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of the United Nations

# Weather indexes in agriculture:

## A review of theoretical literature and low income countries' experiences

**Federica Angelucci**

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## List of Acronyms

| | |
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| ADB | Asian Development Bank |
| AICI | Agricultural Insurance Company of India |
| AZHR | Agro climatic Zones with Homogeneous Response |
| BIP | Base Insurance Product |
| CAT – bond | Catastrophe Bond |
| COMECON | Council for Mutual Economic Assistance |
| CRMG | Commodity Risk Management Group |
| DOC | Disaster Option for Catastrophic risk |
| DR-CAFTA | Dominican Republic Central America Free Trade Agreement |
| DRP | Disaster Response Product |
| ENSO | El Nino Southern Oscillation |
| FAPPRACC | Fund for the Care of Rural Population Affected by Weather Contingencies |
| FONDEN | Fondo Nacional para Desastres Naturales |
| IBLI | Index Based Livestock Insurance |
| IBRTP | Index Based Risk Transfer Product |
| ICRISAT | International Crops Research Institute for the Semi-Arid Tropics |
| IFC-PEP | International Financial Corporation – Private Enterprise Partnership |
| IRI | International Research Institute for Climate and Society |
| MFI | Micro-Finance Institution |
| MMPI | Malawi Maize Production Index |
| MUAC | Mid-Upper Arm Circumference |
| NAIS | National Agricultural Insurance Scheme |
| PCA | Principal Component Analysis |
| SADC | Southern Africa Development Community |
| SHR | Selyianov Hydrothermal Ratio |
| WFP | World Food Programme |
| WRSI | Water Requirement Satisfaction Index |
| WTO | World Trade Organisation |

## Table of Contents

***Abstract***

*Index insurance is one of the most innovative insurance schemes. During the last decade Index Based Insurance Products (IBRTP's) have been piloted in a number of developing countries. The aim of this paper is to make the point by describing the features of index-based insurance as an effective risk transfer tool to cope with weather related risks. Secondly, experiences of index based insurance implementation are commented in order to highlight the aspects that have brought to success or failure of these instruments in developing countries. Furthermore, the analysis of pilot projects was useful to outline the various issues to be addressed when implementing weather insurance. One of the main findings of the present study is that Index Based Risk Transfer Instruments (IBRTP's) are designed in order to address specific weather risks and as such they should be considered as a component of a more complex risk management strategy which should integrate financial and risk management instruments. To this purpose some indications on how IBRTPs could be combined with financial tools, are provided.*

## ***Introduction***

Production risk is one of the major sources of risk in agriculture. It is estimated that natural hazards affect 1.42 Million hectares crop area annually, 32% of landmass is prone to floods and 68% of total area is subject to periodical droughts (Sarkar and Sarma, 2006). One of the peculiarities of production risk is its nature. Indeed, it can be both independent and highly correlated depending on type of weather event. The majority of weather events, and consequently production risks, are not "spatially independent". The lack of independency of risks can create difficulties to the insurance companies who might not be able to financially sustain covariate risks. On the other hand, most production risks could not be characterised by a sufficient degree of correlation which would allow their hedging on the derivative market (Skees and Barnett, 1999).

The way and the extent to which climate change affects poor people livelihoods is a function of their initial wealth. Household wealth might be negatively influenced by other kinds of shocks such as price variability and/or institutional instability. The present work will be focussed on analysing weather consequences on crop production. Barrett et al. (2007) have distinctively summarized literature regarding the effects of climate risk on poor population. The effects do not produce only *ex post* but also *ex ante* and some of them, as we will see later on, have consequences in the very long term.

Losses due to climate shocks can either be direct and observable, such as damage of crop production, livestock or other productive assets, or "indirect". In detail, the direct losses caused by catastrophic events could damage crop and livestock and destruct other poor productive assets. Furthermore, there could be epidemiological effects such as in-water and insect borne disease transmission that contribute to worsen the health conditions of the poor (Krishna, 2006). Finally, weather caused disasters could entail some type of coping responses which exacerbate human living conditions in the longer term, such as: withdrawal of children from school, depletion or sale of assets, reduction in nutrient intake, migration and crime (Hoddinott, 2006). These responses may, to a certain extent, produce permanent consequences: children stop going to school and assets are depleted, productivity and income growth are seriously jeopardised.

To this category of effects, direct and idiosyncratic, there is an additional component which is often underestimated and consists in all those *ex-ante* behaviours that poor households assume in order to reduce their exposure to weather related risk but at the same time constrain wealth accumulation, for example: small scale crop diversification, lower fertilizer application, cheap seed quality and in general low willingness to invest in more productive but riskier activities and assets. The opportunity cost of risk avoidance has a higher incidence on poor households if compared to those people who are better off.

Finally, it is worth to underline that these behaviours do not necessarily imply some degree of risk aversion. It is the uncertainty about future weather that becomes one of the main drivers of management decisions and reduces profit opportunities even in those years when climate conditions are optimal (Hansen et al, 2007). These *ex ante* strategies are one of the main reasons why extreme rural poverty perpetuates throughout the years (Hoddinott, 2006). In addition, the inefficiencies or the lack of financial and insurance developed markets contributes to the consolidation of poverty due to the dearth or the impossibility to accede to those instruments that would allow some form of consumption smoothing over time. In fact, uninsured risk and the high exposure of rural households to yield loss explain most of the reluctance of credit institutions to grant loans. In this contest, in order to avoid the complete depletion of household assets due to shocks, well developed financial and insurance markets could give the possibility to either insure against shocks or to borrow ex-post in order to restore liquidity by achieving a quasi-insurance coverage whose premium is the loan repayment.

The undersupply of insurance and credit products in low income countries is due to several factors. The ones that are strongly related to adverse weather events are: the covariate nature of weather disasters, asymmetric information and high transaction costs. These are typical issues that emerge when traditional crop insurance was to be developed. In fact, these difficulties have caused the low takeup rate of traditional crop insurance in many developed and a few developing countries that, in order to spur farmers' willingness to pay, had to strongly subsidise crop insurance schemes.

The paper is subdivided into two main sections: the first summarizes the basic concepts and the current and potential uses of index based products, the second section is dedicated to the description of the distinctive features of each pilot project implying the implementation of index based products. The object of this review is to highlight the reasons why index insurance should be preferred, as a risk transfer instrument, to traditional crop insurance. Also potential disadvantages of index based instruments will be described together with viable solutions to be adopted in order to solve some of the issues. Furthermore, we will demonstrate that according to the magnitude of losses due to climate events, IBRTP's can be used in different ways and operate within very diverse contexts: micro, meso or macro-level; institutional, private or both. Finally, some case studies will be analysed and commented in order to provide some general conclusions and suggestions for further research.

## 1. The role of insurance in production risk management

Management of price and production risk can be done by recurring to insurance schemes. Insurance is a tool that allows the transfer of all or part of the loss risk from the purchaser of the policy to an insurance company, after the payment of a premium. Insurance is thus defined as a risk transfer mechanism. After the purchase of an insurance policy, the farmer accepts to bear a smaller loss that is the payment of the premium instead of having to cope with a larger loss in case an adverse weather event occurs. Insurance is not only an instrument that mitigates production loss but an opportunity to increase farmers' earnings. If insurance was used in combination with a commercialisation tool such as forward or future contracts, yield insurance would contribute to stabilize revenues and potentially increase average annual profits.

The two main advantages of insurance as a risk management instrument are:

a) Assurance of a good level of liquidity;
b) Enhanced flexibility and margin for what concerns commercialisation strategies. If it is possible to insure a part of the expected yield, the insured production can be sold through a forward contract and thus increase farmers certainty on future returns.

### *1.1 Insurance and risk layers*

Insurance contracts can be an effective but not comprehensive tool for risk transfer. Some clarification on the risk transfer capacity of insurance has to be done with reference to the different risk layers. For example, an index based weather insurance that protects from catastrophic events would be too expensive for farmers since they should receive indemnity in case of losses in the extreme lower tail. This kind of losses could be hardly sustained by an insurance provider.
On the basis of the entity of losses, risks can be included into different categories (World Bank, 2005):

- *The risk retention layer*

The risk retention layer aggregates those losses that can be managed by the farmers either individually or on a mutual basis. Household behaviour is composed of ex-ante self-insurance strategies such as: plot and/or crop diversification, off-farm diversification and crop-sharing arrangements in renting land and hiring labour and ex-post behaviours: sale of assets such as land or livestock, moving from in-farm to off-farm labour or addressing to financial service providers.

- *The market insurance layer*

In this case the risk is transferable to an insurance company. This can happen through index insurance if the fundamental criteria is met: minimization of basis risk thanks to the high , spatial correlation of risk. Ibarra and Skees (2007) have recently put particular emphasis on the trade-off between basis risk and transaction costs. Provided that one of the principal issue to be addressed when developing an insurance product is to define the costs of monitoring and administration in order to minimize moral hazard and adverse selection phenomena. Even if deductibles and coinsurance are introduced transaction costs become practically unsustainable in developing countries or, in other words, the trade off between transaction costs and basis risk widens. In developing countries it is more likely—if compared with developed countries—that the social costs of having some component of basis risk is relatively small if compared with the social cost associated with high transaction costs of insurance schemes such as weather insurance. One of the priorities of Government policy in this field should consist in finding the best strategy in order to address the existing trade off. Basis risk could be reduced by implementing the weather stations network that should reflect as much as possible the existing agro-climatic zones. Transaction costs could be reduced through

infrastructure policy and by enhancing the sources of information on yields, weather events and crops growing conditions.
Still, in the presence of spatially correlated risks, most of all in low income countries, it might be very difficult for a local insurance company to financially sustain such an insurance scheme even if there is some risk pooling possibility. Alternative solutions could consist in transferring covariate risks out of the region or even out of the country. The World Bank considers three viable ways to transfer risk from the household or micro-level index insurance to reinsurance markets: direct transfer of contracts to the insurance market; transfer of contracts' packages to the reinsurance market; transfer of the excess component resulting from a prior risk pooling activity. The first two strategies do not imply any basis risk. The third, since risk pooling might imply a different probability distribution of indemnities, entails a basis risk component. The positive aspect of pooling prior to the transfer of index insurance contracts to the reinsurer is a lower reinsurance premium.

Risk pooling can refer to different spatial dimensions such as: a region, a country, across different countries or across regions belonging to different countries or even across different sectors. This requires that, when a transfer strategy has to be undertaken at the international level, an analysis of neighbour countries' weather profile should be done. Pooling risks across different countries could significantly reduce costs of reinsurance if compared to a risk transfer strategy of a country at a time. Hess and Syroka (2005) have evaluated the potential benefits of risk pooling for the 14 member countries of the Southern African Development Community[1] (SADC). Referring to Malawi, they have estimated that reinsurance costs would be reduced by 22%. The authors concluded that if the neighbouring SADC countries pool the risks among each others the risk profile of Malawi and its need for outside reinsurance would be significantly reduced.

Furthermore, in countries where other productive sectors are sufficiently developed, such as tourism or the energy sector, it may be possible to do inter-sector risk pooling (Cafiero et al., 2007). Inter-sector risk pooling may be very effective for insurance companies and credit institutions in order to diversify their portfolio of assets. The presence of productive sectors, other then agriculture, may also contribute to value chain development and to a vertical risk management strategy. Indeed, thanks to the stronger linkages amongst agents, individuals' risk exposure can be mitigated. Referring to farmers, if they subscribe procurement agreement with local hotels they will eliminate part of their price risk but at the same time they will be required to purchase weather insurance in order to transfer their production risk. The following sections include some evaluation on the potential of reinsurance and CAT bonds as instruments to address catastrophic risks. In fact, especially where risk pooling opportunities are scarce and in order to plan an effective insurance strategy the presence of tools to cope with natural disasters could be a good incentive for insurance companies to enter the agricultural insurance market and lower insurance premiums.

- *The market failure layer*

This risk layer contemplates severe losses or more precisely those losses between zero and the limit. This risk layer cannot be transferred through insurance because an index insurance market would never develop due to the previously described cognitive failure by the farmer

[1] The Member States are: Angola, Botswana, the Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, United Republic of Tanzania, Zambia and Zimbabwe.

and ambiguity loading by the insurer. By consequence, in case of natural disaster, Government or international community intervention is unavoidable. The World Bank and researchers in general are recently proposing different alternatives to mere ex-post disaster relief (World Bank, 2005). Some of them envisage the use of different types of weather indexes to mobilize resources before natural catastrophes occur. Governments, for example, could provide financial support to risk transfer schemes such as Disaster Option for CAT risk (DOC) which covers the entity of losses between zero and the limit of the insurance contract. Once a Government issues a DOC, it can reinsure with international reinsurers or on the capital markets. Obviously the primary insurer has to pay a premium for the DOC' s coverage but, since the DOC is partially subsidised by the Government, its cost would never be higher than what the market would charge.

## 2. Index Based Insurance: a better alternative for production risk management?

### *2.1 The limitations of traditional crop insurance*

Traditional crop insurance has many limits that impede its wide use to transfer the vast range of production risks to which farmers are exposed. With the only exception of hail, the large majority of production risks are not "spatially independent". The positive spatial correlation among losses can limit the positive effects of risk pooling amongst geographic areas or crops.

The difficulty to obtain a probability distribution to calculate an actuarially fair insurance premium and the severity of losses that events in the long tail may cause, lead insurance companies to load premium rates which are usually too high and unaffordable for the farmers. On the consumer side, according to Skees and Ibarra, the general finding regarding subjective crop yield distribution is that agricultural producers tend to forget low frequency/catastrophic events, in other words they do not have the right perception of the variance in yield distribution. This quite diffused opinion has never been demonstrated empirically due to the difficulty in estimating subjective yield distribution. Authors like Hardaker (2000) have proposed some changes in order to improve methods of elicitation of subjective probability distribution.

To summarize, the insurer is faced with: low potential demand for crop insurance, the difficulty to define an actuarially fair premium, and finally, high transaction and damage assessment costs. These elements create a gap between the premium that the farmer is willing to pay for catastrophic crop insurance and the price of the policy as quantified by insurance companies.

The just mentioned issues do still characterise traditional crop insurance programs in many developed countries where insurance policies are made affordable to farmers thanks to Government subsidies. In many cases premium subsidies to crop insurance are used as an indirect way of aid transfer to agricultural producers still considered compatible with WTO Green box rules. Although, during the current negotiations, some countries argue that some of the subsidies might not meet WTO criteria because of the large amounts paid, or because of the nature of these subsidies, the trade distortion they cause might be more than minimal. Furthermore, a growing literature exists (Roberts et al., 2004; Anton and Giner, 2006) that shows how the presence of insurance subsidies and other risk management aids do affect production decisions and, therefore, cannot be considered fully decoupled. Indeed, the most discussed State subsidies are: direct payments to producers, including decoupled income support, and government financial support for income insurance and income safety-net programmes, and other paragraphs. Developed countries increasingly recur to this form of aid: a growing share, 9% in 2007, of the United States funding to the agricultural sector is entitled to insurance premium subsidies. In the European Union, insurance premium subsidy is one of the few forms of state aid which is still allowed according to the EU rules on state aid to the agricultural sector.

Ibarra and Skees (2007) argue on how subsidies to traditional crop insurance are just an attempt to mask the information discrepancy between the insurance company and agricultural producers. The authors assert that the information gap is due, on one side, to the difficulty of the insurer in evaluating probability distributions of future weather events, further compounded by the lack of complete time series. This results in premium loading. Some authors have used experimental economics, to demonstrate that when risk estimates are ambiguous and weak, insurance premiums can be 1.8 times higher than when insuring events with well specified probability and loss estimates (Kunreuther et al., 1993). These results have to be evaluated with caution especially if considering the impossibility to reduplicate crucial aspects of reality (incentives) in experimental economics.

Skees and Ibarra neglect another aspect that is the presence of a monopolistic or oligopolistic insurance market which could favour premium loading. The possibility exists that governmental participation to the premium paid by the farmers might end up in feeding insurance companies' rents, rather than helping farmers to protect their income. For example, in countries like Italy, where insurance premium is subsidised till 80 per cent of the premium, the oligopoly on the supply side entails a premium loading and by consequence absorb part of Government subsidy (Capitanio and Cafiero, 2006).

