubs (step 5), and is paid for the seed expense (step 6).

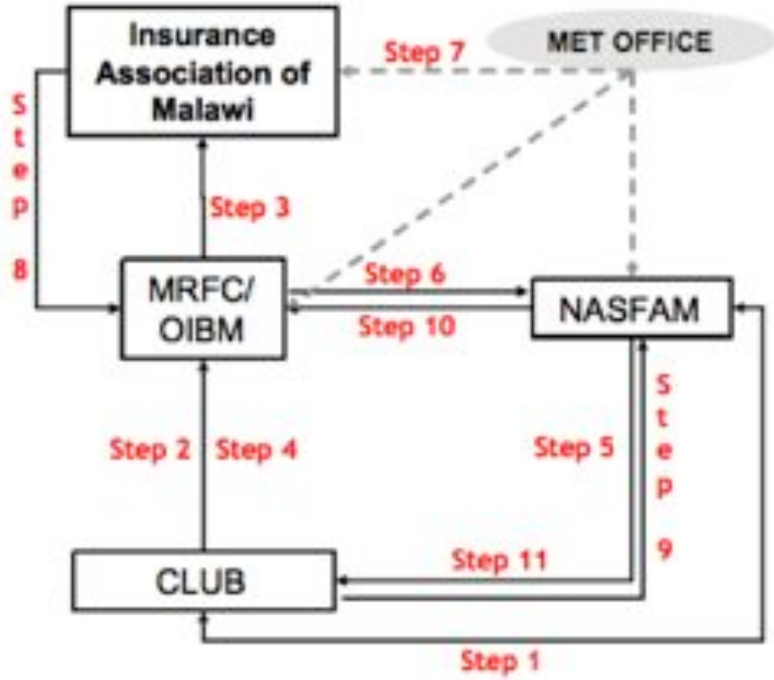

Figure 5: Logistics of the Malawi pilot insurance scheme (source: Bryla and Mapfumo 2005)

After the end of the season, the rainfall information collected by the Malawi Meteorological Service is distributed (step 7). If insufficient rains trigger any of the payouts established in the insurance contract, the corresponding payout is given by insurers to the corresponding micro-finance institutions (step 8). Farmers sell the output to NASFAM (step 9), which in turn pays off loan balance to the bank (step 10). Any additional revenue from the sale of the groundnuts is finally given to the farmers club (step 11).

A notable feature of this arrangement is that, though the farmer signs the loan contract, the actual repayment of the loan is made by NASFAM. When paying for the harvest NASFAM also performs the important role of ensuring loan recovery. This is one of the most important features of this complex arrangement, providing the bank with added security by assuring repayment of the loan.

The bundled contract is signed by individual farmers; yet, if one farmer should default (not deliver to NASFAM) due, for instance, to a bad harvest or financial mismanagement, members of the club are collectively liable to cover the deficit. The club is legally thus a Joint Liability Group (JLG), an arrangement that forms the basis of many micro-credit schemes, and also has a history in Malawi. In the past, micro-credit schemes have been targeted to specific crops, mainly tobacco, that are traded in an organized marketing system that allows systematic recovery of the loans. If anyone defaults, the other members are motivated to pay the deficit since otherwise they lose future access to loans. This arrangement, generally discussed in the microfinance literature as “social collateral” (see for example Brau and Woller, 2004) has worked well, delivering loan recovery rates of at least 95% (Osgood and Warren, 2007). This collective arrangement, aims at reducing the risk of default (which in rural Malawi is high given the relative lack of experience in establishing or enforcing formal contractual obligations).

With the loan in place, the local bank transfers money to (1) NASFAM for its payment to the seed provider and to (2) the Insurance Association of Malawi to cover the premium. NASFAM, in turn, distributes the seeds to the clubs. Note that seed providers play no direct role in this scheme, but provide seeds at the market price. After the harvest, the farmer delivers groundnuts to NASFAM, which pays the farmer the pre-specified price minus the repayment of the bank loan, which NASFAM pays directly to the bank. In the event of a drought (as measured by the rainfall index) and reduced harvest, the loan repayment is partly or fully met by the insurer.

Throughout this process the farmer does not personally purchase the seeds, pay the insurance premium, receive cash payments from the insurer, or pay the bank loan. Except for receiving a net payment for the harvest, the farmer does not handle any cash transactions. This reduces the risk to the bank.

3.2.2 Index-based weather insurance contracts

Traditional multiple-peril *crop insurance*, common in developed countries, indemnifies losses to crops on an individual farm basis. Many observers view crop insurance as a "global failure" since it is plagued by moral hazard (risk of the insured party altering the outcome of the insured event), adverse selection (risk of an overrepresentation of high risk insureds in the pool), and high administrative costs (see Skees et al., 2005). Crop insurance requires significant investment in monitoring farm yields to prevent both higher losses than the initial rating and serious actuarial problems. In the words of Skees, Hazell, and Miranda (2002):

> The financial experience with publicly provided, multiple-peril crop insurance has been disastrous. In all cases, programs are heavily subsidized and governments not only pay part of the premium, but also most of the delivery and service costs.... (quoted in Hess and Syroka, 2005, p.15)

Weather insurance, as an alternative to *crop insurance,* mitigates these added costs. Payouts are determined by an easily quantified parameter (index), such as millimeters of rain. The monitoring costs of weather insurance are substantially reduced since the physical-trigger basis avoids individual assessment of crop damage, and the balance of information about the weather is equally shared by the insured and insurer (avoiding adverse selection).

In Malawi, the insurance payout is tied or "indexed" to rainfall as measured at four weather stations operated by the Malawi Meteorological Services, each located centrally to the insured regions. Since the primary risk to groundnut in Malawi is drought during critical growth periods, the contract specifies three levels of rainfall that trigger payment. These levels take into account the different rainfall needs during the three major phenological stages of the plant, "establishment and vegetative growth", "flowering and pod formation", and "pod filling and maturity". If rain is above a certain level (e.g. 60 mm during the "establishment and vegetative growth" or germination stage), then there is no insurance payout, and the insurer retains the premium. If rainfall is below the critical amount for crop survival (e.g. less than 30 mm during germination), then the insurer pays the bank the full amount of the loan, and the farmers are no longer liable for payment. If rainfall lies between these critical parameters, the portion of the loan paid by the insurance company is determined by interpolation. The contract also contains a "no sowing condition," which triggers a payout if a minimum level of rainfall is not received in order for the farmer to successfully sow the plant during the contract's initial stages. Note that the index does not take account of agricultural risks from other sources, for example, price fluctuations, pests or civil strife.

Since the farmers targeted by this scheme typically do not have legal title to their land, the insurance is used to guarantee the loan by requiring the farmer to purchase insurance so that the maximum liability is equal to the loan size including interest. The package is unitary, that is a farmer can only purchase the entire package or nothing. The farmer cannot purchase partial packages or multiple packages.

In the first operational season of this scheme, three of the locations experienced rainfall above the trigger level. The fourth location (Kasungu district) received rainfall slightly below the trigger and consequently there was a small insurance payout.

3.2.3. Increased productivity

Although the insurance premium and loan interest make up a significant percentage (approximately 10%) of the farmers' expected revenue (in the case of no drought), the farmer can still expect a substantially higher net profit than is the case with conventional cropping. The economics of the scheme in financial terms are detailed below and summarized in Table 2.

In its first year of operation, each farmer from the participating clubs received 32 kg. of hybrid groundnuts worth a total of 4,000 Malawian kwachas (MKW), or about 28.8 US dollars (US$ 1 = 140 MK)[6]. This amount of seed suffices for about half an acre (or 0.2 hectares), usually only a small part of the participating farmer's total cultivated land. In a good season, a kilogram of hybrid seed produces around 10 kg. groundnuts, so the farmers can expect to harvest about 320 kg. groundnuts. The guaranteed purchasing price that NASFAM offered farmers was US$ 0.32/kg, with the possibility of a negotiated higher price depending on post-harvest conditions. Given the price offered by NASFAM, in a good season the farmer expects to receive US$ 102.40 (14,000 MK) from the hybrid seeds.

The farmers' expenditures include the loan principle to cover the cost of seeds (US$ 28.80), the loan interest (US$ 7.12), insurance premium (US$ 2.16) and processing fees (US$ 0.53). Insurance premiums were significantly less than the approximately 33% interest (17-25% inflation rate) charged on the loan. If no drought occurs, the farmer can thus expect a net revenue of approximately US$ 63.78. In the case of severe drought (maximum payout), the insurance covers the loan, interest, insurance premium, and tax. Thus the farmer will have no out-of-pocket losses (only the opportunity loss of the failed crop).

Table 2: The economics of the insurance/loan/seed package

Insurance/loan/seed package	US$ Hybrid seeds	US$ Traditional seeds
Expenditures		

[6] This was the approximate exchange rate at the time of initiating the pilot project. The annual inflation rate in Malawi is usually between 17 and 25%.

32 kg groundnut seed	28.8 (US$ 0.90/kg)	10.24 (US$ 0.32/kg.)
Insurance premium	2.16 (7.5%)	0
Interest	7.12 (33% per annum, 9 months)	0
Tax and processing fees	0.53	0
Total expenditures	38.62	10.24
Expected revenues		
Sale of groundnuts	102.40 (320 kg at US$ 0.32/kg.)	40.96 (128 kg at US$ 0.32/kg.)
Net gain/loss		
No drought	**63.78**	**30.72**
Severe drought	**0**	**-10.24**

Sources: Osgood and Warren, 2007; own calculations.

This can be compared to planting the plot of 0.2 hectares in traditional seed, which are stored from the previous harvest. The cost of traditional seeds can be assumed thus to be the harvest groundnut price of $0.32/kg. The costs for planting the plot are therefore $10.24. A trial study in Malawi demonstrated that the ratio between Chalimbana groundnut seeds (traditional variety) and improved varieties such as CG7 is between 0.4 and 0.5 (Freeman et al., 2002). According to a NASFAM expert, the traditional groundnut seeds are only about 40% as productive as the Chalimbana 2000 hybrid seeds (Masankha 2006), which means that for a participating farmer the expected crop would be about 128 kg. of groundnuts. Assuming the same guaranteed price, this compares to an expected gross revenue of about US$ 40.96. The net revenue in a good year is then US$ 30.72 (compared with US$ 63.78 with the hybrid seeds), but there are no insurance cost losses in a bad year.

In sum loan-insurance package clearly offers the farmer a much improved alternative:

- If rains are good and no pests or other threats affect the hybrid groundnut crop, farmers can expect substantial economic benefits by joining the insurance scheme, more than doubling net gains.
- If rains are insufficient, the farmer can rely on the insurance to repay part or all of the loan principle. In the case of severe drought and full crop loss assumed by the crop model estimates, participating farmers experience no net loss, compared to the loss of around US$ 10.24 if they used traditional, non-hybrid seeds, and no weather insurance.

3.2.4. Donor support: local and international

There are significant start-up costs for this insurance pilot program. A weather station, for instance, requires an investment of about US$ 10,000, a cost that might be reduced with the development of satellite technology for monitoring rainfall. The Malawi program was possible because of the long existence of weather stations and thus reliable historical data on rainfall. Another start-up cost is the requisite technical risk assessments, which according to some experts can cost hundreds of thousands, if not millions, of dollars. Risk assessments for small drought schemes with good historical rainfall data are less resource intensive, and the Malawi scheme benefited greatly from technical assessments carried out by the Commodity Risk Management Group (CRMG) at the World Bank.

Not only did the CRMG produce the technical risk assessments, but the staff provided valuable expertise in structuring and pricing the indexed insurance contracts (Malawi insurance companies lack the expertise to develop this kind of product). Moreover, NASFAM, which is legally an NGO, played a decisive role by communicating with farmers' clubs and arranging all the logistics pertaining to the purchase of seeds, payments for the harvest and the loan repayment. The scheme is thus a three-fold partnership, including the bank/insurer, an NGO, and a donor.

It is notable that, although covering the start-up and administrative expenditures has constituted a substantial indirect subsidy, the Malawi scheme has not required direct subsidization. The reason is that the costs of the insurance package are more than covered by the increased revenues the farmers expect to receive from the hybrid-crop harvest. At first glance this is non-intuitive since most insurance contracts imply a tradeoff between security and income – in this case both are enhanced. Moreover most insurance contracts are at risk of moral hazard, or the agent taking riskier and costly behavior (e.g., driving recklessly), but in this case the changed behavior (planting higher yield crops) is a positive outcome.

3.2.5. Providing direct security against food shortage

If the Malawi program were broadened to offer benefits beyond loan guarantees, particularly to provide cash payments to farmers during severe droughts, it is questionable whether it would remain affordable. It should be kept in mind that the insurer's liability is only to cover the costs of the seeds – not the lost revenues from a drought-reduced harvest. The latter would add significantly to the costs of the insurance. Moreover, if the scheme is scaled up to include additional systemic risks, it will require reinsurance or other backup capital and thus raise premiums to the farmers.

Ensuring that the Malawi scheme, and others like it, remains affordable when broadened and scaled up presents an opportunity for donor organizations and the climate-change adaptation community. A donor-supported global insurance facility could provide the necessary support in terms of technical support, subsidies and/or reinsurance that would allow climate-insurance schemes to provide security to smallholder farmers on a wide scale. This is an opportunity for donor and other organizations to reorient from post-disaster humanitarian assistance to pre-disaster risk pooling and transfer. There are many advantages to this reorientation (Linnerooth-Bayer et al., 2005). Donor-supported risk-transfer programs would not only leverage limited disaster aid budgets, but would also free recipient countries from depending on the vagaries of post-disaster assistance. Both donors and recipients stand to gain, especially since if instruments can be closely coupled with preventive measures and increased productivity.

3.3. Challenges and risks

Despite its merits, there are significant challenges of the current Malawi program, many of which were revealed from experience gained from the first year of operation. The system has been carefully designed to reduce risks common to agricultural insurance schemes serving low-income clients, namely risks associated with moral hazard, falsified claims and default on loan repayment. As discussed previously, index-based systems avoid moral hazard, or the inclination of clients to take fewer precautionary measures because they are insured – in this case protection of crops against drought. Since claims are independent of crop damage, farmers retain incentives to avoid drought-related losses. Moreover, there is no danger of falsified claims. Finally, also as discussed previously, the risk of default is minimized by peer pressure within clubs and by NASFAM taking responsibility for the bank payment based on the crop sale agreement.

The first year of operation, however, showed that risks remain. To begin, the system depends on the higher productivity of the hybrid seeds; yet, the seeds purchased and delivered by NASFAM were defective (inadequate storage on the part of the commercial provider resulted in a low germination rate). NASFAM quickly and credibly responded to the seed crisis by obtaining and delivering superior seeds within time for planting.

Price volatility is another important issue. The farmers' agreement to deliver their harvest to NASFAM, thus enabling repayment of the loan, is also an important feature of the system. Farmers may be reluctant to honor this agreement if the market price at the end of the season is higher than the price negotiated with NASFAM before planting, as was the case at the close of the 2005-06 season. Farmers' expectations were high, and they anticipated negotiating a higher price for their crop (50-55 MK/kg. vs. the pre-agreed 45 MK/kg.), also because of the expected high price of seed for the next planting period. This raises the issue of so-called 'side-selling' – farmers marketing to opportunistic traders who offer a higher price than NASFAM. Although groundnut seed prices rose sharply as the 2005-06 season progressed, eroding the premium offered by NAFSAM. According to Osgood and Warren (2007), only few farmers broke their contract with NASFAM, but the incident revealed that the insurance-loan package may be vulnerable to contract violations. NASFAM responded to this challenge by offering to reimburse anyone who had sold early to the association with the difference between the price paid and the higher price obtaining at the end of the season.

The collective liability of clubs was also strained, particularly for those farmers who were compelled into forming new clubs in order to access the loan offered by the pilot scheme. Apparently, the liability arrangements worked best for clubs that were naturally self-selecting and socially cohesive (Osgood and Warren, 2007).

Hindsight also demonstrated the risks associated with overdependence on NASFAM. It can be recalled that a notable, and rather unique feature of the Malawi project, was NASFAM's role of ensuring loan recovery by deducting the loan, adjusted for any insurance payout, from the cash payments to the farmers resulting from their harvest. This was one of the most important features of this complex arrangement, providing the bank with added security by assuring repayment of the loan.

NASFAM played a critical role, one which was dependent on a trusting relationship of the farmers with this organization. Without this trusting relationship, the insurers, banks, and farmers clubs would likely not have taken on the risk of this bundled loan/insurance package. The negative aspect of this overdependence is its vulnerability; if the stakeholders lose trust in the organization, the entire system is jeopardized. Some members of NASFAM field staff have expressed concern about their institutional capacity vis-à-vis the growing demand from farmers.

There was also disappointment regarding the insurance payout, which demonstrated an incomplete understanding of the loan conditions on the part of the farmers (see Section 4.1). In one pilot area, claim payments had been triggered by slightly deficient rainfall. As pro-rated, the insurance payout was low (only about 80 MKW ($0.86) out of a total of MKW 5,625 owed to the bank by each farmer). If payouts do not meet expectations, there is a risk of farmers leaving the program in the next planting period.

There are also risks on the part of the insurer, who is relied upon to make payments to the bank in the case of drought. While no problems were encountered in the first year of operation, bank officials expressed concern about the insurers' ability to pay in the case of extreme drought.

Finally, a potentially serious problem with index insurance systems is basis risk, in this case if a farmer's rainfall is not closely correlated with rainfall at the respective weather station. To minimize this risk, only farms within 20 km of the weather stations were eligible to join the program. Still, upon visiting two fields with participating farmers from Kasungu, about 7 km apart, it was reported that the rain had been quite different and in both cases much lower than that measured at the weather station (located at the local airstrip). At the end of the 2005-06 season, the farmers expressed concern that the rainfall data used to determine payouts were from a single rainfall station. As a result some farmers were winners and others losers, as rainfall on their farms differed from that at the station. This basis risk is one of the major challenges facing the design and implementation of index-based insurance in heterogeneous rainfed environments.

3.4 Outlook: Scaling up the Malawi program

While the Malawi pilot program in its first year of operation raised many challenges, practically all the farmers involved were reportedly keen to participate again in the second year, and demand from new farmers greatly outstrips the capacity of the project to enroll, educate, and manage them (Osgood and Warren, 2007). Many farmers reported that signing up for the insurance scheme is their preferred way of adapting to climate variability and change.

The pilot scheme has recently been extended for its second year of operation. The number of farmers participating in the insurance scheme increased from 892 farmers in the first pilot to 2536 in the second season, and the geographical scale expanded to an additional pilot area, Tembwe, based on the Mchinji weather station. To date, as the second pilot season comes to a close, the system is functioning smoothly. Inputs were delivered on time, germination rates are very high, and most participating farmers are expecting an exceptionally good harvest.

