Design and Use of Weather Derivatives in Agricultural Policies: the Case of Rainfall Index Insurance in Morocco

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A. Stoppa and U. Hess[1]

Introduction

In the last decades, agricultural policies of certain countries focused on adopting and strengthening crop insurance programs. Traditional agricultural insurance schemes are known to be plagued by problems of asymmetric information and systemic risk (Quiggin 1994, Miranda and Glauber 1997) and, consequently, in order to be operated, need substantial government support. In supporting such programs, the intention of policy makers is usually to provide more “market-oriented” policy instruments – reducing producers’ incentives to rely on free disaster aid – and, compared to disaster relief intervention, to attain a more efficient and equitable use of resources (Skees 2001a). Given such policy orientation, a significant number of innovative and sophisticated insurance programs were tested and developed. The most advanced experiences are the ones of Canada and of the United States, where producers can choose between a vast array of policies, including farm level multiperil, revenue and income products and area-based multiperil and revenue schemes. This vigorous development of supported insurance markets raised a number of questions regarding the actual impact of such programs on production and trade, leading some researchers to question the actual progress in efficiency, and to suggest the need to reconsider the scope and use of such programs (Skees 2001a, Makki, 2002).

In this line of thinking, recent innovations in energy markets suggest the possibility of addressing agricultural risk factors by issuing derivatives on weather elements. Such instruments appear particularly attractive as they are not affected by asymmetric information and loss adjustment issues. From an agricultural policy perspective, the possibility of adopting programs of the kind could represent significant progress in terms of cost savings and market transparency. These schemes could be used in production risk management but also in reinsurance transactions, as they are by nature particularly effective in addressing the “systemic” portions of weather risks. In the latter case, there is significant scope for governments to implement more cost effective disaster aid programs. Such intervention, appropriately designed could qualify as "green box" measures and be exempted from WTO's Aggregate Measurement of Support reduction commitments.[2]

The following sections describe the origin and use of financial weather contracts, some current and prospective experiences of agricultural weather risk management and, through a detailed analysis of the design of a farm level product, highlight the necessary conditions for a successful application of such instruments in the agricultural context.

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[2] See articles 7 and 8 of Annex 2 of the Uruguay Round Agreement on Agriculture.

Financial Contracts on Weather Variables

Definition

A financial weather contract can be defined as a "weather contingent contract whose payoff will be in an amount of cash determined by future weather events. The settlement value of these weather events is determined from a weather index, expressed as values of a weather variable measured at a stated location" (Dischel and Barrieu 2002).

A financial weather contract can take the form of a weather derivative (WD) or of a weather insurance (WI) contract. While the differences between the two types of contracts might be important from regulatory and legal viewpoints, from an economic perspective both instruments share the common feature of being triggered by an underlying weather index. In discussing agricultural policy and risk management tools, this is probably the most relevant aspect. From now on we will therefore refer to WDs, highlighting the differences between the two types of instruments only when necessary. More relevant to the current discussion is the difference between a weather financial contract and a traditional insurance contract on a weather variable (e.g., hail insurance). In traditional insurance contracts, indemnities are paid only after actual damages are quantified by proper loss adjustments, and not simply upon the occurrence of the specific state of nature. This is an important difference that, according to the specific circumstances, can make one of the instruments more attractive than the other.

The Weather Market

Origins and Types of Trades. Weather contracts can be used to hedge businesses exposition to weather variables. If the activity of a firm is influenced by temperature, snowfall or sunshine, a derivative on the appropriate weather variable could be used to reduce revenue fluctuation.

For example, the owner of a golf course might want to reduce revenue fluctuations caused by rainy days, or the management of a snow resort may want to hedge against the consequences of low snowfall, or a wine producer might find it useful to protect farm income against frost in grapes' flowering season.

Weather has always been a source of risk for many economic activities, but it was not until the late '90s that firms explored the possibility of hedging against weather-related variability through WDs. The impetus for developing weather markets was given by the deregulation of the US energy sector, when local monopolies had to start competing on broader markets and find measures to stabilize fluctuating revenues. Ordinary insurance and reinsurance tools were traditionally designed to target catastrophic events, and were probably too expensive and not sufficiently flexible for ordinary risk management practices that focus on fluctuations closer to the mean of the distribution (Element Re). Faced with these challenges, energy traders started thinking of financial solutions for trading their exposure to weather risks within their own industry. The first move in this direction was the development of objective and reliable indices that could capture weather fluctuations in ways appropriate for hedging their economic exposure.

One of the first indexes developed, and still the most popular one, is the Heating Degree Day (HDD) index. The idea of structuring a HDD index came about in order to correlate revenue fluctuations and temperature. Analysis of the relationships between temperature and demand for heating in the US showed that the threshold of 65° F was the turning point for increase in energy demand for heating. Based on such a threshold, the number of heating degrees per day is given by

$$\text{HDD} = \max\,[0;\ 65^\circ - T], \qquad (1)$$

where T is the average of the high and low temperatures of the day. For example, if T is 45° F, the number of HDD is 20. In other words, the colder the temperature of the day, the higher the number of HDD. Just as for any other financial index, once the proposed index is recognized as having the necessary specifications, a variety of derivatives can be issued on it. WDs can be binary if the payment is in one lump sum, depending on the occurrence of one specific state of nature (e.g., if on a specific day there is sunshine or not), or continuous if the payment follows a specific progression for all values of a predefined range (e.g., a specified amount for every mm of rain). The most common types of contracts are swaps, call options (weather caps), put options (weather floors) and, among derivatives' combinations, collars.

