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# Weather Risk Management for Agriculture and Agri-Business in Developing Countries

**Ulrich Hess, Kaspar Richter, Andrea Stoppa<sup>1</sup>**

IFC, World Bank and Procom Agr, Rome

Risk is a pervasive characteristic of life in developing countries, especially in rural areas. The economies depend heavily on weather conditions, and experience frequent weather hazards, such as drought, floods and windstorms. These factors typically affect most households and companies in the same area at the same time. Furthermore, as households and companies typically have a low asset base and little access to well developed insurance and credit markets, they are financially ill-equipped to deal with weather shocks. As a result, their weather risk management (WRM) is inefficient resulting in negative implications for economic and social development. New WRM insurance instruments, like area-based weather indices, provide a viable alternative to traditional insurance instruments, and offer real advantages to households, companies and governments in developing countries.

## **Introduction**

This chapter has three components. The first part argues that weather risk causes substantial inefficiencies in developing countries; agri-businesses, faced with underdeveloped formal financial markets, have to rely on traditional WRM that is associated with underinvestment and overdiversification. We discuss how new WRM can overcome the pitfalls of traditional WRM and have a large development impact. In the second section, we discuss the range of potential uses of new WRM. The final part turns to the operational aspects of a new WRM, studying in detail the case of WRM for cereals in Morocco.

## **WRM and rural development**

### **VULNERABILITY TO WEATHER-SHOCKS**

Agriculture and agri-business are the prime source of income for most families and businesses in developing countries; in 1999, 69% of the population in low-income countries lived in rural areas, compared to 50% in middle-income countries and 23% in high-income countries.<sup>2</sup> Agriculture accounted for 27% of GDP in low-income countries, compared to 10% in middle-income countries and only 2% in high-income countries (World Bank, 2001). These numbers understate the importance of agriculture for economy growth, which is magnified by multiplier effects (through linkages from agriculture to other economic sectors), the role of agricultural exports

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as a foreign exchange earner, and the overriding importance of subsistence farming for the livelihood of the bulk of the population.

Agriculture is inherently dependent on the vagaries of weather, such as the variation in rainfall. This leads to production (or yield) risk, and affects the farmers' ability to repay debt, to meet land rents and to cover essential living costs for their families. But the effects of weather events also matter for rural lending institutions and agri-businesses, as they determine the risk exposure of borrowers and input providers. With weather conditions affecting a large share of business activity, many developing countries in Sub-Saharan Africa and other parts of the world display a high sensitivity of both agricultural and GDP to fluctuations in rainfall (Benson and Clay, 1998 and Guillaumont, Guillaumont, Jeanneney and Brun, 1999).<sup>3</sup> Ultimately, the precariousness of farmers and producers translates into macroeconomic vulnerability.

Developing countries are not just more dependent on weather conditions but also suffer the brunt of natural disasters (due to the hazardous environmental conditions), many of which are caused by weather hazards. According to World Bank (2001), between 1988 and 1997 natural disasters claimed an estimated 50,000 lives a year and caused direct damage valued at more than US\$60 billion a year. Developing countries incurred the vast majority of these costs: 94% of the world's 568 major disasters between 1990 and 1998 took place in developing countries. In Asia, which experiences 70% of the world's floods, the average annual cost of floods over the 1990s was estimated at US\$15 billion. On the basis of current trends, these numbers are likely to rise in the future. The incidence of El Niño events, associated with anomalous floods, droughts and storms, has increased over the last 10 years (Freeman, 1999).

### TRADITIONAL WRM IS COSTLY AND INEFFECTIVE

Farmers in developing countries have always been exposed to weather risks, and for a long time have developed ways of reducing, mitigating and coping with these risks (Besley, 1995 and Dercon, 2002). Traditional risk management covers actions taken both before (*ex-ante*) and after (*ex-post*) the risky event occurs (Siegel and Alwang, 1999). Examples of *ex-ante* strategies include the accumulation of buffer stocks as precautionary savings and the diversification of income-generating activities through changing labour allocation (working in farm and non-farm small businesses, and seasonal migration) or varying cropping practices (planting different crops, like drought-resistant variants, planting in different fields and staggered over time, inter-cropping, and relying on low risk inputs). Similarly, companies may self-insure through high capitalisation and diversification of business activities. Communities collectively mitigate weather risks with irrigation projects and conservation tillage that protects soil and moisture. Examples for *ex-post* strategies range from farmers seeking off-farm employment, to distress sales of livestock and other farm assets, to withdrawal of children from school for farm labour, and to borrowing funds from family, friends and neighbours (Hanen and Skoufias, 1998).

While such risk management has assisted developing countries in coping with weather risks (Hazell, Pomareda, and Valdes, 1986), it has important shortfalls. These strategies are costly, as they often lower vulnerability in the short term at the expense of higher vulnerability over the longer term. For example, when a farmer diversifies he gives up higher income due to specialisation in return for a lower variability of income. Equally, a farmer who sells productive assets, like draught oxen, to make ends meet lowers his future income stream. Similarly, a company misses out on profitable business opportunities if it decides to draw credit below its optimal level in order to keep a credit reserve in case of a weather shock.