Several important changes and additions to the scheme have been incorporated (Syroka, 2007), including:

- Hybrid maize has been added to the second pilot season, in response to farmer demand. Participating farmers are required to grow groundnut in order to access a loan for maize package (seeds + fertilizers);

- The lending rules have been strengthened. Moreover, up-front deposits are now required on all loans;
- Inputs are provided by NASFAM, but farmers will be able to sell their outputs to different buyers, which will be chosen by the Group Action Committees (agglomerations of NASFAM clubs from the same area).

4. FARMERS' VIEWS ON THE MALAWI PILOT PROJECT

This chapter reports on a household survey of farmers' views, discussions at focus group meetings, and interviews with NASFAM representatives, focusing on their perspectives on the performance and future viability of the project. The survey, focus groups and interviews were carried out between August 2005 and October 2006, and thus reflect mainly the views on the 2005-06 pilot program.

4.1. Household survey

Section 3.3 highlighted some of the risks posed to the pilot insurance scheme, which included the incomplete understanding of the scheme and the possible lack of trust among participating farmers in the responsible institutions. For the purpose of gaining insights on the farmers' perceptions and understanding of the pilot project, a household survey was carried out during October 2006 (after the harvest of the groundnuts from the first pilot) in the districts of Lilongwe (with the largest number of participants in the first pilot) and Kasungu (the only location where insufficient rains led to a payout by insurers). The survey instrument was designed in collaboration with NASFAM, and representatives from the participating financial institutions were invited to include questions that could improve their understanding of the clients of the bundled credit-insurance package.

A random sample of 200 farmers was targeted based on the list of clubs that had participated in the first pilot (2005-06 season). It is important to highlight that the farmers invited to join the first pilot were selected by NASFAM based on their credit history and past performance in other NSAFAM initiatives, and are therefore not necessarily representative of the rural population in the region. A local consulting company was hired to carry out the training of enumerators, translation, testing and revision of the survey instrument, interviews with farmers, and data entry.

Unfortunately, a number of logistical and implementation problems on the field resulted in an actual sample that did not meet the standards called for by this research project. A key issues was the non-availability of club members who had migrated, were traveling or had deceased, as well as reported cases of farmers who had defaulted on MRCS loans and believed that the survey enumerators were actually debt collectors (thus avoiding them or leaving the area altogether). As a result, only 168 farmers were interviewed (131 in Lilongwe, and 38 in Kasungu). The sample may be biased (particularly due to the exclusion of defaulting participants), making it impossible to obtain reliable hypothesis-testing results through tests of significance. Nonetheless, the data allows for a first-order description of farmers' perceptions about the weather insurance scheme and related issues.

4.1.1. Understanding of index-based weather insurance scheme

Several survey questions aimed at eliciting participating farmers' understanding of the bundled credit-insurance scheme. Results indicate that there is a need to substantially improve the communication process. Only 55% of respondents reported understanding the scheme before joining it. When asked what aspects of the insurance scheme were not sufficiently clear, 43% mentioned the price of groundnuts sold after harvest as being among the top two aspects, 36% mentioned the cost of interest, 35% mentioned the extent of the insurance pay out (claim payments) , and 25% mentioned the timing and conditions of the insurance payments. In the case of Kasungu, only 5% identified "insufficient rains at weather station" as what had triggered insurance payouts (which is the correct answer for this index-based scheme), compared to 26% answering "insufficient rains on plot", 31% answering "crop failure", and 38% not knowing.

With regards to the cost of the different components of the loan, 75% reported knowing what was the cost of the 32 kg of groundnut, compared to 55% for the cost of the insurance premium and only 14% for the cost of the interest charged by the bank. Many of those who reported knowing the cost actually gave a value that was substantially different from the actual value (this was particularly true for the insurance premium).

4.1.2. Trust

Farmers were asked to indicate who (what) they trusted the most and the least in the insurance scheme Table 3 summarizes the answers.

Table 3: Reported most and least trusted elements of the scheme.

	Trust the most (%)	Trust the least (%)
Rainfall measurements	1	27
Club members	12	3
NASFAM	46	30
Insurance company	10	11
Lending institution (OIBM or IFRC)	23	15

It is worth noting the very low trust in the rainfall measurement: over one fourth of respondents think that this crucial component of the index-based insurance scheme is the least trustworthy. NASFAM itself is by far the most trusted institution in the scheme for almost half of respondents, although it is also considered the least trustworthy by almost one third.

In Lilongwe, according to the rainfall station measurements, the season had provided sufficiently abundant rains (in the field however, spatial variability in rainfall had resulted in relatively weak harvests for some participating farmers). 59% of respondents from this site considered themselves to be entitled to a payout. Of these, only 9% considered their lack of reimbursement to be due to the difference in rains between their plot and the weather station: 43% placed responsibility on the unreliability of NASFAM, and 14% on the unreliability of the insurance company.

Given the major role played by this farmer organization in the implementation of the insurance scheme, it is important to ensure that trust in key institutions is not compromised. A better explanation of basis risk during the marketing stage can help in this regard.

4.1.3. Perceptions about the insurance scheme

When asked why they had joined the pilot scheme, 26% of respondents indicated that the most important reason was access to credit or to better seeds, and 10% reported wanting to grow more groundnuts, compared to just over 9% who cited protection of the loan. This result highlights the fact that, in this scheme, the insurance component is mostly perceived as a means to access the loan, and not so much as a risk sharing mechanism intended to ensure repayment of the loan. Other answers included advice from NASFAM or other farmers (15%), and risk reduction (22%). Since 83% of respondents said that the improved groundnut seed provided by the scheme is more resistant to drought and dry spell than the traditional groundnut seed, "risk reduction" probably refers to the reduced risk of crop failure in case of dry conditions.[7]

The best evidence supporting the claim that this pilot initiative is considered desirable by participating farmers is given by answers to the question "will you want to join the insurance scheme next season?": over 86% of respondents answered positively. Two thirds of respondents indicated that they had encouraged other farmers to join the scheme next season, and 62% answered that they will be better able to cope with drought and food shortages if they are in the insurance scheme (21% said they would not be better, and 18% didn't know).

Farmers were also asked what they would most like to change if the insurance scheme were implemented again. The most often cited aspect was the price of groundnuts sold after the harvest (37%). The timing of the delivery of seed was chosen by 13% of respondents, and when the insurance has to pay farmers was selected by 10%. The cost of premium was selected by 9% of respondents, and the issue of how much the insurance has to pay was top priority for 7%.

4.2. Focus groups with farmers

During May and September 2006, a series of meetings were held in Lilongwe and Kasungu sites with groups of farmers that had joined the first pilot (mostly representatives from participating NASFAM clubs). Overall the availability of the bundled credit-insurance insurance was welcomed as a positive development, chiefly because of improved access to credit for seeds and not so much for the insurance component. Indeed, many farmers didn't know the details of the payment structure: All they knew was that if rains are bad, the insurance should pay the loan.

[7] Chalimbana 2000 is a semi banched variety, which makes it not lose of water (unlike traditional Chalimbana which is a runner). Chalimabana 2000 can escape terminal dry spells occurring toward the end of the season because it matures earlier (traditional Chalimbana has a slow growth rate). However, no scientific study has been carried out carried out on physiological characteristics of the two varieties to differentiate their response to drought (Masankha 2006).

Figure 6: Focus group at Chitedze site (photo: J. Chirwa)

There was very limited understanding of the exact relationship between rainfall and payment (as a matter of fact, the very concept of "millimeters of rain" seemed foreign to them). When these issues were explained with adequate time and giving farmers the opportunity to ask questions, they fully understood and successfully calculated insurance payouts for different rainfall deficit scenarios. Many participants felt sufficiently comfortable with the new knowledge as to express the desire of being in charge of explaining the details of the scheme to fellow farmers. This points to the possibility of a peer-to-peer communication approach, assuming adequate training can be provided.

Many participants expressed that they would want to have the scheme expanded to other crops, chiefly maize and tobacco (and to a lesser extent cassava and soybean).

The complaints most frequently raised during these meetings included (i) cost of interest (ii) insufficient payment from insurance, (iii) timing of the delivery of seeds (too late into the season), and (iv) low germination of groundnut seeds given to participants. The last issue was not 'caused' by the scheme's architecture, and farmers recognized that NASFAM had worked intensely to address the germination problem (getting the seed provider to deliver replacement seed, a solution that would have been much more difficult to implement by individuals or clubs acting independently).

Farmers also raised basis risk as an issue. Because rain at the weather station was often perceived to be better than at farmer's plot, many requested that rain gauges be installed closer to their club. When explained that in other years the difference may work in their favor several farmers expressed understanding that the insurance payment is determined by what happens at the distant weather station, but they would expect a more fair deal. Nonetheless, all participating farmers declared they wanted to participate again in the scheme.

4.3. Interviews with NASFAM

Representatives from this NGO (both at headquarters and at district level) indicated that limited access to credit is one of the major obstacles to rural development, and that farmers greatly welcome the opportunity of qualifying for loans. Even when they may have enough money to purchase inputs, they often prefer to keep the cash for school fees, health expenses, funerals, clothes and other expenses.

According to NASFAM representatives the general structure of the scheme could be improved for upcoming seasons. It would be opportune to expand to other crops, in part to diversify drought risk (different crops do relatively better with different rains). Reducing premiums would be another important step. One way to accomplish this would be to consider including commercial farmers, who represent only a small fraction of the farming population and own about 30% of arable land. Another issue is lack of competition among insurers: if more companies join the scheme, premiums will likely decline. Additionally, the representatives believe that premiums should be shared by farmers and the bank, not borne exclusively by farmers ("if insurance is to protect the loan, why should farmers pay it all?"). Interest rates should be brought down as well, since drought risk is so reduced. NASFAM will aim to negotiate for reduced costs to farmers. The general opinion was that all of the above is more likely to happen when the pilot is scaled up, resulting in more trust and more bargaining power for NASFAM.

When it comes to scaling up the scheme, a key aspect of success will be to screen recipients of loans, in order to reduce risk of default. Another challenge is the need to reduce basis risk: a radius of 20 km from the weather stations may be too much for Malawi's diverse topography. Widespread illiteracy may pose a serious problem for attempts to reach a larger number of farmers in future seasons: expanding the scheme too rapidly may lead to inadequate marketing, miscommunication, misunderstandings, and consequently loss of trust.

A long-term concern for NASFAM is that financial institutions may try (and succeed) to make weather insurance obligatory for farmers to access credit. This is perceived to be wrong in principle: if someone has other forms of sharing risk (e.g. through family network), or can reduce drought risk (e.g. through irrigation), why should the loan for improved seeds be contingent on paying a weather insurance premium? There is also the risk that obligatory insurance would drive up the price, making it unaffordable for many subsistence farmers who should be a priority of this kind of scheme, and therefore reducing their access to choices of improved seed varieties.

4.4. Summary

The results of the household survey, focus groups and interviews are probably not representative of the 982 farmers who participated in the Malawi pilot scheme, but they nonetheless do provide some indication of farmers' views and concerns about the insurance program, and point to possible revisions. These can be summarized as follows:

- *There may be a need to substantially improve the communication process.* It appears that many participating farmers do not fully understand the index-based system.
- *It might be beneficial to include farmer club representatives in monitoring the weather station data.* Over one fourth of respondents considered this crucial component of the index-based insurance scheme to be the least trustworthy.
- *Diversification of responsibility for the logistics of the system might be considered.* Although NASFAM has played a critical role in the logistics of the program, winning the trust of the majority of participating farmers, the low trust

rating on the part of the minority points to the fragility of the dominance of one single institution.

- *It is important that farmers fully agree to accepting basis risk.* Most of the survey respondents were not fully aware of basis risk, nor fully accepting it. Without this awareness, the system may lose its legitimacy to the participants. Farmers participating in the focus groups easily grasped the concept.
- *If adequate markets for the agricultural products exist, it may be advisable to allow farmers a choice of where to sell their output.* The farmers voiced concern about restricting sale of their output NASFAM through the pre-arranged agreement. A non-restricted strategy may jeopardize repayment of the loan (now the responsibility of NASFAM), but experience in Malawi, and elsewhere, shows that joint liability will substantially reduce this risk.

5. INTEGRATING SEASONAL FORECASTS AND INSURANCE FOR ADAPTATION AMONG SUBSISTENCE FARMERS

5.1 Introduction

Southern Africa is particularly vulnerable to climate variability and change. Droughts, which are strongly related to ENSO in many areas within the region (see Figure 7), are expected to become more frequent and intense under a changing climate (Hewitson and Crane, 2006, IPCC, 2007). This poses a major risk for the subsistence agriculture sector, which is the main source of livelihood for the majority of the population in this region. While development initiatives can certainly help farmers cope with droughts, the increased risk of disasters associated with climate change needs to be integrated into more robust development planning initiatives (World Bank, 2000; van Aalst 2006), and climate predictions can play a role.

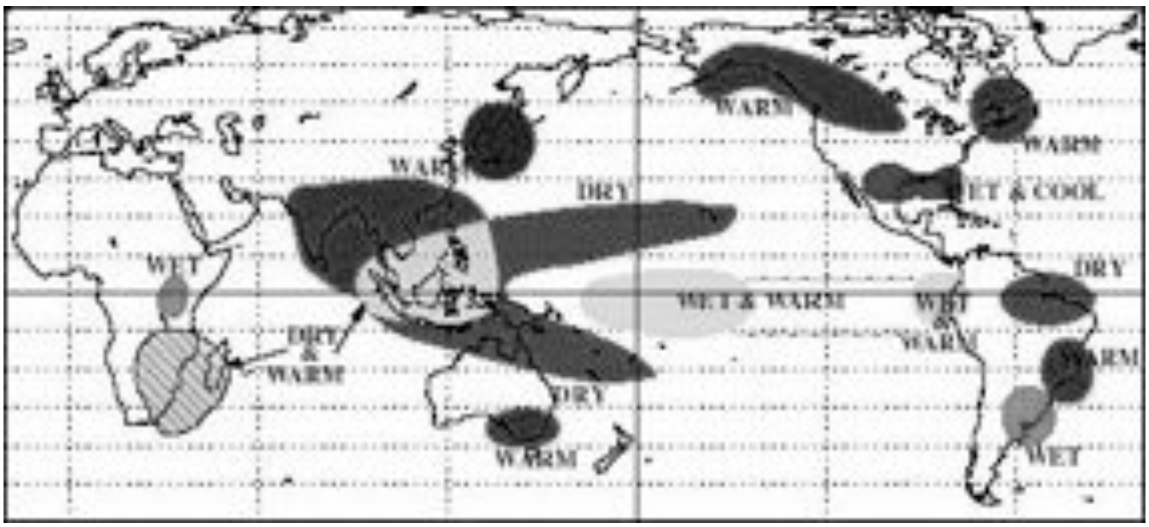

Figure 7: Typical influence of El Niño-Southern Oscillation (ENSO) events on the global climate, December to February. (International Research Institute for Climate Prediction, 2003)

Even though there is a significant relationship between the ENSO phenomenon and seasonal rainfall in Malawi, the pilot insurance scheme does not take ENSO-based predictions into consideration. Premiums, payouts and other insurance parameters are set independently of the interannual variability in probability of drought occurrence. Similarly, the kinds and amounts of agricultural inputs to be loaned to farmers through credit do not reflect expected seasonal rainfall, even though they are given to farmers at a time when the seasonal forecast is already available.

Forecasts have not played a role in the structure and pricing of index-based weather insurance contracts in the first two years of piloting in Malawi. Seasonal forecasts for both the 2005/2006 and 2006/2007 seasons did not show a higher probability of a wet or dry season for either year and, together with the operational constraints and limitations of launching a pilot, there was no impetus to consider the forecast issue and how it could be incorporated into the program. Yet, since a drought forecast will eventually materialize, it is necessary to define how the change in probability of loss will affect the insurance price

– a conventional approach to risk-sharing products (Wang et al., 1997; Tsanakas and Desli, 2005).

Additionally, at least three issues may have contributed to the exclusion of forecasts into the structure and pricing of the scheme: (i) the perception that ENSO-based forecasts may lack sufficient skill, (ii) the risk of asymmetric information between insurers and farmers generating inequitable deals or adverse selection, and (iii) the possibility that high variability in demand (associated with changing contract conditions across seasons) may complicate the insurers' management of capital stocks and flows.

Car theft insurance can encourage the reduction of theft risk if premiums are reduced for those who install an anti-theft alarm system in their car (Grabosky, 1998). Kleindorfer and Kunreuther (1999) examine the impact that insurance coupled with specific risk mitigation measures could have on reducing losses from hurricanes and earthquakes. We are interested in a similar goal: using the bundled loan-insurance concept to stimulate among Malawian farmers a set of climate-sensitive production choices that can reduce their long-term drought risk. The purpose of this paper is to explore the potential integration of seasonal rainfall forecasts into weather insurance schemes, promoting risk reduction through risk sharing mechanisms, with the Malawi pilot as a case study.

We propose a model that ties the forecast to the magnitude of the loan (adjusting the amount of high-yield agricultural inputs given to farmers to favorable or unfavorable expected conditions), maintaining the insurance premium constant across seasons. Simulation results, combining climatic, agricultural and financial models, can help assess whether this approach substantially increases production in La Niña years (when droughts are very unlikely for the study area), and reduces losses in El Niño years (when insufficient rainfall often damages crops.

The remainder of the paper is structured as follows: Section 5.2 presents a basic overview of seasonal climate forecasts in southern Africa and their potential role in reducing risk. Section 5.3 discusses challenges and opportunities for integrating forecast-based risk reduction approaches into risk sharing mechanism like the Malawi pilot. Section 5.4 outlines a proposed approach to such integration, presenting the models used to simulate the climatic, agricultural and financial dimensions of such approach, as well as model results. Section 5.5 concludes, highlighting implications for risk management and climate change adaptation.

5.2 ENSO, seasonal climate forecasts and risk reduction

An El Niño – Southern Oscillation (ENSO) event can be described as an anomaly in sea surface temperature and atmospheric pressure in the tropical Pacific Ocean that occurs roughly every four to seven years, changing circulation patterns across the planet. ENSO is the major single source of climate variability on seasonal-to-interannual scales. There is abundant evidence of the relationship between El Niño events and precipitation patterns in various regions of the globe, including Southern Africa (Glantz, 2001). Seasonal climate forecasts based on ENSO, while limited in their skill, have the potential to help millions of people (Murphy et al., 2001). By providing a probability distribution indicative of what weather the coming year may bring, people can plan ahead and reduce risk.

Climatic information can play a crucial role in reducing risk of food insecurity: If a seasonal precipitation forecast indicates that a drought is likely to strike a certain area, this information can facilitate the process of delivering food aid in time, or help farmers choose a drought-resistant crop variety (resulting in larger food stocks in rural households). Similarly, a seasonal forecast suggesting high likelihood of good rains can help reduce the long-term vulnerability of subsistence farmers. For example, if they can implement sustainable, high-yield farming practices, farmers can increase production and accumulate wealth. This can help reduce future risks by making farmers more able to withstand the negative impact of future droughts on agricultural production. A review of studies addressing seasonal forecast use in Africa is available in Patt (2007).