### *2.2 Basic features of weather index insurance*

Weather indexes can be designed with reference to specific and single events or a combination of events that show a high degree of correlation between the index value and crop or herd losses, depending on the type of contract. The index has to refer to a specific and predefined region or area which is covered by the local weather station. Usually, farms that purchase the index based insurance to protect against one or more perils are located within a 20-30 km distance from the local weather station, which is the commonly adopted criterion in many countries, such as Malawi, India, Kenya, and Ukraine. Insurance is sold in standard units (e.g. $10 or $100) with a standard contract for each unit purchased. The premium rate is the same for the buyers of the same index contract in a given region and each certificate, if the event occurs, receives the same indemnity. Buyers can purchase as many units as they wish.

The effectiveness of an index is determined first of all by the existing correlation between farm yields or revenues and adverse weather events. In other words basis risk should be reduced to a minimum. Furthermore, in order to be reliable and easy to understand, an index should be: observable and easily measurable; objective; transparent; independently verifiable; reportable in a timely manner (in some developing countries this requisite is very difficult to achieve); stable and sustainable over time (World Bank, 2005).

The terminology used to describe features of index insurance contracts resembles that used for futures and options contracts rather than for other insurance contracts. Instead of referring to the point at which payments begin as a trigger, index contracts typically refer to it as a strike. They also pay in increments called ticks.

Once the index is constructed it starts to pay whenever its value falls below a defined threshold or strike value, with indemnity which is usually proportional to the difference between the index value and the strike. The maximum indemnity is paid when the index falls below the limit. The limit is a pre-specified value which is indicated in index contracts to define the border between catastrophic losses and insurable ones. In other words, it is used to circumscribe the insurance company exposure to catastrophic events. Without a limit the index contract would be extremely expensive for farmers who would express a very low willingness to pay due to the low probability that is usually subjectively assigned to events in the lower tail of yield distribution (cognitive failure) and on the other side the insurer, due to incomplete information on the real probability distribution of extreme events, increases the premium. Thus, the presence of a limit is fundamental in order to remove some of the obstacles on the demand and supply side.

**Graph1. Payout structure of a hypothetical rainfall contract**

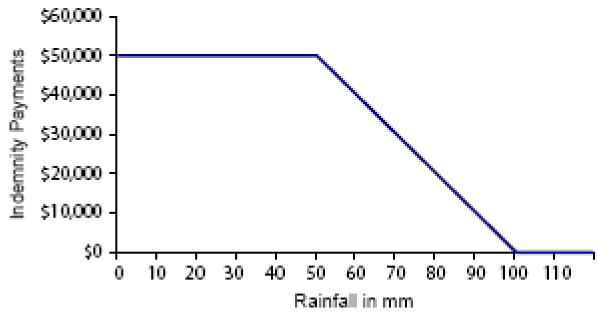


Fig. 1. Payout structure for a hypothetical rainfall contract. *Source:* Skees (2003).

*Source: Skees, 2003*

An index contract which contains these three parameters: strike, limit and maximum indemnity is defined as an elementary contract. Vedenov and Barnett (2004) consider elementary contracts more convenient for analysis also because they give the possibility to design more complex instruments, such as a combination of elementary contracts with different parameters' values. This would allow the creation of payout schedules that may improve risk protection whenever expected losses are not linearly correlated to the index (Vedenov and Barnett, 2004).

### *2.3 Types of indexes*

In order to hedge different types of risk, indexes can be based on a variety of different variables and can also be structured to depend on more than one weather variable. The most commonly used variable is temperature, as hourly values, daily minima or maxima, or daily averages[2]. In addition to temperature, wind and precipitation measurements are also used.

[2] Of these, daily average is the most frequently seen. In most countries daily average is defined by convention as the midpoint of the daily minimum and maximum. However, in some countries daily average is defined as a weighted average of more than two values of temperature per day. The exact time period over which the minimum and maximum temperature is measured and exactly how minimum and maximum are defined, also vary from country to country.

Wind-based hedges are, for instance, of interest to wind farms, which want protection against lack of wind and construction companies which may have to stop in case of high wind. Rain based hedges are used by the agricultural sector and hydropower generation industry. Snow based hedges are important for ski resorts and the ski gear industry. Hedges based on other variable such as number of sunshine hours or sea surface temperature, are also feasible (Jewson, 2005).

Other examples of index contracts to be applied to the agriculture sector are: area yield indexes, combination of weather events such as snow and temperature (see Dischel 2001 and Ruck 1999), insufficient or damaging wind (from hurricane); tropical events such as typhoons or earthquakes, to be reported using the Richter scale database.

Index based instruments can take different forms. This study presents a detailed description of some of these financial instruments namely: insurance, reinsurance and CAT bonds.

Classification of contracts can be also based on the different payout criteria:

a. Zero/One contract. If the threshold is crossed the payout rate would be 100 percent;
b. Proportional payment schedule. The writer of the contract may choose to make a fixed payment for every 1mm of rainfall below the strike
c. Layered payment structure. Different thresholds are defined and once one of them is crossed a predefined percentage payment is provided. The percentage can change depending on which threshold is crossed (Skees 2005).

### *2.4 The advantages and drawbacks of index based insurance*

Researchers have found out that if a traditional crop insurance product was to be implemented in a developing country, the gap between the supply side (insurance companies) and the demand side (the farmers) would be wider if compared to developed countries. Problems of high transaction and loss-adjustment costs, underestimation of rare but severe weather events by farmers, unavailability of data on weather, yield and farms productivity, are exacerbated in developing countries where the attempt to develop a traditional crop insurance program has generally failed.

On the contrary, index contracts may work even better when the risk being transferred is somewhat systemic (Vedenov and Barnett, 2004). A high systemic component increases the chance to obtain high levels of correlation between index and losses, thus decreasing basis risk.

The objectivity, transparency and reliability of index based products would make their rating on the international market or on the secondary market easier. This would have two types of advantages: more effective risk pooling thanks to the presence of speculators (indeed, unlike hedgers, it is more likely that speculators hold opposite positions); possibility to cash the tradable value of the contract at any time; more coherent pricing of risk as conditions change (Skees, 2005).

Index insurance could also serve, as we will see later on, as a criterion of contingent funding for more prompt government disaster assistance and safety net programs. Asymmetric information, moral hazard, adverse selection, damage assessment and transaction costs have a very high incidence on premiums. Indeed, Governments in developed countries keep on subsidising traditional crop insurance schemes, according to the underlying principle that subsidies would make premiums more affordable for farmers. The presence of subsidy has usually worsened existing inefficiencies of the insurance market in all developed countries. In the United States premium subsidy has been introduced with the objective to increase crop insurance subscription and save financial resources usually spent for *ex post* disaster assistance. The results of this policy are described by Glauber who shows how, even if insurance subsidy has increased over time, this hasn't produced any saving effect on *ex-post* public expenditure that kept on growing during the years. In Italy, due to an oligopolistic market on the insurance supply side the introduction of a Government subsidy has entailed a rent seeking behaviour by insurance companies.

On the contrary, index insurance is an objective criterion on which the payout is based. Payouts depend on the index values and thus problems of asymmetric information and issues such as, adverse selection and moral hazard are eliminated. The more the index is reliable and the more it will gain attention on the international financial markets. With reference to developing countries, where systems of measuring and calculation of the index value might not be considered as reliable by international markets operators, the support of satellite imagery systems and other devices can be a more effective and universally accepted method (Skees et al, 1999, 2005)

Concerning the drawbacks that index insurance might entail, the magnitude of basis risk is certainly the principal one. The more the mismatch between the index triggered payouts and individual yield or revenue losses is minimized the less the basis risk. Basis risk can generate two different effects, the triggered payment is not sufficient to indemnify the whole farmers' loss or the payment exceeds the real entity of loss. In other words, a farmer may receive an indemnity even if he has not incurred in any loss and vice versa.

In case of area yield index insurance: the more the area yield is correlated with the weather index the less the basis risk and the more the area are homogenous and the more the index insurance is able to manage individual production risk. In case of weather index based payouts, the more the weather index is conceived on the basis of the events that are relevant to the farm the more the index can be considered as an effective risk management tool at the farm level.

It is true that in the case of index insurance the presence of a basis risk component could be a disadvantage for the insurer or the insured but this disadvantage is generally not comparable with the additional transaction cost that traditional crop insurance entails. The social cost of having products with some basis risk may be significantly lower than the social cost associated with the high transaction costs of traditional crop insurance (Barnett, 2005).

Basis risk could be very high if index insurance was implemented in areas that are strongly heterogeneous on the meteorological point of view, even if in the case of a diversified cropping area risk pooling would be possible. In addition, basis risk problems that could arise in heterogeneous areas in terms of microclimates could be partially solved thanks to a dense distribution of weather stations.

In spite, as previously mentioned, index based products are not susceptible to asymmetric information problems such as moral hazard and adverse selection, they could be subject to a particular aspect of asymmetric information defined as intertemporal adverse selection. This

type of adverse selection is caused by asymmetric information about the likelihood of an event in the near future (World Bank, 2005).
In order to avoid phenomena of intertemporal adverse selection the index insurance provider should have at least the same information of the insured about the severity and probability of losses. The first experience of drought insurance in the U.S. in 1988 failed because, some time before contracts' sales closing date, farmers increased purchases of the contract. The behaviour of farmers was not correctly evaluated and the closing date was postponed. When severe drought occurred the insurance company experienced very high losses and was unable to pay the whole amount of payouts. The best solution would be to establish sales closing date just before any weather forecast information. Authors have analysed indexes from many different point of view, particular attention has been focused on pricing issues (Turvey, 2001).

Vedenov and Barnett (2004) have investigated the risk reducing opportunities of weather derivatives by simulating their performance in six reporting districts belonging to the most important cropping areas for corn, cotton and soybeans in the United States. The difficulties authors have encountered refer to a developed country such as the United States but could be extended or even amplified if we refer to developing countries.

One of the principal hurdles is the availability of time series. While weather data time series are available for about one hundred years, reliable yield series are shorter and usually refer to the latest decades. Furthermore, yield data do not adequately represent variability of yields deriving from technological innovations. Even if de-trended, the data set suitable for observation usually reduces to 30 to 40 observations and the large number of independent variables poses problems of identification. Even if some other authors (Cafiero et al., 2007) have demonstrated the possibility to eliminate those independent variables, that do not show any correlation between each others and with yields, by recurring to Principal Components' Analysis (PCA)[3].

Vedenov and Barnett used yield data from 1972 to 2001. In all selected crop sectors, indices obtained were the result of a combination of independent variables that did not have any relationship between each others even if referred to the same crop or within the same state. This heterogeneity in the combination of variables from which the index is calculated, demonstrates the need to customize indices for each crop and according to the single geographic area. This could cause confusion in potential buyers that may encounter difficulties to understand the relation between yields and the synthetic index. The results of the analysis conducted by Vedenov and Barnett show that the risk reducing effect of weather derivatives varies significantly across crops and districts and that there is no relationship between in and out-of-sample performances. The results express the need to differentiate according to the crop and geographical unit and further sustain the importance of conducting analysis on a case-by-case basis.

Dischel has highlighted the inherent difficulties of designing index insurance based on precipitation levels (Dischel, 2000). Unlike temperature, precipitation can be intermittent and

[3] Principal component analysis is probably the oldest and best known of the techniques of multivariate analysis. The central idea of principal component analysis is to reduce the dimensionality of a data set in which there are a large number of interrelated variables, while retaining as much as possible of the variation present in the data set. This reduction is achieved by transforming to a new set of variables, the principal components, which are uncorrelated, and which are ordered so that the first *few* retain most of the variation present in *all* of the original variables (Jolliffe, 2002)

not necessarily spatially correlated. This is why precipitation, constructed on the basis of precipitation (rain, snow or hail), entail a higher basis risk than do temperature index based products. The design of reliable weather indexes, based on precipitation, require the solution of some major issues:

- precipitation measurement is susceptible to considerable error especially if it relies on traditional weather stations that measure rainfall on the basis of ground collecting buckets. Snow measurement is even more imprecise; the need to melt snow for measuring causes evaporation. In recent years, big progress has been made on new weather measurement technologies which in some cases (radar and satellite instruments) have a worldwide coverage. If these technologies where applied to index based products they would provide a larger perspective on the spatial and time point of view. Averaging over time smoothes the effects of short period events and averaging over a region could be more reliable than considering single weather stations. The idea is to design basket contracts that are indexed on a weighed average of multiple stations in a region and multi-year contracts. Anyway, it has to be taken into account that none of the metering methods is able to provide perfect information. Rain gauges[4], radar and satellite, if considered singularly, can provide imperfect and/or incomplete information on rainfall, otherwise if they serve as a complementary source of information they could improve and enrich precipitation databases;

- Scarce correlation of daily rainfall patterns at different weather stations. This does not mean that the statistical distribution of rain realization changes from one site to the other. In fact, statistical distributions of rainfall, on which derivative pricing is calculated, appear to be quite correlated if compared to momentary precipitation. This is why cumulative rainfall measures are used instead of daily levels;

- Precipitation data are difficult to represent through mathematical generalisation. Usually, derivative modellers use normal or Gaussian distribution to describe temperature and degree days, but this would not be suitable for precipitation. Some attempts have been done to fit less familiar equations to model rainfall realizations distributions over time. Weather precipitation modelling for precipitation has just begun.

### *2.5 Indexes and risk layering*

#### *2.5.1 Reinsurance*

The covariate nature of production risk may entail the possibility for the insurance provider to pay unsustainable amounts of indemnities during the same cropping year. In order to mitigate the effects of such events, the insurer may try to diversify its portfolio by recurring to different strategies of diversification: regional, by insuring different crops which are exposed to different weather hazards; multisector, trying to involve different sectors which might be interested in buying the opposite positions. Not all developing countries allow the implementation of these strategies of portfolio diversification mostly because agriculture is still the dominant sector. But even if this is the case, Governments and concerned institutions could take some actions which do not require enormous resources and that consist in

[4] Progress has been made also for what concerns rain gauges, e.g. a US: company has projected a particular rain gauge which is very sensitive, does not require rain collecting and storing and has an affordable price (Skees, 2005).

respecting some essential requisites necessary in order to transfer part of this risk on the international financial market. The first step might consist in the creation or modernization of the weather station network in order to assure objective and transparent weather data with some level of protection from data manipulation by individual farmers. Reaching an acceptable level of liability of the metering component is a first fundamental step that could be achieved with a limited government spending[5]. The presence of a reliable network would gain the attention of international reinsurance firms that would be keener to offer coverage in case of adverse weather events.

Pooling climate risks across different countries through international reinsurance could be an answer to the difficulties and the limits of pooling risks within a single country. International reinsurance is already available for some kind of disaster risk.

There are two different schemes of reinsurance: The simplest one is a "stop loss agreement" according to which the primary insurer pays a premium that assures protection in case the primary insurer losses exceed certain defined levels. This is the most common form of reinsurance agreement where it is clearly specified the amount of risk the insurance company can retain. One of the countries where weather insurance has been fully implemented and marketed is Mexico. In Mexico, the reinsurance company is fully State owned but now that the insurance market has expanded the Mexican Government is planning to transfer the risk to private reinsurance companies. With the recent weather insurance implemented in Mexico the Government has succeeded in transferring part of the risk to the international reinsurer. Government intervention, on the reinsurance side or at least as a last appeal intervention, is strongly recommended especially in the early years of implementation of the weather insurance.

The second reinsurance scheme is a quota share agreement based on the co-sharing of premiums and indemnities between the primary insurer and the reinsurer. Some of the principal international reinsurers show a growing interest towards developing countries. The main issue for developing countries is to meet the standards required by reinsurance companies to enter the market. The following box describes the basic required requisites.

***Box 1***

- Weather data time series;
- Preferably 30 years time series
- Missing data should not exceed 1 percent
- Availability of "buddy check" weather stations for cross checking of weather data
- Consistency of technical observations: manual vs. automatic;
- Reliable reporting methodology;
- Low exposure to external manipulation

*Source: Skees, Barnett and Hartell (2005). These requisites were presented by "Partner RE New Solutions" during the Annual meeting of the International Task Force on Commodity Risk Management. FAO, Rome 5-6 May 2005.*

[5] According to Skees last generation gauges are not extremely expensive.

