# Integrating seasonal forecasts and insurance for adaptation among subsistence farmers: The case of Malawi

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ABSTRACT

Climate variability poses a severe threat to subsistence farmers in southern Africa. Two different approaches have emerged in recent years to address these threats: the use of seasonal precipitation forecasts for risk reduction (e.g. choosing seed varieties that can perform well for expected rainfall conditions), and the use of innovative financial instruments for risk sharing (e.g. index-based weather insurance bundled to credit for agricultural inputs). So far these two approaches have remained entirely separated. This paper explores the integration of ENSO-based seasonal forecasts into an ongoing pilot insurance scheme for smallholder farmers in Malawi. We propose a model that adjusts the amount of high-yield agricultural inputs given to farmers to favorable or unfavorable rainfall conditions expected for the season, according to ENSO status in October. Simulation results, combining climatic, agricultural and financial models, indicate that 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). Cumulative gross revenues are more than twice as large for the proposed scheme, given modeling assumptions. The resulting accumulation of wealth can reduce long-term vulnerability to drought for participating farmers. Conclusions highlight the potential of this approach for adaptation to climate variability and change in southern Africa.

## 1 INTRODUCTION

Recent advances in science and technology have encouraged a remarkable growth in the development of forecasts (Wang et al., 2004). Two major areas of scientific inquiry have immense potential for addressing risks involving natural hazards: climate change (IPCC, 2001; 2007) and climate variability associated with El Niño – Southern Oscillation, or ENSO (Dilley, 2000; Glantz, 2001). Humanity faces two new challenges: 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).

Southern Africa is particularly vulnerable to climate variability and change. Droughts, which are strongly related to ENSO in many areas within the region (see Fig. 1), 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 vast sectors of the population in this region. There is a need to harmonize the fields of disaster risk reduction and regional development (World Bank, 2000), and climate predictions can play a role.

The international community is paying increasing attention to insurance against climate-related hazards, seeing it as a potentially effective ex-ante risk management strategy (Linnerooth-Bayer et al., 2005, World Bank, 2005). 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., 2002). Article 4.8 of the United Nations Framework Convention on Climate Change

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(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. Similarly, the Hyogo Framework for Action calls for the development of risk sharing mechanisms, particularly insurance and reinsurance against disasters (UNISDR, 2005). 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.

Several micro-insurance schemes have emerged in recent years to address drought risk among smallholder farmers (Linnerooth-Bayer et al., 2006). Of particular relevance is an innovative pilot drought insurance scheme currently under way in Malawi, which is one of the poorest countries in southern Africa. First implemented in 2005, the Malawi scheme offers index-based weather insurance to smallholder groundnut farmers. The Malawi insurance scheme improves farmers' credit worthiness and therefore their ability to access credit for investing in higher-yield/higher return crops (Hellmuth et al., 2007). 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.

Forecasts have not played in 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).

Car theft insurance can encourage the reduction of theft risk by reducing premiums for those who install an anti-theft alarm 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.

The remainder of the paper is structured as follows: Section 2 presents a basic overview of seasonal climate forecasts in southern Africa and their potential role in reducing risk. Section 3 offers an introduction to the Malawi pilot scheme that bundles microcredit with index-based insurance. Section 4 discusses challenges and opportunities for integrating forecast-based risk reduction approaches into this kind of risk sharing mechanism. Section 5 outlines a proposed approach to such integration, presenting the models used to simulate the climatic, agricultural and financial dimensions of such approach, and model results. Section 6 concludes, highlighting implications for risk management and climate change adaptation.

## 2 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.

[Figure 1 about here]

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).

Hansen (2002) presents a simple illustration depicting the determinants of the potential for human populations to benefit from climate predictions (Figure 2). *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 $(t + t)$. *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 2 overlap.

[Figure 2 about here]

This paper focuses on vulnerable systems that could benefit from climate predictions but lack the decision capacity to do. 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 (Stern and Easterling, 1999, Roncoli et al., 2001). Phillips et al. (2002) 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 predictions.