Size and Operators. The weather risk market is in continuous evolution, but three factors have shaped this market more than others: the ENRON effect, the critical mass factor and the entry of banks. From 1997 to March 2002 the total notional value of all transactions written reached US$11.8 billion (WRMA 2002). For a nascent market this is an impressive size, although the number is slightly flawed by the initial phenomenon of inflated notional values which largely exceeded real values at risk of transactions. The other limitation of the market was its concentration in the US energy industry where it started following the power industry liberalization. The driving force of the early years was the ENRON weather desk whose key members came mostly from Koch Industries. ENRON online, in particular, with its automatic and binding online transaction execution capabilities, was instrumental in starting a weather trading market and creating liquidity. At certain times more than 40% of the outstanding notional value was held by ENRON. The ENRON demise, totally unrelated to its profitable weather desk, did not at all dampen liquidity in the market. Existing and new market participants picked up the ENRON deals – the market had reached a critical mass where even the exit of a dominant player does not matter. Recently, large banks with better credit ratings than the US energy traders entered the market and helped to expand the market out of the US and the power industry. Société Générale, an early entrant in the market and recently Crédit Lyonnais, ABN AMRO and Deutsche Bank generated more and more end-user deals rather than concentrating on trading. The reinsurer Swiss RE reentered and ACE, AXA and XL entered the market along with smaller insurers. Exchanges such as CME have offered contracts for a long time, LIFFE and the Frankfurt Börse expect to launch their contracts soon. Following the readjustment of the weather market structure, according to the Weather Risk Managent Association 2001 Survey, the new market share were of 37% for energy operators, 37% for insurers/reinsurers, 21% for banks and 5% for commodity traders (Element Re). US deals are still predominantly energy driven, European deals cover all weather exposed sectors.[3] The World Bank Group discovered the potential of the weather risk markets to absorb weather risk from emerging markets and invest in know-how and companies. First emerging market transactions were published in South Africa and Mexico.

Weather Derivatives in Agriculture

Scope of WDs in Agriculture. When a weather event is a source of economic risk for agriculture, a WD can become an hedging tool for agricultural producers and for risk underwriters.

In order to develop WDs for agriculture, just as for any other WD, the weather variable must be measurable, historical records must be adequate and available, and all parties involved in the transaction must consider such measures objective and reliable.

In addition, more so than with other WDs, the existence of a complex relationship between the product and the weather factor must be carefully explored.[4] For many WDs traded in the energy sector, e.g. derivatives on HDD, the relationship between temperature and demand for heating is simple and direct: the lower the HDD the lower the demand for energy. For agricultural production the relationship is not always as straightforward since differences in products, crop growth phases, soil textures etc. have different responses to the same weather factor. Also, the more skilled and advanced the cultivating techniques, the greater the entrepreneurial influence on yields, the smaller the portion of variability generated by the specific weather elements.

Generally speaking, the development of WDs in agriculture does not seem to be limited by availability of adequate weather statistics, as many developed and developing countries have extensive and reliable weather data records. What may prove problematic is access to the data, both in terms of bureaucratic procedures and cost of purchase. Clearly, the easier the access and the less expensive weather data, the more the opportunities for developing WDs.

The crucial issue for the application of WDs at the agricultural production level lies in the actual presence of a clear and satisfying relationship between the weather factor and the production variable. In order to be successful, the WD must be able to explain a very high portion of the variability in production, loosing otherwise its attractiveness as a hedging device. Hence, appropriate identification of the relationship between production and the weather variable is very important. This particular aspect will be discussed more extensively in the next section. It must be

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[3] The increase in reinsurers' market shares is relevant for agricultural risk management purposes as WDs based reinsurance agreements seems to be one of the most promising areas of application.

[4] See Vedenov and Barnett for a related discussion on a sample of Us crop districts.

said that this constraint is not as binding for the use of WDs at the reinsurance level, since WDs can be used to retrocede the specific layers of the overall aggregate risk exposure that are triggered by the weather event. In addition, the smoothing effects generated in a portfolio of agricultural risk underwriters makes often easier to diversify the impact of a weather variable.

WDs, Crop Insurance and Commodity Price Derivatives. From a policy perspective, it is interesting to discuss the differences between WDs and crop insurance. As already mentioned, one important difference is that a WD is triggered by a specific state of nature and it will generate payments regardless of the actual damage occurred. Conversely, insurance policies address the sources of risk stemming from one (single peril policies) or more variables (multiperil policies) and pay only according to the assessed damages that such variables are supposed to have generated. In this respect, it is important to highlight the advantage that WDs have over traditional crop insurance. Given the absence of the reference to the level of production, and being linked for pricing purposes only to the weather parameter, WDs eliminate problems of moral hazard and adverse selection.[5] Another important advantage of WDs is that, relative to traditional insurance products, the elimination of loss adjustment procedures reduces the cost of administering a WD.