Additionally, some of the informal risk management strategies are ineffective to deal with weather risks. Weather-related events constitute covariate risk, as they typically affect many households in a community or region at the same time. Yet, in

times of great stress, like crop failure due to drought, informal arrangements tend to break down, as the members of the community, or “risk pool”, are jointly affected. The income of the village as a whole is reduced, triggering a collapse of community-based informal insurance arrangements (Morduch, 1998). As in the above example of the farmer who attempts to sell livestock to make ends meet after a drought, livestock prices will fall as supply outstrips demand. Similarly, when farmers seek off-farm employment in response to a natural disaster, the sudden rise in the labour supply will drive down market wages.

#### **FORMAL FINANCIAL MARKETS ARE UNDERDEVELOPED**

While traditional WRM mechanisms provide at best partial coverage, formal financial markets are insufficiently developed to fill the gaps. Private insurance markets are impeded as a result of information asymmetries, the covariance of weather risks, lack of acceptable forms of collateral, and government programmes. These factors all lead to high unit transactions costs, limited spread of institutions, and less access for the poor.

The classical problem of asymmetric information limits the scope for crop insurance schemes; farmers will always be more knowledgeable about their production risk than credit institutions. From the insurer's point of view, this makes it difficult to separate farmers accurately into low- and high-risk groups, raising the possibility that only the high-risk farmers will take up insurance. Additionally, once insured, farmers may reduce their efforts to control production risks, leading to higher losses for the insurance company. In order to control such adverse selection and moral hazard problems, insurance companies have to raise rates, invest in monitoring mechanisms, and require marketable collateral as precondition for borrowing, which increases premiums and reduces demand for insurance.

In addition, weather risks are correlated within a region. This spatial covariance makes it difficult for local insurers with limited regional diversification to pool risks and offer affordable insurance coverage. While in principle primary insurers could pass on risks to an international reinsurance market, there is little transfer of such risk from the emerging markets for a number of reasons. The size of weather risk readily available for underwriting is limited, and transaction costs are high due to lack of standardisation and asymmetric information between insurer and reinsurer (Skees, 2000).

Finally, government risk management programmes may crowd out private sector risk management. In many countries, government have stepped in with a range of interventions for farmers. Governments mitigate risk for example through price stabilisation, subsidised crop yield insurance and drought relief. Most programmes, especially the multiple-peril crop insurance, have absorbed large sums of public resources, yet there is little evidence that these interventions had positive effects on agricultural lending or production. Instead, they have led to excessive risk taking of farmers and a growing dependency from public disaster relief (Skees, Hazell, and Miranda, 1999).

#### **EFFECTIVE WRM – A “CATCH 22” SITUATION?**

The discussion so far raises serious questions about the possibility to effectively insure farmers and agri-businesses against weather risks, be it through formal or informal insurance. The failure of formal and informal risk management mechanisms preserves high production risks, and disadvantages farmers in dealing with the numerous other risk sources deriving from markets, policies and institutions (Siegel and Alwang, 1999). For example, weather risks can be linked to price fluctuations, especially when the natural hazard has a broad spatial spread. Equally, health, institutional and political risks can trigger and exacerbate production risks.

These uncertainties not only hurt the livelihood of farmers, but also impede the development of a financial market. This leads to a ‘Catch 22’ situation (Skees, 2000):

credit institutions realise that income of farmers and agri-businesses are subject to large risks, and either ration credit or charge higher interest rates to cover these risks; without access to affordable credit, farmers delay the adoption of new technologies and the introduction of new farming systems, and keep relying on ineffective informal risk management strategies.

Hence, successful weather risk-sharing arrangements in developing countries would offer potentially huge benefits not just to farmers, but also to agri-business and financial markets (Skees, 1999). With the advent of effective WRM, finance institutions would be able to collateralise rural credit more efficiently and extend loans to groups of weather-exposed farmers that otherwise would not be bankable. Other sectors of the economy would benefit as well; for example, companies in the energy sector are also exposed to weather risk through the impact on energy demand, and could improve their insurance coverage through effective WRM.

## PANEL 1

### A MARKET FOR NEW WRM

One important example of new WRM is “weather index insurance” (Turvey, 2001). The key innovation of such contracts is that insurance is linked to the underlying systemic risk (ie, low rainfall), defined as an index (measuring rainfall) and recorded at a regional level (local weather station), rather than the extent of the loss (the resulting reduction in crop yields). In other words, the economic incentive of a farmer to work hard for a good harvest are unaffected by the weather-based insurance, avoiding moral hazard. Adverse selection is minimised as premiums are fixed without taking into account the composition of the risk pool of farmers in the insurance scheme. At the same time, as long as weather parameters correlate sufficiently with yields, it will result in a substantial reduction in a farmer’s risk exposure.

Weather index insurance has a number of advantages (Skees, Hazell and Miranda, 1999). It is inexpensive to administer, as it allows for standardisation, avoiding the need to draw up and monitor individual contracts. It can be supplied by the private sector with little or no government subsidy, as it avoids the incentive problems of crop insurance programmes related to asymmetrical information. It is affordable for poor and rich farmers alike, and accessible to agri-business and other sectors. Furthermore, by eliminating the systematic production risk component linked to the weather index, it improves the risk profile of farmers and companies. As a result, insurance companies can offer “wrap-up” contracts for the remaining independent risk. An example of such an insurance programme is the Nicaragua Risk Management Project, funded by the World Bank. This pilot project started in 1999, and provides farmers and agri-business – or anybody else who may want to protect themselves against weather risk – with the option of purchasing “rain lottery tickets”. They are sold in small denominations and entitle the holder to a payoff whenever rainfall in a given area drops below a specified level.