## 3 INDEX-BASED INSURANCE AND RISK SHARING: THE MALAWI PILOT

### 3.1 Context: Drought risk in Malawi

Malawi is one of the most food-insecure countries in the Southern African region. Recurrent droughts, the AIDS pandemic, chronic malnutrition, declining soil fertility, shortages of land (most farmers have small holdings, from 1.2 to 7.5 acres) and inadequate agricultural policies contribute to the country's vulnerability. Life expectancy in Malawi is approximately 38 years, and about 6.3 million Malawians live below the poverty line (the majority in rural areas with more than 90% relying on rain-fed subsistence farming to survive). Food insecurity is chronic, 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).

Hess and Syroka (2005) point out the strong linkage between food security and weather risk management. According to the authors, Malawi should be a net exporter of food since agro-climatic conditions are relatively good, despite the volatility in rainfall patterns. The management of drought risk in Malawi should involve adapting production, making markets function, establishing effective social safety nets and preparing for food emergencies through ex ante emergency risk management.

Droughts are not only a source of risk of food shortage, but also inhibit farmers from planting higher yield hybrid seeds. Smallholder farmers lack traditional collateral. 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, 2005).

### 3.2 The Malawi pilot: credit for inputs bundled with index-based insurance

To address the credit constraints discussed above, the World Bank Commodity Risk Management Group, in collaboration with local stakeholders, designed a weather insurance scheme in Malawi for the 2005/2006 crop season in order to enhance groundnut farmers' ability to manage drought risk and, in turn, access loans for improved agricultural inputs. A more detailed description of the scheme is available in Hellmuth (2007). Bundled loan and insurance contracts were offered in four pilot areas: Kasungu, Nkhotakhota, Chitedze and Lilongwe. These pilot areas were chosen because the National Smallholder Farmers Association of Malawi (NASFAM) had farmer clubs located near meteorological stations with reliable precipitation data. Additionally, the relatively good rain patterns for Malawi standards made the pilot scheme more feasible there (the most vulnerable Malawian farmers, located in more drought-prone areas are currently excluded from this scheme).

In November 2005, through their NASFAM clubs, 892 smallholder farmers bought the weather insurance that allowed them to access a loan package for 32 kilograms of improved groundnut seed (enough for cultivating one acre). The mechanism could be 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 estimated using the entire available rainfall record (regardless of ENSO), 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).

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 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 greatly reduce transaction costs and eliminate moral hazard (payouts are independent of the farmers' practices). By enabling farmers to engage in higher productivity agriculture, the insurance program can operate independent 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 involved in the scheme foresee a lucrative new market.

While a rigorous assessment of the program is still underway, anecdotal evidence suggests the potential for substantial positive impacts (Hellmuth et al., 2007). A household survey of 160 farmers that participated in the first pilot was implemented in Lilongwe and Kasungu. Survey data shows that 86% of subjects wanted to join the scheme again the following season, and 67% said they had encouraged other farmers to join. In response to farmers' demand, hybrid maize and maize-related fertilizer were added to groundnuts in the second season as a choice for farmers. A total of 2536 farmers joined the scheme in October and November 2006, and plans for covering more farmers and more regions are under way. Stakeholders interviewed during this research indicated that they expect demand to systematically exceed supply for the foreseeable future.

There is a need to develop a strategy for addressing the 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 discussed in the following sections.

## 4 INTEGRATING RISK SHARING AND RISK REDUCTION

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. (1999) show that improved skill in seasonal climate forecasting can negatively affect certain index-based insurance schemes. Adverse selection resulting from asymmetric information can create problems for the financial viability of the scheme (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.

### 4.1 Opportunities for the Malawi 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 with insurance in Malawi is illustrated in Figure 3. This graph, presented by 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 55% (5 out of 9 years), whereas for non-ElNiño years this probability is only 9% (3 out of 33 years). There are no simulated payouts in La Niña years in the study period, indicating a low probability of payout[ii]

[Figure 3 about here]

The insurance scheme would be undermined if clients purchased insurance only in El Niño years. Hypothetically, this problem could be solved by selling 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 we compare forecast-based products with products that are transacted before forecasts are available

### 4.2 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. The household survey mentioned in section 3.2 was designed to test farmers knowledge and views on this issue, and results indicate that integrating seasonal forecasts into the pilot scheme is feasible, particularly if participating farmers are adequately educated about the marketed product (Suarez et al., 2007).