On the other hand, the reference to a weather index, generally measured at a regional level, leads to the possible existence of "basis risk". Basis risk arises when the production pattern of the individual operation is not perfectly correlated with the aggregated pattern of the area for which the derivative has been designed. Expressing this concept in WDs' terms, it is possible that the weather variable underlying the WD has different behavior and effects for a producer located in a site different from the place where the variable is measured. For the case of a rainfall index, for example, basis risk may increase with the distance from the weather station or with the onset of different geographic conditions that generate a different microclimate in part of the area covered by the WD.[6] Of course, basis risk can be negligible for WDs designed for specific producers (e.g., temperatures measures taken on the specific vineyard insured against frost) and, again, at a reinsurance level, when WDs are used for retroceding weather risks underwritten at the production level, basis risk becomes less of a problem as the index is generally tailored on the parameters of the area.

WDs also have important differences with respect to traditional commoditiy price derivatives. The fundamental difference is that the underlying of a WD is not a traded good. Without trades on the underlying asset there is clearly no possibility of developing weather futures contracts. For all other derivatives, options in particular, the traditional Black–Scholes algorithms seem not to be an appropriate solution for pricing the products (Dischel 1998, Martin et al).[7] Pricing of WDs is therefore usually

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[5] See Turvey (2001) for a more detailed discussion.

[6] Based on the contribution of Benninga et al. (1984), Mahul and Dermersch (2000) propose an interesting formalization of basis risk where, under the assumption of "regressability", the total individual risk can be decomposed into a component that is perfectly correlated with the area yield index, the "systemic" portion of risk, and a component that is not correlated with the area index, or the "basis risk".

[7] Black–Scholes based procedures rely on specific assumptions on the possibility of purchasing the underlying (Hull 1997).

based on actuarial calculations. The absence of a universal pricing method generates lack of market transparency and increases transaction costs.

Examples of Current and Prospective Applications of WDs in Agriculture. One of the first experiences of WDs for agricultural operators has been the Ontario forage program developed by Agricorp, the State agricultural insurance corporation. The Agricorp forage plan protects farmers against forage crop losses with rainfall insurance settled on local weather stations. The scheme enjoyed great success with farmers and increasing participation rates. Rates are subsidized at around 50%. The scheme matured from a pilot program to a normal insurance product in 2003/2004.

In Alberta, Canada, the Agricultural Financial Service Corporation (AFSC) developed a Satellite Imagery Insurance based on data from satellites that use specific wavelengths of light to estimate growth conditions on native pasture. It compensates producers when the average accumulated Pasture Vegetation Index (PVI) in a township falls below a threshold value of 90% of the township normal PVI value from previous years. The program has been running for several years. AFSC also developed lack-of-moisture insurance where Spring Soil Moisture is used to estimate moisture conditions at the beginning of the growing season for pasture and silage producers. Rainfall information is also collected for the months of May, June and July to determine the final insurance payments.

Mexico has experience with using weather indexes to reinsure their crop insurance. In 2001, the Mexican agricultural insurance program (Agroasemex) used the weather markets to reinsure part of their multiple crop insurance programs. By using weather indexes that were based on temperature and rainfall in the major production regions, a weather index was created that was highly correlated with the Mexican crop insurance loss experience. This method of reinsurance proved to be more efficient than traditional reinsurance.

Prospective risk management programs are under evaluation in India for monsoon indexed crop loans and in Mongolia for winter disasters index insurance for livestock mortality.

Help from Progress in Technology. Progress in technology and communications will significantly influence the development of the weather market. The quality of satellite imagery has made so much progress that, as mentioned above, some agricultural insurance deals already make use of vegetative indexes as insurance triggers. Weather station technology combined with better telecommunications allows continuous transmission of weather data through mobile phone technology at a reasonable price. Soil humidity measurements, an important factor in plant growth, can be taken at low cost and again be transmitted to the trader's screen. Minuscule temperature gages can be placed in farmers' fields and can transmit data at regular intervals. All these examples show that the weather market industry greatly benefits from specific progress in various hi tech applications. However, it must be also noted that the progressive improvement of weather forecasting ability could lead to potential sources of asymmetric information.

A Case Study on a Rainfall Index Derivative in Agriculture

The General Framework

A Rainfall Index Derivative. The case study discussed in this section is a rainfall index derivative for protecting Moroccan cereal producers from the economic impact of drought. The case analyzed is particularly interesting for the discussion on the use of WDs in agricultural policies since it is a representative example from various points of view. First, it shows how significant improvements in the farm level coverage of the derivative can be obtained through accurate design. Secondly, it shows how weather derivatives can be used to retrocede the exposure to weather risk. Finally, it provides insights on the role of public support in such programs.[8]

Agriculture and Rainfall in Morocco. Without indulging in metaphors, it is possible to say that rainfall is of vital importance for Moroccan agriculture, and that its consequences for agriculture easily spillover to the entire economy. In fact, the share of agriculture on the GDP of Morocco can easily oscillate between 10% and 20% according to the level of precipitation in the crop year. Consequently, the quest for means for protecting farmers income from the effects of drought has always been on the agenda of the Moroccan government. In recent times the specific focus has been placed on cereal crops (wheat in particular) that account for approximately 70% of cultivated land.[9] Accordingly, the Moroccan government activated in 1995 the *Programme Secheresse* (Drought Program), a state sponsored insurance program that addressed the drought problem through the implementation of a yield insurance scheme. The program, revised in 1999, is structured on the coverage of three revenue levels of 1,000, 2,000 and 3,000 Moroccan Dirhams (MAD) per ha. Payments are triggered by a Ministerial declaration certifying the occurrence of drought. For the first revenue threshold the payout is based on an area-yield base mechanism, while for the 2,000 and the 3,000 MAD/ha level, specific farm yield assessment are required.

