Agricultural Insurance Schemes II

Index insurances

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Agricultural Insurance Schemes

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1. Executive summary

Introduction

This study focuses on the assessment of index tools for agricultural insurances. Index insurances basically differ from traditional agricultural insurances in that they do not refer to the actual farm losses, but to the losses evaluated from an index. This index can be, for example, some area yield or revenue, some meteorological or agro-meteorological parameter or a satellite imagery parameter. The analysis considers the coherence with the WTO agreements and the effectiveness to deal with the risk of substantial income reduction of farmers. The study evaluates index insurances in EU-27, and makes a cross-validation of index insurances based on the loss risk calculated from FADN data. The analysis covers all 27 Member States of the EU. However, most aspects of the study are restricted to EU-15 because of data availability, in particular for the FADN loss risk assessment, for which long time series are not available for the new MS. Income indicators based on FADN data are taken into account since 1994, yield indicators from Eurostat data since 1975, meteorological and agro-meteorological indicators since 1975 and indicators based on coarse resolution satellite images since 1998.

Review of index insurances

This chapter starts with a thorough review of index-based risk management tools. Index contracts are more properly financial derivatives or options than insurances. However, under certain conditions, they can be considered as insurance: “the weather derivative can be brokered as an insurance contract or as an over-the-counter traded option”, according to Turvey (2001). Weather derivatives or weather options are managed by the private sector, and limited information available about them. The financial weather contracts market has been originally in the hands of the energy sector, but from 2005 to 2007, the Over-The-Counter end users related to the agricultural sector has doubled. In Swiss Re’s client database, the majority of the business covering weather risks outside developed countries (North America, Europe, Japan and Australia) is with counter parties in the agricultural sector. Anyway, as a whole, this market is in the early stages. The pricing of index insurance is a complex issue: traditional methods for pricing financial derivatives have been used, but insurance or actuarial methods can be more adequate. On the other hand the possible impact of climate change is difficult to assess.

The main advantages over classical insurance is that they avoid moral hazard and adverse selection problems, which allows higher levels of coverage; it is easy to sell through banks and any financial organisations; it is transparent and affordable with very low administrative costs. However, an insured event may not always reflect the production losses experienced by the individual farmers, so it is better adapted for very homogeneous areas and for reinsurance.

There is a wide variety of types of index insurance. We can distinguish two main groups:

- area yield and revenue insurance (the index is directly an area average yield or income);;
- indirect index insurance: exogenous and yield tailored. At the same time, they can be based on one or several indicators, which can be either:
    - meteorological, (the indices are variables such as rainfall or temperature);
        - agrometeorological (the indices are indicators which include agronomic parameters relative to the crop, such as soil moisture or leaf area index);
        - satellite imagery indicators (vegetation indices computed from satellite images).

The literature review includes both studies that analyse area yield insurance and studies that refer to indirect insurances based on meteorological indicators. Among these, there are seven examples of exogenous index insurance, and five of yield tailored insurances. A particular example which combines an exogenous standardised contract and yield-tailoring is the work by Torriani et al. (2007) in which the weather derivative which triggers the payment is exogenous but he proposes a yield-tailored combination of weather derivatives for the farmer.

The exogenous indexes can either have a fixed payment per unitary index decrease (for example a payment of 1€ per 1mm rainfall shortfall), or be proportional (a decrease of the rainfall of 50% would trigger a compensation of the 50% of the insured capital). The yield-tailored examples with multiple indicators adjust yield with the estimation of a model combining different indicators. Other yield-tailored indexes have only one indicator. They optimize the index-yield correlation by the application of weights for the different agronomic growth stages. The three examples available of them are calculated for drought and use the cumulated precipitation. Their results show that a better correlation is achieved when the exogenous single indicator is weighted on the agronomic growth stages. Globally, most of the studies agree on the fact that the better or worse results from index products depend fundamentally on the correlation existing between the real loss of the farmers and the index analysed.

There are several area yield insurance experiences in the world; we have classified the main ones in four categories, according to the nature of the indicators used:

- Area-index insurance has been tested for several years in USA (area yield), Canada, Brazil, India (area revenue); Morocco (area yield insurance for drought).
- The weather or meteorological index insurances are rather new in the market. There is one based on rainfall in Ontario (Canada); still in Canada, in Alberta an insurance is available based on lack-of-moisture and another one on temperature index for silage maize. Other experiences of indirect index insurance based on weather data exist as pilot programs in many developing countries: Mongolia, Mexico, India (rainfall for several crops-very developed scheme), Romania (rainfall), Nicaragua, Ethiopia (drought and food insecurity), Malawi (crop protection based on weather indices against drought).

- In Malawi there is an agro-meto index insurance for maize production based on plant water availability.
- Satellite index insurance for fodder exists as pilot programs in Canada (2001).

In the European Union there are, to our knowledge, only two examples of indirect index insurance: the pilot projects in Austria of a weather index insurance based on meteorological data to cover yield from the risk of drought, and the satellite index insurance for fodder in Spain

Feasibility of index insurance in the EU

Some characteristics of index products have to be taken into account in the analysis of feasibility:

- Index products are useful for systemic risk, at the aggregate level, so they are more adapted to reinsurance and catastrophic risks.

- Index-based products are best suited for homogeneous areas, where all farms have correlated yields. Given the heterogeneity of climates and geography in many European countries, the efficiency of index products will be probably lower than in the large homogeneous areas of the USA (for example, the corn belt).

- Insurance can be properly designed when there are yield time-series available (or losses time series). In Europe time series are only available for relatively large regions. Some of these regions are quite heterogeneous in cropping conditions, climate, topography and soils. This creates difficulties for the efficiency of index insurance for all farmers in the region.

Besides, insurances have to comply with European and international regulations. If insurance was to be considered within the CAP framework, the subsidies should comply with WTO green box criteria. Subsidies to index insurance could be considered as payments (made either directly or by way of government financial participation in crop insurance schemes) for relief from natural disasters (Paragraph 8 of Annex 2 of WTO Agreement on Agriculture), because indexes are intended to reproduce yield or production risks. However, it is not clear whether an index insurance by its nature can be considered under the Green Box, given that its nature is not to compensate the actual loss of an individual, but the loss indicated by a parameter (a farmer that did not suffer from a loss could potentially benefit from compensations). Practical difficulties would also arise from the requirement of a formal recognition by the Governmental authorities of natural disaster, as it would have to be linked to a certain threshold for the indexes used. Other technical characteristics of the insurance and its compliance with the Green Box criteria are also analysed.

Regional (FADN region) yield index

We have analysed the potential of a hypothetical Regional Yield Insurance (RYI) from Eurostat-REGIO data applied at the level of FADN region. We have estimated the premiums rates and the maximum total premium amounts. The calculation of the risk that is covered by the insurance company results in a risk rate which is known in technical terms as “actuarially fair premium” rate (also risk premium or fair premium). We have expressed it as a percentage of the total insured amount. From this fair premium, the commercial premium is then estimated by adding the management and administrative costs and the profit of the insurance company, reinsurance, etc. The fair premium rates for wheat with a trigger of 30% and no deductible ranges from 0 to 14%, with average of 1.1%. The average seems quite affordable, but the maximums are very high. This highlights the large variation of yield risks between different regions. The premium with a 30% deductible was also calculated. In this case, the maximum would reach 6.48% and the average 0.25%. We should underline here that the risk of fall by 30% of a regional average is much lower than the risk of fall by 30% for an individual farm. This explains why the average fair premium of 0.25% is low. With a 15% trigger wheat premiums reaches the 15.7% in Spain. On the whole, these results show that premium rates are very sensitive to the deductibles and trigger levels. The total premium amount can be multiplied by 2 or even up to 6 when reducing the trigger from 30% to 15%.

The commercial premiums of Regional Yield Insurance (RYI) with a 30% trigger and a 50% market penetration (and assuming there is no adverse selection) and assuming a load on the fair premium of 42%, could be around EUR 77.6 million for potato, EUR 79.5 million for barley and EUR 69.8 million for wheat, of which EUR 54.67 million, EUR 56 million and EUR 49.1 million respectively are the pure premiums. The country average fair premiums per hectare oscillate between EUR 4.17 and EUR 9.17 for most arable crops, but reach EUR 30.70/ha for potato.

Meteorological parameters or weather indexes

Some meteorological indicators were analysed following the model of the area yield-tailored insurance from several indicators. An insurance product could be thus designed for each region on the most relevant parameter or combination of parameters according to the results. However, these combinations of indicators do not explain yields optimally, as the Multiple R-Square is only 30%. Perhaps other indicators should be explored. Besides, it is also possible that there is too much heterogeneity within each NUTS2 region and a meteorological yield-tailored index could only have a good explanation capacity at a more disaggregated level. The meteorological indices analysis is useful to underline that the index risk can differ very much from one European region to another. The example shown in Chapter 4.3 aims to explain the level of vulnerability of the same crop, at the same development stage can vary in function of climatic conditions. The results of the late frost study expresses the need of analyse the climatic risk under many points of view, accounting with many physiological aspects related to the crop and more expertise is needed to aggregate data in order to reach robust outputs.

Parameters computed from an agro-meteorological model

Agrometoerological parameters are built by modelling the crop growth, based on the Crop Yield Forecasting System (MARS). Three parameters were selected to study their potential to explain yield variability: Relative Soil Moisture (RSM), Total Water Consumption (TWC) and the Water Limited Storage Organ Weight (WLSOW).

Assuming that the Eurostat-REGIO yield is a good indicator of the yields to be insured (or reinsured, since we are working at regional level), the parameters which have been analysed reach sometimes high correlations. Some examples regards the relative soil moisture, which reaches in Baden-Wurttemberg (Germany) a 0.96 correlation on 10 years, or TWC which reaches 0.74 on 29 years in Bretagne (France), both for grain maize. Unfortunately this high level of correlation is far from being achieved in general.

The analysis of the agro-meteorological indices is made on a large scale (EU 27); this factor certainly limits the quality of the results, because the domain of observations is very wide. We have to take into account is the climatic differences in Europe: Certain areas suffer lack of water, while others face problems due to excessive rain; this means that it is sometimes problematic to analyse the same index on areas with different meteorological problematic. The idea to divide Europe into climatic zones could represent an improvement for the analysis; this could help to refine the outputs and to determine which index can better represent the yield variability for each zone and for each crop.

At present, the results raise major doubts on the opportunity to apply index insurances based on agro-meteorological indicators in the EU. The study suggests several directions that could be taken to comprehend how far an index can serve to assess losses due to climatic event or to prevent income losses through an insurance scheme based on agro-meteorological indices.

Parameters from satellite images

Analyses for NDVI (Normalised Difference Vegetation Index) computed on SPOT4-VEGETATION images show that the maximum NDVI appears as a poor indicator of crop yield risk in the European conditions. While a good spatial correlation can be observed between maxNDVI and yield, the time correlations in each FADN region are low. A factor influencing negatively these correlations is the small number of years available (only 7). However, correlation results improved when taking into account only those maximum NDVI which fall in the period when the crop is more sensitive to nutrients and water stresses. This means that the capacity of NDVI for explaining yields could be improved by exploring other NDVI-based indicators, such as the maxNDVI of this sensitivity period. On the other hand, ongoing activities within the Agriculture Unit of the JRC have proved that the correlation between the indicators derived from NDVI and yield is dependent on the regions. A study in Spain showed that the max NDVI but also cumulated NDVI values for different periods of the growing season are significant. Further analysis could include indicators such as the start NDVI or the end NDVI of the growing season; the cumulated NDVI during the length of growing season; and cumulated NDVI between start and max NDVI, or between max NDVI and end NDVI of the season.

Quantitative assessment of the loss risk on the basis of FADN data

The individual farm income and yield risk have been analysed in order to compare them with the risk from the index insurance analysis. We use the data from the Farm Accountancy Data Network (FADN). FADN is the best available source of data at single farm level. The use of FADN data allows setting up the link between the index-based triggers and the risk of loss of yield or income at farm level.

The concept of risk is the expectation of the loss compared to the "normal" yield or income. It can be calculated as the loss averaged on time, after applying a trigger or deductible, if necessary. This is often labelled in the academic literature as "fair premium", although in practice the premium is higher because of the management costs (including loss expertise) and the profit of the insurance company. The WTO agreements define the normal income or yield as the average of the "*preceding three-year period or a three-year average based on the preceding five-year period, excluding the highest and the lowest entry"*. An alternative option is to consider as "normal" the value of the long term trend for the yield or the income at the farm level. Limiting the sample to the farms for which data are recorded for more that 4 consecutive years reduces the sample size to less than 30% of the total sample. Moreover, if we only consider farms with data on 6 consecutive years, the sample will then be too scarce in many regions for any calculation. On the other hand the application of this rule requires an individual record of yearly production for each farm, but such system does not exist in most European countries. Therefore we need to find an alternative criterion that can be seen as equivalent. A common definition of normal yield is the long-term trend for the farm, but again we seem to be in a cul-de-sac: unfortunately no data are available to estimate long term trends for each farm of the FADN sample. We have developed a procedure to indirectly estimate the variation compared to the trend without estimating the trend for the farm: it is what we call the "2-year constant sample" method. The procedure is model-based and consequently its validity depends on the acceptation of the model, but we consider it is reasonable enough and it allows to exploit the data of a farm whenever data are available for that farm on two consecutive years. The results obtained with this method are compared with those from the 3-year moving averages as defined in the WTO agreements.

The analysis of yield reduction risk is carried out for EU-15 countries and for wheat, barley, grain maize, sunflower and soybean. The analyses are restricted to EU-15 because long time series are not available for the new MS. Both approaches give results that are consistent with each other, but the two-year constant sample method gives in general slightly lower values for the risk than the 3-year moving average method for winter cereals. A possible explanation for this fact is that the WTO criteria do not take into account the long term trend, which is often increasing. We point out that the practical application of the WTO rule would require a farm-level register of yields going at least 3-5 years backwards; this does not seem to be available in most EU countries.

A spin-off of the study is the characterization of the regional yield trends with different functional shapes (linear, quadratic and logarithmic). This is a product that has a value as a tool to improve the current procedures of yield forecasting. However some additional work is necessary to collect time series of yields longer and more complete than the data available in the REGIO database.

The analysis of the income reduction risk is made by farm type instead of by crop. The application of the same methods to the income level measured through FNVA (Farm Net Value Added) is more problematic. We find a conceptual challenge in the application of the “30% deductible” when the average income in the previous year(s) is very low or even negative: What does it mean “a loss of more than 30% of the average income of the previous three years” when this average is negative? This inconvenient has been skipped by eliminating “awkward” ratios, but we have to warn that this may have a strong impact on the results, probably reducing the computed levels of risk. Even with this data cleaning implying a reduction of apparent risk, the risk levels computed for the income reduction are much higher than the risk of yield reduction. The reason for that is easy to understand: assuming relatively stable prices, a yield reduction of 30% correspond to an income reduction of much more than 30%, because the cost of production does not decrease with the yield. An additional analysis has been carried out on the value of production, or revenue, for which the estimated risk is much closer to the risk of yield reduction.

Cross validation of indirect index insurance with FADN data

We have made a cross-validation of the RYI (FADN region and yields from Eurostat-REGIO data) with the farm revenue from the crop. In order to attain this objective we have proceeded in the following way. We have applied to each FADN farm revenue (assuming a unitary price) the indemnities and the premiums from the RYI. By thus simulating the effects of RYI on the farms, we have obtained new values for the farm revenues with insurance. The risk was calculated with the “moving averages” method both for the original sample with no insurance and for the new sample with insurance. The comparison of both results allows to quantify the potential effects of the insurance on the average risk of the farms.

As could be expected, given that area yield indexes are more adequate for homogeneous regions, the risk reduction capacity of RYI is not very high for the example analysed. We can expect that the results do not depend from the crop type, but on the scale of the analysis. Besides, we have to take into account that it was underestimated due to the data constraints (the percentage indemnities were multiplied by actual farm yields and not by average or expected farm yields). However, there are some regions where the risk can be reduced up to a 68%. These results have to be considered cautiously, given that the quality of the data is not optimal. The correlations between Eurostat yields and FADN yield averages are often weak.

General conclusions

As collected from the literature review, index-based products are best suited for homogeneous areas, where all farms have correlated yields. Given the heterogeneity of climates and geography in many European countries, and that analysis had to be performed at NUTS2 or FADN region level, which is at large scale, index products efficiency results to be relatively low. It could be expected to be more useful for reinsurance, at the aggregate level, than at the farm level.

Premiums have been evaluated for a Regional Yield Insurance (RYI) for FADN regions and a number of arable crops. Results show that fair premium rates are very sensitive to the deductibles and trigger levels. Some meteorological indicators were analysed following the model of the area yield-tailored insurance from several indicators. The combinations of indicators analysed do not explain yields optimally. Perhaps other indicators could be explored, but there seems to be too much heterogeneity within each NUTS2 region and a meteorological yield-tailored index could only have a good explanation capacity at a more disaggregate level. Similar conclusions were derived from the agrometeorological indicators tests. The meteo- and agromoteorological indices analysis is useful to underline that the index risk can differ very much from one European region to another. The results suggest many directions that could be taken to comprehend how far an index can serve to assess losses due to climatic events. Analyses for NDVI show that the maximum NDVI appears as a poor indicator of crop yield risk. However, the capacity of NDVI for explaining yields could be improved by using the cumulated NDVI between the more sensitive crop development stages.

FADN data are used to compute and map the level of risk of yield reduction for major field crops at the level of the farm. Preliminary results confirm that the risk level at the scale of the individual farm is much higher than the risk level using regional yields. The analysis of the income reduction risk is made by farm type instead of by crop. The income risk reduction computed is much higher than the risk of yield reduction. The reason is that assuming relatively stable prices, a yield reduction of 30% corresponds to an income reduction of much more than 30%, because the cost of production does not decrease with the yield. An alternative concept has been analysed: the value of production, or revenue, for which the estimated risk is much closer to the risk of yield reduction.

The cross validation of area yield insurance with FADN data shows, as could be expected, that the risk reduction capacity of yield area index is not very high for the case analysed, even though it was underestimated. However, there are some regions where the risk can be reduced up to a 68%. The test for risk reduction capacity of other indexes could be done, however, it would be expected to be lower than the one from yield area index, given that theoretically regional yield area should describe the behaviour of farm yield better that other indexes at a regional scale.

2. General Introduction

2.1. Background and objectives

The Commission's Directorate General for Agriculture and Rural Development (DG Agri) commissioned this pilot study, following a request by the European Parliament (EP) for a pilot project to conduct a study on "new means of providing farmers with support when a disaster occurs". The general aim of the study is to improve the knowledge about climatic risks in EU agriculture and to examine the role and the functioning of agricultural insurance as a risk management tool. The study will be published by DG Agri and transmitted to the European Parliament.

This pilot study is a continuation of the study on "Agricultural Insurance Schemes" (Agrinsur-I) conducted under the Administrative Arrangement n° AGRI-2005-0321 by the IPSC-Agrifish unit of Joint Research Centre. The study Agrinsur-I (Bielza et al. 2006) analysed the current situation of agricultural insurances and made a first assessment of some scenarios for a hypothetical EU-wide agricultural insurance system. The aspects analysed in the AGRINSUR-I report are summarised in the Annex 2A, section 9.1. The current study will be used by DG Agri to further assess the potential of insurance systems as a tool for risk and crisis management in agriculture.

Contemporaneously to the study Agrinsur-I, a consortium of European Research centres, Universities and others has carried out another study on the topic of risk management: it is known as "Income Stabilization" project. It was developed under the 6th Framework Program and a short explanation about the study and its main conclusions is presented in the Annex 2B (section 9.2). The project was concluded in March 2008, and it provided the Commission with an analysis of risk, risk perception and economic analysis of different policy scenarios and risk management tools, including recommendations for the design and implementation of such instruments.

This study focuses on the assessment of index tools for agricultural insurances. The analysis considers its effectiveness to deal with the risk of substantial yield reduction of farmers. The report starts with a literature survey on index insurance and derivatives. The core of the study is organised in two main parts. The first part evaluates the feasibility of area index and indirect index insurances in EU-27. The second part makes a validation of index insurance with loss risk computed from FADN data.

The analyses cover all 27 Member States of the EU. However, certain aspects of the study are restricted to EU-15 because of data availability, in particular for the FADN loss risk assessment, for which long time series are not available for the new MS. Income indicators based on FADN data are analysed since 1994, meteorological and agro-meteorological indicators since 1975 and indicators based on coarse resolution satellite images since 1998.

2.2. CAP context

This pilot study is inscribed in the context of the ongoing discussion on risk management tools in agriculture. The Commission communication on risk and crisis management in agriculture (COM (2005) 74 final) presented three options of supporting risk management tools, one of them being the co-financing of farmer's insurance premiums against natural disasters.

The Council conclusions of 17 December 2003 on risk management in agriculture further defined the essential conditions for the implementation of any new instrument:

– The introduction of new tools, and the related financing rules, must not undermine the operation of the instruments already existing at national level, e.g. insurance against natural disasters.

– The new measures must comply fully with the "green box" criteria as defined by the WTO[1].