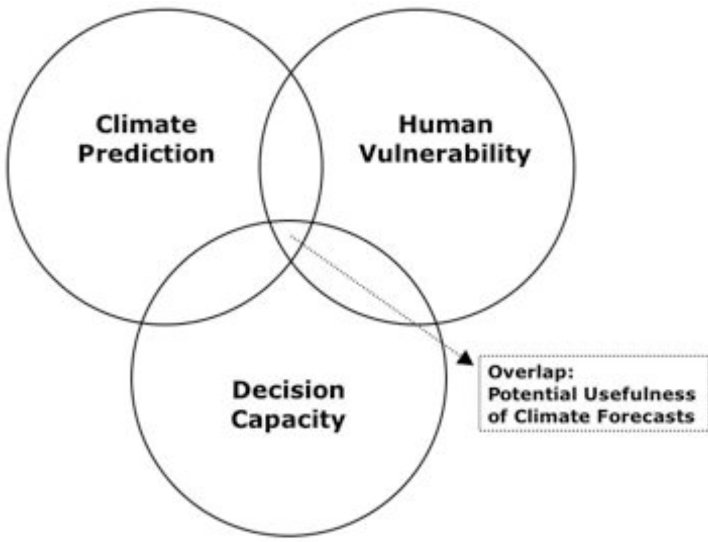

Figure 8: Hansen's (2002) diagram relating climate predictions, decisions and vulnerability.

Hansen (2002) presents a simple illustration depicting the determinants of the potential for human populations to benefit from climate predictions (Figure 8).

Human Vulnerability captures the elements of the human system that are susceptible to harm as a result of climate phenomena. *Climate Prediction* refers to the climate phenomena that are predictable; i.e. their causal processes are understood to the extent that available information at time t allows us to anticipate their probability of occurrence at time $(t + \tau)$. *Decision Capacity* refers to the decisions that a human system is capable of actually making in order to improve its future state; i.e. the deliberate interventions that can be chosen by the system and are compatible with the goals, resources and constraints of decision makers. Forecasts can be useful where these three determinants coexist in space and time - in other words, where the circles in Figure 8 overlap. This paper focuses on vulnerable systems that could benefit from climate predictions but lack the decision capacity to do.

There have been attempts to communicate climate predictions to farmers through agricultural extension services, but the communication infrastructure is not adequate in communal rural areas, and few farmers have incorporated the forecasts into decision making so far (Phillips et al 2001). A pilot intervention in four Zimbabwean communities demonstrated the benefits of communicating seasonal forecasts to subsistence farmers through participatory workshops: subjects who reported adapting their farming methods to ENSO-based predictions significantly increased their harvest by up to 18.7% (Patt et al 2005). This increase was largest when the forecast anticipated relatively low chances of a drought, promoting the use of high productivity choices.

Scaling up this participatory approach through existing institutions will not be an easy task, in part because organizational capacity is usually overstretched among agricultural extension officers and other potential workshop facilitators (see for example Suarez et al (forthcoming)). There are also a number of constraints that farmers face when attempting to use climate predictions, and these constraints operate differently on farmers depending on their cultural, social and economic characteristics (Patt and Gwata, 2002). It can be argued that more vulnerable farmers are less likely to be embrace and use the forecasts in a meaningful, positive way: As stated by Nicholls (2000), most producers are restricted in their flexibility to respond to forecast information; the poorer and more vulnerable the producer, the greater the restrictions to decision capacity. The differential effect of communicating climate information without adequate planning can have profound effects on the distribution of benefits –and costs. Roncoli et al. (2001) document how adjustments to droughts in Burkina Faso entail costs and risk for most farmers, but also gains for those who have the resources to take advantage of distress sales and high prices of agricultural commodities.

Seasonal forecasts can also affect subsistence farmers negatively. If there is a forecast of drought, banks have a history of restraining credit for farming inputs, so that even drought tolerant crops become impossible to grow. Farmers sometimes misunderstand the forecast, and make misguided decisions on the basis of what they erroneously believe (Patt, 2001). Phillips et al. (2002) investigated the implications in aggregate of a widespread response to climate forecast information using data from Zimbabwe during the 1997-98 El Niño, when the official forecast for a poor rainy season was broadly disseminated, decreases in area planted were observed, and actual rains were better than anticipated. They show that the impact of a forecast of drought conditions could decrease production below that which would result from behavior without a forecast, while also noting that this negative impact in poor rainfall years can potentially be balanced by the increases in long-term production. The question then is how to distribute this production advantage over time, so that it can act as a form of insurance for the years in which production drops (for example through increased storage capacity or financial mechanisms). They suggest that, if forecasts are widely disseminated and adopted in the future, appropriate market or policy interventions may need to accompany the information to optimize societal benefit of climate forecasts.

5.3 Integrating risk sharing and risk reduction

While the current Malawi scheme does not take into consideration the predictability of seasonal rainfall, a strong ENSO signal developing before contracts are finalized could threaten the continuity of the scheme. If an El Niño event begins to develop and dry conditions become more likely, insurers would likely increase the premium to address the changing risk. This would result in less farmers being able to afford insurance precisely when they most need it. It could be argued that this price signal can lead farmers to internalize the added risk into their decision, thus acquiring less inputs in anticipation of unfavorable conditions. Yet if premiums are adjusted upwards when bad rains are expected, then during La Niña years they should be adjusted downwards to reflect the reduced risk of drought (thus providing a market signal that promotes more investment in crop production). However, under current institutional conditions (i.e. little competition in the insurance sector, no government oversight), insurers have no incentive to be fair or consistent in their approach to using ENSO predictions for adjusting the contract.

Plans to scale up the Malawi pilot are expected to be accompanied by a strengthening of the institutional framework for insurance in Malawi, promoting competition among insurers and defining a legal and regulatory structure. There is a need to develop a strategy for addressing the potentially negative interactions between index-based weather insurance and seasonal climate predictions. In addition to promoting an actuarially fair approach to insurance, it may be possible to formulate risk-sharing mechanisms that help farmers make better decisions with regards to crop production. This possibility is explored in the following sections.

While the weather derivatives market has received substantial attention with regards to the growing role of climate predictions (Jewson and Brix, 2005), little has been done to formally study the actual relationship between seasonal forecasts and index-based weather insurance schemes like the Malawi pilot. Cabrera et al. (2006) and Mjelde and Hill (1999) explored the farm value of ENSO-based forecasts in the context of common crop insurance contracts. Skees et al. (2002) refer to the possibility that improved skill in seasonal climate forecasting may negatively affect certain index-based insurance schemes. Adverse selection resulting from asymmetric information can create problems for the financial viability of such schemes (Luo et al., 1994). Yet in southern Africa, asymmetric information poses a different kind of problem. Acquiring potentially useful seasonal forecasts may prove too expensive for some subsistence farmers (e.g. even the cost of batteries for listening to the forecast by radio may be prohibitive), and insurers may take advantage of this asymmetry at the expense of the farmers that are supposed to be the main beneficiaries of the Malawi pilot scheme.

Several commentators have highlighted the social implications of a differentiated production of, and access to, information (Doctor, 1991; Lievrouw and Farb, 2003). Like any other commodity, the value of information is often greater from the perspective of an individual who owns it when it is not widely disseminated. If only a small group knows that a drought is expected, they can profit from that information. Information is a key tool for production in a market economy, both in terms of connecting demand with supply and in terms of increasing the productivity of labor, land and capital. Market forces *require* information. In a celebrated article entitled “The use of knowledge in society”, Hayek (1945) refers to equilibrium prices in a decentralized market system as *aggregators and conveyors of disperse information*. Stiglitz and Greenwald(1986) points out that the assumption of perfect information, if questionable in more-developed economies, is clearly irrelevant in less-developed countries. Insurance markets in places like rural Malawi would benefit from initiatives aimed at aggregating and conveying climate information through prices and other parameters affecting farmers’ choices.

5.3.1. Opportunities to use ENSO forecasts in the Malawi insurance scheme

The Malawi pilot is not in its essence an insurance scheme: the main objective is not to share risks among farmers, but to facilitate access to credit for improved agricultural production (the insurance component of the bundled scheme is the key that unlocks access to loans for better inputs). If bundled loan-insurance contracts are designed appropriately, important synergies can be created between seasonal forecasts and agricultural input use, without compromising the feasibility of the scheme or the profitability of its commercial stakeholders.

The potential for linking forecasts and the bundled credit-insurance scheme is illustrated in Figure 9. This graph, based on Hess and Syroka (2005, page 29) shows simulated payouts during the period 1962-2004 for a different scheme. On the horizontal axis, we have added small triangles that indicate years with strong El Niño or La Niña signals.[i] Without consideration for the ENSO cycle, the probability of a payout on any given year would be 19% (8 payouts in 42 years). If only El Niño years are considered, the probability of a payout rises to 40% (4 out of 10 years). There are no simulated payouts in La Niña years in the study period, indicating a low probability of payout.[8]

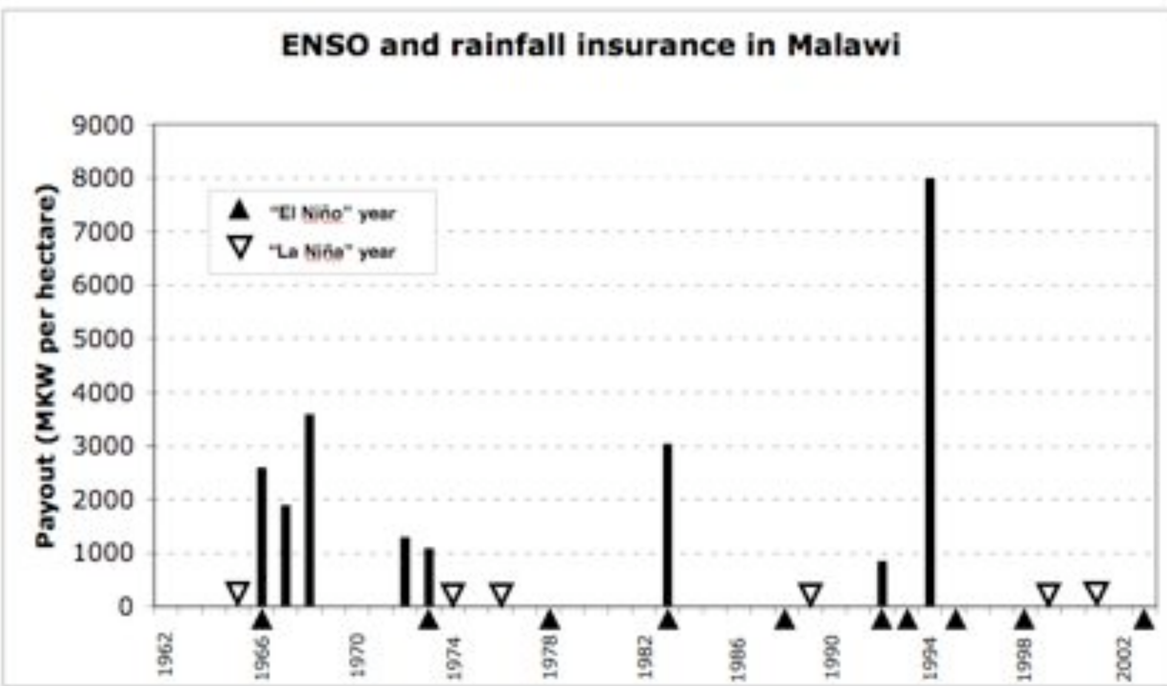

Figure 9: Simulated payouts (Hess and Syroka 2005) and "El Niño" and "La Niña" years (based on Null 2004). No payouts occurred in "La Niña" years, compared to 40% of payouts (4 out of 10) in "El Niño" years.

This risk sharing scheme would be undermined if clients purchased insurance only in El Niño years. Hypothetically, the adverse selection problem could be solved by selling

---

[8] Many different criteria are used to defining whether or not an ENSO event occurs on any given year. In this graph, a year is labeled as El Niño or La Niña if at least three of four commonly used ENSO criteria are met, following Null (2004).

insurance before forecast information becomes available (ENSO signals in the equatorial Pacific can emerge as early as April, six months before the planting season in Malawi). However, this strategy has two disadvantages. First, the logistics of this timing may not be feasible in a developing country context, and second, the potential benefits of using the forecast information for risk reduction are lost. In the analysis presented in section 5.4 we compare forecast-based products with products that are transacted before forecasts are available.

5.3.2. Stakeholder views on ENSO

During participatory workshops held with NASFAM club members in the Kasungu and Lilongwe pilot areas, farmers expressed that they were aware of the relationships between El Niño and seasonal rainfall in their region, and were interested in exploring possibilities of adjusting the insurance scheme depending on the ENSO-based prediction.

During participatory workshops held with NASFAM club members in the Kasungu and Lilongwe pilot areas, farmers expressed that they were aware of the relationships between El Niño and seasonal rainfall in their region, and were interested in exploring possibilities of adjusting the insurance scheme depending on the ENSO-based prediction.

The household survey mentioned in section 3.2 was designed to test farmers knowledge and views on this issue. 67% or respondents had heard of El Niño and seasonal predictions produced by the meteorological service. Of those, over 80% believe that ENSO can affect rainfall (mostly reducing amount of rain). The following question was posed: “If the seasonal rainfall forecast says that bad rains are more likely, would you be willing to pay a slightly higher insurance premium?” It was answered positively by 48% of respondents. Considering only respondents who reported understanding the insurance scheme well before joining it, this proportion grows to 70%, compared to only 38% among those who reported not understanding it (see Figure 10). The difference is significant at the 99% confidence level. This suggests that integrating seasonal forecasts into the pilot scheme is feasible, particularly if participating farmers are adequately educated about the marketed product.

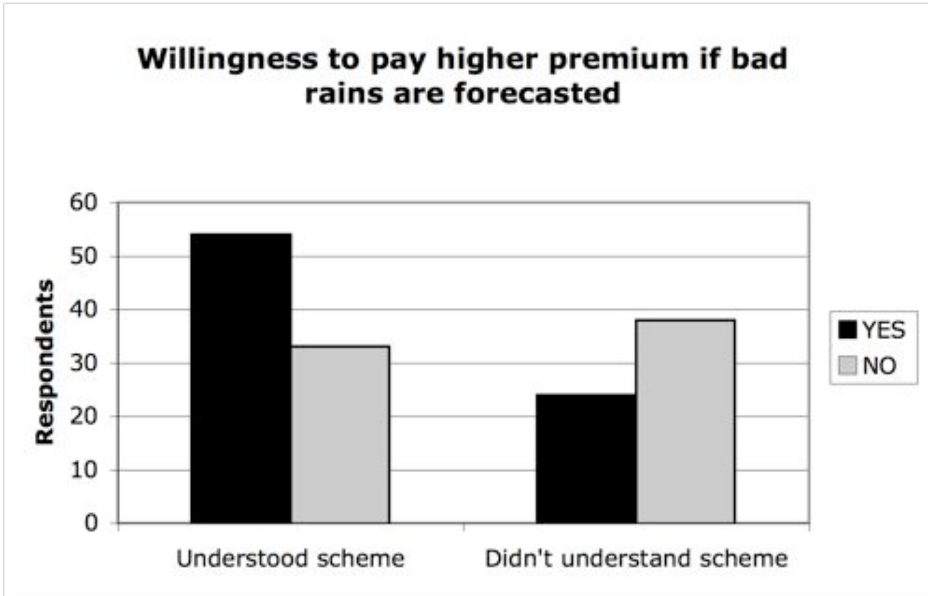

Figure 10: Farmers who understand the insurance scheme are more likely to be willing to pay higher premiums if the forecast indicates higher chances of insufficient rains.

Representatives of the insurance sector involved in the Malawi pilot scheme were interviewed during 2006. They were fully aware of ENSO and its relationship to seasonal rainfall, and asserted that if an El Niño were to become evident before the implementation of contracts, they would want to address the increased risk of drought by raising the premium. When presented with additional information about ENSO-based forecasts and their the potential integration in the pilot, they expressed being interested in the exploration of options, and provided feedback on challenges and opportunities associated with different possible approaches.

Assuming availability of capital and institutional capacity for design and implementation, a variety of approaches could be explored for integrating seasonal climate forecasts into the bundled credit-insurance Malawi scheme. Variables that could be controlled based on predictions include premium price, size of individual loans, kinds of inputs provided, and total number of participating farmers. We are interested in exploring potential schemes that not only share the financial risk associated with droughts, but also actually reduce the vulnerability of subsistence farmers to droughts and climate change. One way to accomplish this goal may be to adjust the kinds and/or quantities of agricultural inputs given to farmers in accordance to expected rainfall conditions.

5.4. A model to include seasonal forecasts into index-based weather insurance

The models proposed in this section do not attempt to be realistic. Instead, the models we present aim to offer a set of ideas that can help define a *plausible* approach. While unlikely to be adopted by Malawian stakeholders in their exact form, they can illustrate the potential use of climate predictions and lay the foundations for exploring more sophisticated, realistic schemes. We begin by quantifying the differences between El Niño, La Niña and neutral years on several parameters of the current ENSO-independent pilot scheme in the Kasungu pilot area. We use ENSO phase as a basic forecast in order to clearly illustrate the relationships between forecasts and insurance. ENSO is a useful starting point because it is commonly used, simple, transparent, requires few assumptions to apply, is a measured index (as opposed to a forecast model), and its potential impacts have been mentioned by each stakeholder group in the Malawi insurance project (see section 4.2).

Building on the theoretical framework for the relationship between forecasts, production, decisions and insurance laid out by Carriquiry and Osgood (2006), we explore alternative contract structures with growing degrees of complexity, evaluating the outcomes resulting from each strategy in comparison to the current scheme. We formulate a contract structure in which ENSO-based changes in the price of the insurance are used to adjust the size of the loan. Two hypothetical farms are used for modeling gross revenues: In scenario A farmers only plant hybrid maize given by the scheme. In scenario B the total land area of the farm can be allocated either to locally-available traditional maize or to the hybrid maize inputs provided by the insurance scheme.

We base the comparisons on an indicator of gross revenues that a farmer might enjoy in a given year. The gross revenues are calculated using information from the Malawi 2006 contract design process. The gross revenues for a given year (in MKW)[ii] are the difference between revenues and costs, where revenues are the yields in kg multiplied by the price of maize per kg plus any insurance payouts in that year. The costs are the summation of the price of inputs, the insurance premium, and interest on the farmer's loan for inputs.[iii] For some comparisons we include an additional shadow cost of alternate uses for the farmland and labor.