The program proved to be very popular (in 2002 subscription reached 80% of the 300.000 authorized hectares) but also affected by typical yield-insurance problems such as high costs for supporting insurance premia and severe management problems related to individual farm yield assessment (Skees et al. 2001).

Given the limitations of the Drought Program, the Moroccan Government agreed to participate in a World Bank research project aimed at exploring the feasibility of weather based insurance as an alternative to traditional yield insurance. The investigations lead the team project to conclude that "[a] drought insurance program based on rainfall contracts could have potentially significant benefits over the current scheme, minimizing moral hazard and adverse selection risk and promoting a more rapid, streamlined pay-out process, in addition to increasing the

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[8] On a broader policy level, it can be argued that the objectives of policy makers dealing with risk management programs should be to support means to address income variability, rather than dealing separately with risks of the single agricultural activities. While both the discussions on the objectives of farm policies and on whether to address global or single sources of risk is beyond the scope of this paper, it can be noted that, in the case of the rainfall index derivative for wheat yield risk, the government of Morocco is expressly focusing on farm revenue, since the prevalent production environment is represented by small, single-product wheat farms, and price variability is offset by government price regulating rules.

[9] Only 14% of cultivated land is irrigated.

potential interest of international re-insurers and capital markets in investing in the program. Based on analysis of rainfall and cereal yield data across the country, this study has determined that a rainfall index-based insurance product could be feasible in Morocco." (Skees et al. 2001)

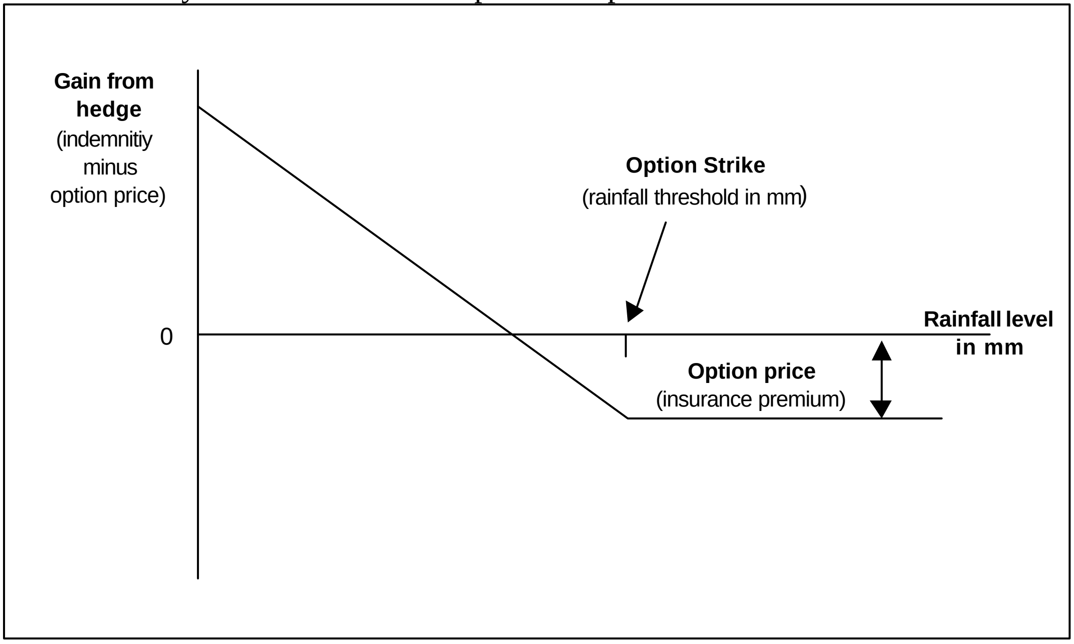
Contract Design

***The Concept*.** The structure of the WD proposed in the World Bank feasibility study is that of a European put option, where the option price is the cost of the derivative for the wheat grower (i.e., the cost of purchasing rainfall insurance) and the strike is the rainfall threshold below which an indemnity is triggered (Figure 1).

According to such indications, a pilot rainfall derivative scheme was developed for the region of Meknes, a representative wheat growing area in the North of Morocco.