– Although public financing may be essential, especially for the establishment and smooth start-up of new tools, joint responsibility and therefore a financial contribution from agricultural producers is also essential.

In the CAP Health Check proposal the Commission has offered a possibility of using a part of the Member States' direct payment funds to grant specific support, among others, in the form of contributions to premiums for crop insurance against losses caused by adverse climatic events (article 68 and 69 of the proposed Council Regulation establishing common rules for direct support schemes for farmers under the common agricultural policy and establishing certain support schemes for farmers). The specific conditions include the rate of co-financing, definition of "adverse climatic events" and the requirement of its formal recognition as such by the competent authority of the Member State. These have been set up as to comply with WTO Green box regulation, in line with the abovementioned Council conclusions.

2.3. Risk and losses

We define the loss of income (or production) as the difference between the income (or production) under normal conditions and the actual income (or production) for a particular year. We use the word "loss" only when the actual income is lower than the expected (although theoretically the expression "negative loss" could be used for an income higher than the expected). The loss can be defined or estimated at farm level or for a category of farms, for example cereal specialists in a given region or country. The income under normal conditions is most often estimated through a long-term trend adjusted to available data as a smooth-behaving curve. We tackle more explicitly this problem later.

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[1] See Annex 2C, section 9.3

The risk is defined as the expectation of loss when no information is available on the behaviour of a particular year. The loss has a different value for each year, while the risk is approximately constant, although there may be an evolution of risk under a climate change scenario. The risk can be intuitively understood as the probability of a loss, it is in fact the mathematical expectation of a loss, that is, the average of possible losses weighted on their probabilities. For measure terms, it can be understood as an average loss, so it can be quantified in monetary terms, production units or, most often, as a percentage. So, for example, a yield risk of 20% would mean that the average probability of loss is the 20% of the "normal" or average yield. If the average yield was 5 T/ha, then this risk would be equivalent to 1T/ha.

An important concept to stress for this study is that of the "actuarially fair premium" of insurance. The fair premium corresponds to the expectation of the indemnities that would be given by the insurance company to the insured. So, for a situation with no deductibles (they are explained next), the fair premium corresponds exactly to what we have defined as the risk (in fact it is also called "risk premium"). Insurance companies, once they have quantified this risk or fair premium, add some loadings to it to account for their costs, and this results in a final or "commercial premium" at which they sell the insurance. The fair premium is often expressed in percentage of the insured capital, but it can also be expressed in production or monetary units (the same as the risk). For example, a 0% fair premium would mean that the probability of an indemnity is zero. In other words, that the yield is never lower than what is guaranteed by the insurance.

Deductibles and triggers can be applied to compute loss and risk. Even if a trigger can be considered a type of deductible, we will identify here a deductible with a straight deductible, in contrast with the concept of trigger.

We consider synonyms the straight deductible, absolute deductible and indirectly, level of coverage. The coverage level refers to the proportion of the insured value that is effectively covered by insurance. Or, in a symmetric way, the straight deductible is the fixed amount of the loss as a percentage of the sum insured that will always be assumed by the insured. For example if we consider a 30% straight deductible (or 70% coverage level), the loss will refer only to the differences beyond 30%, and the risk is the expectation of the loss after applying the deductible. Deductibles reduce moral hazard because whenever there is a loss the insured will have to assume at least a part of it. In this way, there are fewer incentives for increasing the risk exposure due to insurance.

We consider synonyms trigger or trigger level, threshold and franchise. The threshold is the percentage of the insured value the losses must exceed in order to trigger the payment. Once this value is exceeded, the payment of the indemnity can take place for the entire loss or only for a part of it. In other words, a threshold or trigger can be associated to a deductible or not. An example is shown in Table 1. For example, if there is a trigger of 30% and no deductible, with a loss of 25% there would not be any compensation. On the contrary, if the loss is 35%, then the total loss would be compensated. On the last row, if the insurance has a 30% deductible and trigger, in case of a 25% loss there would be no indemnity, and in the case of a 35% loss, the indemnity would be of 5%.

Table 1. Example of indemnities due at different levels of triggers and straight deductibles

		Examples of possible losses (in percentage of expected production or income)	
Trigger or threshold	Deductible	25%	35%
30%	0%	0	35%
30%	15%	0	20%
30%	30%	0	5%

Source: Elaborated by authors

2.4. Methods for the measure of risk

There are a few tools used to measure risk and to compare risky situations. According to Turvey (1991), many academics work with mean-variance optimization and with stochastic dominance models, while some extension offices provide publications that include risk measures such as the coefficient of variation.

Turvey recalls that there is another approach to measuring risk in agriculture, which may prove fruitful for both academics and farm managers or extension agents: the single-index model (SIM). The single-index model by Sharpe (1963) has been used to derive optimal mean-variance-efficient portfolios, to examine the relative riskiness of farm enterprises, and to estimate the marginal costs of diversification. The single-index model is not an equilibrium-type model such as the capital asset pricing model (CAPM). While the underlying mathematics are the same, SIM can be applied to any portfolio using any index, whereas CAPM requires knowledge of a specific market portfolio.

The single-index model assumes that revenues associated with various farm enterprises are related only through their covariance with some basic underlying factor or index. The risk correlated with this index is called non-diversifiable, or systematic, risk. Specifically, systematic risk measures the proportionate contribution of an individual enterprise's risk to the variance of the underlying index. The second risk component, called nonsystematic risk, is the portion of enterprise returns uncorrelated with the index. That is, nonsystematic risk is the commodity's specific risk. Diversification can potentially reduce nonsystematic risk (Turvey, 1991). This index can be, for example, the regional yield.

Another commonly used measure of risk is the Value at Risk. According to the definition in Investopedia (www.investopedia.com) the Value at Risk (VaR) is a technique used to estimate the probability of portfolio losses based on the statistical analysis of historical price trends and volatilities. VaR is commonly used by banks, security firms and companies that are involved in trading energy and other commodities. VaR is able to measure risk while it happens and is an important consideration when firms make trading or hedging decisions.

According to Lonsmeier and Pearson (1996), VaR is a single, summary, statistical measure of possible portfolio losses. Specifically, VaR is a measure of losses due to “normal” market movement. Losses greater than the VaR are suffered only with a specific small probability. Dowd and Blake (2006) review the quantile-based risk measures, and define the VaR of the portfolio at the α confidence level simply as the $q\alpha$ quantile of the **loss** distribution, i.e.: $VaR_{\alpha} = q_{\alpha.}$ Benninga and Wiener (1998) say that VaR measures the worst expected loss under normal market conditions over a specific time interval at a given confidence level. VaR is the lowest quantile of the potential losses that can occur within a given portfolio during a specified time period. The basic time period T and the confidence level (the quantile) q are the two major parameters that should be chosen in a way appropriate to the overall goal of risk measurement. The time horizon can differ from a few hours for an active trading desk to a year for a pension fund. For an internal risk management model used by a company to control the risk exposure the typical number is around 5%. In the jargon of VaR, suppose that a portfolio manager has a daily VaR equal to $1 million at 1%. This means that there is only one chance in 100 that a daily loss bigger than $1 million occurs under normal market conditions. (Benninga and Wiener, 1998). So, a way to compare two risky situations, or the effects of a risk management tool, is to compare the VaR of both situations for the same confidence level.

Benninga and Wiener (1998) in a really interesting article describe how to implement VaR. They also propose a simple example. Suppose portfolio manager manages a portfolio which consists of a single asset. The return of the asset is normally distributed with annual mean return 10% and annual standard deviation 30%. The value of the portfolio today is $100 million. We want to answer various simple questions about the end-of-year distribution of portfolio value:

1. What is the distribution of the end-of-year portfolio value?

2. What is the probability of a loss of more than $20 million dollars by year end (i.e., what is the probability that the end-of-year value is less than $80 million)?

3. With 1% probability what is the maximum loss at the end of the year? This is the VaR at 1%.

We first want to know the distribution of the end-ofyear portfolio value. It will be given by the probability of a PDF[NormalDistribution[110,30].

The probability that the end-of-year portfolio value is less than $80 is about 15.9%.

CDF[NormalDistribution[110.,30],80]= 0.158655

With a probability of 1% the end-of-year portfolio value will be less than 40.2096: Quantile[NormalDistribution[110.,30],0.01]= 40.2096. This means that the VaR of the distribution is 100 - 40.2096 = 59.7904.

We can formalize this by defining a VaR function which takes as its parameters the mean mu and standard deviation sigma of the distribution as well as the VaR level x.

VaR[mu_,sigma_,x_]:= 100-Quantile[NormalDistribution[mu,sigma],x]

So, VaR[110,30,0.01]= 59.7904

Linsmeier and Pearson (1996) describe in detail three methods for computing VaR: historical simulation; the variance-covariance method; and Monte-Carlo of stochastic simulation. They discuss the advantages and disadvantages of the three methos for computing VaR.

Spaulding et al. (2003) use VaR for their study on weather derivative contracts in Romania. Instead, in their work on weather risk management, Woodard and Garcia (2007) prefer to use the expected shortfall measure rather than the Value-at-Risk (VaR). The VaR provides an estimate of the worst loss that one might expect given a tail event does not occur, while the expected shortfall measure is subadditive making it less likely to produce puzzling and inconsistent findings in hedging applications (Dowd and Blake 2006).

The VaR model does allow managers to limit the likelihood of incurring losses caused by certain types of risk - but not all risks. The problem with relying solely on the VaR model is that the scope of risk assessed is limited, since the tail end of the distribution of loss is not typically assessed. Therefore, if losses are incurred, the amount of the losses will be substantial in value. To overcome this problem, Conditional Value at Risk (CVaR)was created to be an extension of Value at Risk (VaR). It is a risk assessment technique often used to reduce the probability a portfolio will incur large losses. This is performed by assessing the likelihood (at a specific confidence level) that a specific loss will exceed the value at risk. Mathematically speaking, CVaR is derived by taking a weighted average between the value at risk and losses exceeding the value at risk. This term is also known as "Mean Excess Loss", "Mean Shortfall" and "Tail VaR". (www.investopedia.com)

Is has been applied to crop insurance, for example by Liu et al. (2006), who study the application of the Conditional Value-at-Risk (CVaR) model to the crop insurance industry under climate variability.

The measure of downward risk if often calculated as a premium. The actuarially fair premium measures the probability below a certain threshold. This is similar to the option pricing in financial mathematics. The threshold or trigger is often the average of the distribution function. In a time series, this can be the temporal trend. In insurance, very often the expected value (average or trend) is multiplied by a coverage rate factor lower than one. We will call this factor the coverage level. In this way, if the coverage is 30%, means that the fair premium quantifies the probability of the outcomes being below the 70% of the expected value. This is equivalent to saying that the insurance has a straight deductible of 30%, in the sense that the 30% of the expected value of the parameter is not quantified in the risk and thus, is not eligible for indemnities.

3. Review on index insurances

3.1. Introduction

Producers can try to compensate the negative economic consequences of bad weather events by buying insurance, and also, since the mid-nineties a new class of instruments, namely weather derivatives. Generally spoken, weather derivatives, also called index-based weather insurance are financial instruments that allow to trade weather related risks.

Index insurances differ from the other type of insurances in that the indemnities are not computed from the individual farmer loss but from a parameter or index external to the farm. The types of indexes most often used in the insurance sector and in general in hedging agricultural risks, are described in section 3.2.2.

Skees and Hartell (2004) give a clear overview on what an index insurance scheme is and how it works. Index insurance products represent innovation offering better pricing for sharing catastrophic risk. There are lower cost approaches to providing crop insurance that also mitigate the traditional problems associated with multiple-peril crop insurance. Index insurance provides an effective policy alternative as it seeks to protect the agricultural production sector from widespread, positively correlated, crop-yield losses (e.g., drought). When index insurance is used to shift the risk of widespread crop losses to financial and reinsurance markets, the residual personal risk often has characteristics that make it more likely that rural banks can work to smooth consumption shortfalls with loans.

3.2. Description of index insurance

3.2.1. Insurance or derivatives?

As stated by Mr. Eckhardt Wilkens in the Income Stabilization seminar from the European Association of Agricultural Economists (Warsaw, February 2007), according to the definition of insurance, it is not correct to denominate insurance to indirect index-based products, given that they do not compensate for the actual individual loss. So, they should be rather called index financial contracts or index financial products.

In order to better understand the difference between insurance and derivatives, we can refer to the explanation by Martin et al. (2001): "*Changnon and Changnon describe the process by which they established premium rate tables for short-term (1-72 hours) precipitation insurance. The policies were* *designed to provide protection against precipitation affecting outdoor events such as fairs or concerts. Data from 211 weather stations were used to calculate empirical hourly cumulative frequencies, averaged over calendar months, for six levels of precipitation (0.01, 0.05, 0.10, 0.25, 0.50, and 1.00 inches). The continental United States was divided into 17 rating regions, and the historical frequencies were then averaged across all the weather stations within each rating region. Patrick presents estimated premium costs for a proposed rainfall insurance contract in the Mallee wheat-producing region of Australia. Though Patrick indicates premiums are derived from "reasonable [parametric] distributions of rainfall," no specifics are provided about distributional forms or parameters. Sakurai and Reardon estimate the demand for a hypothetical "rainfall lottery" in Burkina Faso. The lottery, which is assumed to be administered by an insurance company, would make a lump-sum payment to lottery ticket-holders whenever annual rainfall, measured at a given weather station, is below some predetermined level.*

The instruments described by Changnon and Changnon; Patrick; and Sakurai and Reardon are similar in that each uses weather station data to calculate premium rates. However, Changnon and Changnon set premium rates for a traditional precipitation insurance policy where loss adjustment would be based on realized precipitation at the event site. In contrast, Patrick, and Sakurai and Reardon, consider insurance policies which are effectively weather derivatives. Specifically, their studies describe put options with loss adjustment based on realized values of an underlying index of precipitation measured at a given weather station. Nevertheless, both Patrick, and Sakurai and Reardon ***characterize their proposed precipitation derivatives as insurance, because they assume the derivatives would be sold to farmers through retail insurance channels****”*.

However, given that they have been referred to as insurance since many years and by a most wide literature (see the literature review in this chapter), we assume that this name, even if not the most appropriate, is accepted even by the scientific community. Turvey (2001) states: “the weather derivative can be brokered as an insurance contract or as an over-the-counter traded option”. In fact, this characteristic of index insurance does not remain in the semantic field, but it also has tangible consequences. The fact that compensations are not paid on real losses that need to be checked by experts on the field, involves that these products can be sold more easily from different actors, even from financial entities and banks, so they do not need to be in the hands of the insurance sector, but are potentially subjects to a strong competence. This may also be a possible reason for the insurance companies being less interested in this type of products.

3.2.2. Types of indexes used for hedging agricultural risks

The types of indexes upon which agricultural risk hedging can be based (insurance or derivatives) are summarised in Table 2. Two main types of index insurance products can be considered: (1) those that are based on area direct measure, where the area is some unit of geographical aggregation larger than the farm, and where the measure can be the yield or the revenue (so, these area index, include area yield insurance, and area revenue insurance, in which the area yield of the crop is multiplied by the crop's price in order to obtain the area revenue); and (2) those that are not based in a direct yield measure but on another parameter, which we will call indirect index insurance. In this group are included the insurances known as index-based weather insurance or climatic index insurance. Indirect index insurance can be considered as a type of area insurance, so, it shares many of the advantages and disadvantages of area insurance. In subsection 3.2.3 (Advantages and disadvantages of index insurance), we will first review the advantages and disadvantages of index insurance in general over traditional insurance; then, the advantages and disadvantages of the indirect indexes over the direct (area) ones will be analysed.

Table 2. Most common types of indexes used for hedging agricultural risks

(1) **Area index**	Area Yield Area Revenue		
(2) **Indirect index**	Exogenous	One indicator Several indicators	Meteorological Agrometeorological Satellite imagery
	Yield-tailored (Farm yield tailored or area yield tailored)	One indicator	Meteorological Agrometeorological
		Several indicators	Meteorological Agrometeorological

Source: Elaborated by authors

Following Breustedt et al. (2008), we can classify the indices for weather insurance or derivative (put options) products in exogenous and yield-tailored. The simplest manner of constructing a weather index is to use exogenous indices which are not adjusted to farm yields, i.e. exogenous 'meteorological indices' (for example, Skees et al., 2001 and Turvey, 2001 use either cumulative rainfall or temperature). The other manner is to use regressions of crop yield to be insured on weather indicators in different specifications and construct 'yield-tailored weather indices' from these regressions. In the case of exogenous indices, the problem is a presumably higher level of basis risk compared with weather insurance based on yield-tailored indices. The yield-tailored indices, instead, represent the historical yields as well as possible. Therefore risk reduction from crop insurance based on such indices is, in general, higher than risk mitigation from insurance schemes based on non-tailored weather indices. On the other hand, due to estimation uncertainty, the yield regressions add uncertainty to predictions that must be used for calculating future insurance payments.

The yield-tailored indices are built either from one but more often from several weather indicators. For example, Vedenov and Barnett (2004) as well as Karuaihe et al. (2006) analyse the efficiency of weather derivatives and insurance products based on a combination of several weather indicators. To specify an index, i.e. to determine the weights of the various (transformed) weather indicators defining an index value, two different approaches are possible. One is to use the individual yield to be insured, another option is to use an area yield. In fact, average risk reduction among farms depends upon the variable used for tailoring. Using farm yield for tailoring implies maximum average risk reduction because the resultant index value has the greatest correlation with farm yield. Crop insurance based on farm yield-tailored weather indices thus serves as a benchmark for crop yield risk reduction from weather index insurance. From a practical point of view, additional transaction costs arise for the insurance company, because weather insurance must be adjusted for each farm. However, for large farms these additional costs are small per hectare insured. Tailoring the weather index on regional yields rather than farm yields would reduce transactions costs. Problems of moral hazard or adverse selection do not arise because of yield tailoring because actual indemnity payments are only based on the actual weather variables, which cannot be influenced by a farmer. Yield tailoring only means transforming both premiums and indemnity payments equivalently. (Breustedt et al. 2008)

Last, regarding the type of indicator used for the index, we can subdivide indirect-index in three types of products: those based on weather variables (meteorological or weather index insurance), those based on agro-meteorological parameters (agro-meteorological index insurance), and those based on satellite imagery parameters (satellite imagery index insurance).

3.2.3. Advantages and disadvantages of index insurance

3.2.3.1. Advantages and disadvantages of index insurance over traditional crop insurance

Index contracts offer numerous advantages over more traditional forms of farm-level multiple-peril crop insurance, but also some disadvantages. Mainly, they have low risk of moral hazard and adverse selection and it is easy to adjust the losses but if the area is not very homogeneous, the basis risk can be big enough as to make the insurance no interesting for farmers.

More specifically, the advantages include:

1. No moral hazard*:* Moral hazard arises with traditional insurance when insured parties can vary their behaviour so as to increase the potential likelihood or magnitude of a loss. This is not possible with index insurance because the indemnity does not depend on the yield of an individual producer.

2. No adverse selection*:* Adverse selection is a misclassification problem caused by asymmetric information. If the potential insured has better information than the insurer about the potential probability or magnitude of a loss, the insured can use that information to self-select whether or not to purchase insurance. Index insurance on the other hand is based on widely available information, so there are no informational asymmetries to be exploited.

3. Higher coverage levels. In some situations, index insurance offers superior risk protection when compared to traditional multiple-peril crop insurance that pays indemnities based on individual farm yields. This happens when the provider of traditional insurance must impose large deductibles[2]. Deductibles and co-payments (or partial payment for losses) are commonly used to combat adverse

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[2] The portion of an insured loss to be borne by the insured before he is entitled to recovery from the insurer.

selection and moral hazard[3] problems. Since these problems are not present with index insurance, there is less need for deductibles and co-payments. (Skees and Hartell, 2004).

4. Low administrative costs: Dissimilar from the farm-level multiple-peril crop insurance policies, index insurance products do not require underwriting and inspections of individual farms. Indemnities are paid exclusively on the realised value of the underlying index as measured by government agencies or other third parties.

5. Standardized and transparent structure: Index insurance policies can be sold in various denominations as simple certificates with a structure that is uniform across essential indices.

6. Availability and negotiability: Since they are standardised and transparent, index insurance policies can easily be traded in secondary (future) markets. Such markets would create liquidity and allow policies to flow where they are most highly valued.

Individuals could buy or sell policies as the realisation of the underlying index begins to unfold. Moreover, the contracts could be made available to a wide variety of parties, including farmers, agricultural lenders, traders, processors, input suppliers, shopkeepers, consumers, and agricultural workers (Skees, 1997).

7. Reinsurance function: Index insurance can be used to transfer the risk of widespread correlated agricultural production losses. Thus, it can be used as a mechanism to reinsure insurance company portfolios of farm-level insurance policies. Index insurance instruments allow farm-level insurers to transfer their exposure to undiversifiable correlated loss risk while retaining the residual risk that is diversifiable (Black, Barnett, and Hu, 1999- mentioned by Stoppa 2004).