5.4.1. Examining impacts of ENSO state on the Malawi pilot

We calculate insurance payouts if the 2006 maize contract for Kasungu was applied to the historical rainfall data available during the period from 1962 to 2006. For the sake of illustration, we study a hypothetical implementation of the Malawi insurance contract for one acre of hybrid maize production using the prices, parameters, and constraints agreed to by the stakeholders during the 2006-2007 season.[iv]

We classify years as "El Niño", "La Niña", and "Neutral" based on the ENSO state in October (when contracts are signed).[v] The mean payout values are recognizably different (see Table 4) with average payouts in El Niño phases being substantially higher than average, and average payouts in La Niña years being much lower than average. It is interesting to note that, since the maximum liability of the insurance remains constant, the premium price ratio (i.e. insurance rate) decreases substantially in La Niña years.

Table 4: Differences in key parameters of the insurance scheme according to ENSO state

	El Niño	La Niña	Neutral	All
Insurance Rate	0.1568	0.0178	0.1114	0.1198
Insurance Price (MKW)	1411.45	160.49	1002.47	1077.93
Mean Payout (MKW)	984	108	573.55	579.68

Number of Payments	2	1	3	6
Number of Years	12	11	22	44
Pay Frequency	0.17	0.09	0.14	0.14

Using the formulas applied in the 2006 implementation[9] we calculate the 'historical burn'[10] insurance price appropriate for each ENSO phase (reported in Table 4). Although the differences in historical burn payouts are only marginally significant at best, the insurance rate differs substantially across ENSO phases, with the prices appropriate for La Niña phases almost an order of magnitude lower than the prices appropriate for El Niño phases.

5.4.2. Adjusting insurance premium based on ENSO

For the first set of analyses, we represent agricultural production using the DSSAT crop model yield predictions utilized in the 2006 Malawi contract design and implementation process. Without information on the demand curves, production responses or risk characteristics of the farmers, it is difficult to predict the impacts of directly modifying the price of the insurance. If we simply change the cash price of the insurance based on ENSO phase without modifying input, the impact on gross revenue is negligible, as would be expected. This is because the insurance premium itself (on the order of 1000 MKW) is only a very small fraction of the gross revenues (on the order of 100,000MKW). There is no risk avoidance in this strategy, because farmers do not modify their intensification with respect to the forecast.

Table 5: Gross revenues assuming constant input package

	Mean	Min	Max	Var
Standard (MKW)	89034.87	-5868.69	145951.30	1902719400
Enso priced (MKW)	89166.50	-6215.29	146024.43	1910009636
Enso/Standard	1.0015	1.0591	1.0005	1.0038

[9] Insurance price in MKW= Average(payout) + Loading * (Value at Risk -Average(Payout)). The Insurance price rate is the insurance price in MKW divided by the maximum liability in MKW. Note that although the loading and Value at Risk parameters we use were utilized in the design of the 2006 contracts, they are slightly different from the values used for the final pricing of the 2006 insurance. We use the pricing utilized in the design work of the 2006 insurance, which is a loading of 6.5% and a Value at Risk based on the 99th percentile. Because distributional assumptions are required for an estimation of the 99th percentile when there are approximately 50 years of data, for the sake of transparency, the 2006 insurance was officially priced using the maximum payout as an approximation of the 98th percentile, with a loading factor of 6.5%, which was increased to adequately load the lower 98th percentile size Value at Risk. We do not use that pricing in our analysis because it is based entirely on the largest payout, which could lead to idiosyncratic results. The plans for future pricing of the 2007 implementation of the Malawi insurance are not based on largest historical payout.

[10] Historical burn pricing is performed by relying entirely on payouts determined from historical data, without attempting to characterize the underlying distributions. Although this technique may be overly simplistic, we utilize it for two reasons. First, it is highly transparent, because it does not require specification of distributional assumptions (except that the set of historical draws characterizes the entire distribution). Second, it was the pricing method used for determining the official price of the Malawi insurance.

Table 5 presents summary statistics of the gross revenues, illustrating a less than 0.1 percent change across ENSO states. From the perspective of farmers participating in this scheme, the adjustment of insurance premiums based on seasonal forecasts makes no difference with regards to agricultural production and has negligible impact on gross revenues.

In the context of fully developed, unbundled and fully divisible markets for credit and inputs, it is likely that changing insurance prices would have more measurable impacts. However, that is not the context of the Malawi initiative and other index-based micro-insurance systems being piloted. In the Malawi context, a changing demand due to changing insurance prices would mean that if prices fluctuate sufficiently for demand to change, farmers would opt out of the entire loan, insurance, and input purchase package in El Niño years. This could lead to potentially dramatic year-to-year changes in customer base and capital for insurance and loan financing, as well as farmers having no access to insurance in years with a higher likelihood of drought. While such approach would probably reduce the risk of hybrid crop failure during El Niño years, from the farmers' perspective the outcome would not be substantially different in terms of long-term wealth accumulation, and consequently this scheme would present little advantages with regards to reducing vulnerability to climate variability and change.

5.4.3. Adjusting size of loan based on ENSO

According to focus groups and the household survey, a majority of farmers were interested in larger loans (most participating farmers own at least four acres that they would be willing to dedicate entirely to improved seed varieties). Yet banks imposed the constraint that the loan with interest be equal to the maximum liability of the insurance (which in the current scheme is kept constant across seasons regardless of what seasonal forecasts say: a loan for inputs that suffice for just one acre). As noted by Phillips et al. (2002), a rational means of avoiding losses and benefiting from opportunities would be to decrease the area planted in years with an expectation of below normal rainfall, and to increase the area when rainfall is expected to be optimal for yields.

For this exploratory exercise we propose to adjust the total area cultivated with high-yield inputs provided by the bundled loan-insurance contract, depending on expected rainfall. When La Niña conditions anticipate low chance of drought, farmers receive more inputs and can therefore cultivate more land with the hybrid seeds and fertilizer provided by the scheme. When El Niño indicates high risk of crop failure, the inputs given to farmers will be less. This is consistent with Hill et al. (2001), who simulated global wheat production in the presence of seasonal climate forecasts and found fluctuations in area planted. For modeling simplicity reasons, we propose a scheme in which the input mix (proportion of high-yield maize seed and fertilizer) remains constant across seasons.[11]

Additionally, as mentioned earlier, a key constraint in contract design was that the insurance premium had to be below a maximum acceptable level. Therefore we choose the cash price of the insurance unmodified by ENSO as a constraint for the premium for

[11] Future work will address the case of adjusting proportion of fertilizer based on the seasonal forecast.

all phases, and implement ENSO-based price changes by adjusting the maximum liability, and therefore the respective loan size and budget for inputs.[12]

Table 6 presents the elements of a package that is scaled to reflect a package where the insurance rate (or premium price ratio) is adjusted according to the ENSO phase as presented in Table 4. Holding the cash price of the premium at the level that farmers reported they were willing to pay, the changing ratio between price and maximum liability leads to a maximum liability in La Niña years that is almost an order of magnitude larger than in other years. Referring to the Input Budget Weight row, the budget available for inputs in a La Niña year is 7.75 times larger than in the non-ENSO-adjusted package, with an El Niño budget approximately three quarters of the nonadjusted package.

Table 6: Key parameters for insurance scheme that scales loan size depending on ENSO state

	El Niño	**La Niña**	**Neutral**	**All**
Insurance Rate	0.1568	0.0179	0.1114	0.1198
Insurance Price (MKW)	702.90	702.90	702.90	702.90
Loan (MKW)	3515.25	30915.85	4949.38	4602.90
Interest (MKW)	966.69	8501.86	1361.08	1265.80
Input Budget (MKW)	2812.35	30212.95	4246.48	3900
Maximum Liability (MKW)	4481.94	39417.71	6310.46	5868.69
Input Budget Weight	0.72	**7.75**	1.09	1

5.4.3.1. Modeling scenario A: Farm planting hybrid maize only

Consider a hypothetical farm with 7.75 acres of arable land in which the farmer uses only the inputs provided by the proposed ENSO-adjusted scheme, using the per acre levels of seed and fertilizer recommended for the 2006 package.[13] In other words, the acreage of hybrid maize production is scaled with the ENSO-based input budget, and the rest of the land is left idle.

Although maize price volatility is an important feature in farm profitability, it is a topic worthy of a separate study. We assume maize prices are constant, acknowledging that

[12] Instead of making the series of uninformed assumptions necessary to characterize farmer demand we use the information that we do have in order to propagate the price changes through the insurance/loan/input bundle. We rely on the consensus of design constraints for the Malawi package as revealing the intersection of contracts within stakeholder preferences.

[13] Note that the "typical" farm size used in the design for the actual 2006 pilot implementation was approximately 5 acres. Since the input weight factor is above seven, it would be possible for most farm to scale to full use of hybrid maize and fertilizer in La Niña years building from the current 1 acre budget. Because the hypothetical farm modeled is slightly larger than the "typical" farm, it is important to note that the absolute level of gross returns in MKW would have to be scaled by maximum farm size. This scaling would, of course, not impact relative benefit measures.

supply driven price fluctuations are likely to dampen the gross revenue benefits of forecast-based insurance packages.

Shadow costs of scaling production are also important. Because reliable information on the shadow value of scaling is not available, we first run the analysis with a shadow value of zero, and then determine the shadow value at which benefits of the ENSO-shifting package disappear.

Table 7 presents summary statistics for the gross revenues of this hypothetical farm compared to one that is limited to the standard package (where only one acre of land is dedicated to the hybrid maize, regardless of ENSO phase). Understandably, the differences in benefits are substantial, with the mean gross revenues more than double for the ENSO adjusted package, and the maximum gross revenue resulting higher by a factor of more than seven. Table 7 illustrates the differences across seasons in gross revenues between the ENSO adjusted and non-adjusted package, showing that the gains are due to high gross revenues in a small number of La Niña years. In some El Niño years, the gross revenue is slightly smaller for the ENSO-adjusted scheme because of the smaller area planted. The variability of annual gross revenue that the farmer faces is much higher because the farmer has the opportunity to earn substantially more in a good year.

Table 7: Gross revenues assuming constant insurance premium and hybrid maize only (DSSAT simulation)

	Mean	Min	Max	Var
Standard (MKW)	89034.88	-5868.69	145951.31	1902719400
Enso based (MKW)	246798.42	-6310.46	1113942.41	106489037713
Enso/Standard	2.6663	0.9923	7.1810	55.97

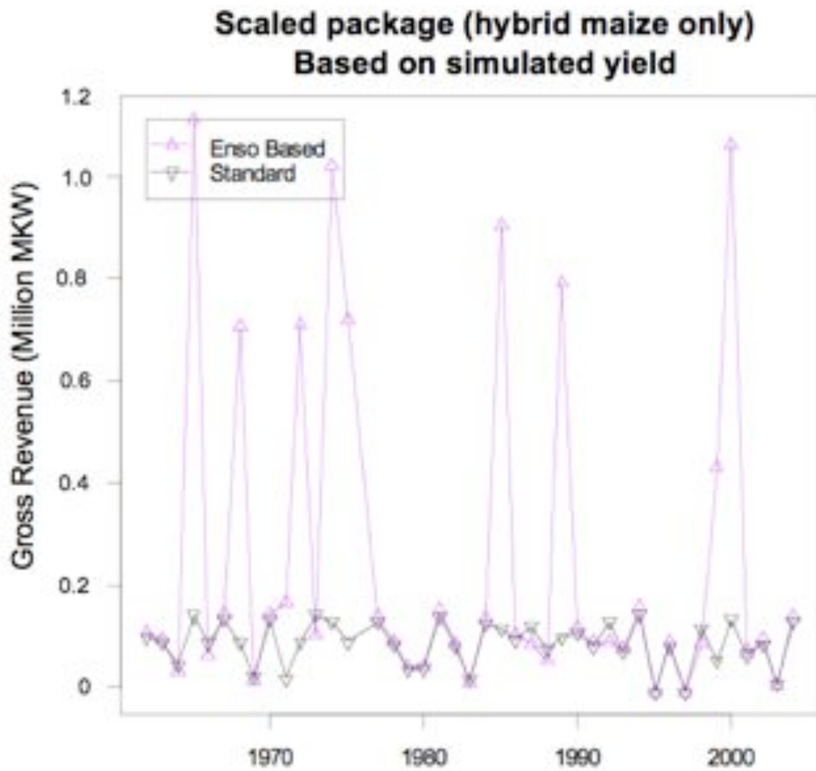

Figure 11: Gross revenues for the scaled and the standard approaches using simulated yields in a hypothetical farm that plants only the hybrid maize given by the bundled scheme. As expected, the ENSO-based scaled approach outperforms the standard one.

The histograms in Figure 11 illustrate how the ENSO scaling shifts the gross revenues of a relatively small number of La Niña years to much larger values. Of course, these large benefits depend on the hypothetical farm being able to fully capitalize on these extremely productive years. If there is limited storage or transport capacity, or if maize prices fall during those years, the results will be attenuated. In addition, these figures represent a farm in which there is a zero shadow cost of scaling up. In reality, the farm would sacrifice revenues from alternate crops that are displaced or would face increased costs due to the additional labor of cultivating a larger amount of land. Including shadow costs into the simulation, we find that a shadow cost of approximately 160,000 MKW would be required to reduce the mean gross revenue of the ENSO scaled package to a value equal to that of the non-scaled package. Since the average gross revenues of the non-scaled hybrid maize package are less than 90,000 MKW, a farmer who is interested in the non-scaled insurance package is unlikely to have a shadow value for labor and land that is this high.

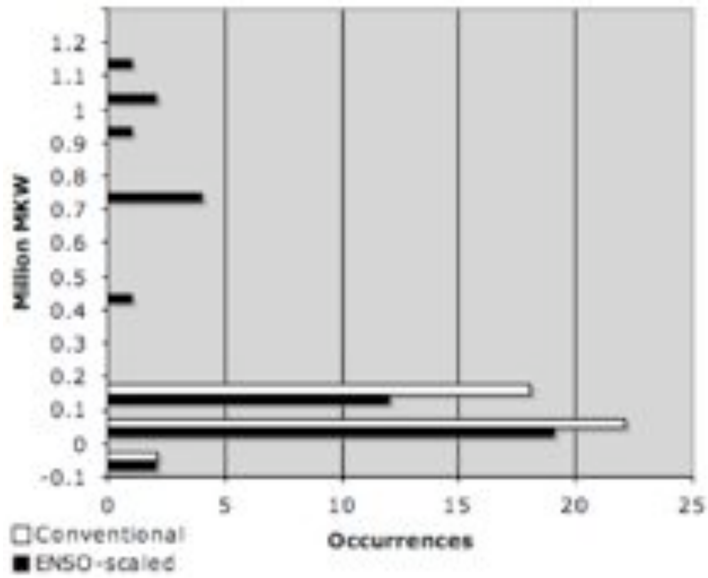

Figure 12: Histogram of gross revenues for the scaled and the conventional approaches for model scenario A using simulated yields. The ENSO-scaled approach shows several occurrences of gross revenue larger than 0.2 million MKW during La Niña.

Because the DSSAT crop simulation yields may be inaccurate in predicting yields, we compare the results based on the simulations with district level historical yields of hybrid maize in the district of Kasungu. This provides an indicator of yields that is entirely independent from the DSSAT crop model. The data is based on actual yields as opposed to optimum yields simulated from rainfall amounts, and therefore this historical data approach is likely to produce a more conservative representation of the link between ENSO and yields.

Some of the caveats to keep in mind when interpreting the historical yield results follow. First, it is not known if the varieties are the same as the ones being utilized in the 2006 package. Second, they represent regional averages as opposed to the yields of an individual farmer, so much of the variation that an individual farmer faces will be averaged out. Third, there may be problems in their estimation. Finally, they are only available for a short time span, beginning in 1984.

We repeat our analysis of the hypothetical farm that scales in area, but use the historical district yields as the basis for our gross revenue calculations. Table 8 and Figure 11 and 12 present the results of this calculation. Results are qualitatively similar to the simulation-based results, with the mean gross revenues of the ENSO scaled package more than two times higher than the unscaled package.

Table 8: Gross revenues assuming constant insurance premium and hybrid maize only (based on historical yields)

	Mean	Min	Max	Var
Standard (MKW)	14327.17	8032.32	21281.40	14850032
Enso based (MKW)	38199.95	7970.43	152822.54	2527871348
Enso/Standard	2.6663	0.9923	7.1810	170.2267

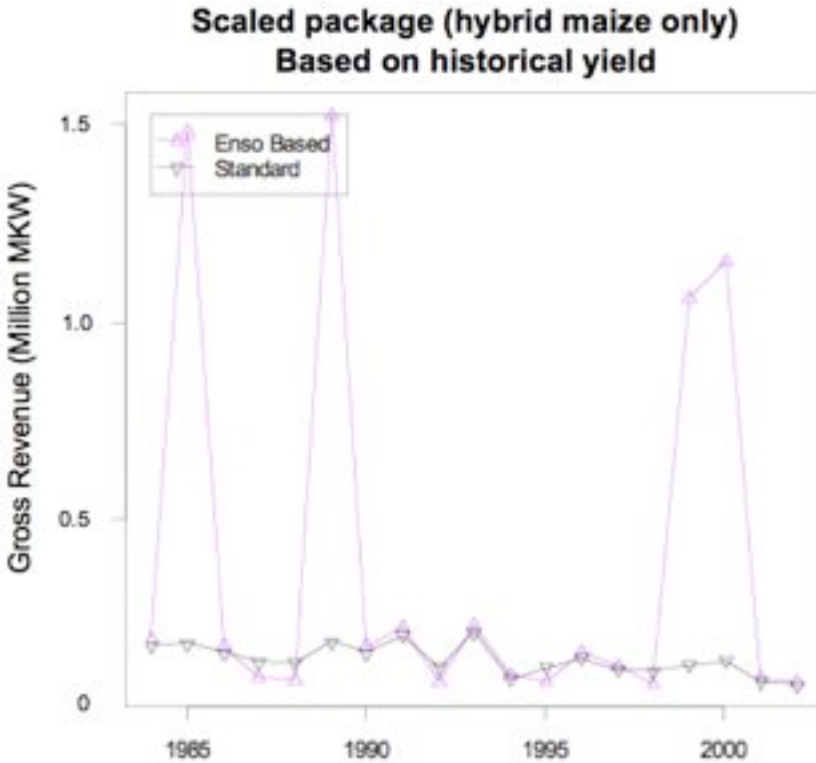

Figure 13: Gross revenues for the scaled and the standard approaches using historic yields in a hypothetical farm where only hybrid maize is planted. The ENSO-based scaled approach again outperforms the standard one.