### *2.5.2 CAT Bonds as an alternative/complement to reinsurance*

Vedenov et al. (2006) have recently investigated the potential of CAT Bonds products as tools able to transfer agricultural risks from insurance companies to investors on the world capital markets. CAT bonds belong to the family of index-based instruments. Indeed, the occurrence of the catastrophic event is usually determined based on realizations of a pre-specified stochastic variable or index. More specifically, a CAT bond purchaser typically agrees to forfeit a portion or all of the expected financial payments from the bond, in the event the index exceeds a pre-specified threshold.

In recent years Cat Bonds have been introduced to hedge against catastrophic risks such as hurricanes and/or earthquakes. The fundamental difference with traditional reinsurance contracts is that Cat Bonds simply transfer risks on the international financial markets instead of pooling them. CAT bonds allow both insurance and reinsurance companies to transfer non diversifiable risks such as natural disasters to capital markets. CAT bonds can be purchased both by private and public investors who have an interest in adding to their portfolio of assets, instruments whose returns have the advantage to be non-correlated with traditional financial instruments (stocks and bonds). Cat bond are conceived in a very similar way to traditional bonds: the investor gives a loan to the issuing firm and, at the end of an agreed period, he receives payment of the interest and repayment of the principal. Thus the issuer may use the money received from the issuing of the bonds to face eventual losses caused by catastrophic hazards.

Cat Bonds have been issued for the first time in 1996 but have never been used to hedge disaster risks in agriculture. The principal advantage of CAT bonds consists in giving to reinsurance companies the possibility to widen their capacity of reinsurance in the low-probability high-loss risk layer because they could transfer a good portion of catastrophic risks on the international financial market.

Vedenov, Epperson and Barrett (2006) have conducted a feasibility study to test if CAT Bonds are viable instruments to transfer systemic risk of agricultural crop production in the US Georgia cotton sector. The Bond has been based on the State average yield as a trigger. Time series of data from 1974 to 2002 for yields and weather have been used in order to estimate the distributions. The instrument whose performance is evaluated in this study is a zero coupon CAT bond priced so as to provide an adequate return plus an additional risk premium. The principal finding of the analysis is that CAT bonds can play a concrete role in reducing catastrophic risk exposure provided their non correlation with traditional financial instruments. In this particular case study, CAT bonds succeeded to reduce the loss ratio of a hypothetical insurance company by 56%. It has to be cited that the study was conducted under the strong and unfortunately unrealistic assumption that the hypothetical insurance company had underwritten all cotton insurance policies in Georgia. In reality insurance policies are underwritten by more than one insurance company and this could increase the basis risk, even if in the case of highly correlated risks, losses are likely to be widespread and similar to all crop areas in a given state.

## 3. Index contracts and poverty traps

Opportunities of risk transfer offered by index based instruments can be evaluated also from a different point of view, that of the clientele. Depending from household condition, persistent, transient or chronic poverty, IBRTP's could assume different tasks and objectives[6].

The first class of uses of IBRTP's is aimed at preventing humanitarian disasters, such as famine prevention instruments like those described in the following paragraph. IBRTP's belonging to the second category are finalised to improve credit access and thus enhance household productivity and wellbeing. By reducing the exposure of poorer household to climate change, IBRTP's become a sort of collateral for loans. An easier access to credit, in turn, addresses the ex ante behaviour of poor households that consists in adopting less productive even if less risky methods of production. Thus, IBRTP's can generate a virtuous process that can result not only in investments in more productive assets but also in real economic growth for the country. Examples of this kind of IBRTP's are those implemented in Malawi, Peru and Vietnam that have demonstrated, during the first two years of the pilot projects, that credit institutions are more willing to grant loans for the purchase of productivity boosting inputs. The third class of IBRTP's uses is addressed mainly to avoid that wealthier households fall back into chronic poverty. Barrett et al. (2007) define this class of IBRTP's as "productive safety nets" devised to reduce non-poor vulnerability to weather shocks. Mexico's FONDEN programs are an example of this kind of products; indeed they offer social protection in case of climate shocks (Barrett et al., 2007).

### *3.1 IBRTP's as a tool for ex-ante emergency relief*

Weather shocks could generate short term negative effects on poor populations such as: selling of assets, withdrawal of children from school, migration and crime. Moreover, some consequences could engender in the long run and produce irreversible asset losses, such as, children physical growth falters, household productivity decrease, asset depletion and income growth hindering (Dercon and Krishnan 2000; Hoddinott and Kinsey 2001; Hoddinott 2006), underinvestment in riskier assets (Carter and Barrett, 2006).

In the wake of catastrophic covariate shocks the recent innovation in index insurance products could contribute to a more prompt emergency response to natural disasters. Thus, index insurance could be used as an indicator to provide contingent timely funding in case of imminent emergency. The index could function as an early warning tool that anticipates an imminent disaster and thus accelerates the procedure of declaring, mobilizing and distributing resources. Currently, food aid and disaster relief in general are conditioned by donor Governments inner approval procedure and budget constraints.

In the majority of cases, food aid, in case of crop failure or weather shocks, is usually delivered well after a disaster. By that time, poor people have already sold their assets in order to achieve some level of household consumption smoothing. In the following paragraph, two different index schemes for emergency early warning are described.

Chantarat et al. (2007) explore the opportunity to use weather index insurance to improve drought response for famine prevention. In addition to the recent innovations on timely

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[6] For more information on what classification of poverty trap has been chosen to differentiate IBRTP's uses, see Barrett et al. (2007)

monitoring and analysis regarding early warning systems and practises of emergency needs' assessment, weather index insurance could give a significant contribution in addressing some key issues that still remain unsolved. In this case, the weather variable (deficit rainfall) expresses some degree of correlation with a dependent value that is not yield loss but a measure of a severe and widespread human suffering condition. The dependent variable that was chosen is the proportion of children between 6 and 59 months who suffers a Mid-Upper Arm Circumference (MUAC) z-score ≤ -2[7]. The innovation stays in replacing the traditional relation between weather and agricultural production, which often does not explain crises, with an indicator that is directly related to human health condition.

By analysing data of three districts in the north of Kenya - Turkana, Samburu and Marsabit - a strong time series correlation emerged between community level MUAC indicators and rain shortfall data. Besides, the correlation between weather events and food crises was verified by analysing rainfalls in the three districts comparing them with WFP aid deliveries into Kenya. The relationship between the entity of food aid and rainfall realization was very weak. This means that food aid programs are not responsive enough to drought shocks. This is partly due to supply side obstacles and inefficiencies that could be reduced through an index which establishes a direct link between cash payouts and predicted humanitarian need.

By matching data on yields, forage availability, livestock information and METEOSAT-based rainfall series it was found that severe droughts have all entailed humanitarian crises and that these drought episodes were strongly associated with herd losses, lower livestock lactation rates and child wasting. These data confirm that rainfall could be used as an effective indicator of forthcoming crises/emergencies.

Furthermore, a preventative action would reduce the cost of aid per beneficiary. In fact, the current delays in aid delivery by donors cause an emergency progress and further need for more expensive processed commodities for therapeutic feeding.

The weather insurance product that could facilitate humanitarian response, by relating emergency relief directly to drought, could be devised in two different ways:

- Put option based on cumulative long rains ((March-May) and/or cumulative short rains (October-December) appropriately weighed, across different weather stations, in a weather index;

- Forecasting model which allows predicting famine, according to rainfall realizations several months ahead. Indemnity payments would be linked to a trigger value established on the basis of the rainfall level below which child wasting would exceed 20%.

Weather based famine index insurance of this sort could complement existing appeals based systems, that currently operate when human suffering is already happening, allowing faster and lower cost interventions (Chantarat et al, 2007).

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[7] MUAC data are standardized using the international standard 1978 CDC/WHO growth chart. The threshold z≤-2 is consistent with the famine benchmark often employed by emergency relief agencies (Howe and Devereux 2004; World Food Programme 2000).

Up to now Mexico is the only country that has implemented a weather risk management policy whose social protection component is only a section of a more complex scheme of intervention. Mexico is considered one of the most diverse countries in the world in terms of geography and climate (World Bank, 1999). The country is vulnerable to a wide range of natural hazards: floods, droughts, volcanic eruptions, earthquake, fires and tropical cyclones. Aware of the country susceptibility to weather risk, in 1996, the Government had established a Fund for Natural Disasters "FONDEN". FONDEN is a last resort source that is activated once disaster relief is needed, beyond index based insurance and reinsurance intervention.

Other examples of weather index used for emergency relief are the recent lending contracts between the World Bank and Colombia or the forms of grants to Mongolia and Ethiopia whose disbursement is conditioned to pre-defined weather event triggers (Barrett et al. 2007).
There is a wide potential to design indexes based on many different variables. One possibility could be to construct an index that draws from international commodity prices. This would allow a more prompt response to food security issues. Furthermore, international prices are transparent, objective and timely source of information on which to rely on. A potential index could also be a combination of price and yield data in order to catch natural hedge effects.

## 4. Countries' experiences on weather index insurance: a summary of lessons learnt

**Table 1. Main types of index insurance applied to agriculture**

| Type of index based product | Characteristic | Country | Main features |
|---|---|---|---|
| **Area Based crop yield insurance** | Requires long and reliable series of area-yield data | **US**<br>Farmer level<br>Marketed | Group Risk Plan (GRP): subsidised by the US Government; Indemnity payments based on percentage shortfalls in actual county yields (the area equals the county) relative to a forecasted yield. County yields are made available by the NASS-USDA |
| | | **Quebec**<br>Farmer level<br>Marketed | Indexed Based Programs: Coverage and claim payment based on area results. Payment schedule relates index data to historical yields. |
| | | **India**<br>Farmer level<br>Marketed | Subsidised (up to 50% of the premium for small and marginal farmers) and mandatory if linked to credit |
| **Area average crop revenue** | Combines production and price risk. Crop-revenue products are well-developed in North America, where their use is facilitated by developed commodity markets. The price element of the policy has to be market based, that is, on futures prices for the coming season | **US**<br>Farmer level<br>Marketed | Crop Revenue Coverage (CRC) provides revenue protection based on price and yield expectations; pays for losses below the guarantee at the higher of an early-season price or the harvest price |
| **Area average livestock mortality rate** | Thanks to weather/mortality correlation and reliable historical data, livestock mortality rate index insurance contract is based on the average livestock mortality rate of a given region. | **Mongolia**<br>Farmer level<br>Piloted | Livestock mortality rates in Mongolia are highly correlated with severe weather conditions during the winter season.<br>The insurance company pays indemnities to herders up to a certain mortality rate. If herd loss is over this trigger value intervention by the Government is provided |
| **Cumulative rainfall (deficit/excess rainfall)** | | **India**<br>Farmer level insurance<br>Piloted and marketed | 2003: castor bean and groundnut producers<br>2004: castor bean, groundnut and cotton producers<br>2005: principal rain-fed crops present in the same agro-climatic region<br>Linkage with credit. A micro finance institution (BASIX), on behalf of an insurance company (ICICI Lombard) started delivering weather insurance contracts. This connection had positive rebounds on farmers' access to credit and insurance premiums |
| | | **Mexico**<br>Mexican public reinsurance program<br>Piloted and | |

| | | | |
|---|---|---|---|
| | | marketed | |
| | | **Ethiopia**<br>National level<br>Piloted | The World Food Program has purchased the insurance in order to protect its exposure to drought induced food crises |
| | | **Malawi**<br>Farmer level<br>Piloted | Ground nut and maize producers<br>Linkage with credit<br>Farmers are given loans to purchase hybrid seeds and index insurance. If indemnities are triggered they are used to repay loans. |
| | | **Uganda**<br>Farmer level | Maize producers (contracts are at a designing stage) |
| | | **Kenya**<br>Farmer level | Maize producers (contracts are at a designing stage) |
| | | **Tanzania**<br>Farmer level | Maize producers (contracts are at a designing stage) |
| | | **Nicaragua, Honduras, Guatemala**<br>National level | (contracts are at a designing stage) |
| **Flood index** | Flood level<br>The index draws from the water level as measured by a weather station which is located at delta of a river | | |
| | | **Vietnam**<br>Farmer level | For rice producers (contracts are at a designing stage) |
| **Soil moisture index** | | Not adopted | |
| **Air moisture index** | The index is obtained by combining rainfall with temperature | **Ukraine**<br>Farmer level<br>Piloted | Winter wheat producers |
| **ENSO[8] based index** | The sea surface temperature shows a strong correlation with rainfall, especially in coastal regions | **Peru**<br>Farmer level | The coastal region of Piura (contracts are at a designing stage) |
| **Vegetation index** | Through satellite devices it's possible to detect available pasture (biomass). Payouts are triggered when the biomass goes below a pre-defined level. | **Mexico**<br>National level<br>Marketing stage | -The Mexican Government purchases the index insurance and if payouts are triggered, support to herders is provided.<br>-Reinsurance is provided by the National Reinsurance Company together with a pool of international reinsurers |

*Source: the author*

Before going through the particular features and aspects that have emerged from single weather insurance projects there are some key general elements that need to be recalled. Credit defaults due to lack of collateral and the high incidence of rainfed agriculture in poor rural areas have widely demonstrated the need for insurance (Dercon, 2006). Authors have

[8] ENSO – El Niño Southern Oscillation is the index that measures the Pacific sea surface temperature.

argued that not all insurance schemes are suitable for developing countries. Indeed, problems related to traditional crop insurance, such as, asymmetric information issues, transaction and damage assessment costs would be further exacerbated in a developing country. The majority of farms are small size, located in remote areas that insurance companies have no convenience to reach unless premiums are high enough to cover the expenses. In these areas it is very likely that yield variability becomes the minor component of insurance premiums if compared with costs. Such premiums are unaffordable by farmers unless they are strongly subsidised as it happens in all developed countries and in some emerging economies like India where yield insurance receives high percentage premium subsidies. Recently, index based insurance has gained wide attention because it eliminates asymmetric information problems and damage assessment costs and minimizes transaction costs.

Even index based insurance is characterised by some issues that need to be addressed. The major concern is to conceive an index which shows a high degree of correlation with farm yields and thus minimizes the basis risk. There are several elements to be considered in order to address basis risk. Firstly, the availability of a weather stations' network that reflects as much as possible the existing microclimates, not susceptible to manipulation and the possibility to validate and/or enrich local weather data by referring to satellite information. The achievement of these requisites makes the weather insurance more attracting to international reinsurers. In some other cases it might be useful to integrate data on weather patterns and yields with crop growing models that can provide information on how plants react to region's related agro-meteorological conditions. These crop growing models have been essential in those countries where yield data were unavailable or very scattered. Another important finding regarding index implementation was that even if yield and weather data were available, interviews to farmers on their perception of major variables influencing yields were an essential starting point for weather data interpretation.

Another essential issue to be addressed before the weather insurance is marketed is to ensure that farmers and other agents have a clear understanding of how the index works. When indexes are constructed on the basis of one major variable, such as rainfall, it should be relatively easy to explain. Difficulties might arise in case the index is a combination of variables where none is effectively prevailing. Understanding by farmers might be even more complicated if a financial package including weather insurance was to be implemented. Sometimes the linkage between insurance, credit and other financial tools might not be straightforward.