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 exploring 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 can not only share the financial risk associated with droughts, but can 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 MODELS FOR USING FORECASTS IN 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. [iii]

Building on the theoretical framework for the relationship between forecasts, production, decisions and insurance laid out by Carriquiri and Osgood (2006), we explore alternative contract structures with growing degrees of complexity, evaluating the impacts of each strategy as compared 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)[iv] 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.[v] For some comparisons we include an additional shadow cost of alternate uses for the farmland and labor.

### 5.1 Examining impacts of ENSO phase on the current scheme

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 2006-07 season.[vi]

We classify years as "El Niño", "La Niña", and "Neutral" based on the ENSO state in October (when contracts are signed).[vii] The mean payout values are recognizably different (see Table 1) 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 1 about here]

Using the formulas applied in the 2006 implementation[viii] we calculate the 'historical burn'[ix] insurance price appropriate for each ENSO phase. 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.

If the scheme were modified to simply change the price of the insurance premium based on ENSO without modifying the input package, the impact on farmers' gross revenue would be negligible (less than 0.1 percent change across ENSO states). The insurance premium itself, on the order of 150 to 1,500 MKW, is only a very small fraction of the gross revenues (on the order of 100,000MKW). From the perspective of farmers participating in this pilot, the adjustment of insurance premiums based on seasonal forecasts makes no difference with regards to agricultural production and has negligible impact on gross revenues. There is no risk reduction in this strategy.

### 5.2 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 suggest a 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. 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.

A key constraint in contract design was that the insurance premium had to be below a maximum acceptable level. Therefore we choose the premium payment of the current insurance scheme as a constraint for the premium for all phases, using the ENSO-based insurance rate to adjust the maximum liability, and therefore the respective loan size and budget for inputs.[x]

[Table 2 about here]

Table 2 presents the elements of a package that is scaled to reflect ENSO-adjusted premium price ratios. 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.

### 5.2.1 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. 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 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 any benefits of the package shifting disappear.

Table 3 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). The differences in benefits are of course 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. Figure 4 illustrates the differences across seasons in gross revenues between the ENSO-adjusted and the standard 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 years with abundant rains.[xi]

[Table 3 about here]

[Figure 4 about here]

The histograms in Figure 5 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 5 about here]

We compared the results based on the simulations with results derived from using district-level historical yields of hybrid maize in the district of Kasungu (available since 1984). While there are caveats to using historical yields, this provides an indicator of yields that is entirely independent from the DSSAT crop model. Results (not shown here) 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.

### 5.2.2 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. 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) maize 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.

[Table 4 about here]

The results of this analysis are shown in Table 4 and Figures 6 and 7. 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 6 about here]

[Figure 7 about here]

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 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.

## 6 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 favourable.

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 more sophisticated seasonal predictions, such as IRI Net Assessment Forecasts, 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 that we have had so far. Future ENSO impacts may not be the same (especially considering 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 (2002) diagram depicted in Figure 2, the proposed approach aims to expand the decision capacity of vulnerable farmers, increasing the area of intersection (see Figure 11).

[Figure 11 about here]

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.