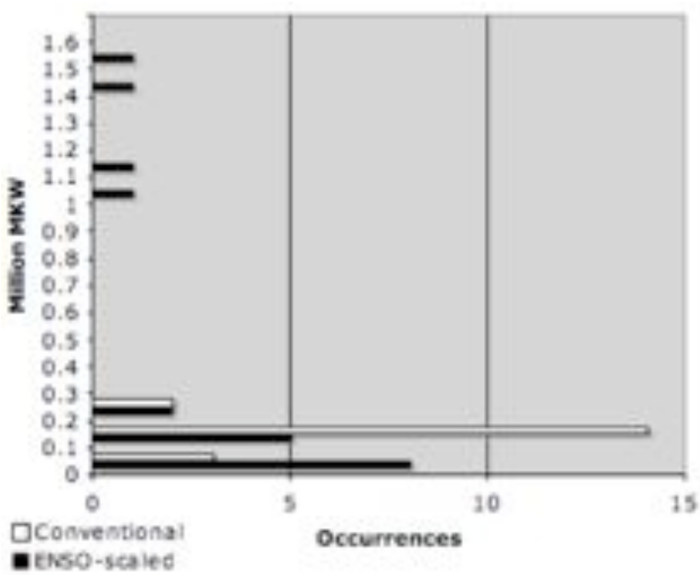

Figure 14: Histogram of gross revenues for the scaled and the conventional approaches for model scenario A, using historical district yields. The pattern is similar to that of Figure 12.

5.4.3.2. Modeling scenario B: Farm planting traditional and hybrid maize

We now consider a hypothetical farm that also has 7.75 acres of arable land, but allocates as much land as it can to hybrid maize and the remaining land to non-hybrid, traditional maize. Applying the historical district yields can provide information on the shadow cost of shifting land between hybrid maize and other choices. According to the study by Carriquiri and Osgood (2006), the yield of hybrid maize in the district of Kasungu was on average 2.3 times larger than that of traditional maize for the study period. We apply a series of assumptions that would lead to low benefit estimates if unrealistic: The price the farmer receives for both types of maize is assumed to be the same. The cost of inputs for the non-hybrid maize is assumed to be the cost of purchasing (or forgoing the sale of) market recommended at the sale prices that the farmer receives for maize. The quantity of maize seed planted per acre is assumed to be equal between hybrid and non-hybrid. The labor required is assumed to be similar between both maize varieties.

Table 9: Gross revenues assuming constant insurance premium – traditional and hybrid maize (based on historical yields)

	Mean	**Min**	**Max**	**Var**
Standard (MKW)	12977.79	6682.94	19932.01	14850032
Enso based (MKW)	37129.32	6565.28	152822.54	2584196785
Enso/Standard	2.8610	0.9824	7.6672	174.0196

The results of this analysis are shown in Table 9 and Figures 15 and 16. These results are qualitatively similar to the benefits calculated using the simple scaling of simulated or historical yields above, showing that the results are somewhat robust to our assumptions. Again the mean gross revenues for the ENSO-adjusted package is more than twice the non-adjusted package.

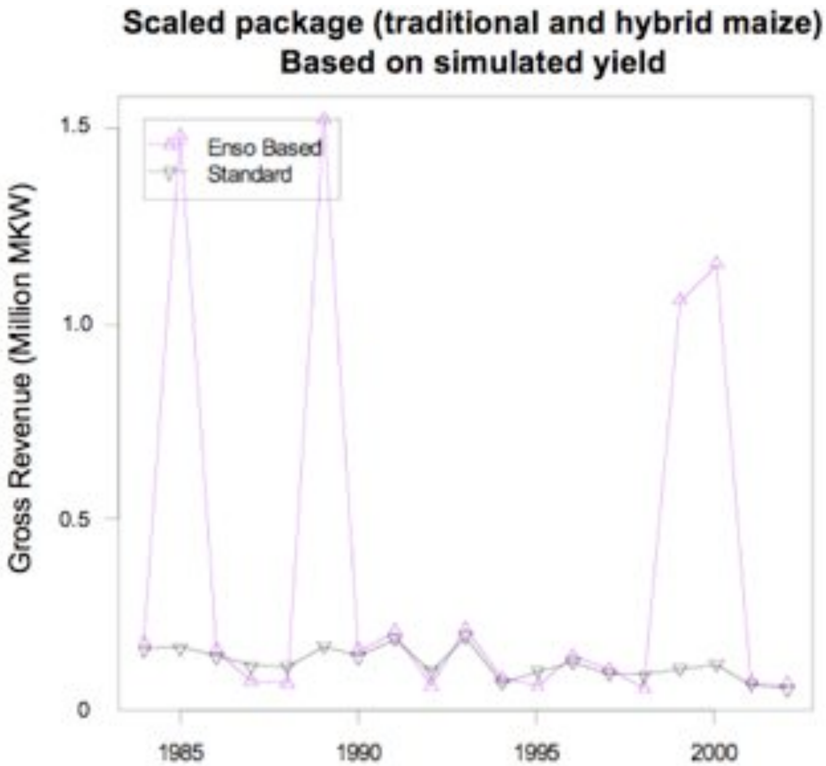

Figure 15: Gross revenues for the scaled and the standard approaches using historic yields in a hypothetical farm planting traditional and hybrid maize. The pattern is similar to that of Figure 13

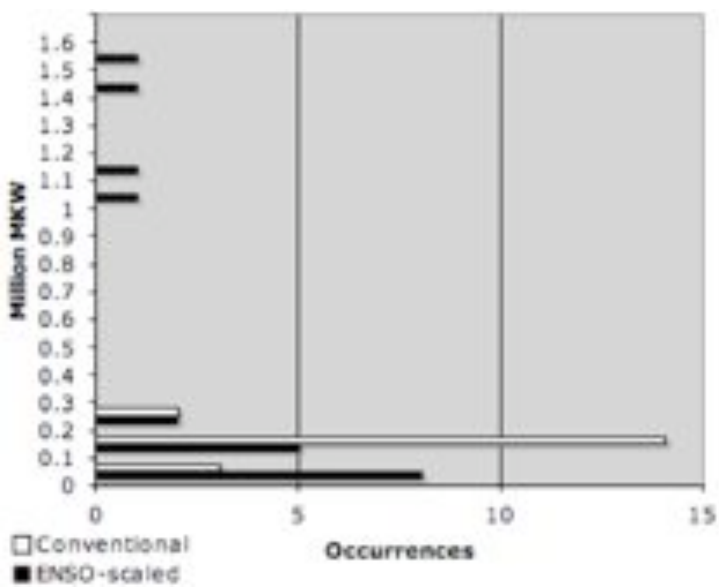

Figure 16: Histogram of gross revenues for both approaches for model scenario B. The ENSO-scaled option remains robust in its taking advantage of La Niña years.

The proposed model is based on numerous simplifying assumptions. Firstly, in the interest of simplicity, the model does not account for increased labor costs to scaling up the hybrid maize acreage, or the cost of land being taken out of other uses beyond traditional maize, or constraints in land or labor. Another key assumption is that maize prices are assumed to be independent of seasonal rainfall (in other words, price variability is removed from the system – a major assumption).

Although this strategy provides for a relatively stable customer base and amount of premiums delivered to the insurance company, it reflects potentially very different values at risk and changes in capital necessary for loans and potential insurance payouts that vary with ENSO state. These ENSO-based variations could provide major challenges for the financial management of the insurance providers and lenders. Yet the availability of innovative financial instruments may allow the design of strategies for managing this issue. Insurance providers and lenders could simply purchase ENSO-indexed insurance or options from reinsurance providers or derivatives markets to stabilize finances, since ENSO impacts are oppositely correlated across different parts of the world. This provides a natural role for reinsurance companies, derivative markets and the emerging Global Index Insurance Facility (GIIF) in supporting local microfinance schemes aimed at integrating risk sharing and risk reduction, whether through pure market approaches or with donor and NGO support.

5.5. Summary and Conclusions

Climate-related insurance markets need to deal with risks that are not stationary. The skill of climate predictions can really affect insurance markets. If insurance schemes do not take forecasts into consideration, they will be negatively affected by adverse selection, inequitable contracts, and other undesirable issues. However, if adequately designed to take advantage of predictions, bundled credit-insurance schemes can reduce financial risk for insured farmers and insuring companies, as well as promote risk reduction.

We have proposed a simple model that integrates seasonal climate predictions into the bundled credit-insurance Malawi pilot scheme by offering a package that uses the ENSO status in October to adjust the maximum liability (i.e. size of loan, which determines the quantity of improved maize seed and fertilizer given to farmers). This approach promotes the cultivation of larger areas with high-yield inputs when good rains are expected, and reduces the exposure to drought risk when conditions are less favorable. Through simulations based on the rainfall record, crop simulation modeling, historical yield data and financial calculations, we compared the gross revenues of the proposed scheme with the current pilot scheme, which does not take ENSO into consideration. Results show that integrating seasonal rainfall forecasts can lead to substantial increases in gross revenues during La Niña years (by a factor of up to seven). This leads to cumulative gross revenues that are more than twice as high and consequently, through wealth accumulation, reduce the farmers' long-term vulnerability to climate variability and change.

This modeling exercise is based on a number of simplifying assumptions that need to be addressed in future work. These include a linear relationship between agricultural output and amount of inputs provided by the scheme (without consideration for the possibility of increased labor costs, constraints in land and other factors), as well as no correlation between price of maize and seasonal rain. It is also assumed that the wealth generated during bumper harvests can actually be accumulated by farmers.

While these constitute weaknesses of the model, we suspect they are unlikely to challenge the main finding of our simulation: a scheme that uses skillful seasonal forecasts to adjust the bundled loan-insurance contract according to expected rains can substantially benefit participating farmers. Additionally, it should be noted that (i) the actual set of management decisions in response to a seasonal rainfall forecast can be more sophisticated than those in our model (for example, using seed varieties with different levels of drought resistance); and (ii) the ENSO phenomenon is just one factor affecting seasonal rainfall in southern Africa: using any of the more sophisticated seasonal predictions currently available could lead to better outcomes. The results presented here depend not only on parameter assumptions, but also on the assumption that future seasonal precipitation will follow the same correlations with ENSO as the 45 years of historical observations used for the model. Future ENSO impacts may not be the same (especially given climatic change). Yet, given the potential for strategic behavior and the potential risk management benefits, one would have to guarantee that future ENSO impacts will not in any way follow the behavior of the past in order to proceed without designing ENSO impacts into the insurance package. The examples we have presented here demonstrate that even simple, crude, and conservative implementable strategies hold the potential for substantial gains, suggesting that refined approaches may provide greater benefits.

Clearly, the work presented here is merely a starting point for forecast-based insurance packages. Additional research using more sophisticated forecasts and better characterization of the underlying distributions, correlations, skill and stakeholder preferences and constraints would be necessary before any new contract structure can be implemented in the field. Uncertainty in the forecast justifies somewhat cautionary responses (Hammer et al., 2001). One option is to design a bundled scheme that moderately adjusts both insurance premium and loan size as a function of ENSO. Integrating seasonal rainfall forecasts into the bundled loan-insurance scheme can make better choices available to farmers, who would in turn be able to make better decisions based on their own risk preferences, their trust in climate information, and a wider set of options for crop production and risk management. Revisiting Hansen's diagram depicted in Figure 8, the proposed approach aims to expand the decision capacity of vulnerable farmers through available climate predictions, increasing the area of intersection (see Figure 17).

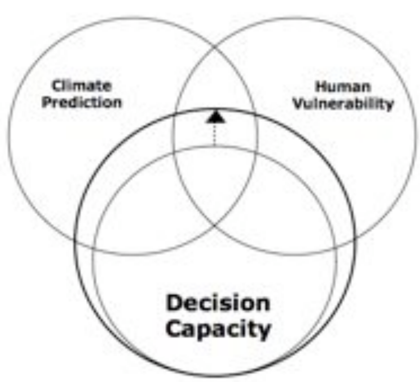

Figure 17: The proposed approach aims to expand the decision capacity of farmers in order to help them benefit from available seasonal climate forecasts.

The implementation of this kind of approach can have substantial implications for adaptation to climate change in southern Africa. On one hand, farmers participating in this kind of scheme would become wealthier faster, and would therefore be better able to prepare for changing climatic conditions (including increased risk of disasters). Additionally, integrating communication and use of climate predictions in the decision making processes of subsistence farmers can help set the stage for the dissemination of long-term climate predictions and the promotion of strategies to adapt to the expected patterns of change. Market mechanisms, when adequately structured, can effectively and efficiently guide the allocation of resources for crop production under a changing climate. Insurance markets can take newly available information into account every season, adjusting prices and other variables to convey to economic actors the dynamic nature of relatively predictable climate risks. Lessons from the use of seasonal predictions in the Malawi scheme can help enrich the conceptual framework required for applying insurance solutions to the climate change problem.

6. CLIMATE CHANGE AND WEATHER INSURANCE IN MALAWI: ASSESSING THE IMPACT

6.1 Introduction

This chapter explores the potential impact of climate change on the viability of the Malawi weather insurance program making use of one scenario of climate change-induced variations in meteorological patterns of rainfall. The analysis is important from a methodological and policy perspective. To date, there has been little attempt to combine insurance modeling with climate-change modeling, and this chapter develops a methodology for this purpose and discusses the challenges. There have also been few attempts to assess the role of climate change on insurance systems, mainly because insurance contracts are generally written on a short-term basis. Yet, for medium- and long-term planning, especially for systems serving poor clientele, climate change can potentially affect the affordability of the system and thus its viability. This is of major concern to insurers, as well as donors supporting these systems.

The research reported in this chapter addresses the following questions:

- Does climate change significantly increase the risk of insolvency of the Malawi microinsurance program (assuming farmers cannot pay higher premiums)?
- What additional capital input would be necessary to reduce the risk of insolvency to an acceptable level (for instance, one percent)?
- What are the key uncertainties and how can they be expressed given the current state of climate and meteorological modeling and impacts assessment?

These questions, and the methodology for addressing them, is of general interest to international and bi-lateral development organizations, which are taking the lead in implementing novel options, including insurance, for financing and managing developing country risks posed by climate variability. They are also of interest to the Global Environment Facility (GEF) and other climate-change institutions, which are exploring financing options that foster adaptation of vulnerable regions to increasing climate extremes (Müller, 2002; Linnerooth-Bayer et al., 2003; Bouwer and Vellinga, 2005; World Bank, 2005a). Both communities could benefit from estimates of the burden that climate change will impose on the viability of the systems, as well as information on the additional capital needed to ensure their survival. For instance, GEF can fund only the *incremental* cost of adaptation activities, and those activities that generate global environmental benefits or are identified as high priorities by national communications. According to this stipulation, if insurance programs are to qualify for GEF funding, it is necessary to identify the extent to which climate change is adding to their costs or increasing the risks of their failure. This issue is not only of interest for disbursing climate adaptation funds, but generally for assessing the robustness of insurance and other mechanisms for managing climate risks in light of mounting evidence that climate change is and will continue to contribute to increasing losses from weather extremes.

6.2 Methodology

6.2.1 Overview

Climate change impacts on the Malawian microinsurance scheme can be assessed from two perspectives: From the view of the insurers, or *supply-side* perspective, it is important to analyze the financial robustness and risk of insolvency of the insurance scheme. From the view of the clients, or the *demand-side* perspective, it is important to consider financial robustness as it affects their livelihoods, for example, premium payments and the extent to which insurance reduces potential losses. Because of the fragility of nascent insurance systems in developing countries, such as the pilot program in Malawi, this analysis takes a supply-side perspective. If the systems cannot withstand shocks from increasing weather variability, they will not only default on claims, but generally discredit insurance as an adaptive measure. Because commercial reinsurance will greatly raise premiums to clients who can ill afford any additional costs, the international development community is considering options for providing backup and pooling the risks of small-scale microinsurers offering catastrophe cover (Gurenko, 2006; Linnerooth-Bayer and Mechler, 2006). A supply side analysis can inform these options.

This chapter makes use of *dynamic financial analysis* to assess the financial robustness of the Malawi insurance scheme under dynamic weather conditions as potentially affected by climate change. Dynamic financial analysis makes use of stochastic simulations of key insurance variables, such as surplus, loss ratios and solvency (or the risk of insolvency) based on inputs on insurance conditions and premium income (for example, see Lowe and Stanard, 1997 or Ho, 2005). In this case, claim payments are contingent on current and predicted rainfall data. The research capitalizes upon climatological and meteorological data computed within the World Bank sponsored project “Institutions for Climate Change Adaptation” by Mark Tadross and colleagues (2006). The analysis is based on observed changes in rainfall characteristics, derived downscaled climate change scenarios from both Regional Climate Models (RCMs), as well as statistical downscaling for one site (Chitedze) in Malawi. Information on actuarial calculations was obtained from D. Osgood (2006), who conducted the original calculations that informed the Malawi scheme. The modeling approach is schematically represented in Figure 18.

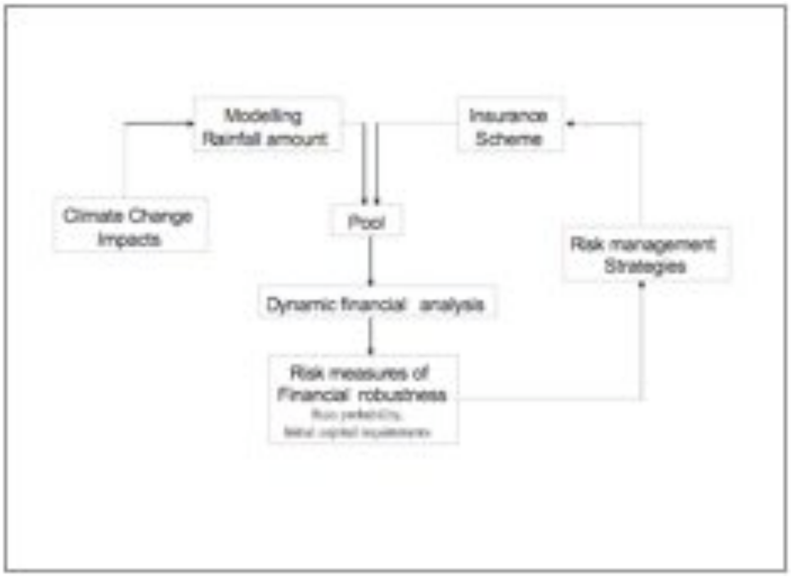

Figure 18: Modeling approach from the insurance perspective.

The input variables for modeling intensity and frequency of rainfall include the current rainfall patterns in Chitedze. To assess climate change impacts, we used the scenario based future rainfall patterns based on the analysis of Tadross et al. (2006) and compared those to the current scenario. Furthermore, we implemented insurance conditions, such as contract and trigger events as currently employed in Malawi, in combination with the simulated rainfall amount to determine the claim payments for each year. A dynamic financial analysis for a 10-year time period is performed to analyze the financial robustness of the contract under the different climate change settings. Output variables include (i) the probability of ruin of the insurance pool as a measure of its robustness and, (ii) initial capital necessary to reduce the probability of ruin to 1% over 10 years.

By considering a 10-year time horizon, this analysis assesses the financial robustness (risk of insolvency) of the Malawi scheme by estimating the scheme's capital accumulation and depletion accounting for stochastic shocks under dynamic climatic conditions. The assumptions of the analysis are detailed below:

- All four regions in the Malawi pilot study are assumed to be identical to the Chitedze region for which more complete data exists;
- Insurance premiums and triggers are held constant;
- Insurance is stand-alone, i.e., the bundled credit-insurance structure and links between these financial instruments are not accounted for in this analysis;
- There is no back-up capital at the outset of the 10-year period.;
- There is no opportunity for the insurer to diversify, and no reinsurance is purchased.