Another example of new WRM is the use of weather derivatives to lower reinsurance or retrocession cost. In 2001, Agroasemex, the Mexican state-owned agricultural reinsurance company, transacted a first weather derivative with a leading weather derivative market maker. Following extensive development work of the World Bank, Agroasemex and the provider developed indices that track the performance of the company’s portfolio for the period of autumn and winter 2001-2 based on 10 weather stations: four for low temperature, five for excess humidity and one for drought. The crops and regions covered were: tobacco in Nayarit (low temperature), tobacco in Nayarit (excess humidity), beans in Sinaloa (low temperature), beans in Sinaloa (excess humidity), maize in Sinaloa and Sonora (low temperature), maize in Sinaloa

and Sonora (excess humidity), garbanzo beans in Sinaloa (excess humidity) and sorghum in Tamaulipas (drought).

The covered exposure was portfolio risk of an agricultural reinsurer. The use of weather derivatives lowered the reinsurance cost of Agroasemex. As a result of this transaction, Agroasemex's retrocession costs dropped by up to two thirds. This supports Agroasemex's efforts to offer competitive products to Mexican agriculture.

With improved risk insurance, agri-business will accelerate the adoption of new technologies, specialise in the most competitive activities, and become more adaptive and flexible. In practice, rural finance institutions could be the primary customers as they hedge their exposure to weather events, and require borrowers to take out insurance as liquid collateral to mitigate part of the default risk. Small and subsistence farmers could become customers through associations and cooperatives, while large farmers could buy weather insurance directly as a hedging tool.

The demand for new WRM is difficult to measure, but it is clear that the inefficiencies in current risk management techniques indicate a substantial market potential. It will be attractive for farmers and agri-businesses as long as the "basis risk" (ie, the probability of incurring a loss that is not covered by the insurance) is not too high. World Bank research concluded that there is demand in developing countries for weather index-based insurance in rain-fed agriculture. Worldwide, weather derivative markets have reached a cumulative transaction size of more than US\$8 billion from 1997 to 2001. While a large majority of deals are still based in the US, the market is expanding in Europe and Asia in very diverse sectors ranging from tourism to agriculture and power (World Bank, 2001). The market potential for weather hedging instruments in emerging markets is large.

### **WRM for agriculture and agri-business in developing countries**

This section looks at the key success factors of new WRM in emerging markets. Five factors are highlighted:

1. good weather data in key locations;
2. the client profile as financial intermediary;
3. facilitation by development organisations;
4. a benign regulatory framework; and
5. risk transfer mechanism into international weather markets.

#### **WEATHER DATA**

A pre-condition for the emergence of a competitive weather risk market is comprehensive and accurate weather data for the past and future. Historical data, usually at least 30 years of daily information on key parameters, need to be accessible and reasonably priced. Operational weather stations have to be identified and basis weather variables defined, also with regard to cleaning procedures. All countries run weather stations that report SYNOP data to the World Meteorological Organization (WMO).<sup>4</sup>

Many countries provide long series of adequate weather data. Examples include advanced economies such as Argentina, Chile, South Africa, Turkey, Morocco, Tunisia and Mexico, but also poorer economies like Nicaragua. Nevertheless, in some countries, the availability and quality of rainfall measures is compromised for different reasons. Many developing countries do not provide easy or affordable access to weather data, although the quality and comprehensiveness of the databases are often good and mostly cleanable and usable.<sup>5</sup> In addition, moral hazard issues related to weather data collection are accentuated in developing economies with weaker institutional frameworks. Finally, just as in OECD (Organization for Economic Co-operation and Development) countries, the lack of universally

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accepted quality control procedures as well as different characteristics of non-SYNOP data – varying definitions of daily average or maximum temperature data, for example – pose a problem to the weather markets.<sup>6</sup>

Various remedies exist to provide secure and reliable rainfall data:

- ❑ First, incentive structures have to be geared towards accurate data measurements.<sup>7</sup>
- ❑ Second, matching weather station series with information from third-party sites, together with comparing historical raw data and cleaned data for pricing purposes, can help to provide an understanding of the cleaning methodology used by weather stations.<sup>8</sup>
- ❑ Third, meteorological services may have close ties with major established weather service authorities in OECD countries, as does the Moroccan weather service with France Météo. These partnerships can be useful in ensuring international quality standards.
- ❑ Fourth, the risk of tampering with the data can be effectively addressed through fallback stations of the weather risk provider as well as crosschecks with nearby stations. Weather data sensors placed directly on premises of the end-user clients, for example, multiple moisture or tiny temperature gauges placed on farm land, can be very effective in deterring data manipulation. In a project with the World Bank, RADARSAT, the Canadian Earth observation satellite investigates the feasibility of using of satellite data for back-up and verification purposes. Contract design can also help to prevent data tampering. For example, proportional contracts provide fewer incentives for manipulation than digital contracts, where payoffs are fixed on an “all-or-nothing” basis.

**END-USERS: FINANCIAL INTERMEDIARIES AND THEIR CLIENTS**

Most demand for new WRM instruments comes from insurance and reinsurance companies as well as other financial intermediaries who either seek to hedge their exposures, or to intermediate or retail weather risk protection. Very few markets allow for direct sale of weather derivatives by international derivative dealers. The profile of end-users and end-user deals of weather markets in developing countries is different from OECD markets in various ways, including the importance of agriculture for most developing countries and the lack of risk management instruments (as were discussed in the previous section), and the link to credit, higher (perceived) credit and regulatory risk (as will be discussed in the following paragraphs).