Disadvantages of Index Insurance

1. Basis Risk: The occurrence of basis risk depends on the extent to which the insured losses are positively correlated with the index. Without sufficient correlation, “basis risk” becomes too severe, and index insurance is not an effective risk management tool. A careful design of the index insurance policy and using in a correct way the parameters (coverage period, trigger, measurement site, etc.) can help to reduce basis risk. Another way of reducing basis risk can be to sell the index insurance to a collective group. The index insurance will cover the systemic part of the risk, and the basis risk will be assumed by the group, that can develop mutual insurance at some level to protect from it. Such a group is in the best position to know their neighbours and determine how to allocate index insurance payments within the group to cope with risks differences.

2. Security and diffusion of measurements: The feasibility of index insurance depends critically on the index being objectively and accurately measured.

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[3] Adverse selection occurs in a situation in which the insured has more information about his or her risk of loss than does the insurance provider and is better able to determine the soundness of premium rates. As a consequence, the level of risk in the insured population is higher than in the total population. Moral hazard refers to an individual’s change in behaviour after having taken out an insurance policy. The change in behaviour results in an increase in the potential magnitude and/or probability of a loss.

The index measurements must then be made broadly available in a well-timed way.

Whether provided by governments or other third party sources, index measurements must be widely disseminated and secure from altering.

3. Precision in modelling*:* Insurers will not sell index insurance products unless they can be sure about the statistical properties of the index. This requires sufficient historical data on the index and good models that use these data to predict the probability of various index measures. Climate change can represent a difficulty for the design, as it happens also in traditional crop insurance.

6. Reinsurance*:* In most of the cases, insurance companies do not have the financial resources to offer index insurance without adequate and affordable reinsurance. Effective arrangements must therefore be established between local insurers, international reinsurers, national governments, and possibly international development organizations.

Index insurance is a different approach to insuring crop yields. Unlike most insurance where independent risk is a precondition, the precondition for index insurance to work best for the individual farmer is correlated risk.

It is possible to offer index contracts to anyone at risk when there is an area wide (correlated) crop failure. Furthermore, another difference from traditional insurance is that there is no reason to place the same limits on the amount of responsibility purchases by an individual. As long as the single farmer cannot influence the outcome that results in payments, then placing limits on liability is not necessary as it is with individual insurance contracts.

Finally, the real advantage of merging index insurance into banking is that the banking entity can use such contracts to manage correlated risk. Consecutively, the bank should be able to work with the individual to help them in managing the residual risk or basis risk. In simple terms, if the individual has an independent loss when the index insurance does not pay, they should be able to borrow money from the bank to smooth that shock. This could effectively remove the principal concern associated with index insurance contracts that someone can have a loss and not be paid.

As more sophisticated systems are developed to measure events that cause widespread problems it is possible that indexing major events will be easier and accepted by international capital markets.

Under these conditions, it may become possible to offer insurance to countries where traditional re-insurers and main providers would previously have never considered. Insurance is about trust. If the system to index a major event is reliable and trustworthy, there are truly new opportunities in the world to offer a wide array of index insurance products (Skees and Hartell, 2004).

3.2.3.2. Advantages and disadvantages specific to indirect index insurance

Advantages of indirect index insurance over area index insurance

1- Because there is only the need to follow the evolution of the index, the control of the insurance and loss adjustment is even easier and in some cases, cheaper.

2- When the quality of area yield data is not good (for example in developing countries), the quality of historical series of meteorological data is usually better. In order to determine the actuarial structure and premium rates of the insurance contracts, the quality level of the data need to be high.

3- Scarcity or excess of rainfall are among the main causes of yield decrease in many regions (also important in developing countries). (Martin et al. 2001)

Disadvantages of indirect index insurance over area index insurance

1- The errors of reproducing the real individual farmer's risks can be multiplied.

3.2.4. Characteristics of an index for weather insurance in agriculture

Before entering into the design of an index insurance for agriculture, some pre-requisites need to be analyzed and taken into account in the design process. According to Chavula and Gommes (2006), an index used for crop insurance should have the following characteristics:

1· Tamper-resistance or reliability: potential beneficiaries of the insurance should not be in a position to directly or indirectly manipulate the index.

2· Objectivity: once the methodology has been defined in precise enough terms, the index value should be independent on who carries out the calculations.

3· Publicity: the methodology has to be made available to potential subscribers of the insurance. Crop insurance indices should be published regularly in national agro-meteorological bulletins and other channels as well as on the web.

4· Measurability: Historical records must be adequate and available (Stoppa and Hess, 2003)

5. Insensitivity to missing data: the best way to circumvent the occurrence of missing spatial data is to use gridded information that is not too sensitive to individual missing stations, provided sufficient data points are available and the interpolation process takes into account topography and climatic gradients.

6· "Good" correlation with crop yield.

The last point on correlation requires further discussion. Chavula and Gommes (2006) declare that rather than the statistical strength of the correlation between yield and crop weather index, it is the number of false positives (good year assessed to be poor) and false negatives (poor year assessed as good) that constitutes the most important criteria.

Stoppa and Hess (2003) explain that for FWs for agriculture, more than for other FWs, the existence of a complex relationship between the product and the weather factor must be carefully explored (see Vedenov and Barnett, 2003, for a related discussion on a sample of US crop districts). For many

Weather Derivates (WDs) traded in the energy sector, e.g. derivatives on Heating Degree Day (HDD) (H index, the relationship between temperature and demand for heating is simple and direct: the lower the HDD index 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. The crucial issue for the application of FWs 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.

Stoppa and Hess (2003) admit that this constraint is not as binding for the use of FWCs at the reinsurance level, since FWCs 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. Woodard and Garcia (2007) arrive to the same conclusions. They observe that previous studies identify limited potential efficacy of weather derivatives in hedging agricultural exposures. In contrast to earlier studies which investigate the problem at low levels of aggregation, they find using straight forward temperature contracts that better weather hedging opportunities exist at higher levels of spatial aggregation. Aggregating production exposures reduces idiosyncratic (i.e. localized or region specific) risk, leaving a greater proportion of the total risk in the form of systemic weather risk which can be effectively hedged using weather derivatives. The aggregation effect suggests that the potential for weather derivatives in agriculture may be greater than previously thought, particularly for aggregators of risk such as re/insurers.

3.2.5. Pricing weather insurance

3.2.5.1. Pricing insurance

When establishing a price for a weather risk management instrument, according to BRYLA AND SYROKA (2007), providers will take into consideration their own risk appetite, business imperatives, and operational costs. While there are a variety of methodologies for pricing, in general the pricing for all contracts will contain an element of expected loss, plus some loading or risk margin that corresponds to a capital reserve charge required to underwrite the risk at a target level for the business, as well as administrative costs. Therefore in general the premium charge for a contract can be broken down as follows:

Premium = Expected Loss + Risk Margin + Administrative Costs

Expected loss is the average payout of the contract in any given season. It is also known as (actuarially) fair premium.

The risk margin is charged by the providers because in some years, when extreme events happen, payouts in excess of this average can occur and the risk-taker must be compensated for this uncertainty. The values of the expected loss and the risk margin must be established from historical weather data. These values include an adjustment to compensate for uncertainties in the data such as trends or missing values. The approach for determining the loading over the expected loss differs from insurer to insurer and many use a combination of methods to determine the risk margin included. A sensible pricing methodology uses a risk measure such as the Value-at-Risk (VaR) of the contract to determine the risk margin. A VaR calculation is aimed at determining the loss that will not be exceeded at some specified level of confidence, often set at 99%.

Administrative costs are essentially the costs for the provider to run the business including charges for data, office costs, taxes and reinsurance and brokerage charges if necessary.

The WB (2005) calculates the market premium as the actuarial fair premium or pure premium plus a number of loadings to account for other insurance costs:

- Loading Based on Standard Deviation: Market standards 20 to 40 percent.

- Loading Based on the Uncertainty due to Gaps in the Historical Weather Data

- Loading for Administrative Expenses: A margin of 15 percent was added.

The Loading based on the standard deviation of the payout series is a common loading procedure. According to Skees (2002), “generally, a loaded of 33% of the standard deviation is added to the pure premium insurance”.

3.2.5.2. Pricing derivatives

Hirschauer and Musshoff (2008) address the problem of pricing a weather derivative. According to them, as the seller’s future results will be negative, even after abstracting from transaction costs, a weather derivative as well as weather insurance cannot be offered free of charge. The price should take into account: (i) the expectation value of the derivative’s future payoff resulting from the design of the derivative and the stochastic development of the weather variable, (ii) the interest rate to be used to discount the future payoff, and (iii) the transaction costs associated with this contract.

If the underlying “weather index” was traded on a perfect market, one could resort to the pricing procedures for financial derivatives. Turvey (2001) examines in detail the pricing of insurance contracts at a given location and across space. He prices the European-type options using the “burn-rate” approach.

3.2.5.3. Pricing index insurance

Weather indices, however, are non-traded assets. This is why pricing procedures like the Black-Scholes model for financial derivatives cannot be applied. Trying to solve the problem Turvey (2002), with reference to the Capital Asset Pricing model, reverts to the blanket assumption that the correlation between weather indices and capital market risk is negligible. So, he assumes that the “market price for the weather risk” is zero and that the value of weather derivatives can simply be determined as a fair premium (actuarially fair price). “Fair premium” means that the value of the weather derivative is calculated by discounting the expected value of the future payoff with the risk-free interest rate. As a zero-correlation between weather risk and capital market risk is a questionable assumption, the fair premium (plus the transaction costs) only defines the minimum sales price for weather derivatives from the underwriter's point of view. (Hirschauer and Musshoff, 2008)

The same reasoning is done by Martin et al. (2001), who declare that even if precipitation insurance is in essence an option, pricing based on standard options valuation models is problematic. Standard options valuation models require that one be able to construct (at least conceptually) a riskless portfolio consisting of both the option and the asset which forms the underlying index. Yet, there is no actively traded forward market for precipitation. So, expected loss cost is the standard basis for establishing insurance premium rates (Skees and Barnett, 1999). Loss cost is equal to indemnities divided by liability. Insurance actuaries calculate an expectation on future loss cost based on historical experience with the insurance product. Expected loss cost can be considered as an expected breakeven premium rate. Using extended time series of weather data, historical loss costs can be simulated for stylized weather insurance instruments. An expected loss cost can then be estimated from the simulated historical loss costs.

Martin et al. (2001) is a reference for precipitation insurance design and pricing (Stoppa & Hess 2003, Spaulding et al. 2003, Torriani et al. 2007). They make a comprehensive review on indemnity designs. We collect these indemnities formulations in Table 3

Table 3. Indemnity designs (option designs) used in index insurance

Author	**Index i**	**Equation for Indemnity**	
Type 1 – Stylized European puts and calls			
Turvey (1999)	CDD, Precipitation puts	0	if i > strike
		$(strike - i)*p$	if $i \leq$ strike
	HDD call	0	if i < strike
		$(i - strike)*p$	if $i \geq$ strike
Type 2 – Percentage European put			
Skees and Zeuli (1999)	Precipitation put	0	if i > strike
		$\frac{strike - i}{strike}$ **liability*	if $i \leq$ strike
Type 3 – Limited percentage call			
Martin et al. (2001)	Precipitation call	0	if i > strike
		$\frac{i - strike}{limit - strike}$ **liability*	if limit > $i \geq$ strike
		1**liability*	if $i \geq$ limit

Source: Made by authors from information in Martin et al. 2001

Notes:

- i is the cumulative realized value of the underlying index
- p is a unitary payment, that is, some predetermined dollar value per unit of the index

For precipitation, i has a natural lower bound of zero. Thus, for puts, the maximum indemnity is *p*strike* for the precipitation put of type 1, and *liability* for type 2 puts. But as there is no natural upper bound on i, there is no cap on the maximum indemnity for calls. This is the reason why Martin et al. 2001 propose Type 3 calls.

3.2.5.4. Pricing reinsurance

According to the study by Hou et al. (2004), rainfall insurance in Romania, can be reinsured through a stop loss contract. Reinsurance plans are often provided by the international institutional such as World Bank, which shares the local risk by pooling the reinsurance risks worldwide. They calculate the reinsurance cost in the following way:

They calculate the total indemnities for all regions or aggregated indemnities in each year t (AI_t) and the aggregated liabilities or total liabilities (AL), assuming that liabilities are constant in time. Last, we call the aggregated final premiums (market premiums) in all regions AP Then, the risk exposure for the reinsurance part in year t (RE_t) is calculated as:

$RE_t = (AI_t - 2*AP)$ if $AI_t - 2AP > 0$

$RE_t = 0$ if $AI_t - 2AP \leq 0$

So, the reinsurance uptakes the losses above the double of the premium values. If we calculate the mean and the standard error of RE_t (REm and REsd), then, the reinsurance costs will be:

$RC = REm + 33\% * REsd$

The expected profit of the reinsurance company will be:

E(Profit)=Total premium – Reinsurance cost-Expected Indemnity=AP-RC-EI

3.2.6. Weather derivatives and weather markets

A financial weather contract (FWC) 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). Once the index is determined, a variety of FWCs can be issued on it. FWCs can be binary if the payment is in one lump sum, depending on the occurrence or not of one specific state of nature (e.g. 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).

A **financial weather contract** (FWCs) can take the form of a **weather derivative** (WD) or of a **weather index insurance contract** (WI). 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.

3.2.6.1. Weather derivatives

Recent innovations in energy markets suggest the possibility of addressing agricultural risk factors by issuing derivatives on weather elements. 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 (Stoppa & Hess, 2003).

The most common types of WD contracts are: swaps, call options (or weather caps), put options (weather floors) and, among derivatives’ combinations, collars. In a swap, counterparts agree to exchange payments conditional on the outcome of the agreed weather event with no fixed premium. Payments are triggered when the actual weather index is different from the strike level, and are based on the unit payment. In comparison to the swap format, the cap format permits the purchaser of the weather derivative to buy protection at a fixed premium. Caps provide protection against adverse upside weather conditions whilst allowing the buyer to retain the full upside potential of unusually favourable weather conditions (such as a warm winter for a greenhouse grower). Floors are similar to caps but provide protection against adverse downside weather conditions whilst allowing the holder to retain the full upside potential of unusually favourable conditions. If the climatic variable remains within the normally expected specified range, as defined by a zero-cost collar, no payments occur. However, if the climatic variable falls outside the collar’s upper limit, an indemnification is provided in return for a non-fixed premium that is paid if the climatic variable falls outside the collar’s lower limit. For the three types of contracts, a maximum indemnity can be agreed upon by setting an upper bound. (Asseldonk and Oude Lansink, 2003)

WDs have important differences with respect to traditional commodity price derivatives. The fundamental difference is that the underlying of a WD is not a traded good. Without trades in 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. 2001). Pricing of WDs is therefore usually based on actuarial calculations. The absence of a universal pricing method generates lack of market transparency and increases transaction costs (Stoppa and Hess 2003).

3.2.6.2. Weather markets

Weather contracts can be used to hedge business exposition to weather variables. 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 developing 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 (see Stoppa and Hess, 2003).

Weather markets have grown at a rapid pace in the USA since their introduction in 1997. Weather markets are dominated by the energy generation industry. However, later, 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. The reinsurer Swiss RE, and the insurers ACE, AXA and XL entered the market along with smaller insurers. According to the Weather Risk Management 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. First emerging market transactions were published in South Africa and Mexico. From 2002/03, weather products (mainly swaps and options which use Cooling and Heating Degree Days as underlying indexes) have been traded in the Chicago Mercantile exchange, which has resulted in a decrease of Over-The-Counter[4] business, but in an increase in total business (Roth et al. 2007)

Banks and re-insurers have introduced the concept of FWCs to other industry sectors, such as agriculture, construction or tourism. (Roth et al. 2007). Weather markets makers are looking for new end users, and agriculture is the unexploited industry offering the most significant growth potential for weather markets. From 2005 to 2007, the Over-The-Counter end users related to the agricultural sector has doubled. In Swiss Re's client database, the majority of the business covering weather risks outside developed countries (North America, Europe, Japan and Australia) is with counter parties in the agricultural sector. Anyway, as a whole, this market is in the early stages. A study from Swiss Re compares the growth in the weather risk transfer market of the agricultural sector with that of the energy sector. According to this study, the growth of the WDs business for the agricultural sector is being impeded by: the lack of exchange-based instruments in this field; the relatively high basis risk between weather indexes and agricultural yield; the fact that agricultural markets are still highly regulated; and inadequate information and training (Roth et al. 2007). Success for weather markets in agriculture may involve a number of uniquely designed products that do not involve farmers directly (Skees, 2003).

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[4] Over-The-Counter business refers to contracts directly closed between two counter parties. Business recorded in this category can either be in from of derivative or insurance and reinsurance contracts. Disadvantages of Over-The-Counter business compared to an Exchange are: more difficult execution, lower price transparency, and no availability of a clearing house eliminating counter party credit risks

Indexes for agriculture

The following information on indexes for agriculture is from Roth et al. (2007, p.8), from Swiss Re. Given the high interest for our discussion, we reproduce it below:

“Whilst the first products were simply based on the aggregate amount of precipitation during a certain period, the market has since become increasingly sophisticated. Today, index definitions typically feature:

- a variable inception date defined as a function of the amount of rainfall during about 10 days prior to inception of cover against dry conditions during planting
- a combination of precipitation and temperature measurements used as input variables for the index definition during sub-periods related to the various growth phases(establishment, vegetative, flowering, yield formation, ripening) to cover weather risks specific to each growth stage,
- an index calculation defined as the weighted sum of index contributions during the above mentioned sub-periods.

Despite these rather complicated index definitions, the typical correlation between such an index and agricultural yield is around **60-80%**. Additionally, as the geographic distribution of rainfall is more complicated than the distribution of temperature, the correlation of weather indexes tends to deteriorate quickly the further they are from weather stations.(…)

There are several developments to overcome these limitations. For example, market participants rely on a combination of temperature, rainfall and soil information to calculate the amount of water available to a plant. Moreover, remote sensing data is being increasingly used to compensate for the lack of a coarse network of weather stations.

In contrast to the above situation for the agricultural sector, the weather risk transfer instruments used for the energy sector typically profit from a high correlation between temperature-based indexes and retail energy consumption: often **above 90%** for gas and about **80-90%** for power.

We therefore have strong reason to believe that the basis risk related to the use of weather risk transfer instruments for the agricultural sector is one of the main obstacles for end users to enter into weather risk transfer instruments.”

3.3. Some examples of index insurance in the literature

Asseldonk and Oude Lansink (2003) study weather index insurance to hedge temperature exposure of Dutch greenhouse horticultural firms. They present a framework for analysing the viability of a weather derivative contract to hedge heating energy demand in greenhouse horticultural firms. This weather derivative can be a risk management tool enabling farmers to cope with adverse weather conditions (i.e., extreme cold winters). A normalized quadratic profit function was used, which includes among the firm inputs a weather indicator: heating degree-days (HDD). HDD are calculated as the absolute difference between a reference or base temperature (T_{ref}) and the daily average temperature (T_{avg}), defined as the average of the maximum and minimum temperatures for each day. If the daily average temperature exceeds the reference temperature, HDD is zero. Subsequently the daily (t) HDD values are summed over the specified period to be hedged (n):

$$HDD = \sum_{t=1}^{n} \max\left\{0; T_{ref} - T_{avg,t}\right\}$$

The reference temperature and the time horizon, in the current application, are 18ºC and a whole year respectively. The sample temperature data originate from a principal meteorology station that is located in centre of the Netherlands and is often regarded as representing the average temperature for the whole country. Monte Carlo simulation was used to estimate the effectiveness of a non-linear weather derivative contract. It is revealed that the derivative contract reduces profit volatility, but a substantial heterogeneity among firms exists.

The study by Breustedt et al. (2008) analyses the potential of index insurances for the Kazakhstan's arid region. It compares several types of insurances: traditional yield insurance; area yield insurance; three exogenous meteorological insurances (rainfall and drought insurances developed for Kazakhstan in the literature); and three farm-yield-tailored indexes (see section 3.2.2) from the same rainfall and drought indicators used in the exogenous meteorological insurances. The indemnities and premiums are calculated assuming the index insurance work as a Stylized European put option (Type 1 in Table 3). Their results show that none of the analysed insurance schemes provides statistically significant risk reduction for every single farm. Weather-based index insurance is found to provide less risk reduction than area yield insurance based on the rayon (county) yield. In addition, rayon yield index insurance can reduce yield risk more effectively for Kazakhstan's wheat producers than farm yield insurance with a low (75%) strike yield.

Hao et al. (2004) provide a theoretical analysis for the optimal portfolio of weather index and individual crop insurance. The analysis is performed at the farm level under the mean-variance framework and stresses the impacts of risk aversion level, transaction cost, and basis risk. It is applied to corn farms in Todd county of Kentucky. The design of the weather index follows the European precipitation put options of Type 1 proposed by Skees and Zeuli (1999). The study utilizes rainfall data from 1985 to 1994 in nearest Bowling Green Weather Station. The rainfall is first aggregated in four different critical growth periods based on climate and plant physiology. Weights for these four periods are then assigned through a mathematical programming procedure that maximizes correlation between county yields and rainfall index. The vector of weights is then checked in order to make it consistent with agronomic information. The final value of the index is calculated by summing the values obtained by multiplying rainfall levels in each period by the specific weights assigned to a particular period. The strike level used corresponds to the average index value.