An important consideration is uncertainty, which is pervasive throughout the analysis. While input uncertainty, such as associated with rainfall projections, should ideally be incorporated in the analysis, because of the lack of information and data on the variability of rainfall, it is not dealt with quantitatively. Uncertainty in terms of natural variability of the system is expressed with sensitivity analysis. Output uncertainty, e.g. uncertainty that derives from the modeling and simulation, is expressed using confidence intervals

6.2.2 Insurance pricing and preliminary analysis based on historical data

The 2005-6 Malawi pilot project (described in detail in Chapter 3) offers a bundled loan and insurance product in four pilot areas in central Malawi, where rain patterns compared to other areas in Malawi are relatively favorable for agriculture. The following analysis considers only the insurance (and not the full loan and insurance package) and assumes uniform conditions in these four areas based on information in only one (Chitedze). The premium pricing for this site follows Osgood (2006) and, in keeping with standard practice, is based on the expected payout (expected value). This can be expressed as follows:

Premium = expected payout + 6.5% (Value of payout at 98th percentile – expected payout)

The value of payout at the 98th percentile is set as the highest losses in the past given specified triggering events. Furthermore, Table 10 shows important input parameters and calculated variables (in bold) used for pricing the insurance scheme.

Table 10: Important parameter settings and calculated values (in bold) for the groundnut insurance contract in Chitedze.

Variable	Value
Seed price (MWK/kg)	100
Seed amount (kg per acre)	32
Ground input price (MKW per acre)	**3200**
Typical yield (kg per acre)	420
Harvest price (MWK/kg)	75
Typical groundnut value (MKW per acre)	**31500**
Loan size (MKW per acre)	4667
Groundnut only insurance premium (%value)	8.4
Insurance tax (%)	17.5
Groundnut only insurance rate with tax (%)	**9.9**
Premium with tax (MKW per acre)	**461**

Note: MKW: Malawi Kwacha. Source: Osgood (2006).

The ground input price (seed price times seed amount) per acre amounts to 3200 Kwachas, the typical groundnut value (as the product of typical yield and expected harvest price) was calculated at 31,500 Kwachas. Adding a premium of 8.4% and an insurance tax on the premium of 17.5% on the typical loan value of 4667 Kwachas leads to a premium of 461 Kwachas (or 9.9% of the loan size).

Since the primary risk to groundnut in Malawi is drought during critical growth periods, the contract specifies levels of rainfall that trigger payment. There are four stages of development for the groundnut crop: initial, crop development, mid-season and late season. Because the mid-season and late season can be grouped as the flowering phase, the insurance contract in 2006 for Chitedze considered only three phases. The insurance scheme, trigger and claim payouts are based on the accumulated amount of rainfall for each of the three phases. The following trigger events are set in the 2006 contracts (Table 11 and Figure 19):

Table 11: Upper and lower claim triggers for each phase (in mm)

	Upper trigger (mm)	Lower trigger (mm)
Phase 1	35	30
Phase 2	35	30
Phase 3	220	20

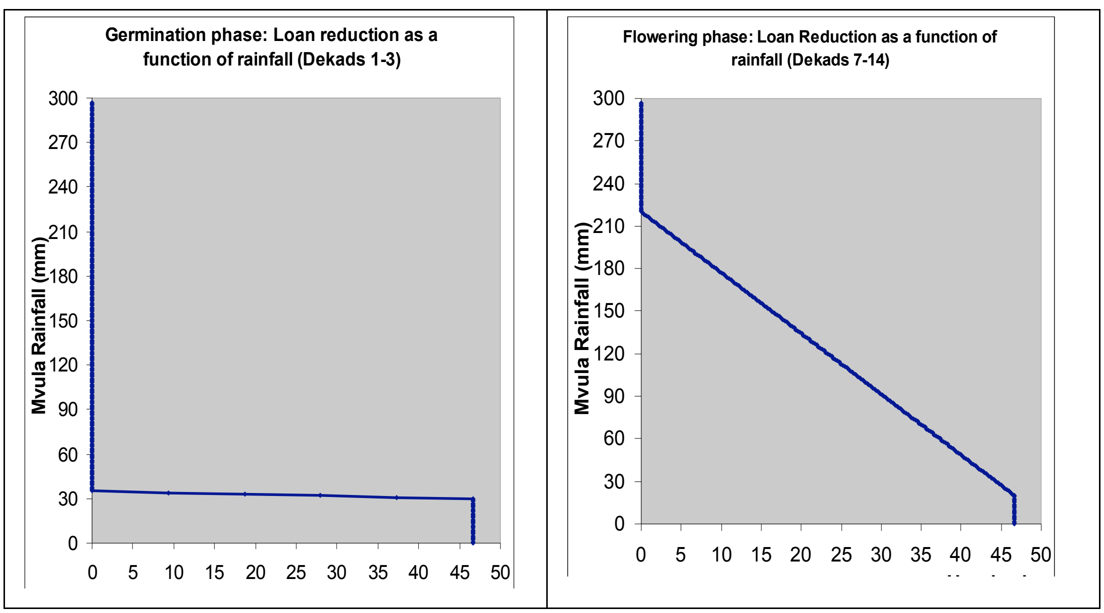

Figure 19: Trigger events for phase one and two (germination and crop development phase) and phase three (flowering phase). Source: Osgood, 2006.

Each phase is further subdivided into *dekads* of 10 days. The contract also contains a "no sowing condition," which triggers a full loan payout if a minimum level of rainfall is not received in order for the farmer to successfully sow the plant during the contract's initial stages. If rain is above a certain level (e.g. 60 mm during germination stage), then there is no payout. If rainfall is insufficient for the crop to survive (e.g. less than 30 mm during germination), then insurance pays back the entire loan. If rainfall lies in between, interpolation defines what portion of the loan is paid by the insurance company. Because excessive rainfall in one dekad does not contribute to the growth in the other dekads the rainfall amount for each dekad is capped at 60 mm per period. Thus, this contract can be viewed as two contracts, one for catastrophic events (first 2 phases) and one for more frequently less dramatic losses (third phase). Figure 20 illustrates the difference of the payout for (i) capped and (ii) non-capped rainfall data between 1961 and 2005.

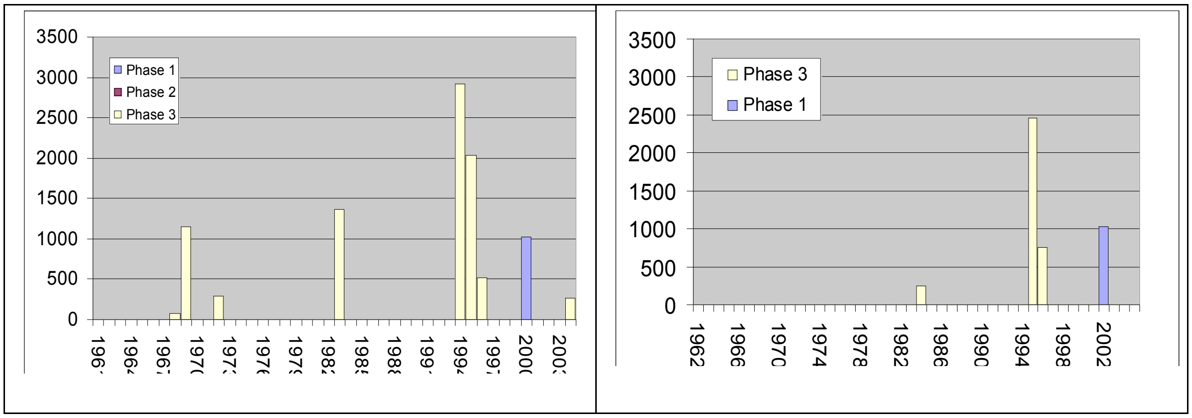

Figure 20: Historical simulated payouts of drought insurance contracts based on (i) capped and (ii) non-capped rainfall data from 1961 to 2005.

With the capped data, the third phase is more often triggered with higher compensation than is the case for the non-capped data. Thus, capping has important implications both for the insured as well as the insurer. The contract in its present form insures more against frequent losses than catastrophic losses. However, this may change in the context of climate change.

6.2.3 Current and future rainfall scenarios

The modeling of accumulated rainfall amount is based on input data of the Chitedze station in Malawi as analyzed and modeled by Tadross et al. (2005). Information of the input data used to construct current and future scenarios is based on the regional climate projection models MM5 and PRECIS (see Table 12).

Table 12: Input data for the rainfall modeling.

• Daily Rainfall amount from 1961 till 2005 from Chitedze station.
• PRECIS rescaled projections (monthly rainfall) of the control and future period. Control is January1960 to December 1979. Future is January 2070 to December 2089.
• MM5 rescaled projections (monthly rainfall) of the control and future period. Control is from January 1975 to December1984. Future is January 2070 to December 2079.

The PSU/NCAR mesoscale model (known as MM5) developed by Pennsylvania State University and the National Center for Atmospheric Research is a limited-area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale atmospheric circulation[14]. Precis (Providing REgional Climates for Impacts Studies) is based on the Hadley Centre's regional climate modelling system[15]. Both regional climate models (RCM) are forced within the A2 emissions scenario global circulation model. The SRES A2 scenario is a standard scenario used in assessing future worlds with climate change and leads to rather high greenhouse gas emissions (IPCC, 2001c). The main difference of the two RCM is that they simulate a hydrological cycle of different intensity. In Precis there is more rainfall with a lower than observed intensity, whereas in MM5 there is more rainfall with a higher than observed intensity (Tadross et al., 2006).

Because future projections were expressed in monthly rainfall amount, it was necessary to rainfall amount in dekads. Hence it is assumed that future rainfall patterns on average are the same as in the past. While this assumption is questionable, other approaches are not reliable due to lack of data. Furthermore, because the insurance trigger events are constructed for at least 3 dekads for each phase, changing distribution patterns in the dekads are of minor interest from an insurance perspective. In this context the variance is of more importance. Figure 21 shows the mean distribution calculated from the empirical data as well as based on the MM5 and Precis models for the whole season (season starts at the beginning of August).

The MM5 future projections show lower rainfall in the beginning of the season compared to the mean empirical estimates. For the Precis model higher rainfall appears to characterize the beginning of the season. On the other hand, a trend with lower rainfall at the end of the season seems to emerge for Precis compared to the empirical data.

[14] See http://box.mmm.ucar.edu/mm5/

[15] See http://precis.metoffice.com/

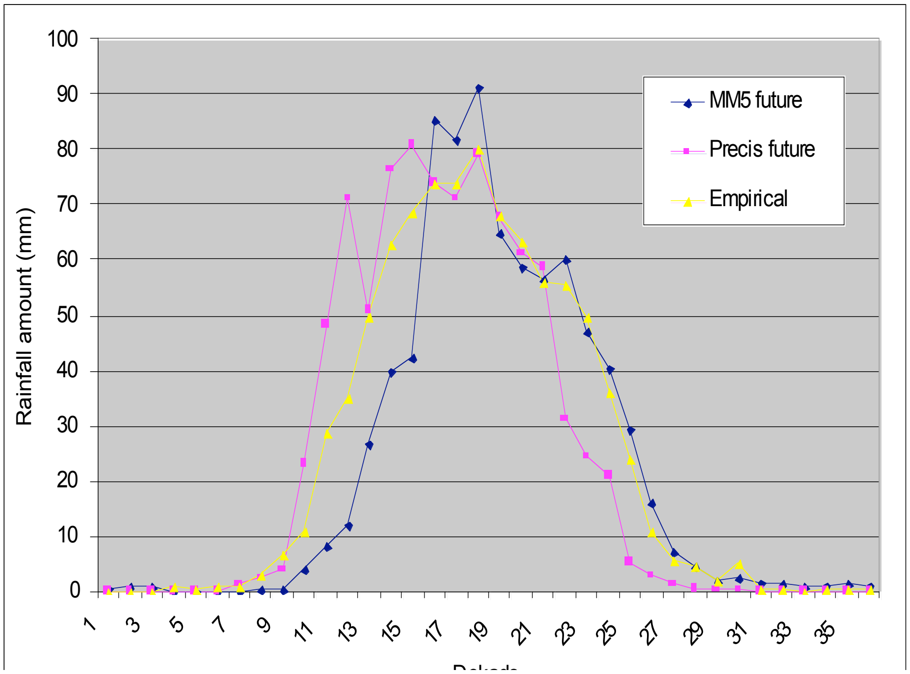

Figure 21: Mean accumulated rainfall per dekad for the empirical data as well as the MM5 and PRECIS Scenarios. Source: Based on data from Tadross et al. (2005).

Usually, one would use the future projections to estimate the future parameters for each dekad and model. However, due to data limitations, e.g. the projections are only point estimates, especially for estimating the standard deviation around the dekads, two different approaches are taken for this analysis, each influencing uncertainty and variability of the results. The two approaches can be described as follows:

1. *Holding future variability constant:* In this approach, the consequences of a mean change in the future are examined while the variance is held constant, i.e., the probability distribution of rainfall in the future has the same variance as the corresponding distribution of the past as calculated from the empirical data.
2. *Changing future variability:* It is likely that future variability also increases; yet, the RCMs do not calculate variability. In order to account for such potential changes, the variance is changed by way of sensitivity analysis as discussed further below.

The original projections lie in the distant future. To study the effects of climate change in the near future, i.e. the next 10 years, the following approach is adopted.

- The empirical mean distribution is set as the baseline case for the year 2005. Observe that this distribution was calculated based on the time series 1961-2005. According to Tadross et al. (2006) climate change effects were already observed in this time period. However, most of the variables were not significant, and those that were significant had very low correlations, so it appears reasonable that the empirical mean distribution is considered as the baseline case for 2005. The mean distributions from the two models, Precis and MM5, serve as the future distributions for 2080 and 2075, respectively.

- The difference between each dekad mean of the empirical and future distribution serve as the incremental steps from 2005 to 2080 and from 2005 to 2075, respectively. One simplistic assumption is that the steps are proportional to the future year minus the base year 2005. However, because the GCM is driven by the mean temperature rise over the time horizon, the incremental steps are assumed to be proportional to the temperature rise from the HadAM3P for the A2 scenario, which was also used for the Precis and MM5 projections. Therefore, for each year a new distribution is used to simulate the rainfall amount for each dekad. Again, first the mean value is changed over the years and the variance is held constant, so that the 'a' parameter can be estimated. Afterwards, also the effects of an additional increase or decrease in the variance are analyzed. The output uncertainty is measured by confidence regions.

For a preliminary examination of the contract based on the rainfall data of the Chitedze station, for each phase a gamma distribution[16] is fitted. Fig. 22 shows the distributions for each phase with the estimated parameter. Due to the longer time horizon of phase three (80 days compared to 30 days for phase 1 and 2), the distribution for phase 3 is skewed to the right, indicating that the rainfall amount is generally higher compared to the other phases. Furthermore, phase 2 seems to have a higher rainfall amount compared to phase 1. For example, with 90 percent probability, the rainfall amount in phase 1 is below 306 mm, whereas for phase 2, the rainfall amount is below 340 mm. Given the upper trigger for each phase, one can determine the probability that the amount of rainfall is below this value. For phase 1 the probability that the amount of rainfall is below 35 mm is 0.53 percent, for phase 2 the probability that rainfall is below 35 mm is 0.045 percent, for phase 3[17] the probability that rainfall is below 220 is 7.59 percent. In other words, a 188 year event (an event that happens on average every 188 years) in phase 1, a 2200 year event in phase 2, or a 13 years event in phase 3 would trigger the respective upper trigger limits.

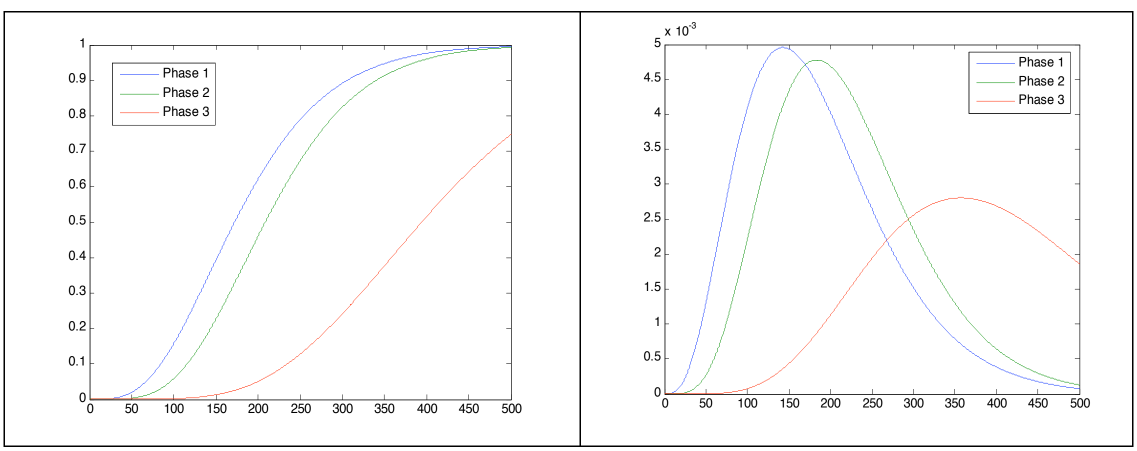

Figure 22: Cumulative distribution and probability density function for each phase based on the rainfall data of the Chitedze station.

[16] A gamma distribution was chosen because it is standardly used for describing rainfall totals (Ref).
[17] Here, the data are not capped.

The expected payout per acre for each phase is also of interest. Instead of analytically solving the integral, Monte Carlo simulation (1 million samples) generates estimates of the expected losses and the standard deviation. The total loan is set to 4667.4 MWK. As a result the expected losses per acre in MWK are

- for phase 1 19.1 (288),
- for phase 2 1.4 (79) MKW, and
- for phase 3 68.5 (310) (standard deviation in brackets).

Summarizing, this contract can be seen as almost two contracts, one for catastrophic events (first 2 phases) and one for more frequently less dramatic losses (third phase).

6.3. Dynamic financial analysis: assessing the financial robustness of the insurance scheme

We study the accumulation of the insurance capital for a time horizon of 10 years for the PRECIS and MM5 data. A random walk model was constructed assuming independence of the annual rainfall amount. For each year, 10,000 scenarios are simulated, resulting in a total number of 100,000 scenarios for each model. Each scenario comprises 36 dekads (i.e. 360 days). If capital accumulation falls below zero in a given year, insolvency occurs. Figure 23 shows estimated extreme value distributions of the insurance pool capital over time based on the empirical data and on the MM5 future projections. Climate change in these projections clearly has negative effects in the MM5 future model as compared to the baseline case. This can be seen by the fatter tails of the distribution for the modeling based on the MM5 projections. This means that the probability of insolvency is higher.