Before commenting specific countries' experiences it is worth reminding that the majority of pilot projects are very recent and, as for now, it is still too early to evaluate their future sustainability and impacts. Nevertheless, some positive signals are worth to be highlighted:

- *Multiple uses.* One aspect that is very much linked to the objectivity, transparency and immediacy of index value reporting makes weather insurance susceptible of multiple uses. The weather index can be a useful early warning tool in case of natural disasters on a national scale (macro-level). It can be traded as a derivative such as in Mexico, Ethiopia and Malawi or, more simply, as a criterion to promptly mobilise aid. On the micro level, index based insurance can be delivered directly to farmers, like in Malawi, individually or on a collective basis (farmers' association) or a micro finance institution can act as intermediary and deliver policies to farmers, such as in India. Otherwise micro finance institutions could purchase index insurance themselves in order to protect their portfolio from weather risk;

- *Risk layering*. The single countries' experiences have highlighted some benefits from the implementation of weather based insurance. In Mongolia, herders who have purchased the mortality rate index have been offered a lower interest rate by credit institutions. The index that has been implemented in Mongolia has many positive aspects that have eased its diffusion amongst farmers; it is very transparent and simple because merely based on livestock mortality rates. The market failure component of risk is transferred partly to the Government, and in last appeal, to the Government contingency intervention program, in which the World Bank is involved. It is advisable indeed that some form of contingent aid were available in the early years of implementation in order to avoid unsustainability of the program in case adverse weather occurs in the first year as it happened in Morocco. Mongolia is in a certain way a proof of how transparency and a well designed risk transfer institutional framework, in accordance to the different layers of risk, are crucial in order to stimulate demand;

- *Linkage with credit and inputs*. In Malawi, thanks to the combination of loans, index insurance and access to advanced inputs, farmers have been able to increase their productivity and their incomes. In fact, the risk exposure to rainfall deficit of Malawi farmers has been mitigated by both insurance purchase and the use of more advanced inputs such as, hybrid seeds and other means of production. The insurance/credit package offered to Malawi farmers has effectively contributed to remove some of the hurdles that impede the emancipation of farmers from subsistence agriculture (Osgood, 2007). There are further examples of pilot project where weather insurance is part of a strategy aimed at favouring credit access. The benefits of this kind of pilot projects are visible from the lower interest rates in Peru or in Mongolia even if it is too early to judge these small scale phenomena (Osgood et al. 2007, Skees, Hartell, and Murphy 2007).

- *Participation of farmers to the index designing process*. Another thing that the most successful pilot projects have in common is the participation of various stakeholders to the index definition process. This has happened namely in: India, Malawi, Kenya and Tanzania pilot projects.

The pilot stage has been successfully concluded only in Mexico and India. The reasons that have brought to the creation of a proper market for weather insurance are different for the two countries. In India, the major factor of success was the intermediation of the microfinance institution BASIX which could dispose of a network of local offices for the delivery of the weather based insurance. The increase of weather insurance purchases has started a virtuous mechanism that has led other insurance and international reinsurance companies enter the weather insurance market. This has brought to further investment by the insurance companies aimed at modernising the metering network. The inclusion of many other crops in the program has favoured risk pooling. The only negative aspect rose by some authors (Vickery et al., 2007) is that poorest and more risk averse households, who did not have any linkage with the microfinance institution or the farmers' associations, have not purchased insurance. The issue related to the involvement of the poorest households might have been addressed through the involvement of the Government who could provide resources to subsidise weather insurance in favour of those households that could not afford it and invest in training activities in order to assure a level of understanding of these innovative insurance products.

Conversely, Mexico experience entailed Government involvement since the beginning of the project. The reinsurance company that was in charge, together with World Bank expertise, to project and deliver the weather insurance was totally state owned. In addition it was clearly defined that in case large scale natural disaster ad hoc payments would have been triggered. This layering of risks has facilitated the widespread of insurance and recently some international reinsurers have entered the Mexican market.

## 5. Concluding remarks

Pilot projects based on IBRTP's in developing countries, in order to cope with adverse weather events, have first of all highlighted the principle that these products are one, but not the only tool that can contribute to income stabilization. Indeed, some of the most successful experiences have been those where index-based insurance was associated to other financial instruments and facilities to invest in more advanced inputs. Nevertheless, even if index based products are not the only tool to achieve some level of income stabilization, in those weather risk prone regions they represent some sort of pre-condition to the access of other tools such as credit loans especially in those contexts where yield is the only form of collateral for poorest households. In those regions or countries where climate change is the major cause of yield variability poor farmers are likely to incur in credit defaults. On their side credit institutions are very reluctant to loan or do lend at very high interest rates.

The difficulty in obtaining loans automatically rebounds in a dearth of investment and productivity. The way loans and insurance are to be combined strongly depends on the regulatory structure within the country. In some cases, it could be sufficient that the microfinance institution purchases the IBRTP's in order to protect its portfolio but it is not automatic that the benefits of purchasing weather insurance are transferred to farmers. Skees (2006) proposes a sequential procedure on how to establish a linkage between credit and insurance that reaches its final step when local insurance companies use IBRTP's as reinsurance and underwrite individual farm level crop insurance policies that are linked to Micro-Finance Institutions loans. Thus, in other words, the MFI would serve as a low cost insurance delivery mechanism.

It appears that the process of linking insurance to credit might not be straightforward especially in those contexts where the two markets are not developed. In this case, the State intervention could play a fundamental role. Especially in disaster prone developing countries the first policy priority should consist in conducting an analysis of the potential adverse events to which the country is subject and, according to their magnitude, define what tool will be utilised to address those risks. In other words, the definition of risk layers is the first step in order to get a clear definition of the portion of risk that can be managed through the development of a private insurance market. In Mongolia, the fact that the Government, together with the World Bank, has its own tools to cope with catastrophic losses makes the insurance companies more secure on what is the portion of risk they are required to manage. Thus index insurance in order to be successful not only has to be considered as one of the tools available to farmers to stabilize consumption but need to be inserted in a more complex policy framework where it has to be made clear what are the risk layers to be addressed and with which tools.

Furthermore, a risk management policy on the national level should create all those optimal conditions to develop weather insurance first of all an effective and reliable metering network and if necessary a subsidy for those small households who cannot afford to buy the index. The example of India demonstrates that subsistence households have not purchased insurance. On the micro-level and on a value chain perspective the introduction of risk management tools such as weather insurance could facilitate relations amongst the agents of the supply chain. The subscription of a policy against production risk would make farmers more reliable for procurement and consequently credit institutions would be keener to offer better lending conditions to farmers. Where value chain are not yet developed the role of the Government should consist in facilitating relations amongst the potential actors of the supply chain. One set of interventions should consist in activities of promotion and capacity building on risk management tools. These capacity building activities should be inclusive of all stakeholders of the value chain, from institutional representatives to banks, processors, traders and farmers.

## Annex 1

## Some of the indicators to be considered for the design and implementation of index based insurance products

*Provided that there is a sufficient level of correlation between weather events and production losses, the institutional and economic aspects to be considered when designing a marketable weather based insurance product are the following:*

***- Institutional and economic context indicators***

**General assessment of the risk profile of the country agricultural sector:**

- Major sources of production loss in the agricultural sector (weather events, pests, diseases), information on price volatility;
- Institutional and regulatory instability.

**Existing forms of insurance and Government intervention**:

- Types of agricultural insurance products, number of insured farmers and share of insured production;
- Existing subsidized crop insurance programs (level of subsidy, loss ratio)
- Other forms of intervention of the Government in case of natural disaster such as, ex post intervention.
- Existing forms of subsidy to the sector. Even other forms of support, not strictly referred to insurance, could crowd out farmers' interest in market based risk management instruments.

***- Supply side analysis of the banking and insurance sector***

- Agricultural insurance application/penetration: number of insurance companies offering products to agricultural sector but also to other sectors, such as tourism;
- Agricultural finance application/penetration: number of banks lending to agriculture; value of lending portfolios for agriculture and existing risk management tools to protect the agricultural loan portfolio; segments of the value chain to which finance is provided (farmers or big trading companies); the willingness to accept alternative forms of collateral (such as insurance)

***- Micro level indicators***

- Analysis at the micro level to quantify the real risk exposure of farms in order to evaluate their willingness to pay for insurance.
- Existing risk management strategies: diversification, in and off farm diversification strategies, lending, saving etc.
  To this purpose any kind of information relating to the available and widespread strategies of risk management are useful. i.e. the information on the banking system and the access to credit by farmers are good indicators of the potential demand that, in case credit access is difficult, might be driven through insurance (alternative to collateral). If the project implies the building of a financial bundle between loans, insurance and inputs, information on inputs costs and credit market (credit constraints, link between credit default and adverse weather conditions etc.) becomes essential.

- Linkages of farmers with the market such as, contractual arrangements. Level of integration among stakeholders within the value chain.

**- *Actuarial soundness***

- Performance of the contract
- Pricing

Willingness to pay

**- *Risk layering***

If the different risk layers are not addressed by the appropriate tools there won't be any incentive by private stakeholders to enter and invest in agricultural insurance in a certain country. The Government should be able, also with the support of International organizations, to set up an intervention system in case of natural disasters (market failure layer) that cannot be sustained by the primary insurance companies alone.

- Once the index or the indexes have been designed, the information on which risks and which crops would benefit of an index based insurance product would help to evaluate the risk pooling potential within the country and thus assess to which extent reinsurance or other forms of contingent aid are needed. In other words: definition of risk layers.

**- *Data and other required information:***

- Structural farm surveys;
- Prices of agricultural products, quality of commodity price data for 3-4 most important commodities, the ways prices are reported and collected, the frequency of data reporting;
- Distribution of weather stations and distance between the reference weather station and farms;
- Weather events time series at each weather station;
- Information on plants phenology[9] (i.e. time from sowing to germination would be very useful). In case a rainfall contract was to be developed information on soil Water Holding Capacity or any similar constraint on water storage are necessary
- Typical practices and inputs used.

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[9] **Phenology** is the study of the times of recurring natural phenomena. The word is derived from the Greek *phainomai* (φαινομαι)- to appear, come into view, and indicates that phenology has been principally concerned with the dates of first occurrence of natural events in their annual cycle. Examples include the date of emergence of leaves and flowers, In the scientific literature on ecology, the term is used more generally to indicate the time frame for any seasonal phenomena, including the dates of last appearance (e.g., the seasonal phenology of a species may be from April through September).Because many such phenomena are very sensitive to small variations in climate, especially to temperature, phenological records can be a useful proxy for temperature in historical climatology, especially in the study of climate change and global warming. For example, viticultural records of grape harvests in Europe have been used to reconstruct a record of summer growing season temperatures going back more than 500 years. In addition to providing a longer historical baseline than instrumental measurements, observations of natural systems also provides high temporal resolution of ongoing changes related to global warning.

## Annex 2

## A review of weather index experiences and pilot projects in Middle and Lower Income Countries

Apart from a few exceptions, experiences of implementation of weather index products in developing countries are very recent. This doesn't allow an appropriate evaluation of performances but some comments on the need for further improvements are feasible. Given the diverse features of each country project, the general criterion of description consists in dividing developing countries' experiences into two main groups, countries where insurance policies have been already sold and countries where weather index insurance is currently being developed. The description of each country experience will focus on the following topics: country background information and traditional crop insurance past experience (when available), index features and design method, clients (distinction between micro/household and macro/state-government-level projects), addressed risk layers, and factors of success/failure.

### Part 1 (a). Countries where weather index insurance was implemented

### Mexico

- **Background and context**

In Mexico, a broad segment of the rural population practices rain-fed agriculture on small plots (60% of producers own less than 5 hectares). The vulnerability of agricultural producers to rainfall variability is extremely high. Indeed, yield losses attributed to drought represent 80% of total. The high vulnerability of Mexican agriculture to weather events has made crop insurance development one of the priorities of the Mexican Government. During recent years the types of insurance schemes and operational guidelines have undergone several changes in order to meet low income producers' needs.

The most significant evolutions regard the liquidation of the National Agricultural and Livestock Insurance Company, an entirely state owned company which had the insurance monopoly and the inception of AGROASEMEX. Agroasemex is a State owned institution which provides reinsurance to private companies and Self Insurance funds. It also acts as a development agency to drive the growth of the agricultural insurance industry by means of operating and designing risk management products. With the creation of the state owned reinsurance company Agroasemex, the insurance market was opened to private companies.

In 2002, due to the scarce market penetration of the private insurance industry, that used to sell traditional crop insurance only to large scale producers, Mexico has started its weather risk management policy. In 2002, AGROASEMEX begun to investigate the best and cost efficient alternative to traditional crop insurance in order to involve small scale producers in a weather risk transfer scheme. The scheme that resulted from feasibility studies and a pilot project is the "Catastrophic Crop Insurance" based upon a weather index.

- **Rainfall index features**

The insurance policies are based on rainfall levels even if, recently, policies based on wind speed and temperatures have been marketed. The weather insurance based upon rainfall level is the final output of several variables that have been considered in order to reduce basis risk effects as much as possible. In particular, the existing functional relationship between yield and the accumulated rainfall during a specific period of the plant growing cycle is considered. The relationship has been evaluated by using a dynamic simulation model of the vegetative cycle process based upon crop, soil and climate interactions[10]. Of course, these models need to be adapted and calibrated for agronomic crop and region characteristics. All these elements have brought to the definition of thresholds that change according to the three main growing stages of the plants[11] (sowing, flowering and harvesting) and a precise duration of the contract. The starting date of the growing season is flexible. This will start together with the contract coverage, when rainfall reaches the sufficient level for sowing[12]. Another issue that was addressed was the presence of microclimates to be tackled by looking at variability patterns. In other words regions or areas where climate and yields show the same variability are considered as homogeneous and thus would require a weather station to cover that specific geographic area avoiding overlapping with other different microclimates.

Advanced techniques that draw from atmospheric sciences and allow identifying groups of weather stations showing similar patterns are available. The model used in the "Catastrophic Crop Insurance" is the "Agro climatic Zones with Homogeneous Response" – AZHR. Each AZHR reflects similar conditions in the response of the soil and the plant to rainfall and thus allows the definition of regional thresholds. The pilot test, conducted in 2002 in the State of Guanajuato, allowed verifying the goodness of estimated thresholds. The index design procedure is fundamental in order to succeed in the process of transferring the risk on the international reinsurance market[13]. Agroasemex started the reinsurance operation on the international market in 2003. In 2005, index insurance covered 1.16 million hectares in 18 States. In 2006, land covered by insurance doubled (2.3 Million hectares). Up to 2006, 28% of non irrigated cropping area was covered by index insurance. The index performed well during the first four years of implementation, even in 2005 when drought occurred and caused damages to yields in 10 out of 18 underwriting states. In order to verify correlation between yield losses and weather, inspections where conducted to confirm the accuracy of the index thresholds in the various regions.

The obstacle to further improvement of index insurance in Mexico is the lack of weather stations that meet international standards.

- **The recent implementation of the Vegetation Index**

Small cattle ranchers in Mexico rely mainly on natural pastureland to feed their animals. The available biomass is subject to adverse weather events such as drought. Indeed, it was found

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[10] The crop models cited by AGROASEMEX researchers are the Crop Environment Resource Synthesis – CERES (Jones and Kiniri, 1986) and the Erosion Productivity Impact Calculator – EPIC (Sharpley and Williams, 1990)

[11] There are other examples of three phases' weather indexes in Malawi and India.

[12] The rainy season starts when in a ten consecutive days period there is an accumulation of at least 25mm of rainfall

[13] These requirements are mainly related to: (i) the length and continuity of climate data series (missing data for one or several days is a problem inherent with conventional weather stations. To guarantee the continuity of time series it is important to have a backup station for each of the stations used in the insurance or at least the access to national weather services or international centers for climate monitoring; (ii) the availability of information in real or semi-real time

that drought events showed a high degree of correlation with the available biomass, essential to maintain cattle weight and health.

Today the available biomass is measured by an index (the vegetation Index[14]) calculated by using infrared and red daily satellite images. When biomass declines below a certain established limit, economic relief is provided. In the case of the vegetation index based insurance the Mexican Government is the policy subscriber while reinsurance is provided by a pool including Agroasemex as the local reinsurer and Swiss re and other international reinsurers.

- **Comments**

Mexico is one of the few countries where the pilot project ended up with a significant increase in index insurance subscription. Currently, the only obstacle to a further diffusion of weather insurance is due to an infrastructural gap, the lack of weather stations. To this purpose, other climate measuring instruments, such as remote sensors, are under Government examination.