Hirschauer and Musshoff (2008) calculate through a risk-programming model, the willingness-to-pay for risk management in general and in particular for weather derivatives. They make an application to a Brandenburg multi-crop farm of a cumulated rainfall contract that protects from drought. It is a put option based on the accumulated rainfall between April 1st and June 30th. The payment corresponds to 1€ per mm shortfall of the average three-monthly rainfall from 1980 to 2005. This application reveals that even a highly standardised contract based on accumulated rainfall generates a relevant willingness-to-pay. They find that the underwriter could even add a loading (on the actuarially fair price) which exceeds the level of traditional insurances. Since transaction costs are low compared to insurances, this indicates a relevant trading potential.

Mahul (2003) examines the optimal hedging strategy with an individual insurance policy, sold at an unfair price, and a fair contract based on an index, which is imperfectly correlated with the individual loss. The index used in the example is the area yield. The trade-off between transaction costs and basis risk is first analyzed in the expected utility framework in order to highlight the role of the agent's attitude toward risk, and then in the linear mean-variance model to stress the importance of the degree of correlation between the individual loss and the index. As expected, results show that these two hedging contracts are substitutes: the introduction of index insurance contracts into the hedging strategy decreases the demand for individual insurance. The hedge depends, critically, on the correlation between the individual loss and the index.

Skees et al.'s (2001) study for the World Bank proposes drought rainfall index insurance for Morocco. This index insurance is based in a 21 years data series. The Pearson correlations between revenue (calculated from cereals yields) and cumulated rainfall vary from -18 % to 90%. Insurance is advised in those provinces which show an average correlation of 69% in the 21 year period, and 77% in the last ten years. The design of the insurance is quite simple. It is a proportional contract. The proportion is calculated from the cumulated rainfalls (from November to March, period which shows best correlation) and then multiplied by the liability in order to obtain the indemnity. Premiums are calculated from the 21 year period data. In fact, premiums are set for all provinces at 5% and at 10%, and threshold or trigger rainfall levels are calculated accordingly for both levels of premiums. The resulting coverage level (reported to the median rainfall) are around 85% for 10% premium and 67% for 5% premium. On a second step, the study proposes to combine this rainfall insurance with an area yield coverage, so that losses that are not due to drought can also be covered. The threshold of this area index coverage is set so that the total premium becomes 12%, so a 2% increase above the 10% premium of rainfall insurance.

The study by Skees et al. (2001) is improved in 2003 by Stoppa and Hess, in the sense that they try to capture the rainfall-yield relationship in the most accurate way possible. For this, they assign specific weights to the different growth phases. They also included a "capping" procedure taking into account the fact that water in excess of storage capacity is lost and does not contribute to plant growth. The correlation increases from 67% to 92%.

Skees and Hartell (2004) point out that index insurance is suitable for covering systemic risks and risks causing extreme events. But this type of insurance should be combined with saving and credit to provide a good coverage to the farmers. The relationship with the credit world would allow producers to manage the "basis risk" associated to index insurance.

Torriani et al. (2007) have studied an index derivative for maize in Switzerland. It is a rainfall index, defined as the integration of the daily precipitation along the rainfall-sensitive production period. The index itself is extremely simple, in the sense that the payout function of the put option is a linear function of the strike minus the index. However, in order to hedge a farmer corn production, the farmer should buy a combination of these put options, based on the rainfall index but with different strikes. The exact combination of puts was calculated for Swiss corn, so that it reproduces the corn loses. These losses were not calculated from observed yields, but from a crop model, where yield is a function of the radiation use efficiency, global radiation, water stress and vapour pressure deficit limitation. Profits and risks with and without hedging were compared for the current climate situation and for a climate change scenario. The actuarially fair premium charged with the costs of capital was calculated. However, from the Value at Risk calculations, it could be deduced that farmers would be willing to pay more than 90 % above the fair premium for the risk protection. Thus, the conclusion is that hedging might provide a valid risk transfer.

Turvey (2001) examines the economics and pricing of weather derivatives in Ontario. The products presented represent actual products offered by insurance companies and brokerages, but which have not been widely used in agriculture. Using historical data, the relationship between crop productivity and weather is examined. A variety of put and call options (including multiple-event) for rain- and heat-based weather risk are discussed and numerically evaluated. The index indemnities work as a Stylized European put option (Type 1 in Table 3)

The study by Vedenov and Barnett (2004) analyzes efficiency of weather derivatives as primary insurance instruments for six crop reporting districts that are among the largest producers of corn, cotton, and soybeans in the United States. Specific weather derivatives are constructed for each crop-district combination based on analysis of several econometric models. The different models explain detrended district yields in function of weather variables often used in the literature: cumulative rainfall; monthly rainfall; cumulative cooling degree days; average monthly temperatures; all for the period from June 1st to august 31st. The models used are quadratic in absolute values, quadratic in deviations and log-log. The performance of the designed weather derivatives is then analyzed both in- and out-of-sample. The primary findings suggest that the optimal structure of weather derivatives varies widely across crops and regions, as does the risk-reducing performance of the optimally designed weather derivatives. Further, optimal weather derivatives required rather complicated combinations of weather variables to achieve reasonable fits between weather and yield.

Romania rainfall insurance

The study by Spaulding et al. (2003) employs a precipitation contract in the lines of a weather derivative contract as an alternative to traditional crop insurance to combat risks due to drought in Romania. The preliminary structure of the contract is designed and tested for seven judets in south-eastern Romania. The precipitation contract is designed to trigger payments to the insured when monthly rainfall falls below a set trigger amount. The calculation of the pure premium is based on the pure loss cost history and does not cover for the transaction costs or risk preference of partners. Reinsurance firms usually load the pure premium based on the variance of the loss costs. For the purposes of this study, a 33% reinsurance load was imposed on the standard deviations of indemnity payments per liability.

The above procedure was slightly modified for establishing the contract design for the farm level model. This was done considering the unique agronomic growth stages for crops produced as well as knowledge of the value at risk for the representative farm. Corn and Wheat, which represent major crops in Romania, are included in the farm model. Corn is planted in the spring (April-May) and harvested in September-October and Wheat cropping period spans from October and July. Adequate rainfall during the critical periods of crop growth is a crucial factor in determining yields of the above crops. Based on the above fact the precipitation contract was designed to cover only for critical periods of crop growth. Specifically, the contract was designed to trigger a payment when the monthly rainfall in a critical month fell short of a set strike for that crop. The critical months for corn spanned from April to August and for Wheat from October to November in the fall and by May and April in spring. The strike was set as 85% of the average rainfall during critical months for the above crops. For example, the average rainfall during critical months for corn and wheat were 46 mm and 36 mm respectively. Accordingly a strike of 39 mm for corn and 31 mm for wheat were established. It is again important to recall that the precipitation contract was designed to consider only the critical periods of crop growth and not the whole cropping season. It is defined as a “proportional” contract, so it has a “disappearing deductible” of Type 2 in Table 3:

$$\text{Indemnity} = (\text{Strike}-X/\text{Strike}) * \text{liability whenever } X < \text{strike}$$

Where, X is the actual rainfall, Strike is the trigger rainfall amount, Liability establishes the maximum possible indemnity. The liabilities are usually set based on the total value at risk of the produce. The average farm yield in the selected “judet” was considered as a good proxy for the value at risk and used to establish liability estimate by crop. Once the strike and liability are given, indemnity payments and premiums can be formulated.

The impact of such contract on the risk management strategy of producers across risk preference levels is also investigated. Based on the analyses some broad policy implications for Romania are drawn. The study uses a combination of insurance design methods along with expected mean variance model to accomplish its objectives. Preliminary results suggest that if sufficient partnerships are forged to share risk, such contracts can prove useful in Romania. Across levels of risk preference, the contracts were found to increase mean profits and reduce coefficient of variance in net returns when compared to a base scenario with no contract. Further research is needed to corroborate these findings. Market based insurance with minimal government intervention is the key to the development and the success of weather derivative contracts. Risk sharing among farmers, government, private insurance companies, and global reinsurance markets needs to be established. There is also a need for finding ways of trading risk among agro-climatic regions within the nation. Education of groups including farmers, government officials and private insurance companies and marketing of such instruments are essential to have a successful implementation and broad adaptation of these contracts by the buyers and the suppliers (Spaulding et al. 2003).

Hou, et al. (2004) provide prospects of rainfall-indexed insurance in Romania considering the trade-off between moral hazard and basis risks. The article analyzes the rainfall risks' effect on the corn outputs in five judets of southern Romania. Diversely from Spaulding et al. (2003), indemnities are not calculated as Type 2 but as Type 1 contracts. So, the indemnity amount (AI) is given by: $AI_{ij} = Max\ [0, MIN\ [(strike - AR_{ij})*tick, liability]]$ where *tick* is the indemnity amount per unit of rainfall, which is the ratio of liability to the strike, and where AR_{ij} is the actual rainfall in key period j for each judet i. They also calculate the reinsurance cost. To deal with the risk, two types of indexes are analysed: one based on Key Season's Rainfall and another based on Rainfall along the Crop Growth Cycle. They determine the basic parameters and measure the effectiveness. Results show that indexed insurance based on key season's rainfall has less power to reduce output risk though it is specialized for the most risky season in each judet. Indexed insurance based on rainfall along the crop growth cycle does a better job in reducing the output risk. Finally, they propose microfinance programs combined with indexed insurance to deal with the basis risk problems.

3.4. Examples of index insurance in the world

This section briefly presents the experiences on index insurances around the world. However, each type of insurance mentioned here is further explained in Annex 3A (Section 9.4). Index insurances have been classified into three groups or categories: (a) area-index insurance (the index is directly an area average yield or income); (b) weather and agro-meteorological index insurances (the indices are weather or agro-meteorological variables such as rainfall, temperature or soil moisture); and (c) satellite imagery index insurance (vegetation indices computed from satellite images). Even if all of them have a short history, the area-index insurances have been experienced for some years in some countries (USA, Canada, Brazil or India), while the indirect indices are brand new and exist only as pilot programs or are under study in most countries. Table 4 summarizes the types of insurances available or under study for each country.

Table 4. Agricultural index insurance systems in the world

Country	Area index insurance (1)	Weather & agro-met index insurance	Satellite imagery index insurance	Date of most recent info available
Argentina	-	#	-	2002-04
Austria	-	##	-	2006
Brazil	PS	-	-	2002-04
Canada	GS	#	#	2005
Colombia	-	##	-	2002-04
Ethiopia	-	G# (WB)	-	2005
France	-	##	-	2006
India	GS	P# (WB)	-	2005
Kenya	-	## (WB)	-	
Malawi	-	# (WB)	-	2008
Mexico	-	R (WB)	-	2005
Mongolia	## (WB)	-	-	2005
Morocco	PS	-	-	2005
Nicaragua	-	## (WB)	-	2005
Peru	-	## (WB)	-	2005
Spain	-	-	PS	2005
Thailand	-	## (WB)	-	2005
United Kingdom	§	-	-	2006
Ukraine	-	P# (WB)	-	2005
USA	PS	-	-	2005

Source: Prepared from information Bielza et al. (2006), Alasa (1992), ENESA (2004), Ibarra and Mahul (2004), Skees et al. (2005), Skees and Enkh-Amgalan (2002), Skees et al. (2001), Stoppa and Hess (2003), World Bank (2005), Osgood et al. (2008)

Legend:

- : Not existing (empty space means that there was no information about it)

S : Subsidized

P : Private non-subsidized

PS : Private partially subsidized

G : Public non-subsidized

GS : Public partially subsidized

R: Reinsurance from the international reinsurance market or derivative market

: Pilot experience

: On project

(WB): Studied, supported or with a credit line by the World Bank

§: Failed experience

(1) The area index includes area yield and, in the USA, also area revenue insurance

3.4.1. Examples of area index insurances[5]

Area-index insurance is most often based on the yields of an homogeneous area, so that if the area yield decreases below a given value, all the insured farmers in that area get an indemnity with independence of their having a loss or not. In fact, the idea of index insurance is not so new. In the 50's, Sweden was managing an insurance program based on the yield and revenue of geographic areas (Skees and Hartell, 2004). Experiences of area yield index insurance have also been carried out in the United Kingdom, Quebec (Canada), the USA, India and Morocco. A particular type of insurance for animals has been developed in Mongolia.

3.4.2. Examples of meteorological or weather index insurances[6]

Regarding the indirect indices based on meteorological or weather indicators, some essays have been made in Canada: index insurance based on rainfall (Ontario); lack-of-moisture insurance (Alberta); temperature index for silage (Alberta). In the European Union, even if agricultural insurance in general is quite developed, meteorological index insurance exists only in Austria for the coverage of drought as a part of the yield insurance scheme. It was used for the first time in 2007. Besides, as mentioned in section 3.2.6.2, weather index derivatives are used in Europe by the re-insurance sector.

Indirect index insurance or weather-indexed insurance has been applied in several countries with the help of the World Bank. It is sometimes applied for the individual farmers (micro-level), other times for the Governments (macro-level), so that they get funds to give aid to the rural population when there is a catastrophe. The International Finance Corporation (IFC), from the World Bank Group, has interest in funding such innovations, so that these countries can participate in the upcoming technological derivatives markets. The World Bank has worked on the evaluation of feasibility of this type of insurances in Nicaragua, Morocco, Ethiopia, Tunisia, Mexico, Peru, Ukraine, Turkey and Argentina. The main application has been for drought risk at Micro level. However, research is being carried out to expand coverage to other risks: flood, ENSO (El Nino-Southern Oscillation), cyclone. The main experiences on less developed countries are indicated in Table 5:

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[5] Please refer to Annex 3A for further details

[6] Please refer to Annex 3A for further details

Table 5. Applications and experiences of weather-indexed insurance

Micro-level	Weather-indexed insurance for smallholder farmers, intermediated through institutions with rural outreach	Ex. India Malawi Nicaragua Ukraine
Meso-level	Weather-indexed portfolio hedge for rural financial institutions that lend to poor farmers	Ex. India Malawi
Macro-level	Weather insurance or weather-indexed contingent credit line for governments or international organizations that provide safety nets for the poor	Ex. Ethiopia Malawi Mexico

Source: Dick (2007)

A procedure for designing standardized deficit-rainfall insurance contracts for smallholder grain crop farmers is being developed by the World Bank's Commodity Risk Management Group (CRMG) in conjunction with IRI Earth Institute at Columbia University (BRYLA AND SYROKA, 2007). The simple contracts have the following features:

1. A dynamic start date that mimics the decision a farmer would take as to when to sow his crop;

2. Three or more phases depending on the length of the crop growing period, during which cumulative rainfall is measured, with a trigger and exit levels in each phase. The trigger level determines the level at which compensation would begin for the farmer, i.e. if the cumulative rainfall measured during the phase dropped below this trigger the farmer would begin to receive a fixed payout per mm, for every mm that the cumulative rainfall recorded was below the trigger level. These trigger levels correspond to rainfall levels at which the crop would begin to feel water-deficit stress. The exit level determines the level at which the farmer would receive a maximum payout, i.e. if the cumulative rainfall measured during the phase dropped below this exit level the farmer would receive the entire limit (sum insured) for that phase as it is assumed his crop would have failed or would have been permanently damaged. Hence the cumulative rainfall totals per phase are the underlying indices for these contracts.

3. A payout rate per phase, i.e. the payout rate per mm if the recorded cumulative rainfall in each phase falls in between the trigger and exit levels.

The three-phase weather insurance contract design was pioneered by **Indian** insurance company ICICI Lombard and sold to farmers for the first time in 2004. The design proved to be popular with groundnut and castor farmers in Andhra Pradesh and farmers of other crops, and hence was chosen as the prototype structure for the first **Malawi** pilot and subsequent African pilots. Currently this methodology to design deficit-rainfall contracts is being used by CRMG for a second year in **Malawi**, **Tanzania** and **Kenya**.

In India, a big number of index insurance products have been developed, mainly dedicated to deficit rainfall or drought, and to excessive rainfall for different crops (see Table 23 in Annex 3A).

In Morocco, a rainfall index insurance contract was proposed but its implementation did not take place.

To address the drought and food-insecurity situation in Ethiopia, two agricultural risk management structures were being considered in 2005, one at the farmer or microlevel and the other at the government or macrolevel.

Mexico is the first developing country in stipulating a reinsurance agreement based on a bunch of weather indexes. In fact, the reinsurance corresponds, according to the classification of Table 2, to a yield-tailored index based on several meteorological indicators. In fact, it is not yield-tailored but liability-tailored, because liabilities (indemnities) are estimated with a linear least squares regression in function of a climatic index: FCDD (Factores Climaticos Dañinos Diarios). The FCDD term for each crop represents the weather index or indices (usually rainfall and temperature indexes) that best capture the weather risk for that crop. The FCDD calculation methodologies using daily weather data are presented in Table 24 of Annex 3A. Besides using weather indexes for reinsurance, other uses of index insurances (mutual insurance funds, water resources markets, Government catastrophic weather exposure) are being explored in Mexico.

In Peru agricultural weather insurance is under study. (WB, 2005). In the case of Nicaragua, a pilot project is already available and it covers groundnut from deficit and excess rainfall during growth period and from excess rainfall during harvesting.

Regarding Ukraine, a pilot project of a drought index insurance based on rainfall and temperature was developed by the World Bank, for winter wheat producers in the south of Ukraine.

3.4.3. Examples of agro-meteorological index insurances

FAO proposed an effective weather-based maize yield index (WYX, Weather Yield index) that could be used for crop insurance purposes in Malawi. It corresponds to a yield-tailored index based on several agrometeorological indicators. See Annex 5.A for further details.

3.4.4. Examples of satellite imagery index insurances

Satellite imagery (SI) indexes have been applied mainly to insurance of pastures or grasslands. The characteristics of these productions (difficulty to evaluate yields and losses, mainly if animals are directly grazing) make of this technology a potential solution for permitting insurance. Some details on the characteristics of satellite imagery information are presented in Annex 3A, section 9.4.4. We present also two examples: Canada and Spain. According to Garrido and Bielza (2008), index insurance based on vegetation indices to cover against drought episodes also exists in the Unites States, and experimentally in France, South Africa and Ukraine.

3.5. Conclusions

Index contracts are more properly financial derivatives or options than insurance. However, under certain conditions, they can be considered as insurance: “the weather derivative can be brokered as an insurance contract or as an over-the-counter traded option”, according to Turvey (2001). The pricing of index insurance is a complex issue: traditional methods for pricing financial derivatives have been used, but insurance or actuarial methods can be more adequate. Weather derivatives or weather options are managed by the private sector, so there is not so much information available about them. The financial weather contracts market has been originally in the hands of the energy sector, but from 2005 to 2007, the Over-The-Counter end users related to the agricultural sector has doubled. In Swiss Re’s client database, the majority of the business covering weather risks outside developed countries (North America, Europe, Japan and Australia) is with counter parties in the agricultural sector. Anyway, as a whole, this market is in the early stages.

The main advantages over classical insurance is that they avoid moral hazard and adverse selection problems, which allows higher levels of coverage; it is easy to sell through banks and any financial organisations; it is transparent and affordable with very low administrative costs. However, an insured event may not always reflect the production losses experienced by the individual farmers, so it is better adapted for very homogeneous areas and for reinsurance.

There is a wide variety of types of index insurance, but we can distinguish two main groups:

- area yield and revenue insurance;
- indirect index insurance: exogenous and yield tailored. At the same time, they can be based on one or several indicators, which can be either meteorological, agrometeorological or satellite imagery indicators.

The literature review includes three studies that analyse area yield insurance, while all the rest refer to indirect insurances based on meteorological indicators. Among these, there are seven examples of exogenous index insurance, and five of yield tailored insurances. A particular example which combines an exogenous standardised contract and yield-tailoring is the work by Torriani et al. (2007) in which the weather derivative which triggers the payment is exogenous but he proposes a yield-tailored combination of weather derivatives for the farmer.

The exogenous indexes can either have a fixed payment per unitary index decrease (for example a payment of 1€ per 1mm rainfall shortfall), or be proportional (a decrease of the rainfall of 50% would trigger a compensation of the 50% of the insured capital). The yield-tailored examples with multiple indicators adjust yield with the estimation of a model combining different indicators. Other yield-tailored indexes have only one indicator. They optimize the index-yield correlation by the application of weights for the different agronomic growth stages. The three examples available of them are calculated for drought and use the cumulated precipitation. Their results show that a better correlation is achieved when the exogenous single indicator is weighted on the agronomic growth stages. Globally, most of the studies agree on the fact that the better or worse results from index products depend fundamentally on the correlation existing between the real loss of the farmers and the index analysed.