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## FIGURES

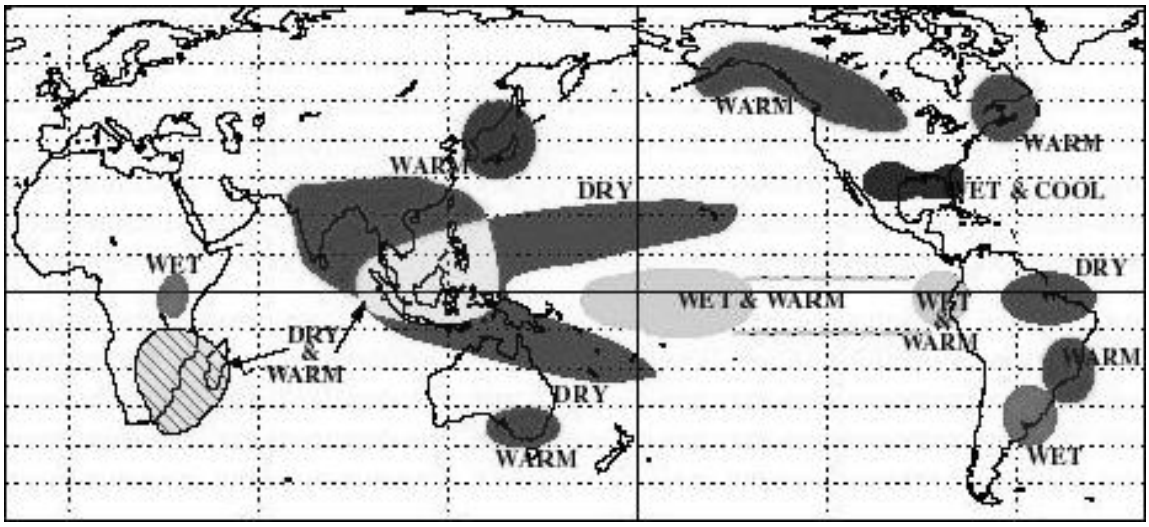



**FIGURE 1:** Typical influence of El Niño-Southern Oscillation (ENSO) events on the global climate, December to February. (International Research Institute for Climate Prediction, 2003)