*Link to credit*

As debated in the previous section, access to formal credit is often limited, and burdensome collateral requirements ultimately make very few rural businesses bankable. For example, traditionally only state-owned agricultural banks would lend to rain-fed agriculture. The exposure to high credit risks and covariate weather risk led to low loan repayment rates and periodic recapitalisations of these banks by the state. The rescheduling of loans not only represented a burden on state finance, but also provided farmers, anticipating the next government bail out, with incentives to default. Recently, a number of countries adopted new regulations to impose market discipline on state banks.<sup>9</sup>

These changes lead to market opportunities for weather insurance. Banks require more liquid collateral from their clients as a pre-condition for crop financing, and demand that customers buy weather insurance from insurance companies. Alternatively, banks become end-users of wholesale weather contracts that protect their systemic weather exposures. Potential clients for weather insurance products therefore include micro-finance institutions, input suppliers, contract farming companies and other intermediaries that lend to agriculture and agri-business.

Demand assessments for weather index insurance or straight weather derivatives do not exist yet for other developing countries, as the products are not marketed. Studies of insurance demand, however, suggest that farmers are willing to pay between 7% and 10% of their input costs. Currently, Moroccan farmers pay a 9% premium of the maximum indemnity for traditional crop insurance. Almost all farmers in the eligible areas take up the insurance. This insurance is mostly sold through the main agricultural bank along with seasonal credit.

#### *Credit risk*

Credit risk arises with all over-the-counter contracts as both parties have promised to pay the other in the future, depending on the final value of an index, and must be trusted to live up to the promise. This can be contrasted with exchange-traded securities where the exchange assures final payment. Credit risk or the risk of default of the counterparty in emerging markets is compounded by currency transfer risk. In other words it does not matter to the weather risk provider whether the default is triggered by a macro problem (the Peso crisis, for example) or counterparty default – the risk rating will be equal or lower to the country risk rating.

This risk can be mitigated by dealing with subsidiaries of OECD companies that are guaranteed by their parent companies. These cases can be structured as OECD jurisdiction contracts. One example are OECD manufacturing companies who outsourced production to the Caribbean and Central America and have difficulty finding business interruption insurance covering production shortfalls due to hurricane disruption.<sup>10</sup> Weather risk providers would enter into hedging contracts with the US parent companies, who in turn would pass on the protection to their affiliates.

A second option for risk mitigation is the purchase of political or credit risk insurance. International organisations such as the Multilateral Investment Guarantee Agency (MIGA) (political risk insurance) or International Finance Corporation (IFC) (partial credit guarantees) are also providers of these instruments for emerging market clients.

#### **FACILITATORS**

The introduction of weather risk management into emerging market economies requires development work that sometimes cannot be recuperated in trading margins of contracts. Development institutions, such as the World Bank Group, promote pilot cases to generate demonstration effects to raise awareness. The IFC, as part of the World Bank Group, entered into a partnership with a leading weather risk market maker in order to promote WRM in emerging markets. IFC also obtained board approval for an investment in a weather insurance company to be established in Morocco (Haggerty 2002).

#### **REGULATORY FRAMEWORK**

Credit risk and regulatory risk will result in WRM in the form of insurance contracts. Up-front premium payments protect the weather risk providers by reducing credit risk to transaction risk. Documentation of the deal as an insurance or reinsurance contract is often the only way to introduce WRM in emerging markets. Derivatives are seldom accepted by regulators and are generally associated with gambling or negative cases of over-hedging, such as the so-called “Ashanti Goldfields” problems.<sup>11</sup>

Insurance contracts usually require an “insurable interest” by the insured, which may be viewed as incompatible with a weather contract settled on the basis of third-party data as opposed to losses suffered by the insured. However, the emerging experience in several countries shows that this departure from the traditional insurance concept is not a major obstacle. Mexican, Moroccan and Turkish regulatory authorities indicated that weather index-based insurance policies could comply with existing insurance regulations.

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Weather risk transfer into international markets will mostly follow the insurance and reinsurance route, before the risk becomes transformed into a weather derivative. Derivative providers are usually not licensed to engage in reinsurance business in developing economies. Highly rated reinsurers step in and write a reinsurance treaty for a local insurer that represents the business. The reinsurer then passes on the risk to a weather risk market maker and thereby effectively transforms the risk into a derivative.

**POTENTIAL APPLICATIONS**

New WRM has a range of applications.<sup>12</sup> Precipitation contracts are preponderant due to the dominance of the agriculture sector in the work of the authors, but the first wave of major deals in emerging markets will probably be covering power sector operators, in particular hydropower generators. These applications are either weather hedging structures or substitutes for traditional insurance.

*Weather hedging*

Income smoothing through the financial mitigation of weather shocks is relevant for few large sophisticated operators. Most of the deals will be closer to the catastrophe zone of insurance, or the one in seven- or even one in ten-year event range. Extreme events such as the 100-year hurricane are *de facto* covered by emergency and government handouts, so weather risk management in emerging markets comes in for the mezzanine range of risk between hedging and CAT insurance. Another class of applications are operators facing penalties in case of failed deliveries, such as high-value agricultural exporters, eg, broccoli farmers from Mexico face heavy penalties in case of non-delivery to the large supermarket chains in the US.