In the case of Mexico the spread of weather insurance has been favoured by the following factors: Government intervention has been clearly oriented towards the creation of a safety net which operates in case of widespread losses and addresses natural disasters consequences on low income rural producers. The Fund for the Care of Rural Population Affected by Weather Contingencies – FAPPRACC and Fondo Nacional para Desastres Naturales – FONDEN that is linked to the insurance program and operates as a contingent aid are in place since year 2003. The transfer of catastrophic risk to the Government through the emergency funds has allowed the development of more affordable insurance products for the farmers. Concerning insurance, the ratio beyond Government intervention through the state owned reinsurance company Agroasemex was actually aimed at ensuring that even the small and low income household had access to some form of insurance. Indeed now that index based insurance is widespread Agroasemex future strategy envisages the transfer of the achieved technology to private companies. The other essential success factor is the accuracy with which the index was designed and its continuous adaptation to changing weather conditions in order to mitigate basis risk.

### Ethiopia

- **Background and context**

Agriculture accounts for 47% of GDP and employs about 80% of the labour force. Within agriculture, crops represent 30% of GDP. Ethiopia is one of the largest livestock producers in Africa (about 35m cattle, 25m sheep and 18m goats). The sector accounts for almost 10% of GDP and employs over 30% of the agricultural labour force.

Production remains mainly at a peasant, smallholding level and is mainly rain fed. Ethiopia is subject to highly variable rainfall. Drought events can occur on a regional or even national basis and can generate devastating effects on farmers. The vulnerability of Ethiopian farmers derives mainly from the utilisation of traditional agricultural practices that require little irrigation and rely strongly on livestock.

[14] Vegetation Index is available worldwide and administered by the National Oceanographic Aerospace Agency

The uncertainty that characterizes rainfall realizations negatively affects farmers' willingness to invest in more advanced technology and impacts on the availability of food in the country. The Ethiopian Ministry of agriculture has estimated that the national level of production (on average 8.9 million metric tons per year) is not sufficient to feed the whole population even in good rainfall years.

- **Macro- level index features**

One of the first feasibility studies, conducted in 2004, envisages four possible utilizations of weather index insurance in Ethiopia (Skees et al., 2004). Each of the four proposed declinations requires a certain quality of data used and an evaluation of the territorial degree to which the indices can be localized.

The four potential uses for rainfall insurance in the Ethiopian context are:

1. linking rainfall insurance to loans;
2. linking rainfall insurance to input usage;
3. Stand alone rainfall insurance;
4. tying rainfall insurance to international food aid.

The first three solutions can also be combined together such as in the Malawi pilot project which is a blend of credit, insurance and inputs delivery to farmers.
Being food security Ethiopia's main concern the first step that was undertaken consisted in the implementation of a macro-level project able to assure food delivery in times of crises. Analysis of the country risk profile highlighted the strong correlation between severe rainfall deficit and WFP's emergency assistance to the country. The existing correlation supported the idea that a rainfall index could help predict drought emergency and be used as a trigger for immediate drought relief. Furthermore, index based insurance would mobilize cash aid in advance thus avoiding in-kind food aids which take months to be delivered.

In 2006, the drought insurance pilot project at the macro level, to address national food security, has been undertaken. The project was developed in collaboration with a European Reinsurer, AXA re, which provided the World Food Program with insurance coverage against drought in Ethiopia, via a weather derivative. In case rainfall, in some selected regions of Ethiopia, falls below a certain trigger during the months before harvest (that is likely to cause low maize yields), the World Food Program receives a payout which will be used to integrate the necessary budget to face aid demand during the forthcoming famine years. More specifically, the contract premium was $930,000 for a maximum payout of 7.1 Million $ in case of severe drought. The project relies on a total of 26 weather stations which are used to estimate the distribution of payouts and for the underlying weather index on which the derivative contract was based. Regions where livestock is the main activity are not included in the pilot index due to the lack of weather stations and reliable time series. The contract covers the entire growing season that includes two rainy seasons. The expiring date of the contract is in October. By that time, if it is verified that rainfall data, gathered during the whole duration of the contract, fall significantly below historic averages, warning on potential crop failure is automatic. The index draws from yield data on the main crops and is designed on a country basis. The performance evaluation showed that the index picks up all the catastrophic droughts occurred during the last 40 years. There might be the possibility that due to basis risk, the index threshold is not triggered but famine still occurs. In this case, the undelivered payouts will be used by national agencies for more prompt response to food crisis.

World Food Program's index triggered aid would provide cash-for-work to only 60,000 households in the event of a maximum payout. In fact, the WFP reinsurance is complementary to the Ethiopian government forms of support to the chronically food insecure population "the Productive Safety Net Program", in place since 2002. A rainfall deficit would trigger money both to WFP and the Government of Ethiopia. The innovative aspect of the financial mechanism stays in the prompt response provided by the reinsurance company, if compared to donors' aid delivery procedures, and the immediate cash availability for wages instead of food. The financial sustainability of the project is strictly linked to the donor's willingness to pay for the premiums in the future.

Ethiopian weather data have also been disaggregated according to the different climatic zones and crops in order to point out eventual risk pooling opportunities. A slightly negative correlation emerged between severe droughts during the two cropping seasons in the southern region of Ethiopia. Furthermore, if livestock production was included to the portfolio of risk the degree of correlation among risks declines for the south of the country. (Alderman and Haque, 2007)

- **Micro level index insurance**

Concerning micro-level weather insurance, the state-owned Ethiopia Insurance Corporation (EIC) planned to launch a small pilot weather insurance program for wheat and pepper farmers in southern Ethiopia in the woreda (district) of Alaba. A pilot program, for which it receives technical support from CRMG, was due to start in year 2006 (World Bank, 2005).

- **Comments**

The use of weather index for a more prompt intervention is a very effective criterion but this is not conclusive in terms of enfranchisement from poverty. It was found that even households that receive food aid are forced to sell assets (see Carter et al., 2007) In addition, provided that livestock is a very important sector and usually when disaster occur very poor people are forced to sell the only ox they have it would be fundamental to develop insurance products where livestock is more widespread in order to avoid depletion of this specific asset during crises.
Additionally further implementation of pilot projects both on the micro and macro level is strongly hampered by the insufficient quality of the weather measurement network. Only a minority of the five hundred stations, dislocated throughout Ethiopia, would be consistent with the standards of international financial markets. The macro level project relies on only 26 stations contributing to social isolation of those farmers who don't live near a good weather station and in remote regions. A first step toward an improvement of the weather stations' network could be an assessment of the needs in terms of metering devices in order to understand the feasibility of a private/public investment in this field.

**Part 1 (b) The use of index based risk transfer products to facilitate the access to credit**

The occurrence of correlated risks creates a dual problem:

1. a higher probability of loan default amongst agricultural producers/clients;
2. households tend to draw their savings and simultaneously increase demand for borrowing in order to cope with the disaster (Skees et al., 2005)

When there is a lack of collateral and household incomes derive mainly from agricultural activity, credit access could be very difficult. In case of natural disaster lenders curtail the volume of credit available and simultaneously the demand for credit falls due to higher cost of borrowing
Researchers have found that when insurance markets are lacking, credit markets fail to work effectively. This phenomena slow economic growth and increase vulnerability of the poor to poverty traps (Dercon 2005).

Some of the pilot projects, described in the following paragraphs, highlight the importance of introducing a risk sharing mechanism, such as index insurance, in order to mitigate the consequences of covariate risks on development.

**India**

- **Background and context**

Agricultural production in India consists mainly of foodgrains. These crops are an important determinant of overall economic growth and a huge employer of the rural population. Total foodgrain production in 2006/07 was 209m tonnes. However, yields remain low by international standards. Other major crops grown include: oilseeds, cotton, pulses, sugar, tea, coffee, rubber, jute and potatoes. Some economists argue that for annual GDP growth to sustain rates of 8%, the agricultural economy will have to grow much faster than the rates of 2-3% recorded in recent years. However, in spite of normal monsoon rains and efforts to stimulate the sector, agricultural growth has remained low. After no growth in 2004/05, the sector grew by 6% in 2005/06 and 2.7% in 2006/07.

Agriculture accounts for 18 percent of national GDP and employs 65 percent of the population. The majority of producers are small scale with household that own parcels of less than two hectares. 50 percent of crop production variation in India is caused by either inadequate or excess rainfall (Barnett and Mahul, 2007). The exposure of Indian crop farmers to weather hazards causes many difficulties in accessing to credit mainly because of the strong positive correlation between micro-credit default and deficient rainfall.

The government response to drought risk consisted in the introduction of a crop insurance scheme based on an area yield index that is offered through state-owned insurance companies. The National Agricultural Insurance Scheme (NAIS) is conceived to cover credit default risk for most crops at premium rates of 1.5 to 3.5 percent of the loan amount. The insurance coverage is proportional to the loan size (loans are given by the rural public sector banking system) with small farmers receiving a 50 percent premium subsidy. The Agriculture Insurance Corporation (AIC) implemented this scheme and collected premiums of Rs 2.5 billion covering an area of 1.3 million hectares—a negligible fraction of cultivated land in

India. Total claims were Rs. 4.7 billion, resulting in a claims ratio of almost 200 percent in a normal year. In 2002 the claims to premium ratio recorded a 4.17 value (Manuamorn, 2007). In addition, premiums and claims do not seem to be "equitably" distributed across crops and states (Hess, 2003).

In 2003, a study was conducted to verify if weather insurance would have extended the reach of financial services to the rural sector thanks to the reduction of the exposure to weather risks (Hess, 2003). The pilot project started in 2003 and involved BASIX, a microfinance institution and ICICI Lombard an insurance company.

- **The linkage with credit**

The weather index is based on rainfall level and conceived to protect farmers from drought risk during the growing season. Initially, the index was designed for two crops: castor beans and groundnuts which are more profitable, if compared with others, but also more sensitive to drought. The high exposure to drought induced yield losses was one of the major reasons for credit defaults by farmers.

The connection between drought risk exposure and credit default was one of the rationales of the partnership between BASIX and ICICI Lombard, established in 2003 aimed at developing rainfall index insurance in the State of Andhra Pradesh with the technical assistance of the Commodity Risk Management Group of the World Bank.

The direct involvement of Basix as deliverer of the index insurance products has produced several positive effects:

- the fact that Basix was selling insurance policies acting as an intermediary between the insurance company and the farmers has contributed to the scaling up of weather insurance not only amongst Basix clients. Basix could count on a wide network made of 1.281 staff present in 10,026 villages in seven States. Especially in the first two years of the pilot project several village meetings were organised in order to raise farmers' interest and understanding of the insurance project and gather recommendations on how to improve the insurance product. All this information has been provided through Basix to the insurance company which has gained advantage in terms of insurance take up in the following years;
- another success factor, and maybe the most important one, is the livelihood based approach adopted by Basix that through its extended delivery system was already selling a wide range of products that included life insurance, livestock insurance, loans but also technical assistance to rural households. In more detail, the innovative approach by Basix is threefold: (1) "Livelihood Financial Services (credit, insurance, and savings); (2) Agricultural and Business Development Services (productivity enhancement and market links); and (3) Institutional Development Services". This approach entails staff productivity maximization and cost-effectiveness (Manuamorn, 2007). Indeed, the involvement of private stakeholders such as a micro-finance institution and/or an insurance company requires some level of profitability. To cover capacity building costs such as staff training and the automation of the insurance system Basix needed to sell a well defined amount of policies. In the trial phase the pilot was financed thanks to the surplus accumulated by Basix from selling life insurance but ultimately the weather insurance component had to become an income generating asset able to sustain itself. The agreement between Basix and the insurance company ICICI Lombard, as in 2005, envisaged that Basix would have remitted the

entire amount of collected premium to the insurance company. After the insurance company underwrites the policies and pays a commission to Basix of up to 15 percent of the amount of each premium collected by the microfinance institution.

- **The rainfall index contract**

The pilot phase covered three growing seasons from year 2003 to year 2005. During this period, the contract has undergone several changes consisting mainly in adapting the contract structure to plant growing conditions and farmers' needs.

In the first year, 2003, rainfall index insurances were sold to farmers to protect them against drought during the ground nut and castor beans growing season. indexed contracts were subscribed by 230 farmers with an average land holding of 2.5 acres.

In 2004, thanks to farmers' witnesses and feedback from the previous year pilot project. First the project was expanded geographically by including to other districts that referred to four additional weather stations and secondly, in order to minimize the basis risk, the new index based contract was based on a three phase payout structure. To summarize, the contract divides the Monsoon cropping season (Kharif) into three stages: sowing, flowering and harvest and pays out in case rainfall levels fall below a certain trigger value. The trigger values are different for each crop growing stage and reflect the relative importance of rainfall during different phenological stages (Manuamorn, 2007). An upper and lower threshold is fixed for each of the three phases. If the cumulative level of rainfall exceeds the upper threshold the policy does not pay for that phase. Otherwise the policy pays a fixed amount for each mm below the upper threshold and until the lower threshold. If rainfall level falls below the lower threshold the contract pays a fixed and higher payout. The total payout is thus given by the sum of the payouts across the three phases. The policy also includes a payout in case of excess rainfall for a number of consecutive days (during the harvest period) that can seriously damage the harvest. Finally, if the crop fails during the sowing stage farmers receive a payout that can be used to re-invest in a new crop. Farmers that were included in the pilot program were not more than 20 km far from the nearest rain gauge. The duration of the different phases, trigger values for each phase and other parameters were determined by using a crop growing model (Gadgil, Rao and Rao, 2002) and interviews to farmers. The premium was calculated on the basis of projected payouts of time series yield data at least 25 years long for each weather station.

To promote the new product among farmers meetings and workshops were organised. The entire portfolio of weather insurance that was sold by BASIX was insured by ICICI Lombard through reinsurance from one of the leading international companies. After the one in Andhra Pradesh other pilot projects for several crops were started: cotton and soybeans protection from excessive rainfall, orange in Rajasthan against insufficient rainfall, coriander and again castor and groundnut growers against excessive rainfall. In Year 2004-2005, it is estimated that 20,000 weather insurance were sold. In 2005, ICICI Lombard made further progress by automating the subscription system and claim settlement and succeeded in further diversifying its portfolio of risks by insuring other sectors. During the same year, new insurance companies entered the weather insurance market. It is estimated that, in 2005, 250,000 farmers bought weather insurance products and new weather stations were installed.

- **Comments**

It is essential now to understand if the availability of weather insurance products in India has produced positive effects on lending behaviour both of financial institutions and farmers.

In order to deepen the knowledge of the elements that have played an important role in farmers' willingness to pay for rainfall insurance a study was conducted to analyse the data relative to year 2004 on rainfall insurance participation in Andhra Pradesh. The study was conducted by Gine, Townsend and Vickery by using a microeconomic survey, held in 2004 just after the monsoon season, of rural households in the region of Andhra Pradesh. Insurance purchasing patterns are evaluated by using a neoclassical benchmark model[15]. The insurance product whose performance is analysed is the rainfall index based contract made available for castor and groundnut growers against scarce rainfall. The main findings of the research are that households which face lower basis risk are more prone to buy the insurance; in addition, purchasing rates increase in wealthier household and decrease for those households which are credit constrained. The results regarding the influence of credit constraints on insurance participation have implications on insurance design itself. Firstly, indemnities should be paid immediately after rainfall is measured and verified. Surveys show that the period of the year during which farmers are mostly in need of liquid assets is at the time of sowing and the period during which they are less in need is at the time of harvest since they are able to sell their crop production. Thus, according to the authors, optimal timing of payouts should be phase by phase without waiting the end of the harvesting period. One obstacle to prompt indemnities payment is the two months that the Indian Meteorological Department takes on average to verify rainfall data. To solve this problem ICICI Lombard is setting up a private network of automated rain gauges, which in the future will facilitate faster payouts and reduce basis risk. A second useful innovation would be to combine insurance with a short term loan that helps credit-constrained households pay for the premium. This solution was proposed to BASIX that expressed its doubts about mixing insurance and micro-credit products.

Some results show no consistency with the neoclassical model but are extremely common in developing countries; risk averse farmers are less willing to pay for the index insurance unless they are familiar with insurance or with the microfinance institution (BASIX) which delivers the insurance. Surveys on subsistence farmers in India show that, in order to achieve perfect consumption smoothing, households tend to diversify spatially their plots and amongst less risky but also less profitable crops. According to Morduch (1995) these activities reduce the variability of agricultural revenues, but at the expense of lower average income and probably reduce the possibility to pay for an insurance product that would transfer part of their risk.