There are several area yield insurance experiences in the world; we have classified the main ones in four categories, according to the nature of the indicators used:

- Area-index insurance has been experienced for several years in USA (area yield), Canada, Brazil, India (area revenue); Morocco (area yield insurance for drought).
- The weather or meteorological index insurances are pretty new in the market. There is one based on rainfall in Ontario (Canada); still in Canada, in Alberta is available an insurance based on lack-of-moisture and another one on temperature index for silage.
- Other experiences of indirect index insurance based on weather data exist as pilot programs in many developing countries: Mongolia, Mexico, India (rainfall for several crops-very developed scheme), Romania (rainfall), Nicaragua, Ethiopia (drought and food insecurity), Malawi (crop protection based on weather indices against drought).
- In Malawi there is an agro-meteorological index for maize production based on plant water availability.
- Satellite index insurance for fodder exists as pilot programs in Canada (2001).

In the European Union there are only two examples of indirect index insurance: the pilot projects in Austria of a weather index insurance based on meteorological data to cover yield from the risk of drought, and the satellite index insurance for fodder in Spain.

4. Feasibility of index insurance in the EU

4.1. Introduction

In this chapter the peculiarities of Europe relative to potential index insurance products and the limitations imposed by WTO agreements are discussed. Afterwards, we analyse the potential of different indexes for insurance in the EU. The index insurance assessment is organised in four main parts: a first part deals with area yield insurance, the second part analyses the use of meteorological parameters in order to create weather indexes, a third part deals with different types of agro-meteorological parameters, and a last part considering an index from satellite images (NDVI).

First, an area yield insurance based on regional yields (Regional Yield Insurance RYI) is designed and the possible costs of the premiums are quantified. The other indices will be calibrated or evaluated (analysis of correlation) with regional yield data and not with FADN farm data because the latter does not provide time series. Consequently, the good performance of the regional yields showed by the RYI would be determinant for the good performance of the other indices.

Meteorological indicators from the literature are calibrated with Eurostat-REGIO NUTS2 data. A model combining several of these indicators is applied in a way similar to the “area yield-tailored index insurances with several parameters” (see section 3.2.2)

The parameters analysed for the agro-meteorological part come from the Crop Growth Monitoring System (CGMS). This system is presented in Annex 4A (section9.5), which explains its methodology and its outputs.

The Satellite imagery parameter analysed is the NDVI, which is the same used for the Canadian and Spanish insurance products for pastures. We explore the possibilities of using this indicator for arable crops yield risk.

The analyses cover all 27 Member States of the EU. However, when enough data are not available, the analysis has to be restricted to EU-15. Meteorological and agro-meteorological indicators are analysed since 1975, but for a few new MS and Eastern Germany data are only available since 1990, and for all new MS data are only available since 1995. Indicators based on coarse resolution satellite images are analysed since 1998.

4.1.1. General discussion on the technical application of index insurance in EU

In the design of an index insurance, there are some general characteristics that are required by this type o products and that must be taken into account for its design. They can be found in section 3.2.4 (Characteristics of an index for weather insurance in agriculture)

- Index-based products are best suited for homogeneous areas, where all farms have correlated yields. Given the heterogeneity of climates and geography in many European countries, index products efficiency will be probably lower than in the large homogeneous areas of the USA (for example, the corn belt).

- As has been insistently repeated in the literature, index products are useful for systemic risk, at the aggregated level. So, they can be very useful for reinsurance. Less correlated risks at a more disaggregated level (farm, or areas smaller than a region) can be easily pooled by private insurance companies or by mutualities.

- Due to the reason above, index products can address more easily catastrophic risks, while normal farm risks could be covered by existing insurance companies.

- Yield time series are only available at NUTS2 (region) level. Some regions, like Andalucia or Castilla y Leon in Spain have no homogeneity. This makes difficult to create an index for the region that can be useful for all farmers in the region. Thus, the coverage provided by and index product in this type of large regions is expected to be quite low.

4.1.2. Insurance design: accommodation of insurances design to WTO constraints

If index insurance was to benefit from a CAP subsidy, according to the Council conclusions from 2003 (see section 2.2), it must comply fully with the "green box" criteria as defined by the WTO agreement. Assuming the just mentioned restrictions, these would be the consequences for a potential index insurance:

1- **Index insurance under Paragraph 8 of WTO Uruguay Round Agreement**. Aids given to insurance could potentially be given under either Paragraph 7 (Income risk programs) or Paragraph 8 (Production risk programs). As Paragraph 7 refers to programs addressing directly income losses, index insurance seems to fit better in Paragraph 8, because indexes are intended to reproduce yield or production risks. However, it is not clear that index insurance by its nature can be considered under the Green Box, given that its nature is not to compensate by the actual loss of an individual, but by the loss indicated by a parameter (a farmer that did not suffer from a loss could potentially benefit from compensations).

2- **Formal recognition by government authorities of natural or like disaster**. Assuming that index insurance could fall under Paragraph 8, there should be a formal recognition by the Governmental authorities that when the index is below a certain threshold, it corresponds to a situation of natural or like disaster. However, as mentioned above, it can not always be ascertained for all those who benefit from the compensations.

3- **The trigger or threshold.** Both for income programs as well as for production programs, there is a minimum loss or trigger that must be exceeded, and there is a maximum payment from public money. Paragraph 8 states that the trigger is 30% of a reference production, and the maximum payment is 100% of the production loss.

4- **Individual vs. area yield data**. In the insurance design, we need to define the expected yield which is the reference yield needed to calculate the loss. The WTO agreement defines the reference production mentioned above as: "*the average in the preceding three-year period or a three average based on the preceding five year period, excluding the highest and the lowest entry*". This means that the reference yield for WTO compliance should be calculated from individual farm data. This poses a practical problem, as registers of individual farm data are not available for many productions in many countries. This raises the question on how these reference parameters should be estimated: based on area data? As averages tend to smooth the variations, individual losses can differ a lot from area losses, and thus, a trigger applied to individual yields can be very different from a trigger applied to area yields. In Annex 4B (section 9.4) we show that a 30% deductible on individual yields can be similar to a 15% deductible on area yields. A similar result can be expected for a trigger.

5- **Trend vs. moving averages.** The calculation of the reference parameter also rises a second question: is it advisable an insurance product that takes as insured amount one of these moving averages, or would it be better to guarantee an expected production based on other parameters, for example a detrended average over a longer period of time? What effects could have taking one or the other? This is analysed in Annex 4C (section 9.4). From the analysis we can see that moving averages oscillate a lot compared to the trend, as could be expected, and so are less advisable for insurance purposes. It can also be observed that the moving averages sometimes are more restrictive than the trend, and sometimes less. However, if the detrended average and not the WTO moving averages are to be used for establishing the insurance coverage, then when the trend is increasing (which corresponds to most of the cases), the probability of not complying with WTO rule is higher. In these cases, it would be useful to have some additional margins in the deductibles or in the rate of subsidization of insurance, so that insurance subsidies could be notified under the green box.

6- **Trend vs. moving averages in area vs. individual data.** The losses have also been calculated at individual farm level for FADN data in section 5.2.1 (from a trend in section 5.2.1.1 and from the WTO moving averages in section 5.2.1.2). Results show that, on average, for winter cereals, the risk is bigger when referred to the WTO 3-year moving average than when the trend is taken as a reference. This might be due to the fact that oscillations in individual yields are larger than oscillations in regional yields, so that the 3-year moving average are still more instable than the detrended average (presenting more differences from one year to another), thus, increasing the risk globally. This observation and the one in the preceding point could indicate that, in certain cases, the WTO restrictions would be less restrictive for individual farm losses than for regional losses.

4.2. Regional yield index insurance (RYI)

4.2.1. The insurance

The proposed design of this insurance scheme is a simple one. It is similar to the USA GRP (see Section 9.4.1.5), however, it is non-proportional insurance, in the sense that the deductibles do not decrease as the loss increases.

The indemnities are calculated as follows:

$$Indemnity = \max\left(0, Guaranteedyield - indexyield\right) \times insuredvalue$$

where the "index yield" is the effective yield of the region where the farm is located, and the "guaranteed yield" is the region's expected unitary yield (average of the detrended yield series) reduced by the deductible ($Guaranteedyield = Averageyield$ x(1-$deductible$)). As problems of moral hazard and adverse selection are low in index insurance, we have set the deductible to zero, but instead we have used a trigger. WTO criteria require a trigger of 30%, but taking into account that the variability of regional yields is much lower than the variability of farm yields, and that in Annex 5B (section 9.6) we have shown that an individual deductible or trigger of 30% can be equivalent to an area trigger or deductible of 15%, we have simulated the RYI with both trigger levels (30% and 15%). The "insured value" is the product of the estimate of the price (average of national Eurostat prices from 2002 to 2006), the scale and the crop surface in the farm. The scale is also chosen by the producer, depending on how is his/her individual expected yield in relation with the regional yield, and it can vary from 50% to 150% [7]. For our insurance design, considering that it is a fist attempt for the calculation of the premiums, we make the assumption that the scale is 100%. For the area, we will calculate the total cost of the premium for the total area of the crop in the region.

4.2.2. Data used

The index is to be based in regional yields. In order to be able to calculate the premium, historical statistical yields are needed. They should be obtained at the more disaggregate geographical level possible. Because FADN data do not offer individual farm yield records for a consistent series of years (usually only one, two or three years for a same farm), we prefer to use the next level of data available. For most countries data are available at NUTS 2 (regional) level in the Eurostat REGIO database. Given the size of the NUTS2 regions, we can consider its use acceptable for the countries where they are relatively small and homogeneous: The Netherlands, Luxembourg, Belgium, Germany, Austria and Czech Republic.

However, we have found a constraint in the length of the data series. The information at NUTS2 level, for some countries is not available for more than ten years. This is the case, for example, for the small NUTS2 regions in Germany. Considering that a shorter time series does not give an adequate idea of the risk, we have opted for working at FADN region level. This has three main advantages. On the one

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[7] The GRP allows a scale from 90% to 150%, these values being constrained politically (Skees et al. 1997).

hand, it solves the problem mentioned above, because it means that Eurostat data in some cases are applied at NUTS2 level, in other at NUTS1 (it permits to have data series of an adequate length for some countries such as Germany) and in the small countries at NUTS0. Second, it achieves a more homogeneous geographic distribution. Last, it has the further advantage that it will facilitate comparison with FADN data (section 5.2). So, we have used Eurostat data, but aggregating it at FADN-region level.

4.2.3. Methodology

The data have been detrended with logarithmic, quadratic or linear regressions adjusted for each region and each crop. If the yield for a year t is y_t and the trend yield for the same year is y_t^{tr}, then the detrended yield $y_t^{\det}$ for year t has been calculated as:

$y_t^{\det} = y_t \frac{y_{2005}^{tr}}{y_t^{tr}}$, as we assume that the expected yield for our insurance is the trend yield of the last year for which there is data available y_{2005}^{tr}. Also for the crops and regions for which there is no data for 2005, the estimated trend yield of 2005 has been used.

For the calculation of the fair premium, we have simulated for every year from the historical detrended yields, the indemnity of the insurance described in section 4.2.1, with the two deductibles. Then, we have calculated the premium as the mean of the indemnities, and the premium rate as the mean indemnity divided by the insured capital. The insured capital is given by the product of the average yield (so, the expected yield of 2005); the crop price and the region crop surface, assuming thus a hypothetical 100% market penetration. The crop price for all calculations is the Eurostat average price of the years 2002-2006 in all EU-27 countries available (Italy was not available for any crop).

Table 6. Crop prices used for the premium calculations

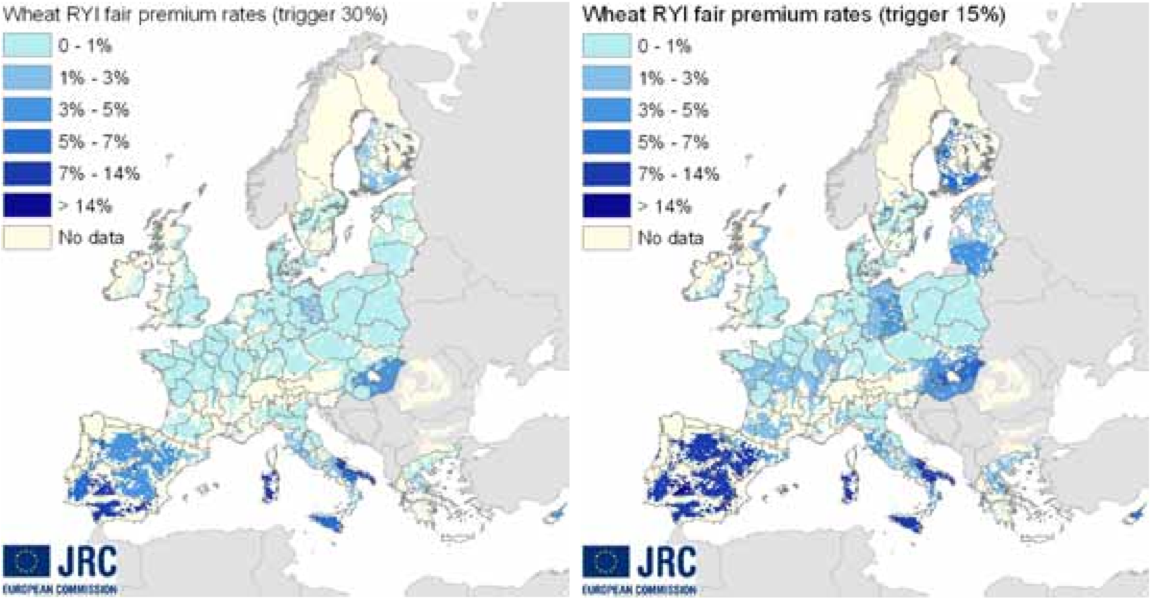
Crop	Price €/T	Crop	Price €/T
Barley	104.7	Rapeseed	306.1
Wheat	113.2	Soybean	209.9
Grain maize	115	Sunflower	206.1
Rice	212.1	Potato	188.1
		Sugarbeet	39.9

Source: Calculated by authors from Eurostat data (2002-2006)

Last, we have not taken into account those pairs region-crop for which the average cultivated area was less than 5 hectares, considering that it is a very marginal crop and that the yield information is not representative of the yield potential variability in the region.

4.2.4. Results

In this section we present first the premium rates results and later, the estimation of the maximum total premium amounts. The results are shown for wheat in this section and for the other crops in the Annex 4E (section 9.9).



Source: Elaborated by authors from Eurostat data

Figure 1. Premium rates for RYI for wheat (trigger 30% and 15%)

Table 7. RYI premium rates (%) for wheat (calculated at FADN-region level)

	Trigger 30%			Trigger 15%		
	Average[8]	Maximum	Minimum	Average	Maximum	Minimum
AT	0.00%	0.00%	0.00%	1.36%	1.36%	1.36%
BE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CY	3.48%	3.48%	3.48%	5.29%	5.29%	5.29%
CZ	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
DE	0.17%	2.34%	0.00%	1.06%	4.29%	0.00%
DK	0.00%	0.00%	0.00%	0.65%	0.65%	0.65%
EE	0.00%	0.00%	0.00%	1.68%	1.68%	1.68%
ES	4.39%	13.98%	0.00%	7.64%	15.73%	1.20%
FI	2.01%	2.01%	2.01%	5.64%	5.64%	5.64%
FR	0.47%	6.85%	0.00%	1.67%	9.10%	0.00%
GR	0.37%	1.48%	0.00%	1.99%	3.82%	1.27%
HU	2.38%	3.84%	0.00%	4.81%	6.51%	3.42%
IE	0.00%	0.00%	0.00%	1.24%	1.24%	1.24%
IT	2.08%	9.85%	0.00%	3.64%	13.03%	0.00%
LT	0.00%	0.00%	0.00%	3.23%	3.23%	3.23%
LU	0.00%	0.00%	0.00%	2.75%	2.75%	2.75%
LV	0.00%	0.00%	0.00%	1.22%	1.22%	1.22%
NL	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
PL	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
PT	5.38%	5.38%	5.38%	9.33%	9.33%	9.33%
SE	0.00%	0.00%	0.00%	1.74%	3.48%	0.00%
SI	0.00%	0.00%	0.00%	3.54%	3.54%	3.54%
SK	0.00%	0.00%	0.00%	4.75%	4.75%	4.75%
UK	0.35%	2.10%	0.00%	1.20%	3.39%	0.00%
Europe	1.09%	13.98%	0.00%	3.33%	15.73%	0.00%

Source: Authors calculations from Eurostat data

The former premiums correspond to a RYI with trigger but no deductible. Theoretically, the elimination of the trigger would mean an increase of the premium rates. Similarly, the addition of a deductible would mean a decrease of the premium rates. In order to appraise the magnitude of this decrease, we have also calculated the premium rates for wheat with a 30% deductible and a 15% deductible. They are shown in Table 8. On comparing Table 7 and Table 8 we can see that with a 30% deductible, the maximum premium is reduced by 50%, and deductible, the average to one quarter. With a 15% deductible, the reduction is much lower but not negligible: from 15.7% to 11.6% the maximum and from 3.3% to 1.38% the average.

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[8] Those cases with a unique value for average, maximum and minimum correspond to countries with only one FADN region.

Table 8. RYI premium rates (%) for wheat with deductible (calculated at FADN-region level)

	Deductible 30%			Deductible 15%		
	Average	Maximum	Minimum	Average	Maximum	Minimum
AT	0.00%	0.00%	0.00%	0.36%	0.36%	0.36%
BE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CY	1.33%	1.33%	1.33%	3.14%	3.14%	3.14%
CZ	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
DE	0.01%	0.20%	0.00%	0.34%	2.14%	0.00%
DK	0.00%	0.00%	0.00%	0.13%	0.13%	0.13%
EE	0.00%	0.00%	0.00%	0.18%	0.18%	0.18%
ES	1.59%	6.48%	0.00%	4.20%	11.56%	0.13%
FI	0.34%	0.34%	0.34%	2.31%	2.31%	2.31%
FR	0.07%	0.85%	0.00%	0.56%	4.10%	0.00%
GR	0.01%	0.05%	0.00%	0.78%	1.67%	0.39%
HU	0.38%	0.84%	0.00%	2.06%	3.51%	0.82%
IE	0.00%	0.00%	0.00%	0.20%	0.20%	0.20%
IT	0.47%	3.43%	0.00%	1.70%	7.67%	0.00%
LT	0.00%	0.00%	0.00%	1.09%	1.09%	1.09%
LU	0.00%	0.00%	0.00%	0.68%	0.68%	0.68%
LV	0.00%	0.00%	0.00%	0.15%	0.15%	0.15%
PL	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
PT	1.38%	1.38%	1.38%	4.83%	4.83%	4.83%
SE	0.00%	0.00%	0.00%	0.59%	1.17%	0.00%
SI	0.00%	0.00%	0.00%	1.23%	1.23%	1.23%
SK	0.00%	0.00%	0.00%	1.75%	1.75%	1.75%
UK	0.18%	1.07%	0.00%	0.42%	1.84%	0.00%
Europe	0.25%	6.48%	0.00%	1.38%	11.56%	0.00%

Source: Authors calculations from Eurostat data

Table 9. Total fair premium (€/ha) for area yield insurance with 30% trigger (premiums calculated at FADN region level)

	Barley	Grain Maize	Potato	Rape	Rice	Soybean	Sugar beet	Sunflower	Wheat
AT	0	0	0	0		0	0	0	0
BE	0	0	103.73	17.30			0		0
CY	30.13		0						8.43
CZ	0	0	0	25.41		0	0	0	0
DE	0.95	5.48	2.107				0	6.35	0.61
DK	5.99		0	0			0		0
EE	7.70		0	22.31					0
ES	19.41	8.54	86.21	20.23	9.51		40.44	11.54	17.41
FI	5.85		79.82	0			29.12		8.15
FR	0.61	4.01	83.86	3.65	17.41	13.18	0.07	4.54	0.31
GR	1.03	0	0	12.83	0		6.81	0.41	0.77
HU	8.13	6.35	45.20	4.40	0	13.87	11.84	6.06	11.20
IE	0		0	14.23			0		0
IT	4.35	4.31	19.52	10.25	8.90	5.33	15.25	5.95	8.51
LT	10.52		104.42	30.20			33.37		0
LU	0		165.83	31.15					0
LV	4.37		0	54.91			0		0
MT			0						
NL	0	52.81	84.23	42.83			0		0
PL	0	0	0	0			0		0
PT	3.64	0	0	11.43	0		28.69	5.54	9.36
SE	0.43		127.14	0			0		0
SI	0	24.34	0	14.06			0		0
SK	12.98	24.27	0	0			0	0	0
UK	0		420.97						0.07
Total	6.35	4.32	30.70	9.17	6.12	7.04	6.72	7.31	4.17

Source: Authors calculations from Eurostat data

Table 10. Total fair premium (€/ha) for area yield insurance with 15% trigger (premiums calculated at FADN region level)