*Substitute for traditional insurance*

Insurance and reinsurance markets have generally hardened during the last years and in particular after September 11, 2001.<sup>13</sup> Higher premiums and shrinking capacity spur demand for alternative risk transfer, such as CAT bonds, but also WRM instruments. The main application of new WRM would be as an alternative to crop insurance, but also as business interruption insurance, which is almost unavailable for most businesses in emerging markets. The risks are often weather related, as illustrated by the case of Venezuela where the cause of recent business interruption indemnity payments was flooding and soil erosion resulting from the combination of high wind speed and excessive precipitation. Similarly, hurricane exposure of property and casualty risk in the Caribbean could effectively be (re)insured through weather contracts.

**The case of rainfall index insurance in Morocco**

**OVERVIEW**

Efforts to develop insurance programmes related to weather events are not new to Morocco. Drought is (*vox populi*) recognised to be one of the main risks for Moroccan agriculture, if not the single most important cause of crop failure, and the attention of both the public sector and the insurance industry has been long focused on developing appropriate safety nets to protect farmers from its dangerous effects.

In 1995 the Moroccan government, in partnership with the insurance industry, activated the “Programme Sécheresse” (drought plan). Despite the clear reference to drought, the scheme, revised and improved in 1999, is in fact a yield insurance programme, the only connection to the weather event being the ministerial declaration that officially declares the existence of a drought period and allows the insurance company to activate the indemnification procedure.

In order to evaluate the possibility of developing an insurance programme directly related to weather events, in 2001 the World Bank helped the Moroccan government to launch an on-field international research project. The research team,

after an accurate analysis of the productive environment in agriculture as well as rainfall patterns and agricultural yields, concluded that Moroccan agriculture could significantly benefit from a rainfall insurance programme and recommended the adoption of a pilot area-based rainfall insurance scheme (Skees, 2001). The programme recommended by the World Bank study is a rainfall insurance programme for crops (cereals and sunflower in particular) that indemnifies producers if rainfall levels fall below a specified threshold. Rainfall would be measured at the synoptic stations of the National Meteorological Service (Direction de la Météorologie Nationale, DMN), and should be accessible in real time to all parties involved in the transaction.

To help the local insurance industry design the practical details of such a programme and facilitate access to international weather risk management markets, the IFC, assisted by the Italian Government, sponsored a project to help structure the weather contracts and set up a company that would launch and manage such products.

#### **CONTRACT DESIGN**

The structure of the rainfall insurance programme recommended by the World Bank study was developed in analogy to a European put option where the option price is the cost of the coverage and the strike is the rainfall threshold below which an indemnity is triggered.

The idea underlying such types of contracts is that, once the existence of a sufficient degree of correlation between rainfall and yield is established, an agricultural producer can hedge his production risk by entering into a contract under which payments would be made if rainfall levels fall below the selected strike. In order to structure the contract, the issues to evaluate are therefore how to determine the strike and at what level to set it.

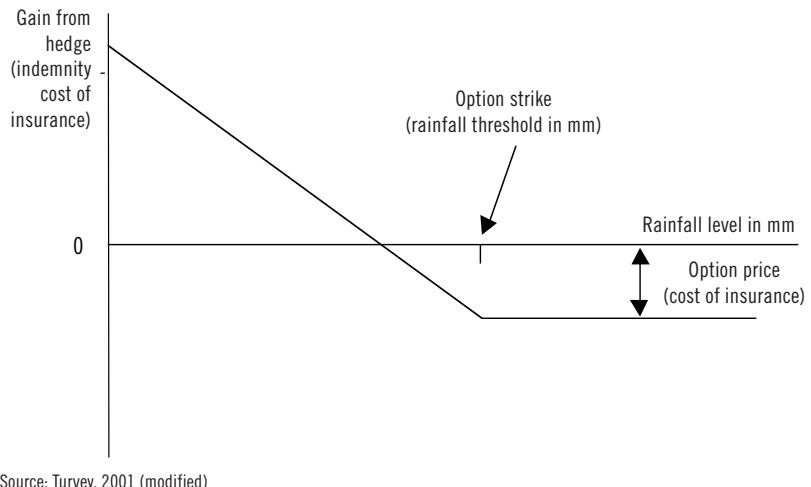
In the case of cereal and sunflower production in Morocco, the adopted procedure for developing rainfall insurance contracts was:

1. production and rainfall data were collected and organised;
2. the most appropriate rainfall period was selected estimating correlations between yields and different rainfall periods;
3. specific rainfall indexes were constructed assigning “weights” to different rainfall periods in order to maximise correlation between yields and rainfall; and
4. different payment schemes were analysed and evaluated.

After having collected and validated the data, the first choice to make in designing the contract is to define the rainfall time period, which should be considered for coverage purposes. Such a choice, of course, is mainly dependent on climate and plant physiology, but marketing issues have their relevance: in order to avoid the possibility of producers making an informed decision on whether to enter into the contract or not, it is clearly not advisable to include rainfall periods that precede contract signing time.