The results also highlight additional elements which play a fundamental role in the decision to purchase the index insurance product: the limited familiarity with the insurance product; the higher take-up rates amongst prior customers of the insurance provider BASIX, or members of social communities; the households who are more connected to village networks show higher willingness to purchase insurance; young farmers and self-identified 'progressive' farmers, are more likely to purchase the product; a significant fraction of households cite advice from other farmers and understanding of the product as important determinants of participation decisions.

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[15] The main hypotheses withstanding the model are: insurance participation is higher when risk aversion is high, basis risk is low and the exposure to risky events is high; finally credit constraints have been included.

The main conclusion of the empirical work is that, in the first stage of its implementation, the insurance product has not yet succeeded in proportionately involving the most vulnerable households (e.g. poor, credit-constrained households, or households that are not members of social networks), who presumably would benefit most from protection against drought or excess rainfall. The scarce diffusion amongst subsistence farmers could be partly due to the barriers that hinder trade in insurance and also by the difficulties in understanding the structure of an index based insurance product.

Among those countries where index insurance has been implemented India is a particular example of how to use insurance to facilitate access to the credit markets. The linkage between the two financial instruments is mostly "institutional" and given by the fact that the deliverer of the weather insurance is the credit institution itself. Currently weather index insurance policies are sold in six states to more then 125,000 farmers. In spite of area yield insurance, weather insurance is not subsidised by the Indian Government. Indeed, ICICI Lombard claims for a revision of the subsidy policy that should also favour the diffusion of weather insurance at least through increasing the investment in the weather station network. By subsidising yield insurance the Government creates a false incentive to buy yield insurance which might not be the best solutions for certain districts or crops. It would be interesting, as Gine' and Townsend suggest, to understand if the diffusion of insurance has relieved credit access and if insurance has been purchased by smallest and poorest households.

**Malawi**

- ***Background and context***

Malawi is highly dependent on agriculture. 85 percent of the population are agricultural smallholders and their dependants; farming activity generates over 90% of export earnings and 35-40% of GDP. Smallholders' productivity rates are very low due to inefficiencies both of the inputs and outputs markets. The main crop product is maize which is produced by smallholder for their own subsistence and only occasionally sold on the market. The largest exported product is tobacco that accounts for half of merchandise export earnings. Other important exports are sugar and tea. Maize and tobacco are grown throughout the country, whereas sugar and tea are produced mostly in the south.

Rural financial services do not operate in marginal areas of the country due to the high transaction costs to reach these areas and smallholders' exposure to weather and idiosyncratic risks. The most common weather risks affecting southern Africa countries are: drought, floods and cyclones. When these weather events occur, small farmers, who have little or no collateral other then their yields, incur in generalised loan defaults. The government intervention in input and output markets has made these markets more risky and unpredictable. Subsidization of inputs purchase did not sort positive effects for smallholders and a marketing board for maize, which used to fix a purchasing price on a national basis to facilitate consumers, has hindered local markets functioning.

The difficulty in obtaining loans restrains the possibility to purchase those inputs that are crucial for productivity enhancement: maize and groundnut hybrid seeds and fertilizer. Due to the high drought risk exposure of Malawi farmers and the dearth of collateral, microfinance institutions are not keen to provide loans. Thus, the matter was to offer Malawi farmers a combination of financial and insurance facilities to reduce their exposure to climate variability and, at the same time, ease their access to loans.

The increase of productivity would only be possible by easing the access to credit that in turn requires some form of weather risk transfer to be purchased by farmers to mitigate their loan default risk.

- ***Main features of the micro insurance product***

The very first step of the pilot project undertaken in Malawi consisted in defining the weather risk profile of the country. This was possible thanks to the Official Meteorological Office that through its weather stations' network collected data for a long period with only few information missing. The availability of rainfall data allowed estimating the frequency of droughts over time, the geographical differences in rainfall distribution and the spatial correlation of droughts amongst different regions. Results of weather data analysis show how drought in some years has involved a major part of the national territory. The covariate nature of rainfall deficit highlighted the need of a weather risk transfer policy not only at the micro-level but also, as we will see later, at the macro and even international level.

Concerning the micro-level component, the project started in 2005 and focussed on two products: maize and groundnut. It consisted in developing a rainfall index based insurance in order to mitigate drought exposure of the Malawi producers and establish a linkage with loans and input purchase (Hess and Syroka, 2005). The rainfall index has been subject to continuous adjustments in order to "represent the impact of weather on farmers' physical crop production and thus reduce as much as possible the effect of basis risk". Since the very beginning the index has been the result of different sources of information that lead to the assessment of rainfall impact in the different growing stages of a crop. Among them: farmer interviews, agro-meteorological studies and the FAO Water Requirement Satisfaction Index (WRSI). A cumulative rainfall level was determined for the whole growing period (130 days) and a weigh was assigned to each of the three crop growing phases. Those growing phases, during which plants are more vulnerable to rainfall deficit, are assigned more weigh in terms of water requirements.

***The contract design[16]***

The contract developed in Malawi is subject to continuous adjustments in order to make it more sensitive to weather changes. Currently, the index value is a synthesis of: rainfall totals during three key growing phases, Water Requirement Satisfaction Index (WRSI) and yield time series when available. In addition, experts are exploring the potential of integrating forecasts based on El Niño Southern Oscillation – ENSO, into the weather index.
For each phase[17] the payout formula has three parameters: trigger, limit and maximum payout. The total payout is the sum of the payout of each phase and limited to the maximum payout size. On the basis of a crop growing model a sowing condition is defined. This means that a certain amount of mm of rain has to be reached in order to start the insurance coverage period. If during the sowing period the trigger rainfall level (25mm) is not reached a failed

[16] For an extremely detailed description of contract features, both former and currently implemented, see last report to the World Bank concerning: Malawi, Kenya and Tanzania pilot projects (Osgood et al., 2007)
[17] Phase 1 corresponds to vegetative growth; Phase 2 covers the flowering period which is the most drought sensitive stage; Phase 3 goes from pod formation to maturity.

sowing occurs, a payout is provided and the contract is terminated, giving the possibility to the farmer to eventually re-sow.

The contract parameters are a combination of agronomic, climatic and financial features. For the agronomic component, in order to establish the timing of the different growing phases, different sources of information were used. The WRSI model parameters were integrated and calibrated with interviews to the farmers and the adaptability of crops to local climate was considered (with the collaboration of agronomists) to better evaluate the real impact of water stress. Yield data could be an additional source of information even if usually long enough time series are not available and if the data concern large district, the information on variance of individual production goes lost. The Malawi contract was designed without the support of yield data. Referring to financial issues the contract premium was as much as possible near to an actuarially fair price. To evaluate the potential demand, interviews to farmers have been made in order to understand their interest in the product and the kind of coverage to be preferred between a higher frequency of small sized payouts or a low frequency of large payouts.

There are several design issues to be addressed in the future:

- Local capacity building. It is necessary to provide local population with know how in order to adapt contract designs to changing needs and climate variability without the help of international institutions. This would have a positive impact on economic and social development;
- Introduction of regional and even global climate trends into index contracts and reinsurance in order to take into account the negative correlation of rainfall between different regions. For example ENSO impact could be useful to consider, usually higher probabilities of drought in Southern Africa are associated with rainfall in the Greater Horn of Africa;
- The aspects related to the linkage of index insurance with other contracts (such as loan contracts) have not been fully addressed in economic contract theory. Indeed, through the application of contract theory it may be possible to reduce moral hazard issues in lending, instead of simply reducing the risk to the lender. For example, incentives for farmers to accurately report rainfall and/or yields might be part of a loan contract. This kind of innovation might also allow market based valuation of the insurance product and tests to verify farmers' understanding of the product" (Osgood et al., 2007).

- ***The financial package***

The package, designed for groundnut and maize growers, is addressed to those farms located within a distance of 20 km from one of the weather stations included in the pilot program. The eligible farmer will receive a loan to be used to buy certified seeds, pay the insurance premium and taxes. Farmers are usually part of larger liability groups (10-20 farmers each). Farmers plant the new seeds and at the end of the season provide their yields to farmers' association for commercialization. Revenues from commodity sale or either insurance payouts are used to repay the loans.

The peculiarities and strength factors of the pilot project undertaken in Malawi are:

- involvement of both international and local actors: World Bank, International Research Institute for Climate and Society – University of Columbia (IRI), National Smallholder Farmers' Association of Malawi, Opportunity international Bank of

Malawi, the Malawi Rural Finance Company Ltd, The Insurance Association of Malawi and the Malawi Meteorological Service

- loan/insurance products are unsubsidised, the contract value is the result of market transactions.

During the last two years of implementation, purchases have increased to the point that demands for these products have overwhelmed the administrative capacity to serve clients. Sales have increased from 892 contracts during the first year of implementation (2005) to several thousands in the 2006-07 seasons. Thanks to increasing purchases of fertilizer and certified seed, productivity has improved and allowed the financial self sustenance of the project. Farmers are now able to pay for more advanced inputs, insurance, interest and taxes thanks to their own profits.
Malawi is the first country where, together with index insurance, the concrete attempt to adapt a crop variety to the local climate conditions was associated to credit and insurance products. This implies that insurance payouts would be mobilized only when plant genetics and other practises have not been sufficient to avoid crop loss.

- ***Main features of the rainfall macro insurance product***

According to Hess and Syroka (2005) effective market functioning requires also a revision of the food aid criteria. In-kind food aid, especially if delivered with a certain delay, could seriously hamper the food chain and generate a downward trend of domestic food price. These mechanisms are generated if food aid is not distributed during the real time of need and delivered outside the normal commercial marketing channels. This situation influences local food chain actors that would be discouraged to invest in infrastructures especially in marginal food deficit regions.

Malawi's economy is highly vulnerable to adverse weather shocks firstly for their negative impact on agricultural production (and GDP) but also for their indirect impact on government finances resulting from the unanticipated need for emergency interventions (which may translate into increased domestic borrowing) and increased pressure on the current account because of the need for exceptional food imports. Researchers have recently advanced proposals on how to devise a more general index to improve the country's preparedness to emergency relief. The proposal envisions the development of a scheme for emergency relief which is similar to the Ethiopia one and is based on the link between "social protection payout" and index based insurance. The feasibility of a national weather index for emergency relief was first verified by looking at the existing strong correlation between the Malawi Maize Production Index (MMPI) and WFP deliveries in case of drought (Alderman and Haque, 2007). The index has been designed using rainfall data from weather stations throughout the country and is based on the Malawi Meteorological Office's national maize production forecasting model (a modified version of FAO' s Water Requirement Satisfaction Index). The model captures not only the total amount of rainfall received at each station, but also its distribution during the agricultural season and how that impacts maize yields. Because rainfall and maize yields are highly correlated, changes in rainfall – its cumulative amount and distribution – can act as a proxy for maize losses.

The government is working to pilot an *ex-ante* risk-management system to protect the livelihoods of Malawians vulnerable to severe and catastrophic weather risks. The pilot would use a weather derivative to ensure contingency funding for an effective aid response in the event of a drought (as defined by contractually specified severe and catastrophic shortfalls in levels of rainfall). The government would, in effect, buy weather insurance from an international provider. The contract would provide contingency funding in case of an extreme drought during the following agricultural season.

The development of this financial instrument could ultimately enhance the Government's national food security strategy. As a first step, it is recommended that the Government of Malawi enter into an initial pilot transaction that would provide contingency funding in the event of extreme drought during the 2008/2009 agricultural season.

- **Comments**

The pilot project in Malawi is one of the few attempts to establish a link between credit and loans. The relationship between these tools has many aspects that need further research. For example, the kind of incentives, in terms of better credit conditions, that a credit institution could provide to those farmers who report their yield losses. The micro level weather insurance program is still at its very first stage both in terms of crops involved, area covered and modalities on how to link loans to insurance.
The macro level project consisting in the construction of a national rainfall index to address or better prevent food crisis is still in its planning stage. Anyway, the idea to use an index based product in order to mobilize resources more promptly in case of national disaster should not be underestimated.

### Mongolia

- ***Background and context***

Until the 1960s Mongolia depended almost exclusively on livestock herding. An industrial sector was developed between 1960 and 1980 with aid from the Council for Mutual Economic Assistance (Comecon), and by the mid-1970s industrial production had overtaken agricultural output. Agriculture's share of GDP has been shrinking since the late 1990s, accounting for 21.5% of GDP in 2006. Livestock (camels, horses, cattle, sheep and goats) numbers fell from 30m in 1999 to 25.4m in 2003, as a result of harsh winters in 2000-01 and 2001-02, but rose again to stand at 34.8m in 2006. Three disastrous winters, dry summers and successive animal epidemics since 1999 have delayed the recovery of the sector. A reform programme to intensify herding and reduce nomadic practices is being drawn up with the help of the Asian Development Bank (ADB). In addition, in 2006, the Mongolian government and the World Bank backed an index-linked livestock insurance project in several provinces on an experimental basis, in order to cover from herd losses due to extreme weather and other natural disasters.

- ***Livestock index main features***

In 2005, Global AgRisk Inc. had a first contract and a grant for consultation activity to structure a livestock mortality index to be experimented through a pilot project in three districts, for a period of three years. The Index Based Livestock Insurance (IBLI) was aimed at protecting Mongolian herders from animal death risk. The availability of data from annual livestock census, issued by the Mongolian Government, allowed the analysis of the correlation between herd losses and harsh weather conditions. The high coefficient of correlation between the two variables was the starting point of the index design process. The payout structure is based on a death rate of adult animals in a predefined area (called *soum*). The risk is layered so that the insurance companies cover for losses between 7 and 30 percent of animals within the *soum*. Due to the fact that in some years the death rate of animals would have been unsustainable for an insurance company, a state program called Disaster Response Plan (DRP) was introduced in order to indemnify herders in case of losses that exceed 30 percent (Skees and Barnett, 2006). Payments are triggered by the index thus there is no need to count dead animals, a nearly impossible task to accomplish if we consider the vast regions of Mongolia. The insurance contracts have different features according to the animal species: cattle, yak, sheep, goat and horses. The herders who have purchased the insurance (Basic Insurance Product – BIP) are automatically eligible to receive relief from the DRP in case of extreme losses. Furthermore, the presence of the DRP produced positive effects on the BIP prices because the insurance provider does not load the premium with extreme events probability. Still, BIP exposure is significant due to the frequency of herds' loss events and due to the covariate nature of the risk. To solve this problem the Government of Mongolia is planning to offer intervention on a stop loss basis beyond the payment of a fair premium by the insurance companies. The reinsurance premium should contribute to build a reserve which would be used by the Government to pay for the losses. Since losses are very likely to go beyond the reserve the World Bank offered contingent loans whose availability is very important in the early years of implementation essentially because if a natural disaster occurs in the years of the pilot project this could ultimately hinder its prosecution.

**How BIP and DRP work**

Herders pay a premium based on the value of their animals reported and the relative risk in the soum that they select. The soum is selected based on herder knowledge of where his animals are most exposed during the first six months of the year. Herders are able to insure between 25 to 100 percent of the estimated value of their animals. Payments begin once the predetermined threshold of mortality for the soum (strike) and species is exceeded. The payment rate is capped once the mortality rate exceeds the exhaustion point (cap). BIP payments are the product of the payment rate times the value insured. DRP payments use the full value of animals. The DRP pay for losses beyond the exhaustion point.

As an example, consider a herder who has 36 sheep where the value of a sheep is 28,320 Tg. The herder decides to insure the total value = 28,320 Tg. x 36 ~ 1,000,000 Tg. The premium rate for the BIP, with a strike at 7% and a cap at 30%, is 1.4 %. The herder would pay 1.4 x .01 x 1,000,000 = 14,000 Tg.

The mortality rate in the herder's *soum* during a bad *dzud* year equals 35 %. The payment rate for the BIP is equal to 30% -7% = 23 %, and thus the BIP payment is 23% x 1,000,000 Tg. = 230,000 Tg. Payment for the DRP equals (35%- 30%) x 1,000,000 Tg. = 50,000 Tg.