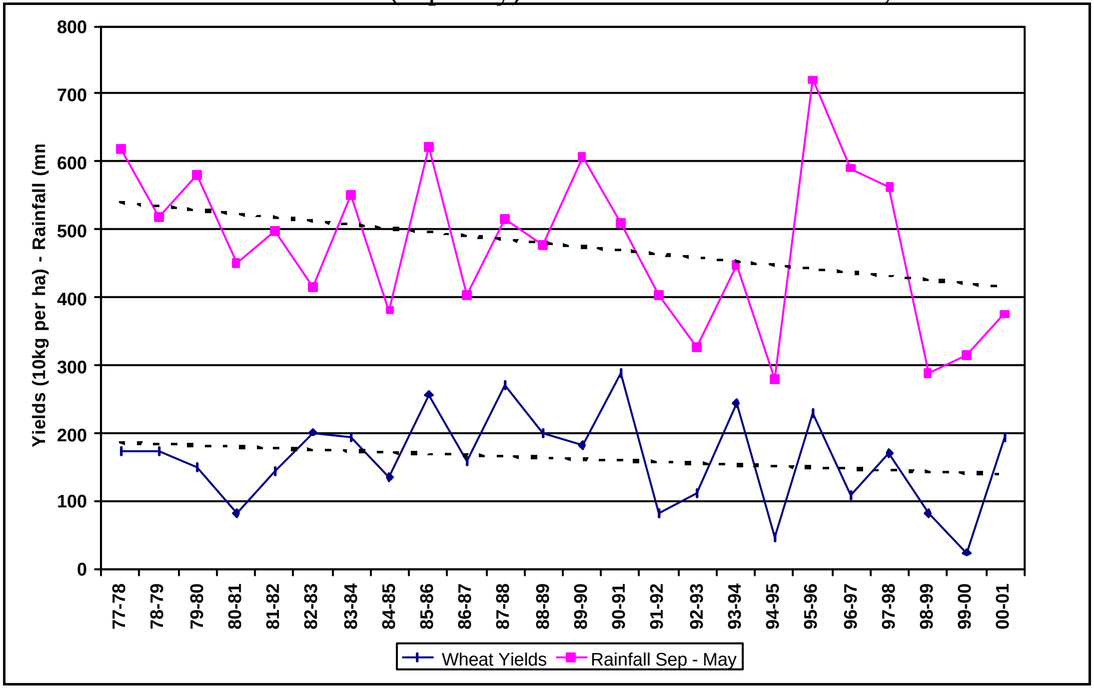
Rainfall data used to design the product was collected at the Meknes synoptic station by the national meteorological service of Morocco (*Direction de la Météorologie Nationale* – DMN) that applied its standard procedures for adjusting and validating it. Yield data was collected and provided by the Economic Service (*Direction de la Programmation et des Affaires Economique* – DPAE) of the Ministry of Agriculture. Rainfall and yield data is represented in Figure 2.

FIGURE 1: Payoff Structure for a European Put Option on Rainfall



Source: Turvey 2001 (modified)

FIGURE 2: Cumulated Rainfall (Sep-May) and Wheat Yields in Meknes, Morocco



Source: Rainfall DMN, Yields DPAE

The Crop Cycle. As mentioned above, in designing a WD for hedging weather risks at the production level, particular attention must be placed in capturing the relationship between the weather factor and the specific product. In particular, for the rainfall instrument it is important to understand the relationship between rainfall and wheat yield.

In the selected region, the crop season for wheat goes from November to June. From 60% to 80% of sowing takes place between the 10th and the 20th of November, while harvest is generally carried out between the end of May and the end of June (Handoufe and Barakat 2002). Tilling practices significantly influence water availability for crops and, therefore, in order to increase storage capacity, soil is ploughed right after harvest. Excluding harvest time, water is always beneficial for crop growth. However, some of the growing phases are critical with respect to water needs: 1) between emergence and the beginning of the tillering, when the root system is still superficial and fragile; 2) between stem elongation and flowering, when the basic elements of production are determined: the number of ear/m^2 and the number of grain/ear. Table 1 shows the reference dates of the main growth stages in the region.

TABLE 1: Growth Cycle of Wheat in the Region of Meknes, Morocco

Growth phases	Reference dates	Cycle in days
Sowing	15 November	0
Emergence	22 November	7
Beginnig of tillering	15 December	30
Beginning of stem elongation	15 January	60
Head emergence	15 January	80 to 90
Flowering	1 March	90 to 105
Beginning of maturity	15 March - 10 April	105 to 135
Harvest	End of May – End of June	135 to 195

Constructing the Rainfall Index. In trying to address yield variability through a rainfall WD the working hypothesis is that rainfall is the main determinant of wheat yield in Morocco and that drought is the quasi-exclusive source of risk. In this framework, the objective of the design phase is to capture the rainfall-yield relationship in the most accurate way possible. Taking into account that different growth stages have different water needs, it is possible to assume that simple cumulative rainfall might not completely frame the relationship between growth and rainfall. In fact, over the time period 1978 - 2001, correlation between yield and cumulative rainfall for the growth season (November-May) reached 67%, a value that suggests a positive relationship, but that is not sufficient to explain most of yield variability. A significant improvement in tracking the rainfall-yield relationship can be achieved by assigning specific weights to the different growth phases.

The process of identifying the importance of rainfall in each growth stage was carried out maximizing rainfall-yield correlation with respect to the index weights. In order to find an appropriate and empirically significant number of weights, rainfall was aggregated in ten-day periods, an interval recognized to be consistent with water storage and plant use dynamics (Handoufe and Barakat). In order to further improve the quality of the rainfall index, a "capping" procedure was introduced taking into account the fact that water in excess of storage capacity is lost and does not contribute to plant growth. Hydrologists estimated that, for the regions' average conditions, soil maximum retention capacity is 60mm.

The optimization problem adopted in order to select index weights can be described as follows. Effective rainfall in period i is defined as

$$r_i \equiv \max \left\lfloor r_i^*, CAP_i \right\rfloor \tag{2}$$

where r_i* is actual rainfall in period i, and $\underline{CAP_i}$ is amount of rainfall in period i beyond which additional rainfall does not contribute to increased yield (60 mm).