	Barley	Grain Maize	Potato	Rape	Rice	Soybean	Sugar beet	Sunflower	Wheat
AT	9.61	8.59	82.12	54.24		0	0	6.48	8.04
BE	4.31	0	207.99	26.30			0		0
CY	30.13		134.81						12.82
CZ	6.85	15.57	0	25.41		15.54	0	0	0
DE	7.88	13.61	173.22				17.91	15.52	7.92
DK	10.62		63.91	17.67			24.21		5.44
EE	14.54		97.78	29.39					5.01
ES	27.57	21.60	155.63	27.28	20.46		99.64	19.30	26.90
FI	15.98		116.40	16.53			53.55		22.88
FR	10.25	16.17	158.32	20.36	38.32	23.48	14.60	13.32	8.17
GR	5.06	0	0	21.93	16.98		25.39	7.55	5.06
HU	15.95	21.50	152.92	17.61	26.91	23.00	71.02	18.54	20.38
IE	8.58		190.18	21.17			38.83		12.12
IT	9.76	19.09	94.90	21.30	16.04	8.86	46.64	19.08	13.25
LT	18.24		145.97	38.06			52.94		12.24
LU	10.72		272.53	60.04					19.40
LV	7.35		0	68.70			54.60		4.02
MT			88.32						
NL	0	124.78	84.26	69.67			27.45		0
PL	7.33	0	38.16	38.24			6.63		0
PT	17.82	34.18	61.60	13.20	20.07		78.40	8.95	16.23
SE	7.88		210.35	13.73			0		1.20
SI	8.12	65.80	138.91	32.77			37.21		16.41
SK	12.98	35.88	131.67	11.02			36.58	10.46	21.51
UK	1.59		432.70						1.38
Total	13.74	25.23	91.83	23.07	18.88	12.10	27.87	15.91	10.35

Source: Authors calculations from Eurostat data

Table 11. Total fair premium (000€) for area yield insurance with 30% trigger (premiums calculated at FADN region level)

	Barley	Grain Maize	Potato	Rape	Rice	Soybean	Sugar beet	Sun-flower	Wheat
AT	0	0	0	0		0	0	0	0
BE	0	0	5,005	65			0		0
CY	1,576		0						44
CZ	0	0	0	9,496		0	0	0	0
DE	2,284	1,496	718				0	306	1,625
DK	6,302		0	0			0		0
EE	1,481		0	386					0
ES	71,836	3,834	22,918	23,049	775		7,528	11,080	40,650
FI	12,816		11,429	0			3,721		4,430
FR	1,231	7,095	16,329	5,837	275	1,168	33	2,917	1,501
GR	261	0	0	1,062	0		297	15	828
HU	2,709	6,810	1,780	2,441	0	300	889	2,472	11,626
IE	0		0	49			0		0
IT	1,617	4,121	2,367	4,669	1,822	1,584	4,103	751	24,242
LT	4,766		11,521	1,317			978		0
LU	0		154	50					0
LV	920		0	653			0		0
MT			0						
NL	0	485	14,256	390			0		0
PL	0	0	0	0			0		0
PT	1,074	0	0	3,862	0		358	1,391	13,303
SE	151		3,403	0			0		0
SI	0	1,209	0	58			0		0
SK	2,964	3,264	0	0			0	0	0
UK	0		19,451						81
Total	111,988	28,314	109,335	53,386	2,872	3,053	17,906	18,932	98,329

Source: Authors calculations from Eurostat data

Table 12. Total fair premium (000€) for area yield insurance with 15% trigger (premiums calculated at FADN region level)

	Barley	Grain Maize	Potato	Rape	Rice	Soybean	Sugar beet	Sunflower	Wheat
AT	2,776	1,617	3,049	3,717		0	0	103,000	2,250
BE	414	0	10,037	99			0		0
CY	1,576		1,025						66
CZ	3,716	822	0	9,496		41	0	0	0
DE	18,954	3,719	59,102				9,338	748	20,991
DK	11,185		2,358	2,583			1,627		2,266
EE	2,795		3,308	509					228
ES	102,050	9,696	41,371	31,086	1,668		18,548	18,528	62,819
FI	35,013		16,666	4,368			6,843		12,445
FR	20,535	28,568	30,825	32,508	606	2.81	7,049	8,565	39,205
GR	1,229	0	0	1,817	392		1,106	281	5,434
HU	5,314	55,255	6,024	9,760	75	498	5,328	7,563	21,152
IE	2,053		5,257	73			1,308		849
IT	3,630,	18,244	11,506	9,700	3,284	2,631	12,546	2,407	37,775
LT	8,266		16,106	1,659			1,552		4,026
LU	162		253	97					166
LV	1,548		0	818			770		563
MT			180						
NL	0	1,147	14,256	635			3,312		0
PL	7,998	0	43,632	18,115			2,366		0
PT	5,263	38,378	30,934	4,458	2,842		977	2,246	23,065
SE	2,817		5,631	828			0		354
SI	94	3,269	1,503	136			211		617
SK	2,964	4,826	3,950	1,913			1,317	759	8,440
UK	1,903		19,993						1,654
Total	242,314	165,543	327,006	134,373	8,865	5,251	74,243	41,200	244,364

Source: Authors calculations from Eurostat data

4.2.4.1. Total premium amounts for all crops

Table 9 and Table 10 show the total fair premium of RYI yield insurance in the case of the total crop surface in the country being insured. However, we have to take into account that these are only actuarially fair premiums, so a market premium would also include some loadings, such as assessment costs, administrative costs, etc. These loadings, according to Bielza et al. (2006), can increase the premiums amount by 42%[26]. A 50% market penetration would consequently mean a reduction by 50% of these quantities. Thus, assuming a load on the fair premium of 42%, the total cost and the per hectare cost of the commercial premiums with 50% penetration is shown in Table 13.

Table 13. Commercial premiums total cost (50% penetration) and average per hectare cost

	Total cost (€M)		Per hectare cost (€/ha)	
Trigger	30%	15%	30%	15%
Barley	79.5	172.0	9.0	19.5
GrainMaize	18.1	115.8	5.5	35.3
Potato	77.6	232.2	43.6	130.4
Rape	37.9	95.4	13.0	32.8
Rice	2.0	6.3	8.7	26.8
Soybean	2.2	3.7	10.0	17.2
Sugarbeet	12.7	52.7	9.5	39.6
Sunflower	13.4	29.3	10.4	22.6
Wheat	69.8	173.4	5.9	14.7

Source: Elaborated by authors from Eurostat-REGIO data

However, if we consider that index insurance has much lower loss assessment costs than traditional insurance, we could think that the loadings on the fair premium would be lower. The estimation of the amount is not straightforward, as these components of the premiums are most often in the hands of the private sector. However, we calculate that the loss assessment costs can represent the 5% of the premiums, and so, the increase on the fair premium could be reduced from 42% to 35-36%.

If we compare the total maximum cost for all countries, we can see that the increase in the total cost from a trigger of 30% to a trigger of 15% is as follows:

- Soybean	1.7
- Barley	2.2
- Sunflower	2.2
- Wheat	2.5
- Rape	2.5
- Potato	3.0
- Rice	3.1
- Sugarbeet	4.1
- GrainMaize	6.4

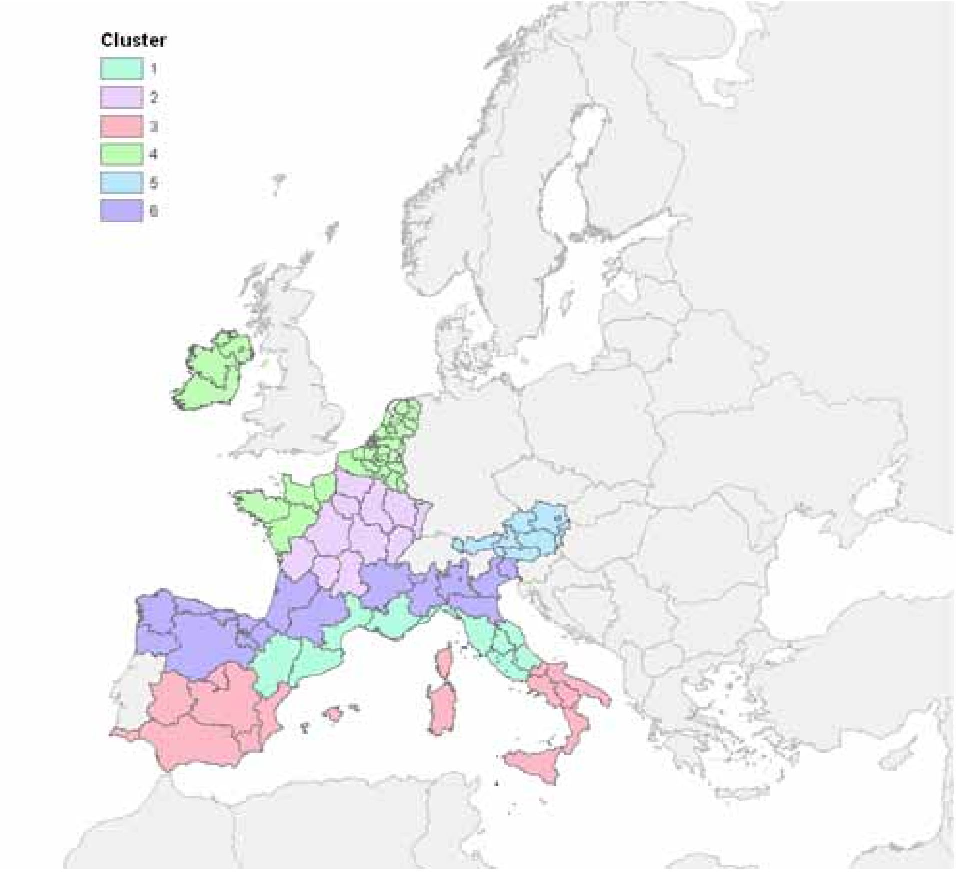
So, for many crops, the cost is multiplied by 2 to 3, and in the case of sugar beet and grain maize, it becomes multiplied by 4 and 6.4 respectively. This big difference probably means that the second group of crops have little catastrophic losses but a lot of "normal" or not extreme variability. Instead, in the first group the difference of the number of catastrophic losses and little losses is not so big.

4.3. Meteorological or climatic indexes

4.3.1. Analysis of possible meteorological indexes

In this section we analyse the possibilities of a number of indexes. Panel models have been adjusted to Eurostat time series of yield at NUTS-2 level. At the moment, tests have been concentrated on wheat, in order to identify a suitable approach to apply to a wider range of crops.

Regions with roughly similar climatic conditions have been grouped in clusters. Figure 2 shows the geographic layout of the clusters of regions. Notice that this map and the related models refer only to countries for which data are available at NUTS2 level. In particular this excludes countries like Germany, where data are available at NUTS1 level, and other countries for which some elaboration is still necessary to adapt the existing data.



Source: Made by authors from Eurostat data

Figure 2. **Some clusters of NUTS 2 regions to estimate the explanatory power of agro-meteorological indexes on the yield of main crops.**

We have estimated some simple explanatory models on the yield based on a number of indexes. A pre-selection of explanatory variables (indexes) in each cluster has been carried out through a stepwise regression, previous to the panel model. The indexes used for these models are defined as follows:

EMBERGERCONTINENTALITY: *Temperature* continentality or Emberger-derived Continentality Index *(M-m)* (Emberger, 1930)

Let M (^{o}C) be the mean daily maximum temperature of the warmest month and m (^{o}C) the mean daily minimum temperature of the coldest month. Then, the continentality is defined as follows:

$M - m < 15$ °C: oceanic insular zones

$15 \leq M - m < 25$ °C: lowland littoral zones

$25 \leq M - m < 35$ °C: semi-continental zones

35 °C $\leq M - m$: continental zones

RAINFALLSEASONALITY: *Precipitation* seasonality or Rainfall Seasonality Index (SI_P) (Walsh and Lawler, 1981)

Let P_Y (mm) be the annual precipitation, P_S (mm) the summer semester (May-October in the northern hemisphere, November-April in the southern hemisphere) precipitation, and P_W (mm) the winter semester (November-April in the northern hemisphere, May-October in the southern hemisphere) precipitation. Then, the rainfall seasonality index is defined as:

$$SI_P = \frac{P_S - P_W}{P_Y}$$

$SI_P < -0.13$: wetter winters than summers

$-0.13 \leq SI_P \leq 0.13$: uniform distribution

$SI_P > 0.13$: wetter summers than winters

DRYSOILDAYS: days when soil moisture < SWC_{WP} (Barnett et al., 2006)

Where SWC_{WP} (mm) is the soil water content at wilting point. Some basic hydrological properties are set to characterize the soil of interest:

- *FC* (m3 m-3): field capacity
- *WP* (m3 m-3): wilting point
- *h* (m): soil depth

MOISTURE: *Precipitation +Temperature* moisture or Moisture Index (I_M) (Carter and Mather, 1966)

Let P (mm) be the precipitation and T (^{o}C) the air temperature. Then, the moisture level is indicated by:

$I_M < -66.7$: arid

$-66.7 \leq I_M < -33.4$: semi-arid

$-33.4 \leq I_M < 0$: dry sub-humid
$0 \leq I_M < 20$: moist sub-humid
$20 \leq I_M < 100$: humid
$100 \leq I_M$: perhumid

GDDYEARLY (GrowingDegreeDaysYearly): Accumulated Degree Days

$\sum T_{avg} > T_c$ for a certain period of time* (Barnett et al., 2006)
Where $\sum T_{avg}$ (^{o}C-days) is the sum of T_{avg} or average temperatures and T_c (^{o}C) is the critical air temperature (in general, 0 ^{o}C; base temperature for growth, e.g. 5.6 ^{o}C)
* the period of time can be either the whole year, the coldest month, the winter trimester (December-February in the northern hemisphere; June-August in the southern hemisphere), or first semester of the year (January-June in the northern hemisphere; July-December in the southern hemisphere).

DESERTIFICATION: *Precipitation+Evapotranspiration* aridity or Desertification Index (I_D) (UNEP, 1992)

Let P (mm) be the precipitation and ET_Y (mm) the annual total reference evapotranspiration. The Desertification level is given by:

$I_D < 0.05$: very arid
$0.05 \leq I_D < 0.20$: arid
$0.20 \leq I_D < 0.50$: semi-arid
$0.50 \leq I_D$: dry sub-tropic

ACCUMULATEDFROSTYEARLY: sum of degree days where $T_{min} < 0.0$ ^{o}C (Barnett et al., 2006)

Where T_{min} (^{o}C) is the minimum air temperature.

DRYNESS: days when $P < P_t$ (Barnett et al., 2006)

Where P (mm) is the precipitation and P_t (mm) is the minimum threshold precipitation (e.g. 0.2 mm)

The panel models are used because they allow taking into account the time dimension in the model. Table 14 shows the coefficients of these models. However, they still need to be improved before tackling the problem of quantifying the risk measured by these indexes.

Table 14. Panel model estimated parameters

	CLUSTER					
Coefficients	1	2	3	4	5	6
EMBERGERCONTINENTALITY	-0.0304	-0.1217			-0.047	-0.0380
RAINFALLSEASONALITY				1.1698		
DRYSOILDAYS	-0.0034	-0.0100		-0.0066	-0.004	-0.0056
MOISTURE	-0.4469	-1.3264		-0.404	-0.358	-0.4913
GDDYEARLY	0.0014	0.0039	0.0009	0.0037	0.002	0.0026
DESERTIFICATION			-0.6692			
ACCUMULATEDFROSTYEARLY			-0.0019			
DRYNESS			-0.0114			
n	10	11	16	32	9	17
T	23-30	30	19-30	12-30	30	16-30
N	274	330	406	798	270	429
Multiple R-Squared	31.4 %	32%	16.9%	31.5%	28.1%	30.5%

Source: Elaborated by authors from Eurostat data

Where n is the number of regions in each cluster; T is the number of years available for every region (or the minimum and maximum number of years per region in each cluster); N is the total number of observations. The Multiple R-Squared indicates that the models with a higher value (for example, cluster 2) explain better the yields than the models with lower values (for example cluster 3). So, the models for cluster 1, 2, 4, and 6 have a similar explanation capacity.

We can observe that the yield in the regions with a more oceanic climate (Cluster 4) is strongly defined by the rainfall seasonality, so it is positively correlated with the proportion of summer rainfall with respect to winter rainfall, and it is negatively correlated with the moisture index, indicating that too high air moisture has a negative effect on yields. Air moisture is also an important index in regions in Cluster 2 (mainly Centre and West of France) On the other hand, yield in regions with a warm Mediterranean climate (Cluster 3) is more determined in a negative way by the desertification index.

An insurance could be thus designed for each region on the most relevant parameter or combination of parameters according the results of Table 14. However, these combinations of indicators do not explain yields optimally, as the Multiple R-Squared is only 30%. Perhaps other indicators should be explored. Besides, it is also possible that there is too much heterogeneity within each NUTS2 region and a meteorological yield-tailored index could only have a good explanation capacity at a more disaggregate level. In section 4.4, we bring another example which underlines the importance of the geographical aspects and combination of agro-meteorological conditions in determining the efficiency of an indicator.

4.3.2. Analysis of late frost on winter wheat

In this subsection we analyse an index for frost risk. Extreme cold in winter can make a substantial damage to crops. The level of damage obviously depends on the minimum temperatures, but should not be assessed by a straight mapping of minimum temperatures as reported by meteorological observatories (temperature of the air at 2 m above the ground). It requires some elaboration taking into account the recent thermal history (last days) and the protective effect of snow. A progressive lowering of temperatures is less harmful than an abrupt frost, because the plant has the time of protecting itself by a physiologic process knows as “hardening”.

The estimation of the frost impact is complicated because, besides the meteorological factors like air temperature and snow depth, one must take into consideration also the development stage of the plant, the gradual increase of plant resistance to frost during the exposing of low but positive temperatures (process known as hardening) and the losing of this capacity (dehardening) at temperatures higher than 10°C (Gusta and Fowler, 1976).

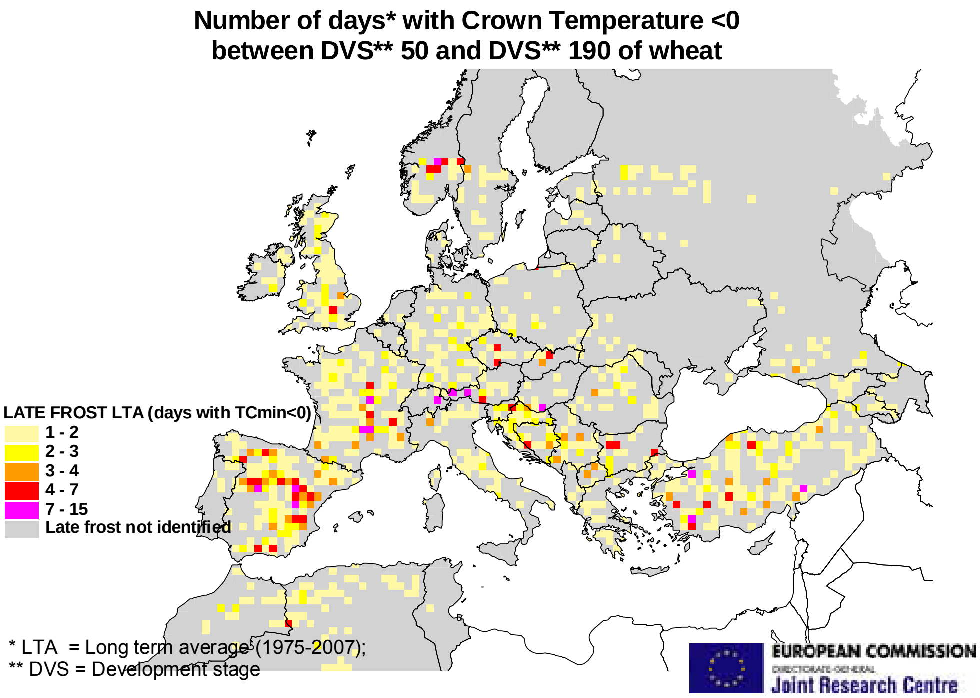
As we previously said, we estimate the temperature at crown level using the following formula (Ritchie, 1991):

Tcr = 2.0 + TempAir*(0.4+0.0018*(SnowDepth – 15)^2)

A temperature of 0°C at 3 cm soil depth (crown level) doesn’t represent menace for the main winter crops but it implies the stop of the growth; temperatures between -6° and -9°C at 3 cm soil depth (crown level) may affect the unhardened sensitive winter cereals (like winter barley or durum wheat). Temperatures between -9° and -12°C at 3 cm soil depth may affect medium hardened sensible winter cereals (like winter barley or durum wheat) or unhardened winter wheat corps. Temperatures between -12° and -15°C at 3 cm soil depth may reduce drastically the plant population of sensible winter cereals (like winter barley or durum wheat) or even affect the medium hardened winter wheat corps. At temperatures between -15° and -18°C at 3 cm soil depth, winter crops like winter barley or durum wheat have very low chances of survival and serious damages for winter wheat are expected (depending on cultivar and hardening index). Below -18°C at 3 cm soil depth, winter wheat crops are subject of severe to lethal damages (spring re-sowing may be necessary in most of the cases) some cultivars of rye are able to resist at -21°C.

Within this study a new aspect of frost, namely late frost was introduced in our MARS Crop Growth Monitoring System. Late frost was assessed for the plant development stages (DVS) between 50 (after the beginning of tillering and start of intensive growth moment in which the plant is considered already dehardened) and 190 (just before maturity).