Once the appropriate period has been selected, the issue becomes structuring the rainfall index. In this respect, the general concept is that despite the high level of yield-rainfall correlations measured for crop production in Morocco (close to 0.8 in the case of wheat), it is nevertheless an advantage to incorporate agronomic information in the contract structure that enhances the measurement of the yield-rainfall relationship. In fact, precipitation in different stages contributes in different measures to plant growth and, in addition, an excess of rain may be of no use for production. Hence, it is useful to develop a weighting system that allows to differentiate the importance of rainfall in different growth periods and to shape the model so as to take into account the fact that excess rain may be wasted without contributing to plant growth.

**1. Payoff structure for European put option on rainfall**



In order to structure the index, trends in yield and rainfall series were examined, rainfall for each synoptic station aggregated in 10-day periods and weights assigned through a mathematical programming procedure that maximises correlation between yields and the rainfall index. The vector of weights is then adjusted through an ad hoc procedure that slightly modifies the optimised vector in order to make it consistent with logic and agronomic intuition. This last step may somewhat reduce correlation between the two series, but allows homogenous rainfall periods to be established, that help to make the contract more understandable and more marketable. An example of one the indices developed for wheat in Morocco is given in Table 1:

**Table 1. Structure of rainfall-index insurance for wheat in Morocco**

Month	November			December			January			February			March		
10-day period	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Weight	2.0	2.0	2.0	0.5	1.0	1.0	1.0	0.5	0.5	1.0	1.0	1.5	1.0	0.5	1.0

Source: IFC, Morocco Weather Index Insurance Project

The final value of the index (the value which, when compared with the threshold, indicates if the insured should be granted an indemnity or not) is calculated by summing the values obtained by multiplying rainfall levels in each period by the specific weight assigned to the period.

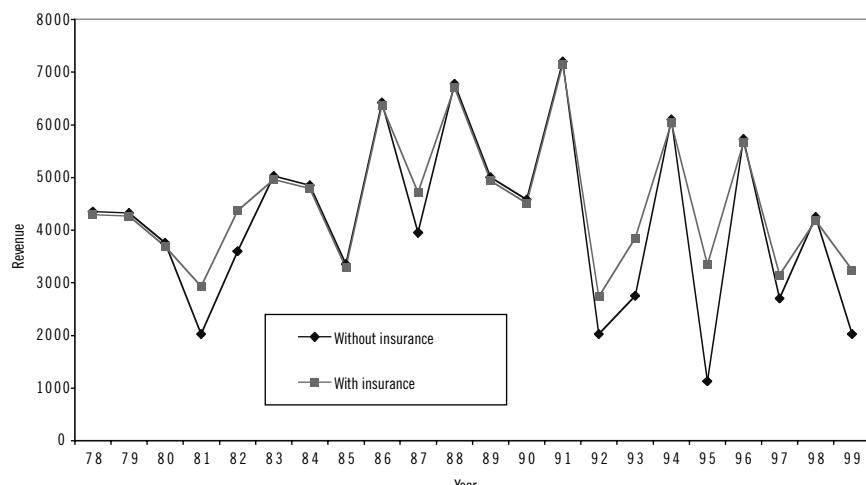
Customers participating in the rainfall-index programme receive a payment if the level of the index falls below a predetermined threshold. The payment is equivalent to the percentage of rainfall-index shortage multiplied by the level of coverage selected.

In applying the programme, the customer should be allowed to select different levels of coverage in order to have the opportunity to insure different levels of potential revenue.

Figure 2 provides a graphical description of the performance of the rainfall index insurance in the case of wheat production for a specific synoptic station of Morocco. The figure represents the different level of wheat revenue with or without rainfall insurance. It should be noted that the insurance programme prevents revenues from falling below a threshold of approximately Dh3,000 (approximately US\$300).

One other useful way to describe the performance of the rainfall index insurance

**2. Wheat revenues with and without rainfall insurance (index threshold 275 mm)**



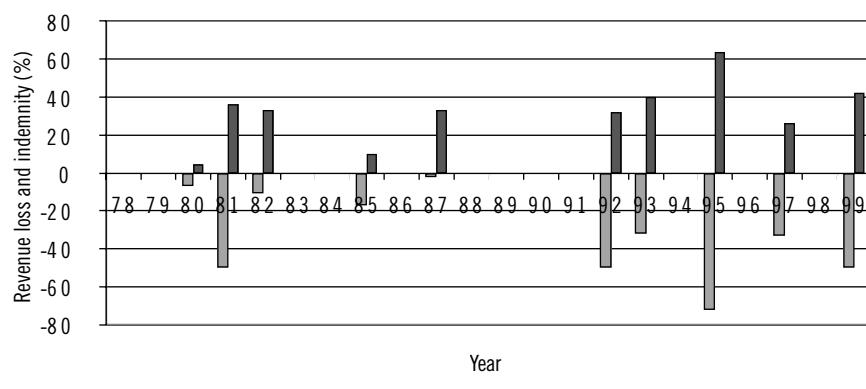
Source: IFC, Morocco Weather Index Insurance Project

is to analyse the dynamics of revenue loss and the payments triggered by the programme in each of the crop years.<sup>17</sup>

Figure 3 shows that the programme triggers a payment in each of the years for which a revenue loss is recorded and also that it does not generate “false positives”, ie, payments in case of no revenue loss. Figure 3 also helps illustrate the issue of the selection of the threshold level. Quite logically, the higher the threshold set for the contract the better the coverage provided, but, by way of a trade-off, a higher threshold results in a higher cost of the insurance coverage. In Figure 3, for example (coverage level 375 mm), indemnities for years 1982 and 1987 are probably too high, wasting resources that are accounted for in the premium of the policy. Figure 4 shows a case for a different threshold level (275 mm) for which the coverage is probably not as good as in the preceding case, but for which the actuarial premium is more than halved.