Source: Authors.

*Mahul and Skees, 2006*

- **The linkage with credit**

The IBLI project is also tied to another project on sustainable livelihoods. The latter envisions activities to strengthen microfinance and microcredit. There is an ongoing effort to tighten the links between the livestock insurance project and the microfinance one. Currently, lenders and insurers are considering how they could link the insurance product (BIP) to lending. Such linkages would reduce the default risk attributable to harsh winter conditions. Also when herders purchase the BIP product with their loans, the cost of delivery should be less than with the current agent-based system for selling insurance. Hence the loan-linked weather insurance should result in both lower premiums and lower interest rates

- **Comments**

Mongolia is a good example of how to conceive different tools in order to address the different risk layers. State intervention, reinsurance and World Bank support occur only in case of natural disaster and in accordance with a predefined procedure. The insurance companies are involved only for what concerns that layer of risk, the market layer they can financially sustain.

***Peru***

- ***Background and context***

The wide diversity of climatic conditions allows most varieties of crops to be grown in Peru. About 1.3m ha of the country (only around 1% of the total land area) is estimated to be under cultivation. Agriculture in the Andes is largely carried out at subsistence level. The coastal plain offers huge potential for export crops, but investment has been hindered by unfavourable legislation. To encourage investment and to modernise agriculture, in the 1990s the government passed a series of land tenure laws.
The major adverse weather event that affects Peru is flooding. In case of catastrophic flood it was observed an increase in loan defaults that are compensated by the economy through credit rationing and raising interest rates. During the mid 1990s Peru had some experience related to traditional indemnity based insurance, but due to the massive crop failures caused by El Nino in those years, farmers lost their interest in conventional agricultural insurance.

- ***Index features***

The objective of the project undertaken by USAID consisted in trying to expand the rural finance sector by providing index insurance against catastrophic events that would have reduced both the portfolio risk of micro finance institutions and the risk of individual farm loans (Skees, Hartell and Murphy, 2007). After a risk assessment analysis it emerged that El Nino events are the major source of widespread flooding in the country. It was also verified that this kind of devastating events induced a widespread dearth of agricultural credit. During the investigation phase it was found that the "El Nino Southern Oscillation – ENSO" 1+2 – the index that measures the Pacific sea surface temperature off the coast of Peru was highly correlated with excess rainfall and flooding in the northern region of Peru (Piura). Increases very much above average in sea temperature usually anticipate an El Nino event. ENSO indexes are considered very reliable, they are issued by the U.S. National Oceanographic and Atmospheric Administration and daily record for 50 years are available. An index which is based on the ENSO value would be very easy to develop and considered reliable by a re-insurer thanks to reliability of data sources. Such an insurance product could be purchased by a microfinance institution which would receive a payout every time that the ENSO value exceeds two. The Peruvian Government has approved the index insurance based on ENSO value in the summer of 2006 and recognised the potential of the index to transfer a portion of the risk that has plagued Peru for centuries. MFI's as well have expressed their interest in purchasing the ENSO based insurance in order to protect their credit portfolio associated with flood risk. Finally, a reinsurer has expressed its interest in developing such a product to be traded on the international financial market. According to recent information, the ENSO based index insurance has been implemented and the market has been just open.

The insurance product will successfully perform only if the MFI will be able to transfer the benefit of purchasing the weather index to households by offering better credit conditions.

***PART 2 (a) Countries where index insurance is at its first stage***

Nicaragua and Morocco have been the first two countries where the feasibility of index based insurance contracts was evaluated even if it did not bring to the marketing of the contracts. The reasons why pilot projects failed or simply did not start are different for the two countries and have been useful as lessons learnt for the successive pilot projects

- **Nicaragua**

Nicaragua together with Morocco have been the first two countries where the feasibility of index based insurance contracts was evaluated even if it did not bring to the marketing of the contracts. The reasons why pilot projects failed or simply did not start are different for the two countries and have been useful as lessons learnt for the successive pilot projects

- **Background and context**

Agricultural yields in Nicaragua are abysmally low by regional standards, and irrigated land has diminished if compared with 30 years ago. Although white corn yields have grown since 2000, red bean and rice yields are no higher than they were in the late 1970s. This poor performance has resulted from a plethora of problems. One is the lack of secure land tenure, as more than one-third of all landholders lack registered land titles. Access to credit is woefully inadequate, as only 6% of all farmers receive formal bank financing. A mere 8% of small and medium-scale producers enjoy the benefit of technical assistance programmes. The rural road network is largely unpaved and in poor condition; the average farmer's holding lies 82 km from the nearest paved road. Efforts to diversify Nicaragua's export crops are enjoying increasing success. Easier access to the US market through DR-CAFTA and expanded sales to Central America have encouraged production of exports such as peanuts, cheese, red beans and fruits, formerly regarded as non-traditional products. A 1998 free-trade agreement with Mexico has also spurred exports of live cattle and black beans.
The Major weather events affecting agricultural activity in Nicaragua are insufficient or excess rainfall and hurricane.

- **The index features**

Since one of the biggest problems for Nicaraguan farmers was the access to credit, insurance contracts could have been an alternative form of collateral to ease credit access. A better credit access would have stimulated investment in technology and specialization. At the time of the feasibility study, only 22% of farms of the region were specialised, the rest diversified its activity among the following crops: peanuts, bananas, sesame and sugar cane.

**I**n the first phase of the investigation (1999-2001) the aim consisted in developing a rainfall index insurance in case of excess or scarcity of rainfall (feasibility study by Skees and Hazell spring 1998 and detailed study by Skees and Miranda in 1998). Nicaragua is an interesting case study since the subjects that have shown the greatest interest in the development of rainfall contracts were the Nicaraguan banks that expressed their availability to lower interest rates in case farmers had purchased the index contract. Nicaragua had, at the time of the investigation, an infrastructure of about 240 weather stations of which 100 that had collected data since 1956 to 1997. In addition, the Ministry of agriculture supplied time series data on area planted and yields by year. Finally the Southern Oscillation Index developed by Florida State University was used to measure the impact of El Niño events on rainfall (ENSO).

The area for pilot test was identified and corresponded to a section of a Region, located in the northern pacific coastal region of Nicaragua considered as the dominant cropping region of the country. Within this region, three weather stations were chosen to conduct the Pilot program: Leon, San Antonio, Chinandega. It was estimated that 10,000 farms were located in the area covered by the above mentioned three weather stations. The availability of data allowed to build a reliable and accurate model of the probability distribution of rainfall over time and space for each rainfall station and taking into account el Niño impacts on rainfall level and timing. Secondly, the degree of correlation between rainfall at contract station and economic losses of farmers was quantified. In the Report by Skees to the World Bank the need of more secure weather stations and the need to increase the infrastructure of stations by investing in new technologies and new measuring gauges was underlined. In fact, a region which is more densely populated with rain gauges allows "geographical smoothing (GS)"[18]. Private and public institutions have been involved: agricultural producers, bankers, insurers, the Government of Nicaragua, the international reinsurance industry and the World Bank itself. The World Bank was supposed to act as a reinsurer providing stop-loss coverage through a contingency loan especially if the loss occurred in the first years of the pilot project

When, in October 1998, Hurricane Mitch afflicted Nicaragua, the World Bank decided to design an aggregate weather index aimed at providing aid to the Government in case of disasters. The aggregate index was projected and also priced on the global reinsurance market. Just before the beginning of the pilot project, the Nicaraguan Government refused to implement the aggregate index insurance declaring it could count on the international community humanitarian aid. According to the most recent information on Nicaragua, the ongoing attempt by the World Bank consists in trying to establish a link between the purchasing of index insurance and credit loans. It seems that banks in Nicaragua have agreed to lower interest rates (for loans to production) to those farmers who purchase index insurance products.

- **Comments**

Nicaragua is an example of failure due to the Government attitude that is reluctant toward the implementation of risk transfer products, such as index based insurance, because of the possibility that this kind of product would crowd out international community free intervention in the event of a natural disaster (Alderman and Haque, 2007)

- **Latest developments in Nicaragua, Honduras and Guatemala**

In the latest years, the World Bank, together with the Inter American bank for Development-BID, the Central American Bank for Economic Integration- BCIE, and with the support from the Inter American Federation of Insurance Companies – FIDES and the Regional Union for

[18] "GS can be used with a heavily populated set of rain gauges to provide point estimates for rainfall. With GS there would be little concern if a few stations went down or were destroyed. GS simply uses information from a set of stations by weighting the information from the nearest stations most heavily. A system of GS and densely populated stations holds great promise for reducing opportunities for any individual to tamper with a single gauge and for reducing any measurement errors for how much it has rain at any particular location" Skees, 2005.

Technical Assistance – RUTA, are joining their efforts in an initiative aimed at enhancing capacity building in the field of weather index based insurance in three countries: Nicaragua, Honduras and Guatemala. In the Central American Region crop production areas show a certain degree of homogeneity and yields show a high level of correlation with rainfall realizations over time.
In order to assess the feasibility of weather insurance, the national insurance companies of Guatemala, Hondurans and Nicaragua are supporting their country based members in the implementation of pilot projects involving small and medium producers of maize, sorghum, mani', soybeans and rice. The first pilot was supposed to start in year 2007. The project is jointly financed by World Bank, the Inter American bank for Development-BID and the Central American Bank for Economic Integration- BCIE.

Nevertheless some bottlenecks generated by national policies in agriculture have emerged in the Region. Most of all, the need of re-orienting Government policies in the agricultural sector was underlined. Indeed, in many cases direct subsidies to farmers have stimulated farmers to produce in highly risky areas that ultimately ended up in a reduction of the competition potential of the sector. In this context several issues need to be addressed:

- Re-orientation of public policies in favour of insurance in agriculture vs distorting subsidies;
- Definition of the field of intervention in case of natural disaster. In other words, analysis of the risk sources and magnitude and in a second stage definition of instruments and institutions charged to cope with each risk source;
- Enhancement of the public sources of information (yield, weather etc) including investment in the weather stations network;
- set up a regulation framework that stimulates innovation in the agricultural insurance sector;

Where this is feasible, address weather risks on a regional basis in order to pool risks amongst different countries. This has been proposed with reference to the SADC countries and recently for the three Central America countries. In the latter case, a regional approach is desirable since when dealing with small countries, reinsurance companies need to minimise transaction costs that are very high in the early stages. Regional integration is very difficult to achieve given the heterogeneity of countries' information and regulatory systems

### *Morocco*

- ***Background and context***

Drought-sensitive cereals dominate Moroccan agriculture. Morocco is largely self-sufficient in meat, fruit and vegetables, but large volumes of other foods, notably wheat, maize, sugar and dairy products, must be imported. Cereals are grown on some 60% of the country's cultivated acreage, including 500,000 ha of irrigated land. The dominance of the cereal crop, its high dependence on rainfall and the regular incidence of drought explain the volatility of agricultural production.
Agriculture remains labour-intensive. Agriculture and fishing together employ about 46% of the total workforce (and over 60% of the female workforce), but account for only 11-16% of GDP, depending on rainfall. There is some 8.73m ha of cultivated land of which around 1.25m ha is irrigated. The rain-fed sector remains largely unmodernised, and is dominated by holdings of 5 ha or less.

The sector also suffers from the relatively high cost of energy, the dearth of investment and, of course, the regular incidence of drought, which requires the government to set aside significant funds for drought-relief measures. Locusts are occasionally a problem in the far south, as in 2003/04, although crop damage was small. The government also plans to speed up investment in irrigation, mechanisation and rural services and to provide better access to credit to farmers for investment.
In addition, the government has yet to overcome the problem of the extreme fragmentation of the land, with most peasant farmers unable to afford to invest in tractors, fertilisers or selected seeds.
The irrigated sector produces export crops such as citrus fruit, tomatoes, early vegetables, including tomatoes and potatoes, a wide range of other vegetables, fruits (including grapes, mostly for wine, and dates) and nuts. Olives and olive oil are produced both for export and local use. Moroccan exporters, faced with keen competition from Greece and Turkey, are seeking to diversify away from traditional EU-bound exports of tomatoes and citrus.

The first attempt to manage drought risk in Morocco was done in 1995 with “Programme Sécheresse”, revised in 1999. The program was sponsored by the Moroccan Government and was based on a yield insurance program which provided coverage to three different revenue levels in order to ensure some coverage to the small farms delivered by the local mutual insurance company (MAMDA). The program had quite success even if it encountered all the typical problems of traditional crop insurance: administrative costs, yield assessment difficulties and high costs for supporting insurance premiums. The objectives difficulties of “Programme Sécheresse” brought the Moroccan government to adhere to the World Bank program whose objective was the exploration of the feasibility of weather based insurance. By analysing rainfall realizations and cereal yield data in the country the study, determined that index based rainfall insurance would have been feasible in Morocco. The Moroccan insurance company MAMDA was assisted by a team of experts to structure the insurance scheme in order to start a pilot program in some cereal growing regions.

- ***The index features***

The proposed product was a rainfall index insurance. Indemnity would have been paid if rainfall fell below a certain threshold. The importance of this experience brought some useful insights that helped to understand some aspects of the complex relationship between rainfall and yields such as the different plant growth rates to which some weights were assigned and included in the index and also the loss of water due to low ground storage capacity was also taken into account. The very detailed design methodology that was employed in Morocco allowed reaching a degree of correlation between the index and yields of over 90% (Stoppa and Hess, 2003).

- **Comments**

Despite the interest showed by producers, insurers, administrative bodies, the implementation of the pilot program did never take place due to the negative trend of rainfall precipitation in the selected areas that made the cost of insurance prohibitive for end users. The main lesson learned was that in the very beginning and especially if the first year of implementation is a bad year these types of project do need the financial intervention of the Government and the World Bank itself. The experience in Morocco was very useful and allowed the achievement of a deeper knowledge on how to conceive rainfall indexes. The lessons learned were particularly useful and facilitated the pilot program undertaken in India.

***Ukraine***

- **Background and context**

Ukraine is one of the biggest grain and oilseed producers in the world. Agriculture constitutes 9 percent of GDP down from more than 20% of total GDP in the early 1990s. Production declined by around one-half in the 1990s, hit by a loss of major export markets; shortages of fuel, equipment and fertilisers; a lack of progress on land privatisation; and the Ukrainian government's slowness in dismantling an inherited system of central procurement, processing and distribution, which reduced incentives for collective farms. Moreover, soil erosion, related to outdated farming techniques and the extent of land under cultivation, has been a problem, particularly in those areas richest in fertile *chernozem* (black soil).
The main adverse weather events to which Ukrainian farmers are exposed are: drought, excess rain and harsh winter conditions. The antiquated and low value farm equipment has lead credit institutions in Ukraine to require future yields as collateral. Banks which are active in the agricultural sector do not lend money to farmers unless their yield is insured by a State authorized insurance company. To ease the lending procedures the biggest banks have set up their own crop insurance agencies.
Ukraine is potentially one of the countries where crop insurance in general and index insurance in particular could be easily developed. The reason is a close to zero correlation between yields in the eastern region and in the southern region near Odessa. The main crops produced in the country are: maize, sunflower, sugar beet, wheat and barley. The insurance schemes available to farmers are input cost insurance and harvest insurance which covers against the following events: hail storm, excessive precipitation, frost and fire risk. Drought was excluded from insured events.
Even if insurance was considered as collateral to obtain credit, policy take-up has always been very low. The main reasons why traditional crop insurance has not spread amongst farmers are: lack of professional and specialised staff among the insurers, high premium rates due to high administrative costs, not objective criteria for loss adjustment and underwriting procedures, lack of information available to farmers. In addition, the delivery of ad hoc disaster aid during years 2003 and 2004 has negatively influenced farmers's willingness to subscribe crop insurance.

- ***The index insurance features***

Thanks to the excellent quality of weather data and a sufficient number of weather stations (187) throughout the country, the International Financial Corporation – Private Enterprise Partnership - IFC-PEP in collaboration with the World Bank Commodity Risk Management Group (CRMG), decided to conduct a feasibility study on weather index insurance in the Kherson oblast (Ukrainian district). The main crop in the region is winter wheat. Due to unreliable yield data but very good weather data it was possible to design an index on the basis of information from the Ukrainian Hydrometeorological Center that made a punctual assessment on the growing conditions and weather risk that could negatively affect winter wheat. The sources of risk that were identified, also with the help of formal interviews to winter wheat producers, were: winterkill conditions during the crop hibernation period and moisture stress during the spring season. Findings on the events that negatively influence winter wheat yield have brought to the conclusion that an effective weather index insurance should include drought.