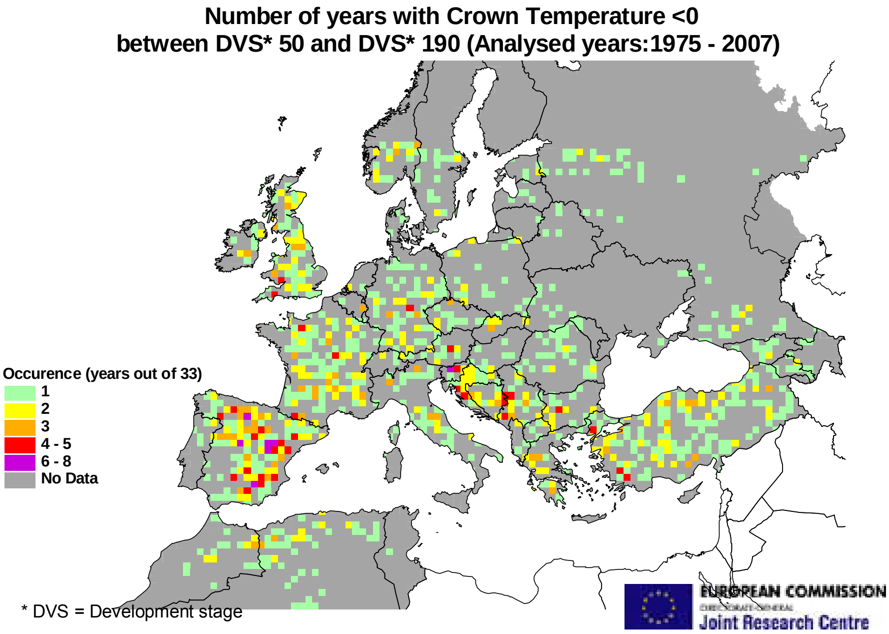
The following maps give an idea of the frequency of late frost events and show in which zones of Europe result to be more vulnerable to this climatic risk.



* LTA = Long term average (1975-2007);
** DVS = Development stage

Source: Authors elaborations from Mars data.

Figure 3. Late frost: number of days with temperature at crown level < 0 °C for winter wheat between development stage 50 and development stage 190, long term average 1975-2007.

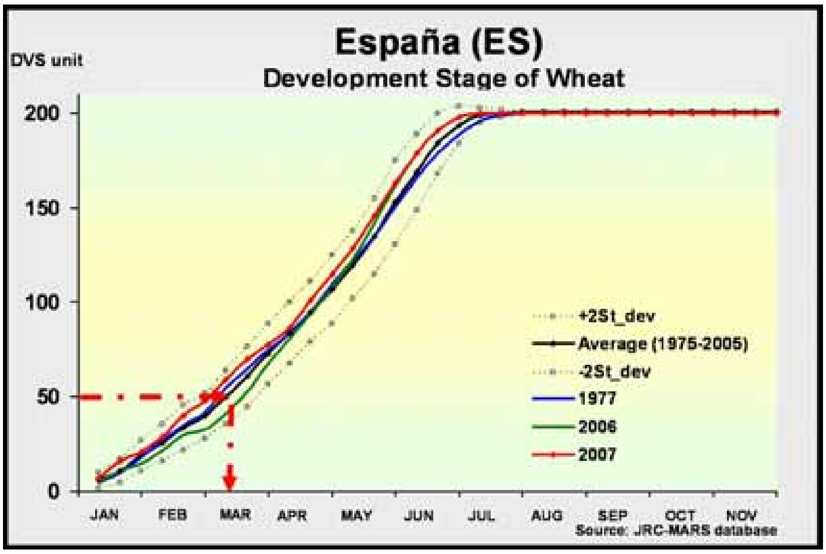


* DVS = Development stage

Source: Authors elaborations from Mars data.

Figure 4. Occurrence of late frost (n° of years out of 33 years)

Figure 4 determines how frequently the late frost event can appear and in which European areas has a more aggressive character.

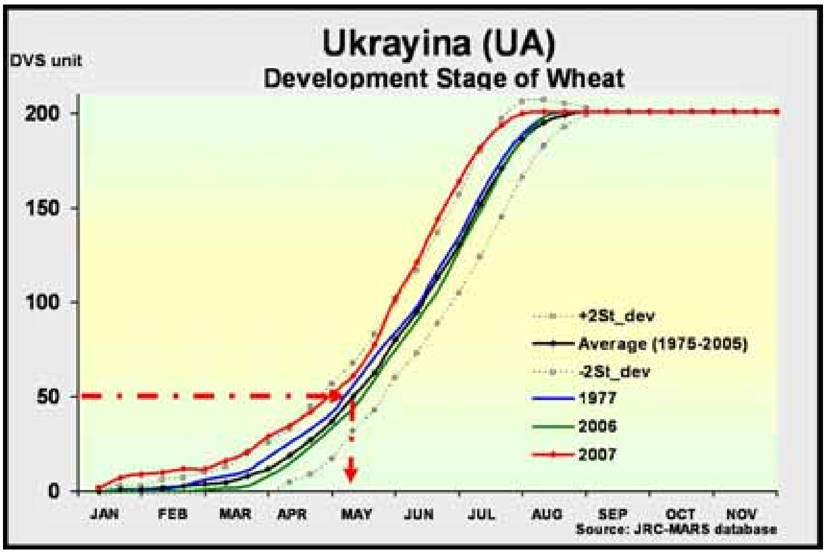


Source: Authors elaborations from Mars data.

Figure 5. Occurrence of the development stage 50 of winter wheat in Spain

The chart (Figure 5) represents in which period of the year the winter wheat reaches the considered development stage for late frost analysis. The model used is able to simulate the crop phenology using the sowing date provided by one of the two crop calendars available in CGMS (Willekens, 1998; Kucera and Genovese, 2004)

It's interesting to link the map in Figure 3 and Figure 4 with the chart in Figure 5. The chart explains why the risk of late frost in Spain is so high. The development stage of the plant 50 occurs in March, winter period in which late frost events are highly probable.



Source: Authors elaborations from Mars data.

Figure 6. Occurrence of the development stage 50 of winter wheat in Ukraine

The figure above (Figure 6) shows an opposite situation. In Ukraine there is practically no risk of late frost (see maps, Figure 3 and Figure 4) the reason is because the development stage of the plant 50 occurs during the month of May, in which temperatures are more gentle.

This analysis is useful to underline that the index risk can differ very much from one European region to another. The examples shown in this subsection aim to explain the level of vulnerability of the same crop, at the same development stage can vary as function of climatic conditions. In the cases observed above, winter wheat in Spain appears to be more exposed to the late frost risk, because the physiological stage in which the plant is potentially vulnerable occurs in March, so the risk of late frost is higher. On the contrary in Ukraine the same crop at the same physiological development stage exceptionally can suffer a late frost event as in that geographical area the temperature is higher as it is May. These conclusions express the need of analyse the climatic risk under many points of view, accounting with many physiological aspects related to the crop and many other expertise needed to aggregate one data with other and reach a robust interpretation of results.

This study still has few limits that need further research to improve the results. For instance, the risk analysis at grid level does not take into account if in the analyzed grid there is winter wheat or another crop. So, the next step of the late frost risk study will consist in crossing the information of the CORINNE land cover that regards “non-irrigated arable” land-use class in the grid with statistical information of crop area in the NUTS and weight the results to the risk considered. Moreover it is necessary to clarify that the late frost risk indicator does not give information on the intensity of the event, so it’s hard to quantify an eventual yield loss due to the late frost event. This indicator gives a picture on the regions where the late frost can occur and with which frequency over a certain period of years.

4.4. Parameters computed from an agro-meteorological model

There is a wide literature of agro-meteorological indexes that should be able to explain potential losses in the yield of main crops due to a-biotic factors. For a good example of an index[9] based on agro-meteorological parameters, see the case of the Weather Yield Index (WYX) in Malawi by Chavula and Gommes (2006) (section **3.4.3 Examples of agro-meteorological index insurances**). In this section we analyse several indicators based on the results from the CGMS system: the relative soil moisture (RSM), the potential water consumption (PWC) and the Water-Limited Storage Organs Weight (WLSOW).

4.4.1. Testing the indices

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[9] It is in fact a yield-tailored index based on several agrometeorological indicators (see section 3.2.2)

We tested three agro-meteorological indices:

- The Relative Soil Moisture index (RSM),
- The Water-Limited Storage Organs Weight Index
- Total Water Consumption index (TWC).

The weather data used for testing the agro-meteorological-based indices for EU27 were collected from the MARS-STAT database. The yield data come from the Eurostat database, for which we also apply the de-trending procedure.

Specifically, the data collected included the following:

a) Long-term (1975-2006) weather data from Mars-Stat database.

b) For the RSM we considered the Plant Development Stage (DVS) form 50-150, for the TWCI the DVS 190 for all crops analysed from the CGMS (see Annex 4A in section 9.5).

We did a linear regression analysis comparing the detrended yield and the various agro-meteorological indicators, outputs of the CGMS.

The aim was to observe the correlation in between the agro-meteorological indices and the yield data.

4.4.2. Relative Soil Moisture (RSM)

In CGMS the relative soil moisture (RSM) may be defined as the percentage of water incorporated into the soil and available to the crops. The available water is estimated as difference of the soil water content between the soil humidity at “field capacity” and at the “wilting point” (for mesophytes plants) dynamically calculated according to the “rooting depth” along the crops cycle (considered the soil properties homogeneous along soil depth).

The relative soil moisture (RSM) is an indicator of drought risk. It is estimated by CGMS using meteorological data interpolated in a 50-km grid. As the different altitudes are recorded in the grid, ,RSM integrates the information on rainfall and on soil water capacity and needs of the plant, taking into account the phenological calendar and actual evapotranspiration.

If CGMS simulates for a given crop a value 0 for the Relative Soil Moisture (RSM), this indicates a considerable water stress for that crop; if this happens during the development stages of flowering (can cause sterility) or grain filling (less biomass production), this corresponds to a serious drought situation with consistent losses. Actually the crop can suffer differently from drought depending on its vulnerability which is given from the development stages. We have made a first rough split before/after flowering starts. After the start of flowering (until short before maturity), a drought event is considered twice as serious as before flowering. When the grains (or other storage organs) have been filled and the plant is close to maturity, dry soil is not considered anymore a source of damage.

Alternative drought indicators can be defined considering intermediate drought situations when:

a) the RSM <10%

or

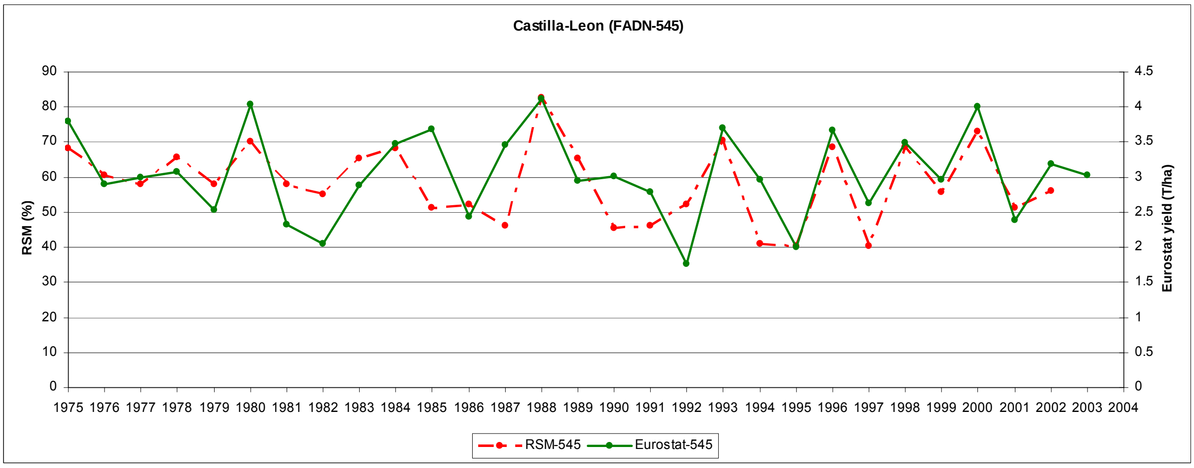
b) the RSM < ½ min (40%, the long-term average RSM for that time of the year).

This means for example that, in case (b), a RSM=15% in an area where the long term average is slightly above 30 % will be considered an intermediate drought situation, but RSM=25% in an area where the long term average is more than 50% will not be considered drought at all. This indicator seems better modulated, as has been shown in Bielza et al. (2006).

For the current study, the values of RSM (GRID_YIELD table) at each 10 days (the output frequency of CGMS) between the development stages “beginning of intense vegetative growth“(DVS 50) and “mid of grain filling” (DVS 150) were summed up for each combination CROP x GRID x YEAR. Later these RSM values were aggregated at FADN level. It was preferred a sum of RSM instead of an average of this indicator in order to account for the differences in developmental rate of the same crop in years with different thermal conditions.

On having a closer look to the positive results, it seems that some cases may raise interest. For example, it’s possible to find very positive results in many of the main wheat producing regions. The correlation for wheat in Castilla y Leon (Spain) is 0.57. In Centre (France) the correlations attains 0.56.

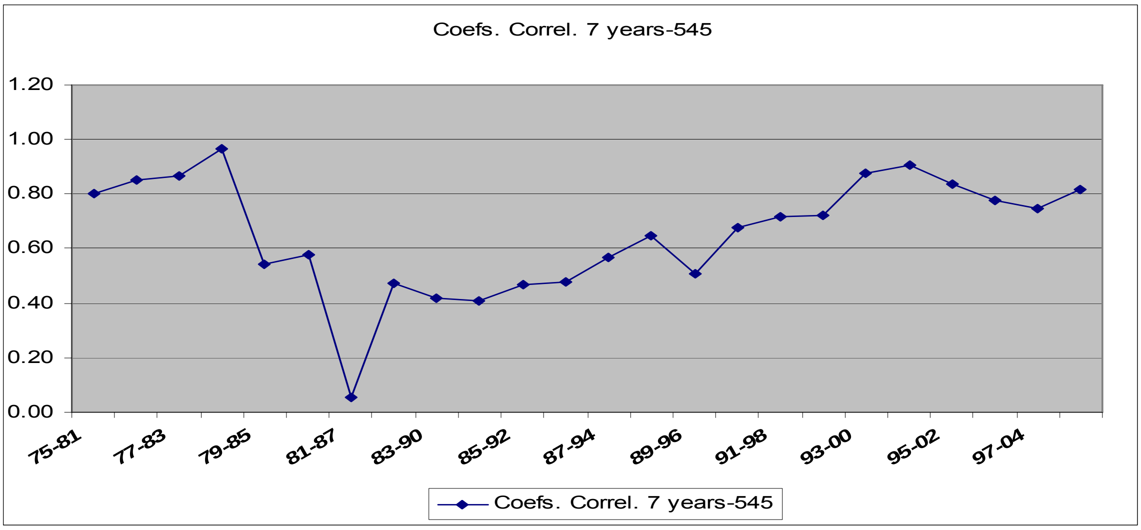
The Figure 7 shows the correlation for RSM Index and the yield variability of wheat in Castilla y Leon (Spain). The fluctuations of the yield, especially in the period from 1995 to 2001, coincide with the RSM fluctuations.



Source: Authors calculations from Eurostat data and CGMS data from 1975 to 2004

Figure 7. RSM index and Eurostat yields for wheat in Castilla y Leon (Spain)

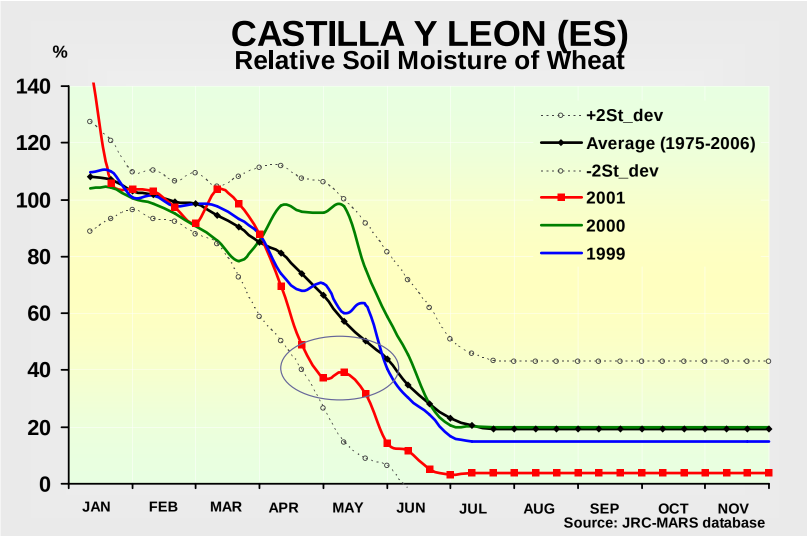
The figure below, represent the trend of correlation coefficient for wheat in Castilla y Leon on a 7-year time lag window. The evolution of the coefficient is clearly improving from the nineties.



Source: Authors calculations from Eurostat data and CGMS data from 1975 to 2004

Figure 8. Correlation Coefficients for TWC index and wheat yield data over a 7-year period. In Cataluña (Spain).

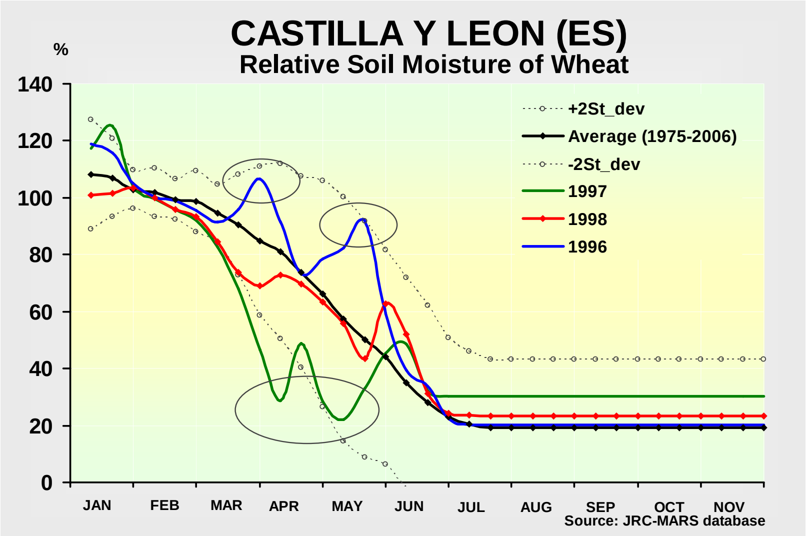
Observing the case of wheat in Castilla y Leon, from Figure 7, it's interesting to notice that the years 1997 and 2001 the RSM index was very low and reflects the lower yield. The graphs proposed below (Figure 9; Figure 10) helps to visualize the variation of RSM index during a period of 3-year in the first graph, were the year 2001 results to be a dry year.



Source: Authors calculations from CGMS data

Figure 9. RSM index and for wheat in Castilla y Leon (Spain); 1999, 2000, 2001.

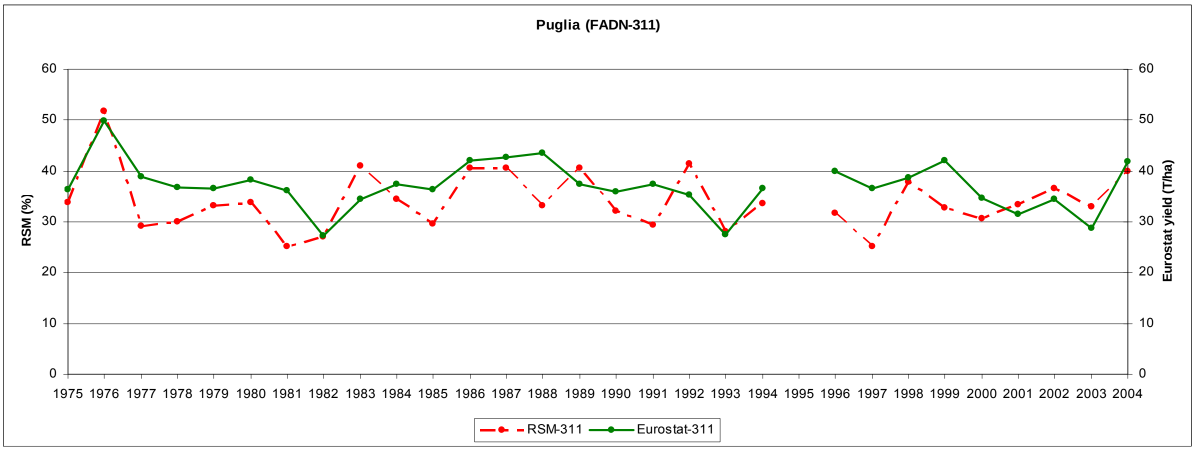
The graph in Figure 10 shows the RSM as in the previous one, but in three different years. Here it's interesting to notice the low RSM recorded for the year 1997, in which also the yield dropped.



Source: Authors calculations from CGMS data

Figure 10. RSM index for wheat in Castilla y Leon (Spain); 1996, 1997, 1998.