The rainfall index for year t is defined as a weighted average effective rainfall:

$$R_t = \sum_{i=1}^{m} w_i r_{it} \tag{3}$$

where m is the total number of 10-day periods in the growing season, $\grave{u}_i$ is the weight assigned to period i of the growing season, and r_{it} is the effective rainfall in period i of year t. The weights, $\grave{u}_i$, are chosen to maximize the sample correlation between the rainfall index and yield using data on rainfall and yield from 1977-78 to 2000-01.

Letting Y_t denote yield in year t, and a bar ( ) denote sample mean, the weights are chosen by solving the following optimization problem:

$$\max_{w_i} corr(R,Y) = \frac{\sum_{t=1977}^{2000}\left(R_t - \overline{R}\right)\left(Y_t - \overline{Y}\right)}{\left[\sum_{t-1977}^{2000}\left(R_t - \overline{R}\right)^2\right]^{1/2}\left[\sum_{t-1977}^{2000}\left(Y_t - \overline{Y}\right)^2\right]^{1/2}} \tag{4}$$

$$\text{subject to } 0 \leq w_i, \forall\, i.$$

Having found appropriate growth phase weights and having limited precipitation measures only to water that can be stored and used, the rainfall index correlation raises to 95%, confirming the hypothesis that water availability can explain most of yield variability and thus being the quasi-exclusive source of risk for wheat cultivation in the selected region of Morocco.

It must be specified that the optimization process was not adopted in search of the pure optimal solution, but rather to point the analyst towards the indicative importance of rainfall for the different growth phases. In fact, the weights obtained through the statistical procedure were adjusted after specific discussions with agronomists and farmers' representatives. This allowed the index structure to be consistent with agronomic intuition, to be more understandable for the end users and therefore more marketable.[10] After rounding and adjusting the optimized weights, the sample correlation between the rainfall index and yield was 92%. The final values of the rainfall index are reported in Table 2.

TABLE 2: Structure of the Rainfall Index for Wheat

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	3.0	1.0	1.5	1.0	0.5	1.5	0.5	0.5	0.5	0.5	2.0	3.0	2.0	1.0	0.5

Payout Procedure.[11] The rainfall index derivative for wheat in Morocco is structured to pay out when indexed rainfall (Rt) in the crop year is below a specified threshold (T). The payment is proportional.[12] The value of Rt is calculated by summing the values obtained multiplying rainfall in each period i of year t by the specific weight assigned to every period i (Equation 3).

The indemnity is triggered according to the following function:

$$indemnity = \begin{bmatrix} 0 \quad if \;\; R_t \geq T \\ \dfrac{T - R_t}{T} \quad if \quad R_t < T \end{bmatrix} \times \;\; liability\,. \tag{5}$$

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[10] In particular, it was considered that rounding the weights to integers or half of integers would have resulted more understandable for producers.

[11] See Martin et al. for a discussion on different indemnity functions for WDs.

[12] Non proportional payment structures were also tested in order to assign more value to catastrophic outcomes (MAMDA 2003).

Performance of the Weighted Rainfall Index. Useful indications on the actual capacity of the rainfall derivative as a hedging tool for wheat growers are given by the analysis of the historical performance on farmers' revenues coverage.[13]

The first interesting indication is given by comparing the weighted rainfall index with a simple cumulative rainfall contract. The cumulative index would be represented by the simple sum of rainfall, without attributing any specific importance to water contribution in different growth phases. Figure 3 illustrates the performance of the cumulative rainfall index contract and Figure 4 the performance of the weighted rainfall index contract. For comparison purposes, both contracts are structured in order to have an actuarial premium of 10% of liability. By comparing the two figures it is possible to note that the performance of the weighted index in tracking revenue variability is significantly higher. The weighted index misses a payment in a revenue loss year only in 1980, while the cumulative index would have not delivered indemnities in four occasions (1980, 1982, 1987 and 1997). In addition, the cumulative contract would have paid producers in 1989 and 2001, when no loss was registered, while the weighted contract makes unnecessary payments only in 2001. Ideally, the size of the indemnity should correspond to the size of the revenue loss. The weighted index seems to perform better in this respect as well. Out of the eleven indemnities triggered by the weighted index, the cumulative index has closer values to the loss only in three instances, with significant differences in 1985, and only slight differences in 1992 and 1993. On the basis of the analysis it is therefore possible to conclude that the weighting procedure adds significant value to the ability of the rainfall index to track yield/revenue fluctuations.

One last and very important issue to discuss is the cost of the rainfall contract for producers. All things been equal, one of the main determinants of the contract price is the rainfall threshold. In Figure 4 the actuarial premium of 10% of liability was determined by a rainfall threshold of 329 mm. It is easy to understand that the lower the threshold selected the lower the cost of the contract. However, it is also clear that reducing the cost of contract the overall quality of coverage is reduced. Figure 5 gives an example of a contract with lower premium (5%) and lower threshold (227).

It must not be forgotten that the actuarial price of the derivative is only part of the final cost of the product. Administration and reinsurance fees must be added. Given the great fluctuations in rain and the apparent downward trend of rainfall in the selected region (Figure 2), reinsurance cost can significantly increase the price of the coverage and result in a potential limit to the diffusion of the product. It must also be said that the cost of reinsurance is influenced by factors such expectations on rainfall trends, and also by business elements such as reliability of institutions that back the deals and the negotiating ability of the contract retailer.