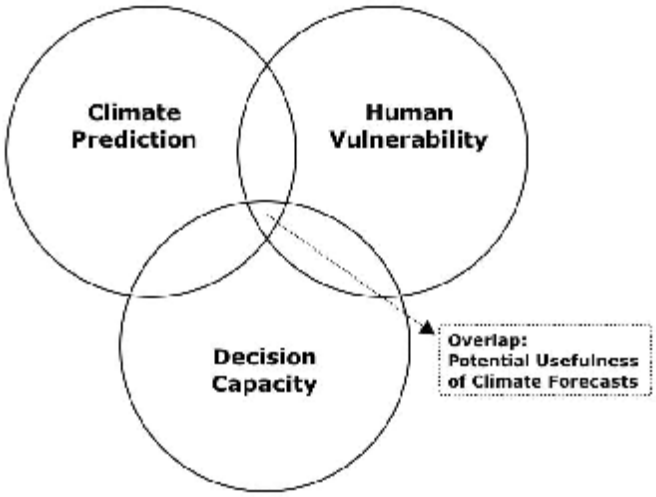



**FIGURE 2:** Hansen's (2002) diagram relating predictions, decisions and vulnerability.

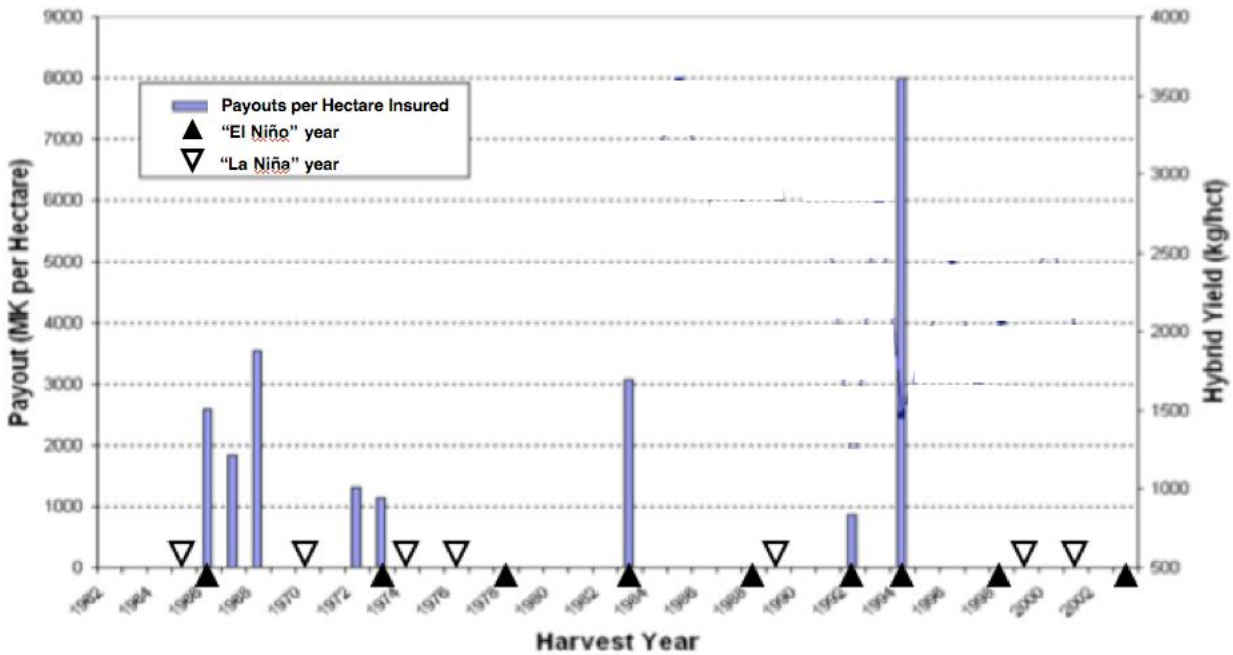



**FIGURE 3**: Simulated payouts (Hess and Syroka 2005) and "El Niño" and "La Niña" years (based on Null 2004). The probability of a payout in an "El Niño" year was 55%, compared to no simulated payouts in "La Niña" years.

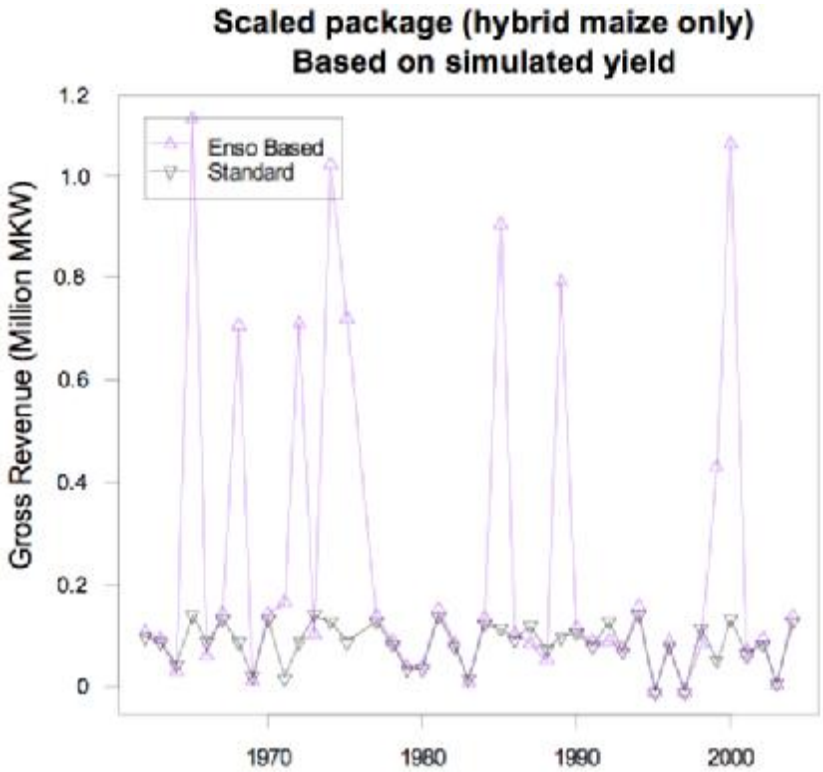



**FIGURE 4:** Gross revenues for the scaled and the standard approaches using simulated yields in a hypothetical farm which plants only the hybrid maize given by the bundled scheme. As expected, the ENSO-based scaled approach outperforms the standard one.