The index has been designed using the Selyianov Hydrothermal Ratio (SHR) which allows to measure air drought and its impact on winter wheat crop yields. It was established that farms should not be further than 30 kilometres from the nearest weather station (which is not the best recommended distance). The SHR index has the advantage to measure air humidity by combining rainfall with temperature. This combination of variables is less spatially variable if compared with rainfall alone. Temperature data were de-trended due to recent years' warmer conditions.

In 2005, weather index insurance scheme has been formally approved by Governmental authorities. Workshops and feed back by the IFC-PEP were held to train the insurance companies, active in Kherson oblast, to sell policies to interested buyers such as, farmers, financial institutions and agribusiness. The contracts that were sold during the first year of the pilot project were only two. This was mainly due to the delay in the procedure of approval of the new index contract that ended in March 2005, and strongly limited the time available for a satisfactory marketing campaign. In addition, the beginning of 2005 was a critical period for Ukraine because of the Orange Revolution that entailed the entire reorganization of institutional bodies.

The failure of the pilot program in 2005, according to Shynkarenko (2007) was also due to the excessive length of the period covered by the index which did not take into consideration the different phases of crop vegetation during which the 'lack of rainfall' might have different impact depending on the water requirements of that specific period or growing phase.

During the last couple of years the attitude towards index insurance has slightly changed. It seems that after harsh winter conditions and spring frost that occurred in 2005-2006, farmers are keener to purchase index insurance during the 2007-08 campaign. Some insurance companies have planned to introduce the following indexes: index scheme against low temperatures in winter for winter onions, orchards and vineyards; late frosts (April-May) for vegetables, peaches and apricots; lack of rainfall in May-June for non irrigated field crops.

Currently index insurance is available for several crops such as, cereal, oilseed and industrial crops. The share of index insurance on total crop insurance portfolio is 25%. Only 15 on 37 insurance companies active in the agricultural sector deal index insurance, also because the cost of weather data is prohibitive.

- ***Comments***

In spite of promotional and educational efforts made by international and national experts, weather index insurance has not been fully accepted as an effective risk transfer mechanism, both by farmers and insurers. From the farmers' point of view, the basis risk component is very incisive due to the distance between some farms and the reference weather station.
To mitigate the basis risk component, prior to the 2005 pilot project, CRMG strongly recommended installing a network of weather stations throughout the country in order to cover big distances between one weather station and the other. Today, the enhancement of the weather metering system is yet to be done. Concerning the index design, Ukraine model diverges form other countries' that thanks to indexes such as a revised version of the FAO-WRSI, included water requirement along the different crop growing stages. Furthermore, to protect the insurance companies, involved in the index insurance market, it was proposed to create a risk pool facility and a national Fund in case of emergency. The presence of the Government and the pool would have allowed the underwriting of agricultural reinsurance through a Government fund. In case of covariate events and once the pool and the national fund have been depleted the international reinsurance would intervene by paying the remaining claims. Risk layering, such as the one that was implemented in Mongolia, might generate a reduction of the premiums charged to farmers since the activity of insurance companies would be limited to the market risk layer.

## *Part 2 (b) Countries at the design stage*

### *Tanzania*

Although agricultural output grew by over 5% in 2004-05 the sector fell back in 2006 owing to the onset of drought conditions, and its contribution to GDP fell to 44.7%. Almost the whole agricultural production is rain-fed and crop production is the main component of agricultural output.
To address the major cause of crop loss in Tanzania, the ongoing pilot project on weather index is focussed on the country staple crop, maize. The index contract is conceived to cover maize grown during the rainy season from drought risk. In this case, and in agreement with the different stakeholders, the contract provides coverage only during the first two growing phases because the third has not shown to have great impact on yield stress. Tanzania is another example of index insurance constructed without the use of yield data. The sources used to verify an existing correlation between production losses and weather are: WRSI based model, supporting documents, discussion with agronomists, meteorologists and feedback obtained during meeting sessions with farmers' cooperatives and local experts (Osgood et al. 2007).

### *Kenya*

The index contracts were developed for maize grown during the rainy season. The index contract developed in Kenya differs from the ones implemented in Malawi and Tanzania only for the fact that due to a longer growing season the original two phases contract was subdivided into sub-phases in order to catch the effect of more isolated dry spells.
Time series yield data were not available thus also in this case the contract design has heavily relied on feedbacks from experts and farmers (Osgood et al. 2007).

### *Uganda*

Agriculture remains the mainstay of Uganda's economy. Although restructuring has lead to GDP fall to around 30%, farming still engages about 80% of the workforce. Output comes almost exclusively from smallholders, most of whom work less than 2 ha of land each, using simple, traditional methods of cultivation and mainly family labour. The budget for fiscal year 2006/07 (July 1st-June 30th) introduced a micro-credit scheme to tempt subsistence farmers into the formal sector. Food production is the primary activity: food crops account for 65% of agricultural output (and for 54% of monetary agriculture), with livestock products making the next largest contribution. Export crops (traditionally coffee, cotton, tea and tobacco, but increasingly supplemented by vanilla, flowers and cocoa) represent about 10% of agricultural production. Crop marketing is handled by cooperatives, marketing boards and private companies, and the export monopolies previously enjoyed by the various crop-marketing boards, such as the parastatal Coffee Marketing Board (CMB), have been abolished in line with the general policy of liberalising trade.

The modernisation of agriculture lies at the heart of the government's poverty eradication action plan (PEAP), but the sector faces increasing problems in coping with the impact of HIV/AIDS on the rural labour force, and this has contributed to poor rates of growth, especially in the informal sector. Extreme weather conditions, including both drought and excessive rainfall, have also had an impact in recent years, resulting in sluggish growth.

Like in India, where a micro-finance institution (BASIX) markets the index insurance, even if this is not directly linked to loans, Uganda experienced insurance delivered through MFI's managed by NGO's. In 2004, 1.6 million individuals were insured in Uganda.

### *Madagascar*

Agriculture remains the foundation of the domestic economy and a significant export earner, although it is no longer the main source of export earnings. Outside Antananarivo, most Malagasy still depend on farming for their livelihood. But two-thirds of all households live at subsistence level, and the underperformance of the agricultural sector is a major cause of the deep poverty that characterises most rural areas. About half of Madagascar's land area is cultivable, but little more than 5% is under crops, and yields are generally low. Farms are small, averaging only 1.5 ha. However, there are causes for optimism: production figures reveal a notable resurgence in the output of most crops over the past two or three years, and a modest but clear recovery in the troubled vanilla sector. The trend is discernible not only in significant commercial crops such as cotton and cloves, but also in less well-known contributors to the farming economy such as cassava, a key staple, and sugarcane.

Madagascar is at the first stage of construction of an insurance product to protect farmers from both drought and cyclones. Currently, assessments on the available weather data, agro-ecological zoning and cyclone models are being conducted in order to design schemes that ensure more prompt social protection and disaster response (Alderman and Haque, 2007).

### *Vietnam*

Although Vietnam is still predominantly an agricultural society, cultivated land is scarce. Only about 20% of the land is arable, and another 6% is devoted to permanent crops. Some of the remaining land may have potential, but most of it has been degraded by soil erosion, usually because of deforestation or, in the deltas, by saline or acid-sulphate conditions. About 70,000 ha per year of cultivated land is lost to soil exhaustion and urban encroachment. Against this background, it is surprising that the area of land sown to crops (including tree crops) continues to increase, reaching 13.4m ha in 2006, up from around 9m ha in 1990. Of the total cultivated area, 55% is devoted to rice and a further 26% is sown to other annual crops, with the remaining 19% being given over to perennial crops. Just over one-third of the increase in land area has been used to grow perennial industrial crops, such as rubber, cashew nuts, tea and coffee, and a further 30% of the increase is due to additional paddy land that has become available as a result of investment in irrigation.

In Vietnam (Skees, Hartell, Murphy, 2007) agricultural activity is hindered by early flooding in the Mekong River that impacts the second rice crop prior to harvest. Approximately 200,000 hectares are considered vulnerable to this event. In this case the index could be based on the water level at a strategic weather station located at the border with Cambodia and the index insurance could provide payouts on a linear basis directly to farmers.

**REFERENCES**


Agroasemex, 2006 “The Mexican Experience in the Development and Operation of Parametric Insurances Applied to Agriculture”

Aldermann H. and Haque T., “Insurance Against Covariate Shocks. The Role of Index-Based Insurance in Social Protection in Low-Income Countries of Africa” World Bank Working Paper no. 95 (2007).

Barnett B. J. and Mahul O., **“**Weather Index Insurance for Agriculture and Rural Areas in Lower-Income Countries”. *American Journal of Agricultural Economics* 89 (Number 5, 2007): 1241–1247.

Barrett C. B., Barnett B. J., Carter M. R., Chantarat S., Hansen J. W., Mude A. G., Osgood D.E., Skees J. R., Turvey C. G. and Ward M. N. “Poverty Traps and Climate Risk: Limitations and Opportunities of Index-Based Risk Financing”. Prepared for the Policy Roundtable on Climate Risk, Poverty Traps and Index-Based Financing, hosted by the International Research Institute for Climate and Society, Columbia University. September 2007

Bhise V.B., Amphore S.S. and Jagdale S.H.: “Performance of Agriculture Insurance Schemes in India. Paper prepared for presentation at the 101st EAAE Seminar “Management of Climate risks in Agriculture” Berlin, Germany, July 5-6 2007

Cafiero C., Angelucci F., Capitanio F. and Vollaro M. “Index based compensation for weather risk in the Italian agriculture. A feasibility study based on actual historic data”. Paper prepared for presentation at the 101st EAAE Seminar ‘Management of Climate Risks in Agriculture’, Berlin, Germany, July 5-6, 2007

Carter M. R., Galarza F. and Boucher S. “Underwriting Area-based Yield Insurance to Eliminate ‘Risk Rationing’ and Crowd-in Credit Supply and Demand”. Paper presented at the International Conference on Rural Finance Research “Moving Results into Policies and Practice, FAO Headquarters, Rome 19-21 March 2007

Carter, M.R., Little P. D., Mogues T., and Negatu W. “Poverty Traps and Natural Disasters in Ethiopia and Honduras.” *World Development* 35(5):835–856, 2007

Chambers, R. G. “Insurability and Moral Hazard in Agricultural Insurance Markets.” Amer. J. Agr. Econ. 71(August 1989):604S16.

Chantarat S., Barett C.B., Mude A.G., Turvey C.G. “Using Weather Index Insurance to Improve Drought Response for Famine Prevention. American Journal of Agricultural Economics, 89 (Number 5, 2007): 1262–1268

Dischel B. “Seeding a Rain Market”. Journal of Environmental Finance, September 2000.

Economist Intelligence Unit Country profiles web site

Giné X., Townsend R., Vickery J. “Rainfall Insurance Participation in Rural India” Federal Reserve Bank of New York Staff Report no. 302. September 2007

Hansen J. W., Baethgen W., Osgood D., Ceccato P., Kinuthia Ngugi R. “Innovations in Climate Risk Management: Protecting and Building Rural Livelihoods in a Variable and Changing Climate”. Submitted to *Journal of Semi-Arid Tropical Agricultural Research*. Invited paper for the ICRISAT 35th Anniversary symposium, "Climate-Proofing Innovation for Poverty Reduction and Food Security," 22-24 November 2007.

Harwood, J., R. Heifner, K. Coble, J. Perry, e A. Somwaru. “Managing Risk in Farming: Concepts, Research, and Analysis.” Agr. Econ. Rep. No. 774, USDA/Economic Research Service, Washington, DC, March 1999.

Hazell P., Skees J. “Insuring against Bad Weather recent Thinking”. Published by: Kentucky, US: GlobalAgRisk, Inc. January 2005

Hess U. and Syroka J. **“**Weather-based Insurance in Southern Africa *The Case of Malawi”*. Agriculture and Rural Development Discussion Paper 13, The World Bank, 2005

Hess U., Skees J. R., Ibarra H., Syroka J., and Shynkarenko R. 2005. “Ukraine, Initial Feasibility Study of Developing Weather Index Insurance, Crop Disaster Assistance in Ukraine.” World Bank Working Paper.

Hoddinott, J. 2006. “Shocks and Their Consequences across and within Households in Rural Zimbabwe.” *Journal of Development Studies* 42(2):301–321.

Jewson S., Brix A. and Ziehmann C. *“Weather Derivative Valuation. The Meteorological, Statistical and Mathematical Foundations”*. Cambridge University Press, 2005

Jolliffe, I. T. *“Principal Component Analysis”* Second Edition Springer Statistics, 2002.

Just, R. E., L. Calvin, and J. Quiggin. “Adverse Selection in Crop Insurance.” Amer. J. Agr. Econ. 81(November 1999): 834S49.

Manuamorn P. O.. “Scaling Up Microinsurance: The Case of Weather Insurance for Smallholders in India”. Agricultural and Rural Development Discussion Paper 36. The World Bank, 2007.

Morduch J. (1995): “Income Smoothing and Consumption Smoothing” Journal of Economic Perspectives vol. 9 (3)

Morduch J. (2003): “Micro-Insurance: the Next Revolution?”. Mimeo, NYU

Osgood, D., et al. “Designing Weather Insurance Contracts for Farmers in Malawi, Tanzania and Kenya. Final Report to the Commodity Risk Management Group, ARD, World Bank.” International Research Institute for Climate and Society, June, 2007.

Shynkarenko R. “Introduction of Weather Index Insurance in Ukraine – Obstacles and Opportunities. Paper prepared for presentation at the 101st EAAE Seminar “Management of Climate risks in Agriculture” Berlin, Germany, July 5-6 2007

Skees Jerry R., Barnett Barry J. 2006. “Enhancing Micro Finance Using Index-Based Risk Transfer Products.” *Agricultural Finance Review* 66:235–50.

Skees Jerry R. Hazell P., Miranda Mario J. (1999) “New Approaches to Crop Yield Insurance in developing Countries”. EPTD Discussion Paper n. 55. Environment and Production Technology Division, IFPRI, Washington, D.C.

Skees Jerry R., Hartell J., Murphy A.J. “Using Index-Based Risk Transfer Products to Facilitate Micro Lending in Peru and Vietnam. American Journal of Agricultural Economics 89 (Number 5-2007)

Skees Jerry R., Miranda Mario J. “Rainfall Risk Contracts in Nicaragua: A Report to the World Bank”. 1998

Stoppa A. and Hess U. “Design and Use of Weather Derivatives in Agricultural Policies: The Case of Rainfall Index Insurance in Morocco.” Contributed paper presented at the International Conference Agricultural policy reform and the WTO: where are we heading? Capri (Italy), June 23-26, 2003

Trivelli, C., M.R. Carter, F. Galarza, A. Tarazona, and J. Yancari. 2006. “Can Insurance Unlock Agricultural Credit and Promote Economic Growth?” BASIS Brief No. 46, Basis Collaborative Research Support Program (CRSP), University of Wisconsin, Madison, May.

Turvey, C. G. “Weather Derivatives for Specific Event Risks in Agriculture.”Rev. Agr. Econ. 23(2001a):333-351.

UNFCCC - United Nations Framework Convention on Climate Change “Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries” 2007.

Vedenov D.V. and Barnett B. J. “Efficiency of Weather Derivatives as Primary Crop Insurance Instruments” Journal of Agricultural and Resource Economics 29(3):387-403, 2004

Vedenov D.V., Epperson J. E., and Barnett B. J. “Designing Catastrophe Bonds to Securitize Systemic Risks in Agriculture: The Case of Georgia Cotton”. *Journal of Agricultural and Resource Economics* 3 *1* (2):3 18-338, 2006.

World Bank 2005. *“Managing Agricultural Production Risk. Innovations in Developing Countries”*. Washington D.C.