The proposed proportional rainfall-index payment scheme is obviously only one of the possible solutions for structuring a weather-related crop insurance programme. Several different alternatives, all aiming at making the coverage as extended and as comprehensive as possible, were evaluated by the IFC research team. From the payment structure point of view, non-proportional contracts (ie,

**3. Performance of rainfall-index insurance for wheat in Meknes (threshold 325 mm)**



Source: IFC, Morocco Weather Index Insurance Project

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increases in unit payments as rain shortfall increases) were tested and other weather variables like temperature were added to the structure of the contract. Overall, however, the simplicity of the rainfall index and the comparatively lower cost of the coverage led to the selection of the simple proportional rainfall index as the preferred model for implementation.

An interesting marketing feature of the rainfall insurance programme that should be launched for the 2002–3 crop year is that, following the successful experience of the drought programme, the contacts will be most probably marketed by linking the insurance policies to farmers' credit requests. Agricultural producers need resources for anticipating cultivating costs and part of the loan granted to the farmer can be devoted by the credit institution to financing the insurance coverage. This marketing procedure will certainly help the development of the programme in its infant stage, at the same time granting revenue coverage to the producer and reducing default risk for credit institutions.

**KEY SUCCESS DRIVERS IN MOROCCO**

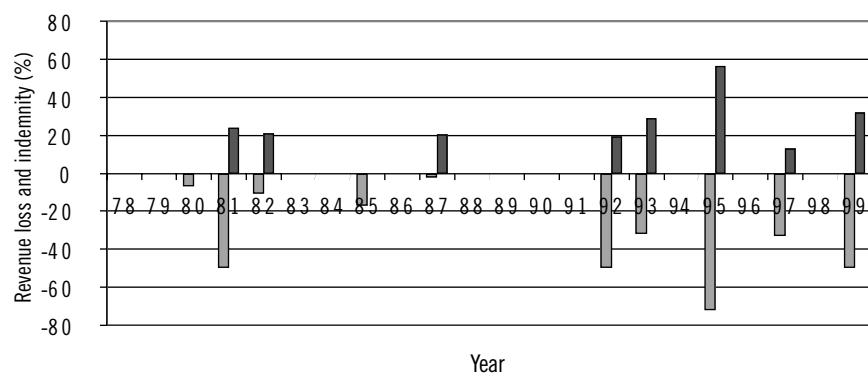
The proposed rainfall-index insurance programme for crop production in Morocco has several interesting features.

As mentioned in the preceding sections, rainfall indices are free of most moral hazard and adverse selection problems.<sup>18</sup> In addition, significant cost savings are achieved by eliminating the need for costly on-field damage assessment activity.

For the programme to be successful, however, certain conditions have to be met. First, of course, rainfall-index insurance should provide adequate coverage of farmers' revenue. The high levels of yield-rainfall correlation – before and after optimisation, see Skees (2001) – seem to satisfy this pre-requisite, but, the programme being an area-based insurance scheme, good levels of yield-rainfall correlation at the area level are not sufficient. Like all area-based insurance programmes, the issue of different risk patterns among producers in the same area (ie, basis risk) is extremely relevant. In particular, if rainfall is not homogeneously distributed in the area, a good level of rainfall recorded at the regional level might not correspond to sufficient rainfall at farm level. In this situation the insurance payment would not be triggered and, despite having purchased an insurance contract, the producer incurs a revenue loss. Consequently, a crucial issue to investigate is the homogeneity of agronomic conditions and of rainfall distribution within a given base area.

In the insurance scheme proposed for Morocco, rainfall will be preliminarily measured at the DMN synoptic stations but the programme designers are evaluating

**4. Performance of rainfall-index insurance for wheat in Meknes (threshold 275 mm)**



Source: IFC, Morocco Weather Index Insurance Project

the opportunity of relying on secondary weather stations to reduce the size of the base areas. Secondary stations are not as reliable as the automatic synoptic ones but, in this respect, the progress in rainfall measurement technology grants low price and high standard measurement devices that could be used for fallback verification purposes.

The ultimate condition for the success of the programme is the price at which the coverage can be provided. This will be decided by the market, but certainly careful programme design, reliable data measurement and access to international risk management players, give the markets opportunities to best express themselves. Weather insurance certainly cannot modify weather conditions, but it can help manage weather risks in a more efficient way.

### **Conclusion**

This chapter has demonstrated the enormous potential for weather risk management in the agri-business sector in developing countries. Theory and first practical examples point to higher entry barriers, but also higher margins for weather risk market makers in these countries. Major barriers include data problems and credit risk concerns. Data quality varies but sophisticated verification mechanisms such as satellites or temperature gauges allow for weather insurance to be offered almost anywhere. A key factor in determining demand for weather risk hedges is credit – farmers do not buy insurance, they are required to collateralise credit with insurance. In current regulatory environments, weather hedges will generally be sold in the form of insurance. End-users will often be intermediaries such as agricultural banks or insurance companies, or input suppliers and agro-processing companies exposed to throughput risk. The weather risk market is able to substitute some of the traditional reinsurance covers and can efficiently offer yield protection to farmers where crop insurance fails due to high expense ratios. The Moroccan example demonstrates how a few modifications to the basic cumulative rainfall contract can minimise basis risk for a particular crop and at the same time provide income protection to farmers.