For a more detailed analysis we look at the probability of ruin and the initial capital required to prevent bankruptcy above some predefined threshold level, e.g. increasing the robustness of the pool. In the following, the consequences of mean and variability changes due to climate change for the near future, e.g. 2007 till 2016, and the future period around 2070, based on the information of the MM5 and Precis model are examined. The uncertainty around the results and possible implications are calculated and discussed.

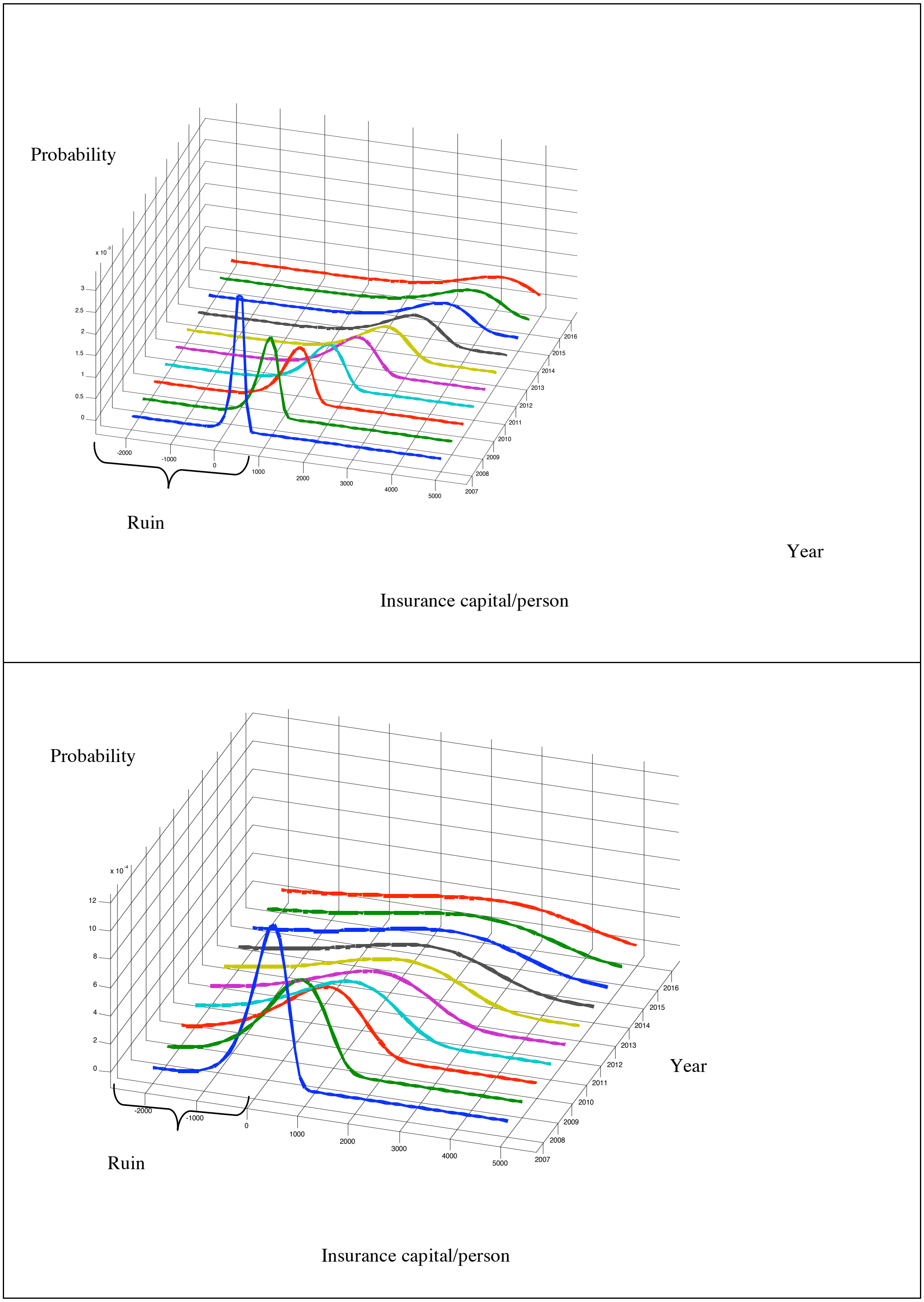

Figure 23: Simulated trajectories of insurance pool's capital for the baseline (above) and MM5 scenario (below) over a 10 year time horizon

6.4 Discussion of results

6.4.1 Mean changes due to climate change

We begin by analyzing the consequences of climate change on the insurance pool based on two conditions: (1) climate change will affect only the mean rainfall amount, and (2) the variance of the rainfall amount remains the same as in the past. A time horizon of 10 years is chosen. Table 13 shows the ruin probabilities (2007-16) for the baseline (empirical data), the MM5 and Precis model for (i) the future case (around 2070) and (ii) the near future case (2007-2016).

Table 13: Probability of ruin for baseline, MM5 and PRECIS cases

Year	Baseline	MM5 future scenario	Precis future scenario	MM5 near future	Precis near future
2007	0.0738	0.2217	0.1081	0.0748	0.0741
2008	0.1139	0.3423	0.1643	0.1157	0.1147
2009	0.1359	0.4136	0.1953	0.1388	0.1368
2010	0.1482	0.4595	0.2138	0.1520	0.1493
2011	0.1551	0.4918	0.2255	0.1599	0.1566
2012	0.1594	0.5159	0.2333	0.1651	0.1611
2013	0.1621	0.5349	0.2385	0.1685	0.1639
2014	0.1639	0.5504	0.2422	0.1708	0.1659
2015	0.1652	0.5631	0.2449	0.1726	0.1672
2016	0.1660	0.5738	0.2469	0.1739	0.1681

There is an increase of the ruin probabilities in the future case for both models. Especially, for the MM5 model the increase is dramatic. The probability of ruin is over 50 percent for a time period of 10 years. The increase is less dramatic for the near future; however, also here an increase of the ruin probabilities can be observed.

Two options to reduce the risk of insolvency to the insurance scheme could be taken:

- Adjusting premiums and payouts,
- Increasing back-up capital, so as to decrease the probability of ruin to manageable levels.

Premium adjustment seems to be difficult as premiums are high already (6-10% of insured value) and thus we look only at the latter option. A simplifying assumption is that the pool does not hold backup capital in the initial year. Of course, the insurer will hold back-up capital either specifically for the Malawi pool, or will diversify its exposure by holding other "pools." The back-up capital necessary for the case without climate change ("empirical") serves as a baseline to which changes in necessary back-up capital are compared.

Reversely calculating the insurance capital required for financial robustness in 95 (99) percent of the cases over the 10-year time horizon leads to the following capital requirements per person (Table 14). The numbers in brackets are the confidence intervals of the outcomes assuming a normal distribution. Each simulation was performed 100 times and the mean and standard deviation were used to calculate the confidence levels.

Table 14: Insurance capital required for financial robustness in 95 (99) percent of the cases over the 10 year time horizon

	Back-up capital to avoid insolvency with 95% probability (kwacha/person)	In % of premium ('00)	Back-up capital to avoid insolvency with 99% probability (kwacha/person	In % of premium ('00)
Empirical	1013.3 [1006.4 1020.2]	2.21	2179.1 [2166.3 2191.9]	4.72
MM5 near future	1078.0 [1070.4 1085.6]	2.31	2283.2 [2267.7 2298.7]	4.9
Precis near future	1027.8 [1021.9 1033.7]	2.23	2196.2 [2181.2 2211.2]	4.75
MM5 future	3874.2 [3861.6 3886.8]	8.34	5943.5 [5918.9 5968.1]	12.73
PRECIS future	1473.5 [1466.2 1480.8]	3.29	2730.6 [2715.9 2745.3]	5.64

In all cases, additional backup capital would be needed to remain solvent at the 95 (99) percent levels. Backup capital in terms of premium ranges from 2.2% and 4.7% for the empirical, non-climate change case up to 8.3% and 12.7% for the MM5 case for 2070. Generally, Precis estimates were lower than those for MM5. The additional back-up capital required for the next 10 years compared to the empirical case is significant, if small: 6.4% and 4.8% for the 5% resp. 1% ruin probabilities for MM5, and 1.4% and 0.8% for the précis model. For more significant climate change (here based on the A2 scenario to occur in the distant future around 2070), these additional requirements would raise very substantially to 282.3% and 172.8% for the MM5 and to 45.4% and 25.3% for the Precis.

An important consideration is the confidence of these estimates. Because Monte Carlo simulations are used, there is uncertainty in these results. Therefore, confidence intervals of the outcomes of the simulations are shown. No overlapping (with one exception for the Precis data at the 1% level) between the empirical and other models occurred indicating that the differences are significant. Summarizing, it seems that the results, incorporating output uncertainty, are significantly different to the baseline case, e.g. significant negative effects in the future and also in the near future.

The analyses of mean changes, therefore, show negative effects on the insurance pool to be expected in the near future and dramatic negative effects in the future. In the next subsection, an analysis of mean <u>and</u> variability changes are studied, whereby variability is added in the form of sensitivity analysis

6.4.2. Mean and variability changes due to climate change

Because it is likely that in the future the variability of rainfall will increase rather than decrease (see Tadross et al., 2006), it is important to incorporate possible effects in the analysis. Ideally, one would estimate the variance of the future projections to get an estimate of the magnitude of change. However, due to data limitations with only 20 years of data availability, such an exploration is not feasible. Possible changes in future variance are implemented by way of sensitivity analysis. The future variance based on the empirical data is increased by a factor of 1.4 and decreased by a factor of 0.78 in the future, which corresponds roughly to a doubling and halving of the past variance (Mearns, Rosenzweig and Goldberg, 1997).

The probability density function of the gamma distribution has the following form

$$f(x \mid á, â) = \frac{1}{â^{á}\,\tilde{A}(á)} x^{á-1} e^{-\frac{x}{â}}, \quad x \geq 0$$

where α is the shape parameter and β is the scale parameter. The mean of the distribution is $\alpha\beta$ and the variance is $\alpha\beta^2$. Hence, an increase of β of 1.4 can be seen as doubling the rainfall variability compared to the baseline case, while a decrease of 0.78 can be interpreted as a one-half decrease of the variance compared to the baseline case. Hence, both parameters of the gamma distribution are now changing.

We discuss the results for the case of an increase of the variability in the future. Again, the analysis is based on the MM5 and Precis models for the future (2070) and near future (2007-2006).

Table 15: Probability of ruin for baseline, MM5 and PRECIS cases with mean and variability changes

Year\ Probability of ruin (%)	Baseline	MM5 future scenario	Precis future scenario	MM5 near future	Precis near future
2007	0.0738	0.3789	0.2157	0.1509	0.1492
2008	0.1139	0.5607	0.3231	0.2362	0.2332
2009	0.1359	0.6621	0.3839	0.2877	0.2832
2010	0.1482	0.7254	0.4222	0.3206	0.3149
2011	0.1551	0.7694	0.4488	0.3434	0.3368
2012	0.1594	0.8019	0.4688	0.3598	0.3522
2013	0.1621	0.8270	0.4839	0.3725	0.3639
2014	0.1639	0.8469	0.4962	0.3826	0.3730
2015	0.1652	0.8633	0.5060	0.3908	0.3804
2016	0.1660	0.8769	0.5141	0.3977	0.3864

Table 15 shows the ruin probabilities under this new setting. As one would expect, the results are more pronounced for all models compared to the baseline case. Additionally, compared to mean changes only, increased variability will worsen the negative effects on the insurance pool. This can also be calculated in terms of the initial capital requirements.

Table 16: Insurance capital required for financial robustness in 95 (99) percent of the cases over the 10 year time horizon with mean and variability changes

	Back-up capital to avoid insolvency with 95% probability (kwacha/person)	In % of premium	Back-up capital to avoid insolvency with 99% probability (kwacha/person	In % of premium
Empirical	1013.3 [1006.4 1020.2]	2.17	2179.1 [2166.3 2191.9]	4.67
MM5 near future	2652.5 [2641.3 2663.7]	5.68	4398.5 [4375.7 4421.2]	9.42
Precis near future	2557.5 [2548.0 2567.0]	5.48	4276.7 [4258.4 4295.1]	9,16
MM5 future	7876 [7861 7891]	16.88	10533 [10503 10564]	22.57
PRECIS future	2973.3 [2963.1 2983.5]	6.37	4687.8 [4669.6 4706.0]	10.04

As shown in Table 16, the initial capital must be at least two fold in the best case, compared to the baseline scenario and 7 times the baseline case for the worst scenario (MM5 future). Figure 24 graphically displays those results including confidence intervals.

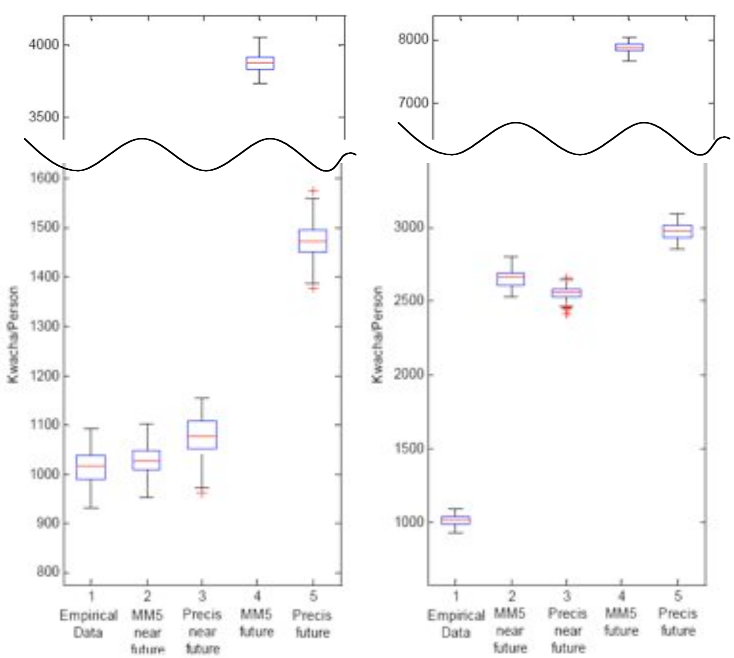

Figure 24: Summary results of insurance capital if means are changed (left plot) and means and variance changed (right plot)

While it is not very plausible to assume decreasing variability, it is also possible to study possible effects on the insurance pool by means of sensitivity analysis. Table 17 shows that, in general, decreasing vulnerability would increase the robustness of all future scenarios and insurance pools. Only the MM5 scenario would give negative results, mainly due to the higher catastrophe losses in phase 1.

Table 17: Confidence intervals of capital requirements

	Baseline	MM5 Future scenario	Precis future scenario	MM5 near future	Precis near future
5% level	1006.4 1020.2	7865 7887	424.5 434.9	359.7 371.0	339.2 351.9
1% level	2166.3 2191.9	10510 10556	1287.4 1309.0	1356.7 1377.2	1331.1 1355.2

6.5 Conclusions

According to this analysis, climate-change induced stress will likely decrease the financial robustness of the Malawian insurance pool in the 10-year period between 2006-2016. With predicted stronger changes in rainfall patterns, climate change will likely have more dramatic negative effects in the 10-year period, 2070-2080. Assuming that premiums are not raised from current levels, additional back-up capital would be necessary to render the Malawi program robust at the 95% and 99% confidence levels. It should be kept in mind that these results are limited by the restrictive assumptions taken, as well as the input data and the climatological and insurance models employed. While data and climate-model uncertainty have not been accounted for in this analysis, uncertainty in terms of natural variability of the system has been expressed with sensitivity analysis, and output uncertainty deriving from the modeling and simulation has been expressed with confidence intervals.

Uncertainties in the estimates and derived projections are high, and further research is needed to refine the methodology. A first uncertainty relates to future states of the world and associated greenhouse gas emissions and temperature rise as represented by the SRES scenarios. A major limitation arises since SRES scenarios do not have associated probabilities. Data availability on rainfall greatly limits future projections, especially estimating future rainfall variability, which is a key factor influencing crop yields. Additional computer runs of the RCMs models would improve capacity for forecasting rainfall variability. This analysis has also not considered inter-annually correlated rainfall and drought patterns, e.g. due to the El Nino effects. Seasonal changes would negatively affect the insurance pool. Some key assumptions used for the simulation are problematic. Because of the complexity of the biological process of crop growth and changing rainfall patterns, trigger events are not changed over time, an assumption that is not valid with climate change. Nor does the analysis consider possibilities of planting new crop types which behave better under new climate scenarios (Gadgil et al., 2002). Finally, this supply-side analysis did not consider basis risk to the farmers.

Notwithstanding the need for further refinements, the importance of this analysis goes beyond its implications for the Malawian insurance scheme. By combining catastrophe insurance modeling with climate modeling, the methodology demonstrates the feasibility, albeit with large uncertainties, of estimating the effects of climate change on the near- and long-term future of microinsurance schemes serving the poor. By providing a model-based estimate of the incremental role of climate change, along with the associated uncertainties, this methodology can quantitatively demonstrate the need for financial assistance to protect insurance pools against climate-change induced insolvency.

Because commercial reinsurance will greatly raise premiums to clients who can ill afford any additional costs, the climate community, alongside the international development community, is considering options for providing backup capital and pooling the risks of small-scale microinsurers offering catastrophe cover. The methodology demonstrated in this analysis, especially the quantitative estimate of the additional stress placed climate change imposes on the Malawi system, can inform these options and thus bolster the case for supporting existing or emerging insurance arrangements for helping developing countries cope financially with climate variability and change.

7. CONCLUSIONS AND RECOMMENDATIONS

From the participating farmers' perspective, the first operational year of the Malawi index-based insurance pilot project appears successful. A large majority (86%) of sampled farmers reported that they would participate again. Despite its merits, there were significant challenges in the original architecture of the program, many of which were revealed from experience gained in the first pilot year. NASFAM was critical for the system logistics, and proved adept at communications and responding to the early seed germination crisis. However, trust in this organization appears to be polarized among survey respondents, which flags a potential problem of vesting responsibility largely in one organization. There were also concerns voiced about the pre-arranged agreement to sell the groundnut harvest to NASFAM. If market prices prove higher than the NASFAM price, as was the case in the first year of operation, there is a risk of side selling to outside traders, limiting NASFAM's capacity to repay the loan. Basis risk, or the risk that precipitation experienced by an individual farmer does not correspond to that measured at the weather station, has also proven to be a controversial issue. The survey of farmers revealed a worrying lack of understanding of the index-based system, and a lack of trust among many farmers in the weather station data on which the system rests. Since institutional trust is a pre-requisite for the sustainability of the scheme, the Malawi experience reveals significant challenges in scaling up operations, particularly given the already overstretched capacity of NASFAM.