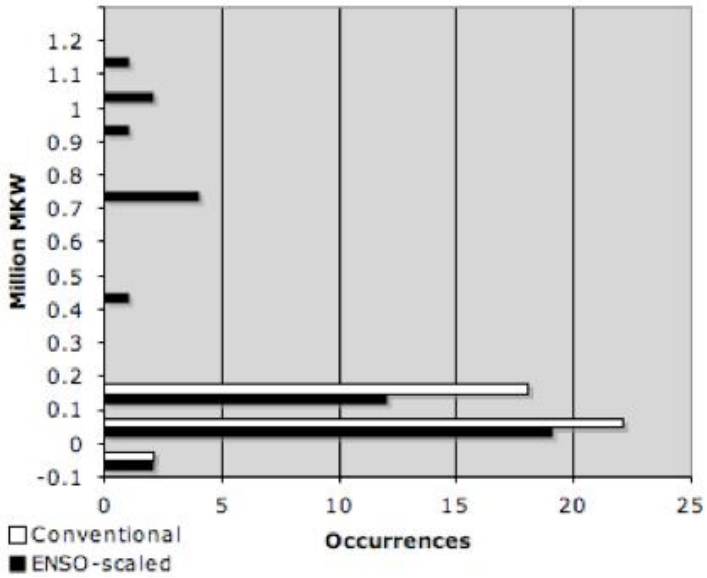



**FIGURE 5:** Histogram of gross revenues for the scaled and the conventional approaches for model scenario A using simulated yields. The ENSO-scaled approach shows several occurrences of gross revenue larger than 0.2 million MKW during La Niña.

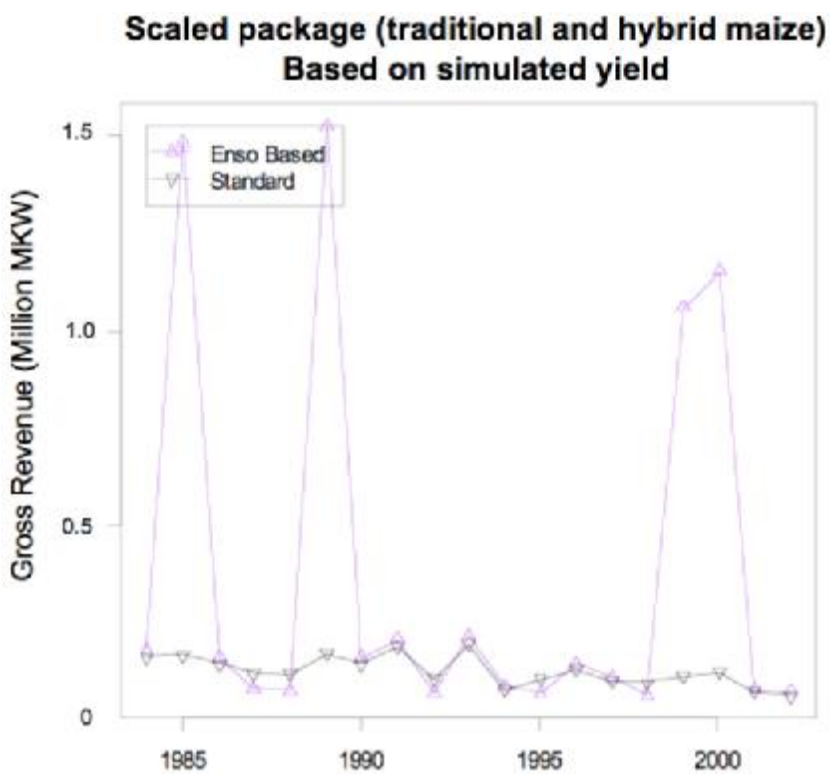


**FIGURE 6:** Gross revenues for the scaled and the standard approaches using historic yields in a hypothetical farm where both traditional and hybrid maize is planted. The pattern is similar to that of Fig. 4