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[13] As already mentioned, price of wheat in Morocco is fixed by the government. Hence, for the case in object, yield variability coincides with revenue variability.

FIGURE 3: Cumulative Rainfall Index (Pure Premium 10%, Threshold 227mm).

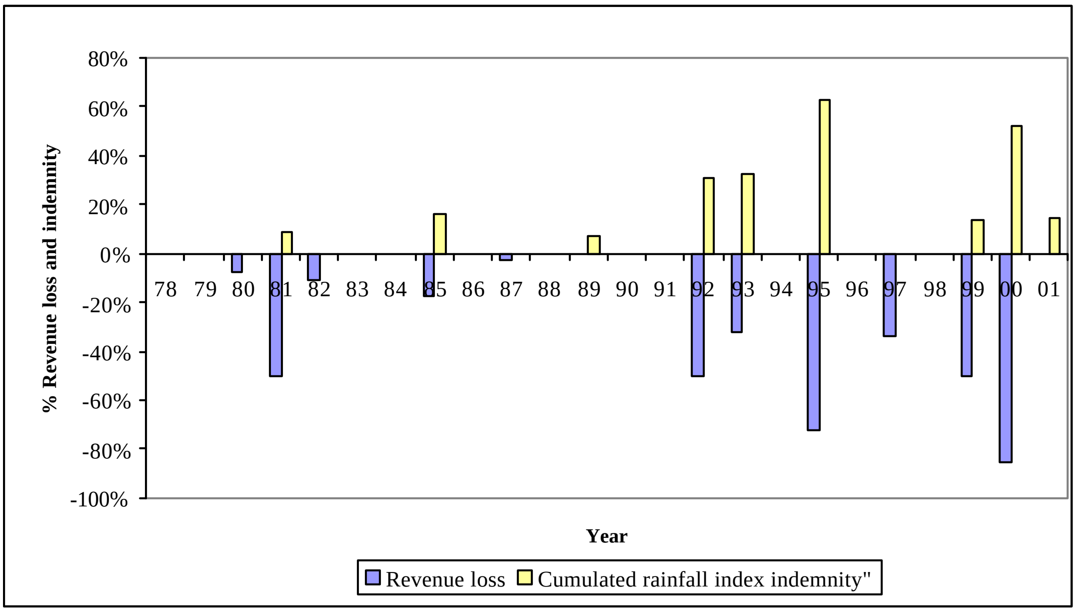


FIGURE 4: Weighted Rainfall Index (Pure Premium 10%, Threshold 329mm).

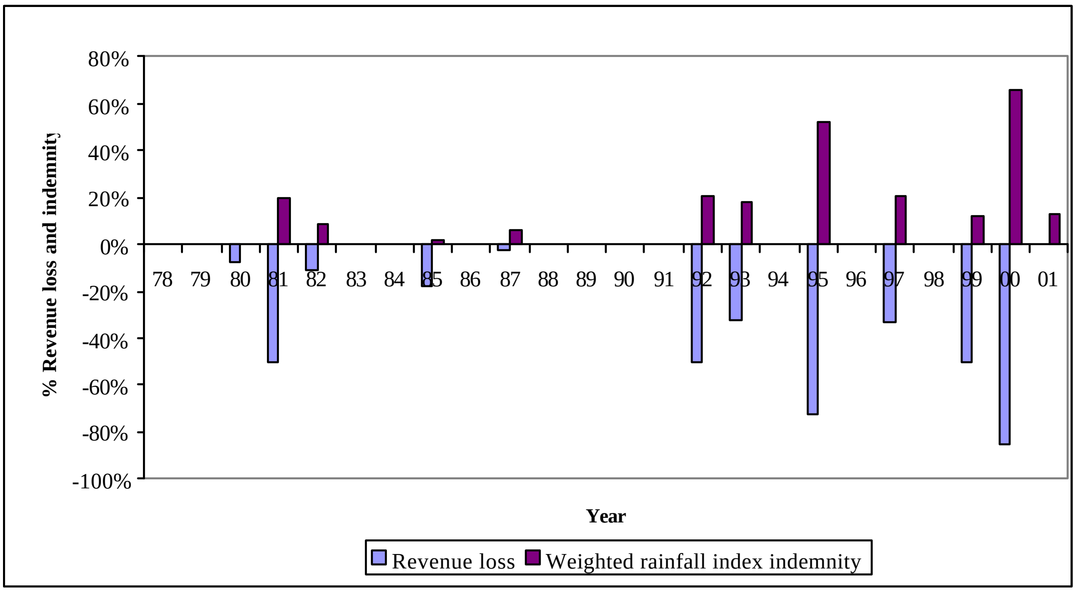
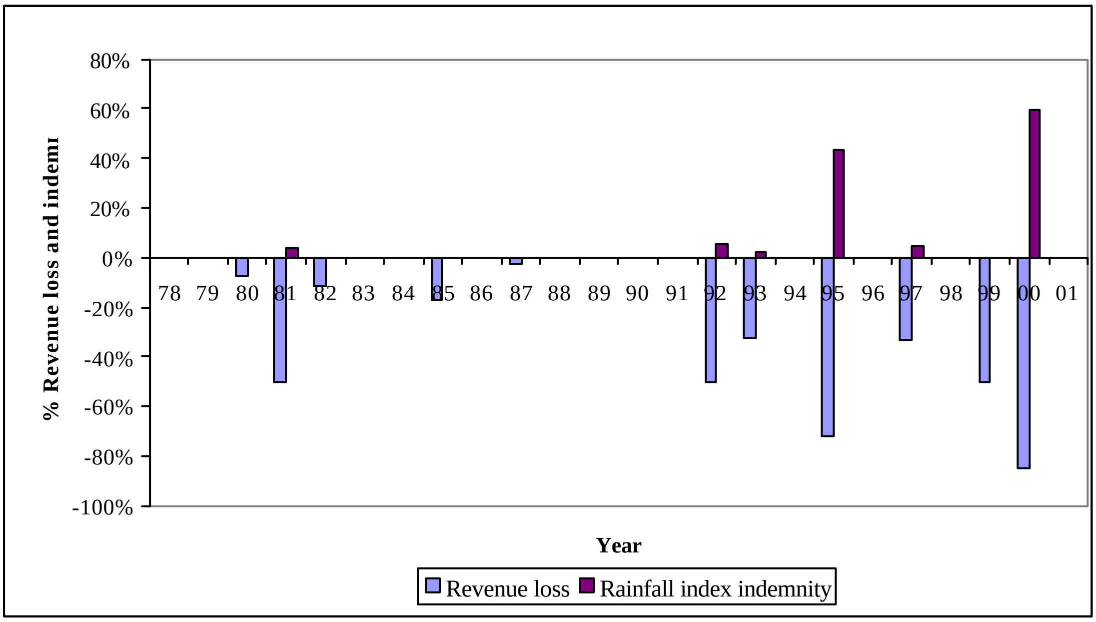