Many of the revealed drawbacks have been addressed in the 2006-7 planting season, during which the scheme has expanded to an additional region and to include maize. NASFAM will continue its role in communicating with farmers and supplying seeds, but there will be more dependence on the market for selling the harvest. In addition, the system designers might consider the following:

- *Improve the communication process, making use of NASFAM capabilities.*
- *Include farmers (farmer club representatives) in monitoring the weather station data, to improve trust in the rainfall measurement.*
- *Diversify responsibility for the logistics of the system.*
- *Ensure that farmers fully agree to the acceptance of basis risk.*

This analysis shows the advantages of making use of ENSO-based predictions in the operations of the Malawi program by promoting the cultivation of larger areas with high-yield inputs when good rains are expected, and reducing the exposure to drought risk when conditions are less favorable. Results of crop simulation modeling and financial calculations show that integrating seasonal rainfall forecasts can lead to substantial increases in gross revenues during La Niña years and thus reduce the farmers' long-term vulnerability to climate variability and change. While the analysis is based on several simplifying assumptions, they are unlikely to challenge the main finding: a scheme that uses skilful seasonal forecasts to adjust the bundled loan-insurance contract according to expected rains can substantially benefit participating farmers.

This result strongly suggests that system designers:

- *Make use of ENSO forecasts by adjusting premium, loans, and other system variables to reflect expectations.*

In addition, it is anticipated that rainfall in Malawi will be influenced by climate change Through the combination of climate modeling and dynamic financial modeling, this analysis shows that climate-change induced stress will likely decrease the financial robustness of the Malawian insurance pool in the coming decade, and more significantly 50-plus years in the future. Assuming that premiums are not raised from current levels, additional back-up capital will be necessary to render the Malawi program robust. These results are limited by simplifying assumptions, as well as large uncertainties in the data and climate models on which the analysis is based. Still, by combining catastrophe insurance modeling with climate modeling, the methodology demonstrates the feasibility, albeit with large uncertainties, of estimating the effects of climate change on the near- and long-term future of microinsurance schemes serving the poor. The methodology and results suggest that

- *The additional burden of climate change on weather insurance systems can be approximately estimated, and these estimates can bolster the case for outside support.*

In conclusion, experience gained from the Malawi pilot program, and insights gained from this research, show that:

- Weather insurance for low-income regions, given donor assistance, appears to be administratively and economically feasible, and shows great potential for reducing vulnerability to rainfall variability and, at the same time, promoting wealth accumulation;
- Insurance schemes that provide cover for livelihoods (beyond the loan-default risk) and for very poor regions would likely require significant donor assistance;
- Communication and marketing efforts are an important pre-requisite for successful operations. The low levels of understanding of the index-based bundled scheme among participating farmers may threaten the continuity of the Malawi scheme, particularly if unexpected events trigger outcomes that result in loss of trust.
- As demonstrated by simulation modeling of the Malawi program, the potential for increasing farmer productivity, and thus reducing weather-related poverty and vulnerability, can be greatly enhanced by taking account of ENSO-based forecasts;
- It is possible to integrate climate and catastrophe insurance modeling for estimating the approximate additional burdens of climate change on weather insurance systems.

These results, and the methodologies applied, are of interest to the Malawi program, and beyond. The Malawi experience, and the ENSO and climate-change modeling, can inform other nascent weather insurance systems in Africa, and also in Asia and Latin America. They can also inform development institutions, as well as organizations supporting adaptation to climate change. The Malawi pilot program was only possible with technical assistance from the World Bank, which illustrates a potential role for development and donor organizations. Another important form of support is providing backup capital, and pooling the risks of geographically diverse catastrophe insurance systems. This will be important, even critical, for these systems as they scale up to include more clients and products adding to the systemic nature of the risks.

Market mechanisms, when adequately structured, can help guide the allocation of resources for agricultural production and risk management under a changing climate. Bundled loan-insurance schemes can take newly available information into account every season, adjusting prices, input packages and other variables to convey to economic actors the dynamic nature of relatively predictable climate risks. Lessons from the use of seasonal predictions in the Malawi scheme can help enrich the conceptual framework required for applying insurance solutions to the climate change problem.

ACKNOWLEDGEMENTS

We are grateful to Alex Lotsch, Donald Kamdonyo, Duncan Warren, Ephraim Chirwa, Erin Bryla, Ethel Kaimila, Frank Masankha, Joanna Syroka, Mark Tadross, Shadreck Mapfumo, Xavier Giné and Xiaoyu Liu for discussions that helped shape this work. We also extend our gratitude to the Malawian farmers that participated in participatory workshops in districts of Kasungu and Lilongwe, as well as to NASFAM and the Malawi Red Cross Society for logistical assistance organizing workshops. This research was made possible by a trust fund provided by the Bank Netherlands Partnership Program and managed by the World Bank Development Economics Research Group. The staff time for the specification, development, analysis and modeling of forecast options in section 5 of this report was provided for no cost by IRI. Usual disclaimers apply.

REFERENCES

Action Aid (2005) Climate change and smallholder farmers in Malawi: Understanding poor people's experiences in climate change adaptation. http://www.reliefweb.int/rw/lib.nsf/db900SID/AMMF-6Z4JUW/$FILE/actionaid-development-oct2006.

Arnold, M. and Kreimer, A. (2004) "The Socio-economic Costs of Disasters." In: Mathur, A., Burton, I. and van Aalst, M. (eds.), 2004, *An Adaptation Mosaic: An Example of Emerging Bank Work in Climate Change Adaptation*, Washington DC, World Bank Global Climate Change Team, The World Bank, 5-14.

Bals, C., Butzengeiger, S., Warner, K. (2006) "Insuring the uninsurable: Design options for a climate change funding mechanism" *Climate Policy* **6**: 626-231.

Brau, J. C., Woller, G. M. (2004) "Microfinance: A comprehensive review of the existing literature " *Journal of Entrepreneurial Finance and Business Ventures* **9** (1): 1-26.

Bouwer, L.M. & P. Vellinga (2005) "Some rationales for risk sharing and financing adaptation." *Water Science and Technology* **51**, 89-95.

Bryla, E. and Mapfumo, S. (2005) Pilot 2005: Index based weather insurance for groundnut farmers, Presentation given at the World Bank Commodity Risk Management Group, November 15, 2005, Washington DC.

Cabrera, V. E., Fraisse, C.W., Letson, D., Podestá, G., Novak, J. (2006) "Impact of climate information on reducing farm risk by optimizing crop insurance strategy " *Transactions of the American Society of Agricultural and Biophysical Engineers* **49**(4): 1223-1233.

Carriquiry, M., and D. Osgood (2006) Index Insurance, Production Practices, and Probabilistic Climate Forecasts, The International Research Institute for Climate and Society in the Earth Institute at Columbia University.

Dilley, M. (2000) "Reducing vulnerability to climate variability in Southern Africa: The growing role of climate information" *Climatic Change* **45**(1): 63-73.

Dilley, M., Boudreau, T. E. (2001) "Coming to terms with vulnerability: A critique of the food security definition" *Food Policy* **26**(3): 229-247.

Doctor, R. D. (1991) "Information technologies and social equity: Confronting the revolution. Journal of the American Society for Information" *Science* **42**(3): 216-228.

Emanuel, K. (2005) "Increasing destructiveness of tropical cyclones over the past 30 years" *Nature* **436**(2005): 686-688.

Embrechts, P., Klüppelberg, C., Mikosch, T. (1997) Modeling extreme events Springer, Berlin.

Freeman, H.A., van der Merwe, P.J.A., Subrahmanyam, P., Chiyembekeza, A.J., and Kaguongo, W. (2002) Assessing adoption potential of new groundnut varieties in Malawi. Working Paper Series no. 11, Socioeconomics and Policy Program, International Crops Research Institute for the Semi-Arid Tropics, Nairobi, Kenya.

Gadgil S., Rao P.R.S., Rao K.N. (2002) "Use of climate information for farm-level decision making: rainfed groundnut farming in southern India" *Agric Syst* **74**:431–457.

Geman, H. (Ed.) (1999) Insurance and Weather Derivatives: From Exotic Options to Exotic Underlyings, Risk Books, London.

Glantz, M. (2001) "Currents of change: Impacts of El Niño and La Niña on climate and society " Cambridge University Press, Cambridge.

Gurenko, E. (2006) "Introduction and executive summary" *Climate Policy* **6**: 600–606**.**

Hammer, G. L., Hansen, J.W., Phillips, J.G., Mjelde, J.W., Hill, H., Love, A., Potgeiter, A. (2001) "Advances in application of climate prediction in agriculture " *Agricultural Systems* **70**: 515-553.

Hansen, J. (2002) "Realizing the potential benefits of climate prediction to agriculture: Issues, approaches, challenges" *Agricultural Systems* **74**: 309-330.

Hayek, F. A. (1945) "The use of knowledge in society." *American Economic Review* **35**(4): 519-530.

Hellmuth, M. E., Moorhead, A., Thomson, M. C., Williams, J. (eds) (2007) Climate risk management in Africa: Learning from practice. International Research Institute for Climate and Society (IRI), Columbia University, New York.

Hess, U. (2005) Personal communication. The World Bank, Washington D.C.

Hess, U., Syroka, H. (2005) Weather-based insurance in Southern Africa: The Case of Malawi. Discussion Paper 13. The World Bank, Washington, D.C.

Hewitson, B. C., Crane, R. G. (2006) "Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa" *International Journal of Climatology* **26**(10): 1315-1337.

Hill, H.S., Butler J., Fuller, D., Hammer S.W., Holzworth, G., Love D., Meinke, H.A., Mjelde H., Park, J.W., Rosenthal J.(2001). In: Rosenzweig, C. (ed.) "Impacts of El Niño and Climate Variability on Agriculture" *American Society of Agronomy Special Publication* **63**, 101–123.

Ho, T. (2005) "Asset/Liability management and enterprise risk management of an insurer" *Journal of Investment Management* **3**(1): 45-59.

IPCC - Intergovernmental Panel on Climate Change (2001a) The scientific basis: Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

IPCC (2001b) Climate change 2001: Impacts, adaptation and vulnerability, Cambridge University Press, Cambridge.

IPCC (2001c) Special Report on Emissions Scenarios (SRES). Special Report of the Intergovernmental Panel on Climate Change, Nebojsa Nakicenovic and Rob Swart (Eds.), Cambridge.

IPCC (2007) Climate change 2007: Impacts, adaptation and vulnerability. Summary for Policymakers, *Retrieved April 8, 2007 from http://www.ipcc.ch.*

Jewson, S., Brix, A. (2005) Weather derivative valuation: The meteorological, statistical, financial and mathematical foundations, Cambridge University Press, Cambridge.

Kartha, S., P. Bhandari, L. van Schaik, D. Cornland, C., Kjellen, B. (2006) Adaptation as a strategic issue in the climate negotiations. ECP Report no. 3.

Klein, R.J.T., Eriksen, S.E.H, Naess, L.O., Hammill, A., Tanner, T.M., Robledo, C., O'Brien K.L. (forthcoming) "Portfolio screening to support the mainstreaming of adaptation to climate change into development assistance" *Climatic Change*.

Lievrouw, L. A., Farb, S. E. (2003). "Information and equity" *Annual Review of Information Science and Technology* **37**: 499-540.

Linnerooth-Bayer, J., Mace, M.J., Verheyen, R. (2003) Insurance-related actions and risk assessment in the context of the UNFCCC, Background paper for UNFCCC workshop on Insurance-related Actions and Risk Assessment in the Framework of the UNFCCC, May 11-15, Bonn, Germany.

Linnerooth-Bayer, J., Mechler R., Pflug G. (2005) "Refocusing disaster Aid" *Science* **309**(5737): 1044–1046.

Linnerooth-Bayer, J., Mechler, R. (2006) " Insurance for assisting adaptation to climate change in developing countries. A proposed strategy." *Climate Policy* **6**: 621-26.

Linnerooth-Bayer, J., Mechler, R., Suarez, P. (2006) Microinsurance as a financial coping mechanism for natural disaster risk: A review of the affordability/feasibility of donor-assisted micro risk financing schemes in developing countries, DEC-Research Group, Infrastructure and Environment Unit, The World Bank, Washington, D.C.

Linnerooth-Bayer, J. Mechler, R., Mace, M.J. (forthcoming) "Insurance and Adaptation: Opportunities for the Climate Change Negotiations" In Sjoestedt, G. (ed). Pitfalls in negotiating climate change, Springer: Berlin.

Lowe, S. P., Stanard, J.N. (1997) "An integrated dynamic financial analysis and decision support system for a property catastrophe reinsurer" *ASTIN Bulletin* **27**(2): 339–371.

Luo, H., Skees, J. R., Marchant, M.A. (1994) "Weather information and the potential for intertemporal adverse selection in crop insurance" *Review of Agricultural Economics* **16**(3): 441-451.

Mapfumo, S. (2006) Personal communication.

Mearns, L. O., Rosenzweig, C., Goldberg, R. (1997) "Mean and variance change in climate scenarios: Methods, agricultural applications, and measures of uncertainty" *Climatic Change* **35**(4): 367-396.

Mechler, R., J. Linnerooth-Bayer, and D. Peppiatt (2006) Disaster Insurance for the Poor? A Review of Microinsurance for Natural Disaster Risks in Developing Countries, Geneva: ProVention Consortium.

Met Office (2007) Types of climate models. http://www.metoffice.gov.uk/research /hadleycentre/models/modeltypes.html

Mills, E. (2005) "Insurance in a climate of change" *Science* **309** (5737): 1040-1044.

Mjelde, J. W., Hill, H.S.J. (1999) "The effect of the use of improved climate forecasts on variable costs, input usage, and production" *Agricultural Systems* **60**(3): 213-225.

Müller, B. (2002) "Equity in climate change: The great divide" Oxford Institute for Energy Studies, Oxford.

Murphy, S. J., Washington, R., Downing, T. E., Martin, R. V., Ziervogel, G., Preston, A. (2001) "Seasonal forecasting for climate hazards: Prospects and responses" *Natural Hazards* **23**(2-3): 171-196.

MVAC – Malawi Vulnerability Assessment Committee (2005) Provisional Results of the Harvest Outcome Analysis. Lilongwe.

Nicholls, N. (2000) "Opportunities to improve the use of seasonal climate forecasts" in Mitchell, C. (ed) Application of seasonal climate forecasts in agricultural and natural ecosystems: The Australian experience, Kluwer Academic Publishers, Dordrecht.

Null, J, (2004). El Niño and La Niña Years: A Consensus List. http://ggweather.com/enso/years.htm.

Osgood, D. (2006) Personal Communication.

Osgood, D. and Warren, D. (2006) Personal Communication.

Osgood, D., Warren, D. (2007) "Drought insurance in Malawi" in Hellmuth, M. E., Moorhead, *A., Thomson, M.C., Williams, J.(eds) Climate Risk Management in Africa: Learning from Practice International Research Institute for Climate and Society (IRI), Columbia University, New York, USA.*

Patt, A. G. (2001) "Understanding uncertainty: Forecasting seasonal climate for farmers in Zimbabwe" *Risk, Decision and Policy* **6**: 105-119.

Patt, A., Gwata, C. (2002) "Effective seasonal climate forecast applications: examining constraints for subsistence farmers in Zimbabwe" *Global Environmental Change* **12**: 185-195.

Patt, A., P. Suarez and C. Gwata (2005) "Effects of seasonal climate forecasts and participatory workshops among subsistence farmers in Zimbabwe" *Proceedings of the National Academy of Sciences of the United States of America* **102**: 12623-12628.

Phillips, J. G., Deane, D., Unganai, L., and Chimeli, A. (2002) "Implications of farm-level response to seasonal climate forecasts for aggregate grain production in Zimbabwe" *Agricultural Systems,* ***74***(3), 351-369.

Roncoli, C., Ingram, K., and Kirshen, P. (2001) "The costs and risks of coping with drought: livelihood impacts and farmers' responses in Burkina Faso" *Climate Research* ***19*** (2), 119-132.

Schönwiese, C. D., Grieser, J., Tromel, S. (2003) "Secular change of extreme monthly precipitation in Europe" *Theoretical and Applied Climatology* **75**(3-4): 245-250.

Simtowe, F., Zeller, M, 2006 The impact of access to credit on the adoption of hybrid maize in Malawi: an empirical test of an agricultural household modelunder credit market failure. http://mpra.ub.uni-muenchen.de/45/

Skees, J. R., Hazell, P., Miranda, M. (2002) New approaches to public/private crop yield insurance. The World Bank, Washington, D.C.

Skoet, J., Stamoulis, K. (2006) The state of food insecurity in the world 2006, Food and Agriculture Organization of the United Nations, Rome, Italy.

Stern, P. C. and Easterling, W. E. (eds.) (1999) Making Climate Forecasts Matter, National Academy Press, Washington, D.C

Stiglitz, J., Greenwald, B. (1986) Externalities in Economies with Imperfect Information and Incomplete Markets *Quarterly Journal of Economics*, Vol. **101**, 229-264

Suarez, P., Givah, P. and Storey, K (forthcoming). HIV/AIDS, Climate Change and Disaster Management: Challenges for Institutions In Malawi. DEC-Research Group, Infrastructure and Environment Unit, The World Bank, Washington, D.C.

Syroka, J. (2007), Personal communication.

Tadross, M. A., Jack, C., Hewitson B.C. (2005) "On RCM-based projections of change in southern African summer climate." *Geophysical Research Letters* **32**(23): L23713, doi 10.1029/2005GL024460.

Tadross, M. (2006) "Evidence of a changing climate in Malawi, Mozambique and Zambia: Analysis of daily rainfall data and regional models." *Report for project "Institutions for Climate Change Adaptation"* Development Economics Research Group, Infrastructure and Environment Unit, The World Bank Washington, D.C.

Tsanakas, A. and Desli, E. (2005). Measurement and Pricing of Risk in Insurance Markets. *Risk Analysis* **25** (6), 1653–1668.

UNDESA - United Nations Department of Economic and Social Affairs (2007). Developing index-based insurance for agriculture in developing countries. Sustainable Development Innovation Briefs Issue No. 2. New York: UNDESA.

UNISDR - United Nations International Strategy for Disaster Reduction (2005). Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters. Report of the World Conference on Disaster Reduction. Kobe, Hyogo, Japan, January 18-22, 2005.

Van Aalst, M. (2006) Managing Climate Risk: Integrating Adaptation into World Bank Group Operations, World Bank Group-Global Environment Facility Program, Washington, D.C.

Verheyen, R. (2005) Climate change damage and international law: Prevention, duties, and state Responsibility. Brill Academic Publishers, Bedfordshire, U.K.

Vidal, J., Radford, T. (2005) "One in six countries facing food shortage." *The Guardian,* June 30, http://www.guardian.co.uk/international/story/0,1517746,00.html

Wang, S. S., Young, V. R. and Panjer, H. H. (1997) "Axiomatic characterization of insurance prices" *Insurance: Mathematics and Economics* 21(2), 173–183.

World Bank (2005a) Managing agricultural production risk, World Bank, Washington, D.C.

World Bank (2005b) Commodity and Weather Risk Management Programs to be Expanded, *World Bank News & Broadcast,* May 24 2005, http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:20513603~menuPK:34459~pagePK:34370~piPK:34424~theSitePK:4607,00.html