Ultimately the emergence of a vibrant weather market will be driven by knowledge transfers to local “champions” who grasp the opportunity, as well as the demonstration effects of a few emerging market transactions and the willingness of global weather risk market makers to shoulder some up-front costs in order to reap the benefits of a globally diversified weather market.

**WEATHER RISK  
MANAGEMENT FOR  
AGRICULTURE AND  
AGRI-BUSINESS IN  
DEVELOPING  
COUNTRIES**

**Table A1. Applications by sector and weather parameter**

Weather parameter	Agriculture/agri-business	Livestock	Fisheries/aquaculture
	Crop production		
Precipitation	Sugar (Fiji) Cereals (Mexico, Romania, Morocco, Tunisia, Turkey)	Argentina, Uruguay: Milk production Cattle and sheep (Morocco)	
Precipitation: Monsoon risk	AG and AGB (South Asia)		
Hurricane (wind speed and flooding)	Nicaragua: RI of national emergency fund		Shrimp farm (Honduras)
Temperature – Freeze	Coffee (Brazil)	Meat production (Mongolia, Argentina)	
Temperature – Heat		RI of area-yield index (Argentina)	Shrimp disease risk (Belize)
Precipitation + Temp	Various crops – agricultural products fund (Argentina) Input supplier insurance (Argentina)	Goats: cashmere (Mongolia)	
	RI of AD INS (Argentina)		
	Citrus Business Interruption INS (Caribbean)		
	RI for national emergency fund for farmers (Mexico + Nicaragua)		
Sea Temperatures	Cotton (Peru)		Hake (Namibia)
Niño risk			Sardine (Peru)

Note: These applications are based on proposals and expressions of interest by end-users and intermediaries.

RI  
AG

Reinsurance  
Agriculture INS

AG  
Agriculture INS

AG  
Insurance

**1** The views expressed in this article are those of the authors alone and do not in any way reflect or engage World Bank or IFC policies. The authors would like to thank Luc Christiaensen for helpful comments and Rachid Guessous (MAMDA, Morocco) for valuable inputs.

**2** The World Bank groups countries into low-, middle-, and high-income categories on the basis of their gross national income per capita (gni-pc). In 2000, the cutoff levels for a low-income country were no more than US\$755, for a middle-income country at least US\$756 and no more than US\$9,265, and for a high-income country at least US\$9,266.

**3** Sub-Saharan Africa includes all of Africa except the five nations bordering the Mediterranean.

**4** SYNOP data is recorded at a specified time across the world. Formats are standardised by WMO.

**5** Usually there is no bias in the data, as incentives were not skewed towards over- or understating measurements.

**6** The OECD provides governments a forum in which to discuss and develop economic and social policy. Members are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States.

**7** For example, weather stations in Saudi Arabia have an incentive to underreport temperatures once the measurements reach the vicinity of 50°C, which is the threshold that allows employees to stay home.

**8** The International Rice Research Institute, for example, provides many developing countries with excellent data.

**9** Both Morocco's and Mexico's major agricultural banks tightened their lending policies in 2001-2. Insured or highly collateralised farmers (possibly with movable assets) will receive input credits.

**10** The weather risk market should be able to substitute weather contracts for business interruption insurance on more competitive terms, as they can price weather risk more precisely on standardised and transparent terms. More importantly, the weather market is hungry for diversification out of US temperature contracts and therefore quotes on a portfolio-adjusted basis that drives down premiums.

**11** Like other mining companies, Ashanti Goldfields (AGF) had hedged against falls in the gold price by contracting forward sales (or options) that locked-in the current price. In a falling market this strategy would protect revenue and profits, but in a rising market the hedge book became a liability. AGF's hedge book was unusually large, representing about 10 million ounces of gold. The counterparties in these derivatives transactions were 17 banks that were entitled to call in margin deposits once the negative value of the hedge book – or its 'replacement cost' at the current market price – exceeded US\$300 million.

Following the gold price hike, the replacement cost of AGF's hedge book reached about US\$570 million at a gold price of US\$325 per ounce, requiring deposits of up to US\$270 million which the company was unable to find. AGF later reached an agreement with its counterparties.

**12** As an example, Table A1 lists a number of proposals and expressions of interest by end-users and intermediary related to IFC and World Bank work in various countries.

**13** After steady erosion throughout most of the 1990s, reinsurance rates had increased in almost all sectors at 2000 year-end renewals. Since January 1, 2001, the pace of reinsurance rate increases has accelerated.

**14** Revenue is calculated setting a fixed price of milling wheat at Db250 per ton for the entire period.

**15** For an interesting discussion of moral hazard and adverse selection in weather insurance see Turvey (2001)

**16** Preliminary market assessments for the 17 largest emerging market countries, based on weather exposure estimates and likely insurance penetration rates of 1–2%, lead to overall premium volume of around US\$1.3 billion over the next five years.

**17** Revenue is calculated setting a fixed price of milling wheat at Dh250 per ton for the entire period.

**18** For an interesting discussion of moral hazard and adverse selection in weather insurance see Turvey (2001)

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