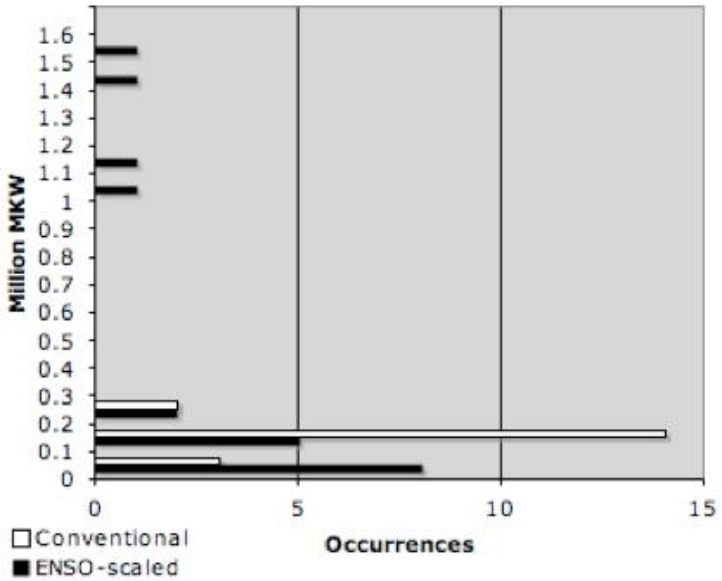
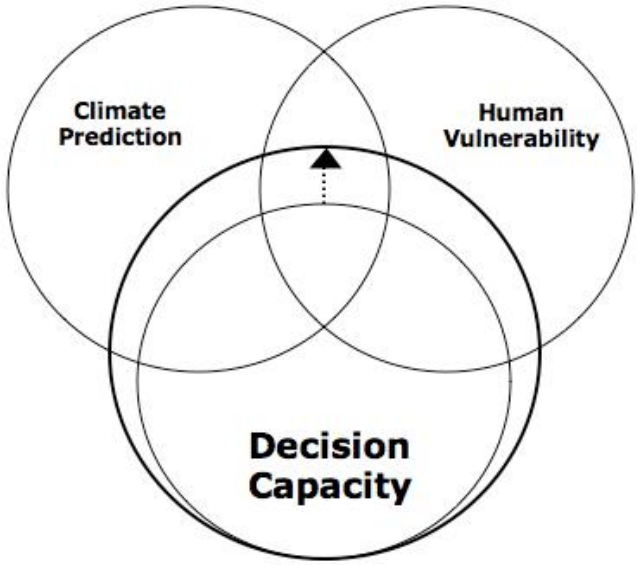



**FIGURE 7:** Histogram of gross revenues for both approaches for model scenario B. The ENSO-scaled option remains robust in its taking advantage of La Niña years.

**FIGURE 8:** The proposed approach aims to expand the decision capacity of farmers in order to help them benefit from available seasonal climate forecasts.



## TABLES

***Table 1:*** *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 Pay (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 |

***Table 2:*** *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 |

***Table3:*** *Gross revenues assuming constant insurance premium and hybrid maize only*

| | 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 |

***Table 4:*** *Gross revenues, traditional and hybrid maize scheme, assuming constant insurance premium*

| | 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 |

## FOOTNOTES

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[i] Many criteria are used by different researchers 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. For more information see Null (2004).

[ii] Because of the low sample size, it is not possible to calculate the precise probability of a payout, particularly for the La Niña case, unless assumptions are made about the tails of the distribution and more advanced statistical techniques are applied.

[iii] ENSO is a useful starting point because its potential impacts have been mentioned by each stakeholder group in the Malawi insurance project.

[iv] The approximate exchange rate at the time of initiating the pilot project was 1 US dollar = 140 MKW. The annual inflation rate in Malawi is usually between 17 and 25%.

[v] The price of inputs for 1 acre of hybrid maize is 3900 MKW and includes the cost of seeds and fertilizers for the management package recommended for the 2006 implementation. The interest was 27.5%. These figures were used in the 2006 package for calculating the package prices. The maize price is assumed to be 20 MKW/kg which was a representative price used for the designing the 2006 implementation. In addition, in the actual implementation a small tax is included. To simplify our presentation we do not include the tax.

[vi] Note that the packages actually implemented in 2006 included a bundle of groundnut and maize. We present a hypothetical maize-only package to allow for clear interpretation of results. We use Maize as the example crop for our analysis because it is highly sensitive to water stress, represents varieties that have been relatively well characterized for agronomic modeling, requires a substantial investment in inputs, and historical data is available for alternative options.

[vii] If the NINO3.4 sea surface temperature index was more than 0.5 degrees warmer than average, the year was categorized as "El Niño". If it was more than 0.5 degrees lower, as "La Niña". The remaining years were categorized as "Neutral".

[viii] 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. 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.

[ix] 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.

[x] 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.

xi Ideally this analysis would use cumulative distribution functions (CDF) to see the net position on yield without and with the insurance in a CDF space. This would give some notion of the tail risk that is removed from these contracts. We leave this approach for future work.