FIGURE 5: Weighted Rainfall Index (Pure Premium 5%, Threshold 276mm).



The Business Structure of the Moroccan Rainfall Index Insurance

The Insurer MAMDA. In order to conform to Moroccan regulation, the rainfall index derivative will be sold in the legal form of an insurance contract through the branches of the agricultural mutual insurance company MAMDA (*Mutuelle Agricole Marocaine D'Assurance*).[14] MAMDA is owned by the insured parties, its members, and effectively run by farmers representatives. The State has an important role in the oversight of its management. MAMDA is the only insurer with a significant presence in rural areas and a sizable rural and agricultural portfolio of mainly hail and fire insurance. MAMDA also manages the state sponsored Drought Program, which is partly based on an area-yield index and therefore has some experience with index products.

Alternatively MAMDA and the rural credit institution CNCA (*Caisse National Credit Agricole*) also consider to build the weather index insurance into farmers crop loans, whereby MAMDA would sell only one large Meknes insurance policy to CNCA. With this coverage in place CNCA would then index interest and principal payments to rainfall in Meknes.

Reinsurance Structure. A rainfall risk portfolio in Morocco cannot be offset or even diversified inside Morocco. Part of the risk needs to be reinsured in international weather markets. MAMDA will enter into a traditional quota share and excess of loss treaty which pays MAMDA on the basis of specific weather indices observed in Morocco. Reinsurers usually require an objective, reliable and transparent index measurement operated by the national weather service. In the case of Meknes

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[14] MAMDA is a traditional insurer and cannot enter into a derivative contract.

the weather station is placed inside a secured military airport and its measurements very reliable, also because weather parameters are vital for air traffic as well.

MAMDA will retain only a small portion of the risk and reinsure the major portion. The tail risk, or disaster risk might be taken by a government fund. Government of Morocco prefers to facilitate the writing of this type of insurance through disaster risk off-taking rather than premium subsidies, because premium subsidies may prove to be more distorting and subject to abuse or even fraud risk. Weather risk takers effectively charge proportionately more and become less competitive with traditional actuarial insurance when the risk lies outside one standard deviation from the mean. Within one standard deviation weather risk writers can benefit from offsetting and other portfolio effects, as they build portfolios according to the Value at Risk methodology. Thus government support of the program is more effective for the tail risk rather than risks closer to the mean.

Conclusions

The description of WDs' risk management features and the analysis of the rainfall index insurance scheme for Morocco show that, if weather elements have a prevalent and observable causal relationship with the production variable, WDs can be effectively used to manage agricultural production risk. However, these conditions can be considered quite restrictive and may not be satisfied in many agricultural production situations.

Current experience shows that WDs can also be useful means for addressing the systemic portion of agricultural risk, leading to potential applications in stand-alone or layer structures of reinsurance of agricultural risk exposure.

In supporting risk management programs, governments are progressively expanding the use of subsidized reinsurance agreements. Well established are the experiences of the US, Canada and Spain but various countries (e.g., Portugal, Italy, Greece) have recently oriented public intervention in that direction. In this respect, WDs may allow for an efficient transfer of systemic risk between different economic subjects, as well as out of countries into global weather risk pools. According to specific policy objectives, the public sector could therefore investigate the possibility of redirecting part of support destined to disaster relief programs towards weather markets. The indications of the Moroccan case study, as well as the reported experience in Mexican agriculture, seem to encourage investigations in that direction.

In order to support new developments in weather markets, at production or reinsurance levels, the regulators could also focus on providing infrastructure, in particular weather stations and the free availability of weather data, and on supporting transaction costs for WD development.

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