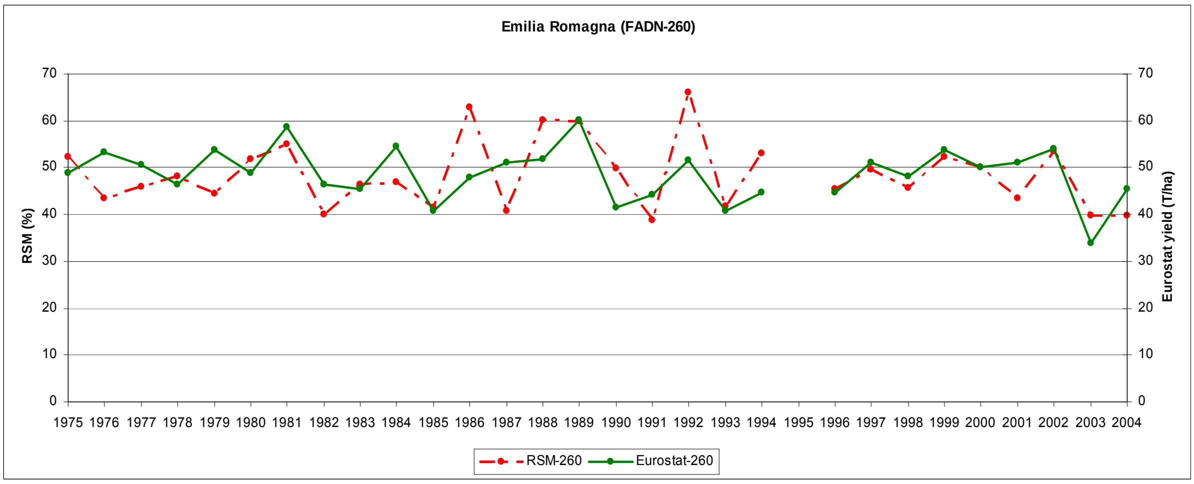
For the FADN region Puglia (Italy) the RSM indicator for sugar beet is well correlated with the yield. Apart from a missing data gap from 1994 to 1996, also in this case it is evident the improvement of the correlation coefficient values for the last period of time analyzed (1996-2004). The RSM seems to explain well the yield variability for sugar beet in Puglia.



Source: Authors calculations from Eurostat data and CGMS data from 1975 to 2004

Figure 11. RSM for sugar beet in Puglia (Italy)

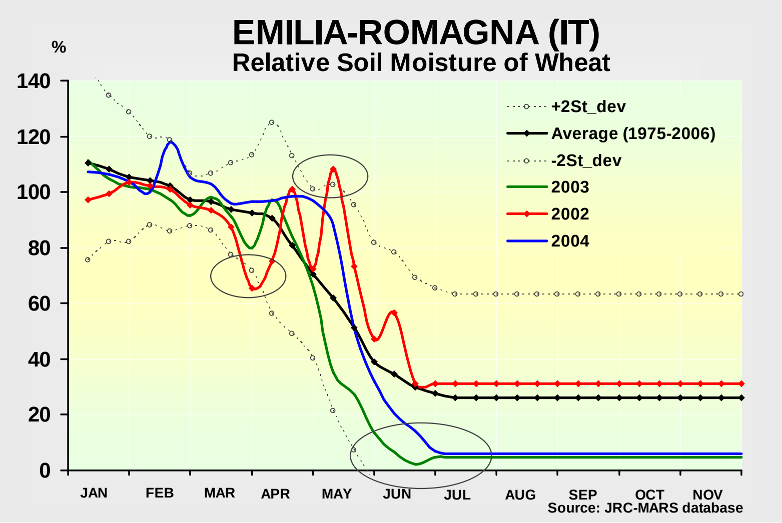
The same situation appears in a central-northern region of Italy, Emilia Romagna, where the correlation coefficient is 0.50).



Source: Authors calculations from Eurostat data and CGMS data from 1975 to 2004

Figure 12. RSM for sugar beet in Emilia Romagna (Italy)

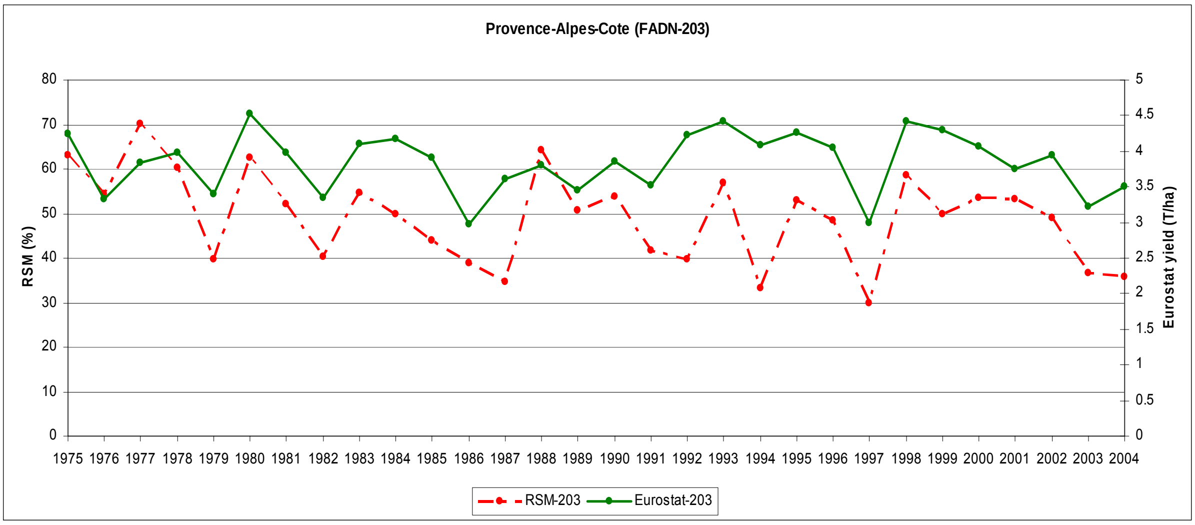
The graph in Figure 13 shows the variation of the RSM indicator for 3 different growing seasons, compared with average. The year 2003 recorded a consistent yield loss and the RSM was much lower than average. The RSM indicates an important water stress in 2003.



Source: Authors calculations from CGMS data

Figure 13. RSM for sugar beet in Emilia Romagna (Italy)

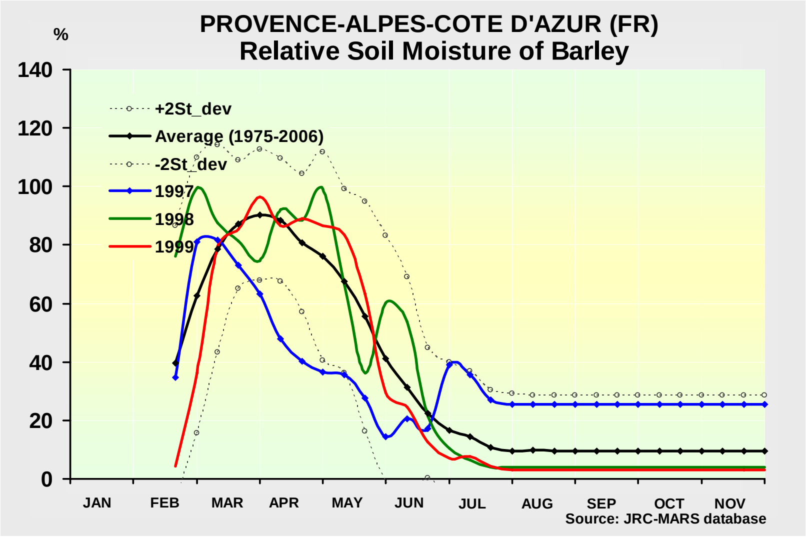
For barley there is an example showing the correlation (0.56) in the south of France.



Source: Authors calculations from Eurostat data and CGMS data from 1975 to 2004

Figure 14. RSM for barley in Provence-Alpes-Cote (France)

The chart below displays 3 growing seasons from 1997 to 1999. The year 1997 suffered a consistent lack of water in during certain development stages in which the crop is highly vulnerable; this might be the cause of the lower yield for that year.



Source: Authors calculations from Eurostat data and CGMS data from 1975 to 2004

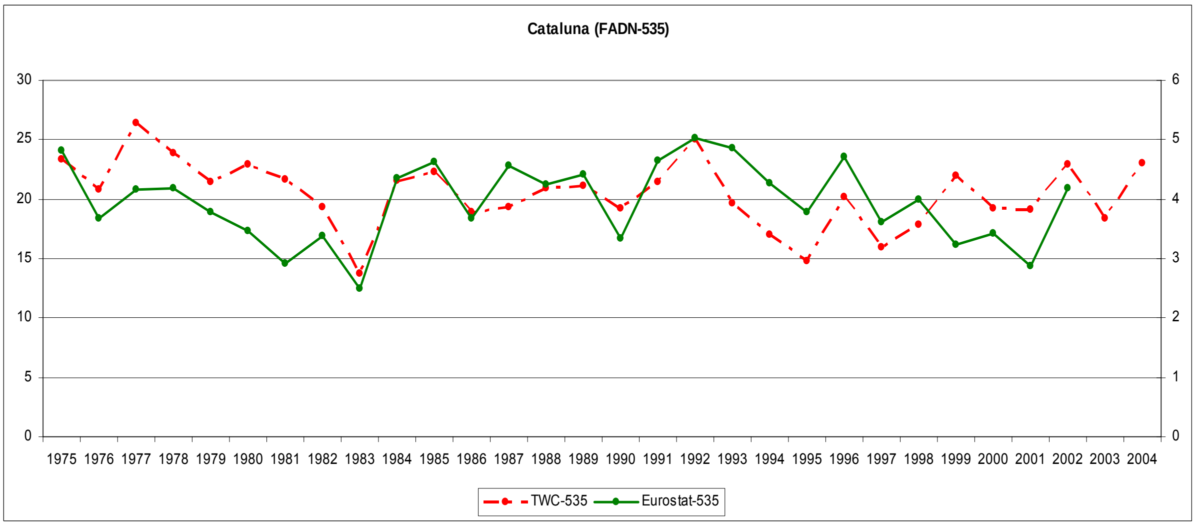
Figure 15. RSM for barley in Provence-Alpes-Cote (France)

4.4.3. Total Water Consumption (TWC)

In CGMS, the TOTAL WATER CONSUMPTION (cm) is a cumulated value of the actual daily transpiration. Transpiration is the loss of water from the crop to the atmosphere. Water loss is caused by diffusion of water vapour from the open stomata to the atmosphere. The stomata need to be open to exchange gasses (CO_2 and O_2) with the atmosphere. To avoid desiccation, a crop must compensate for transpiration losses, by water uptake from the soil. In WOFOST, an optimum soil moisture range for plant growth is determined as function of the evaporative demand of the atmosphere (reference potential evapotranspiration of a reference canopy) .Within that range, the transpiration losses are fully compensated. Outside the optimum range, the soil can either be too dry or too wet. Both conditions lead to reduce water uptake by the roots, in a dry soil due to water shortage, in a wet soil due to oxygen shortage. A crop reacts to water stress with closure of the stomata. As a consequence, the exchange of CO_2 and O_2 between the crop and the atmosphere diminishes, and hence CO_2 - assimilation is reduced. This effect is quantified assuming a constant ratio of transpiration to gross assimilation.

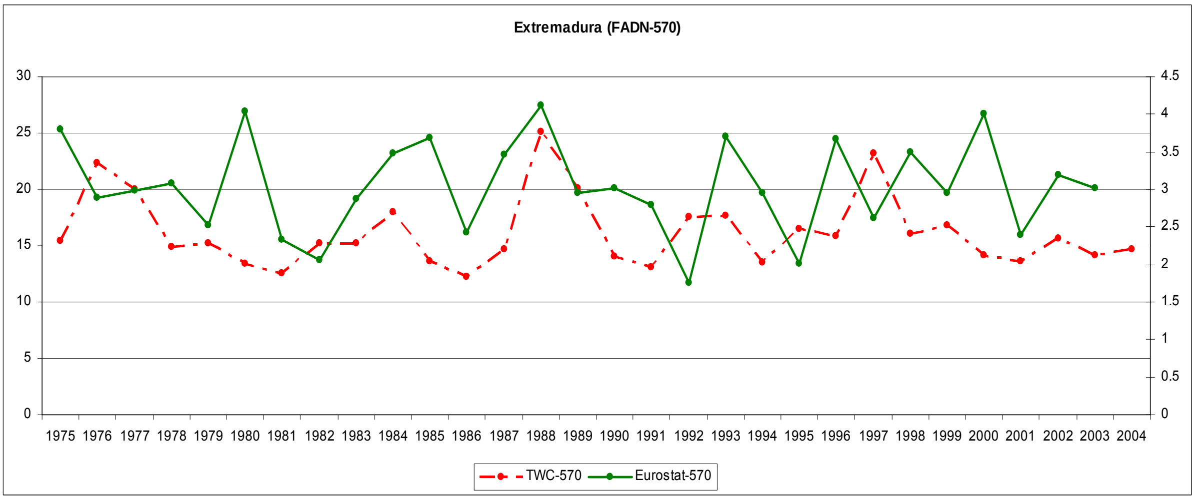
For the current study, the values of TOTAL WATER CONSUMPTION (cm) (GRID_YIELD table) for development stage “maturity” (DVS 200) were extracted for each combination CROP x GRID x YEAR. Later these values were aggregated at FADN level.

There are some positive results which may raise interest. For instance, the correlation for wheat in Cataluña (Spain) is 0.44; in Greece is 0.73. In Bretagne (France) the correlations for grain maize attains 0.74. The figures below show the evolution of in time of TWC and Eurostat detrended yields in both regions.



Source: Authors calculations from Eurostat data and CGMS data from 1975 to 2004

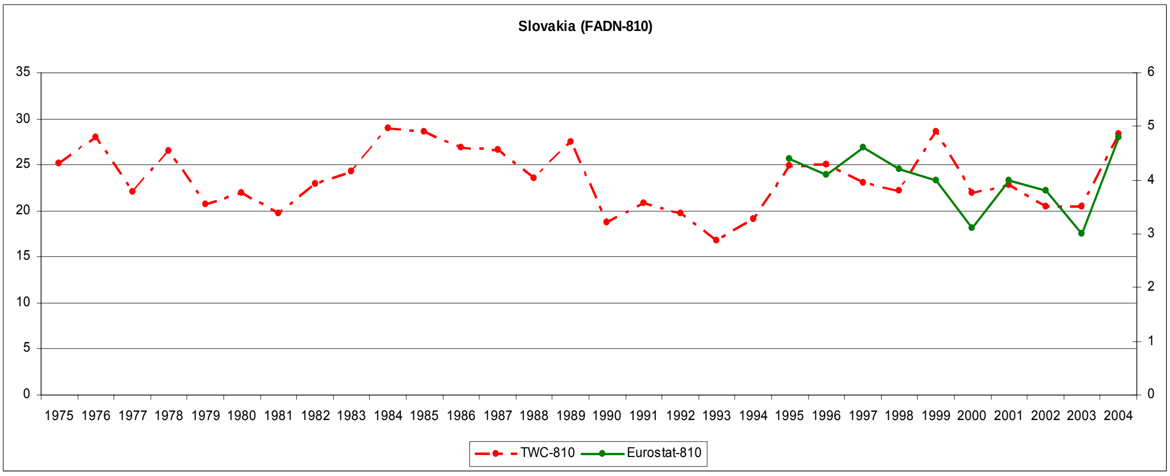
Figure 16. TWC for wheat in Cataluña (Spain)



Source: Authors calculations from Eurostat data and CGMS data from 1975 to 2004

Figure 17. TWC for wheat in Extremadura (Spain)

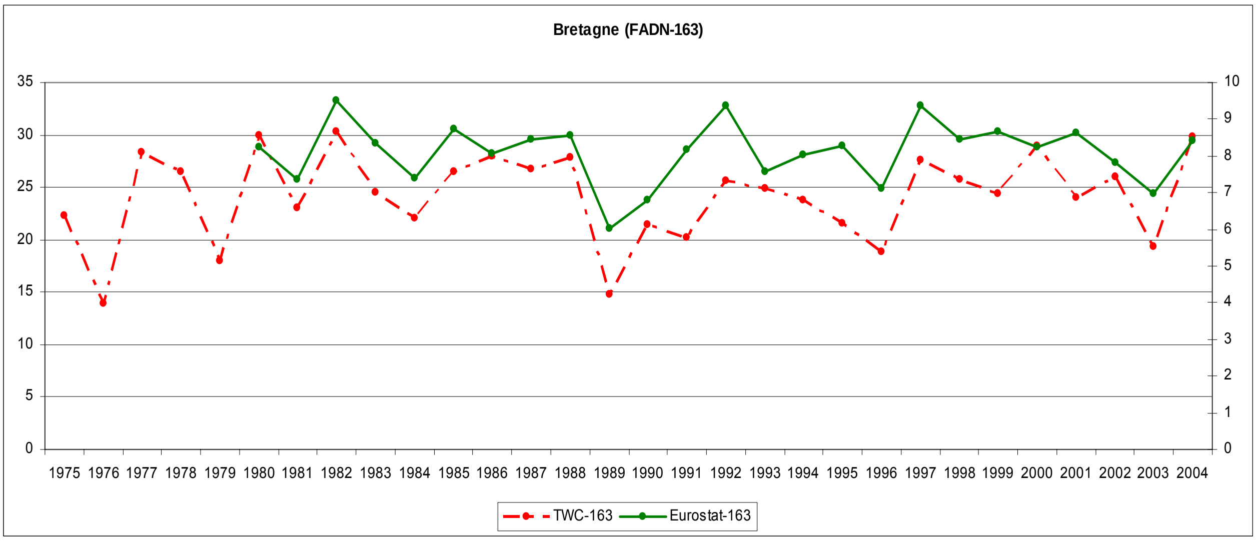
As we mentioned already for new MS the analysis must be limited to recent years because no data is available before 1995.



Source: Authors calculations from Eurostat data and CGMS data from 1975 to 2004

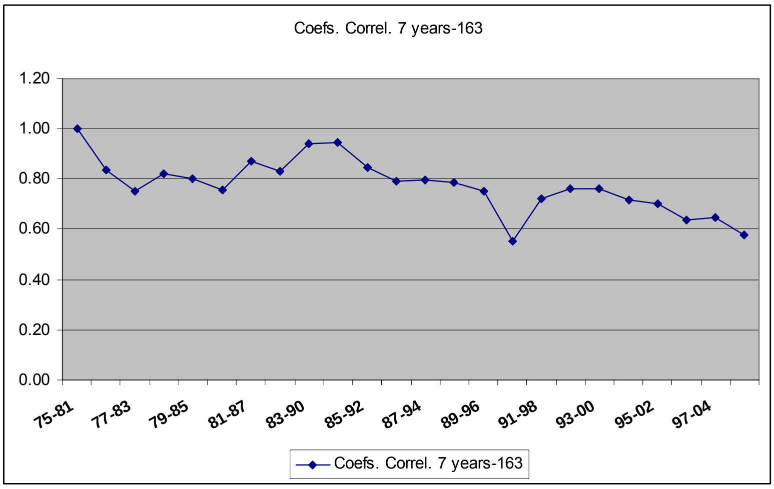
Figure 18. TWC for wheat in Slovakia

The correlation for grain maize in Bretagne (France 163) is 0.74.



Source: Authors calculations from Eurostat data and CGMS data from 1975 to 2004

Figure 19. TWC for grain maize in Bretagne (France)



Source: Authors calculations from Eurostat data and CGMS data from 1975 to 2004

Figure 20. Correlation Coefficients for TWC index and Grain Maize yield data over a 7-year period. Bretagne (France)

4.4.4. Water Limited Storage Organs Weight (WLSOW)

The WLSOW index is included in the analysis of the minimal thresholds for normalised indices, presented in the next paragraph. As explained in section **9.5**, CGMS uses the WOFOST simulation model to simulate crop parameters. WOFOST is a deterministic, dynamic, explanatory “plant model” (see Genovese 2004 for further details). The initial version of this model was developed by the Centre for World Food Studies and AB-DLO (van Diepen et al., 1988; 1989). In the CGMS, WOFOST version 6.0 has been used (Hijmans et al., 1994).

In WOFOST, crop growth is simulated on the basis of eco-physiological processes. The major processes are phenological development, CO_2 assimilation, transpiration, respiration, partitioning of assimilates to the various organs, and dry matter formation. The plant organs considered are: roots, stems, leaves and **storage organs** (grains or tubers). **Potential** and **water-limited** growth is simulated dynamically, with a time step of one day. The **potential** situation is only defined by temperature, day length, solar radiation and crop parameters (e.g. leaf area dynamics, assimilation characteristics, dry matter partitioning, etc.). For this situation the effect of soil moisture on crop growth is not considered and a continuously moist soil is assumed. The crop water requirement, which in this case is equal to the water consumption, is quantified as the sum of crop transpiration and evaporation from the shaded soil under a canopy. To calculate the potential crop growth, the soil parameters rooting depth and soil physical group are not needed. Therefore in a climatic grid cell all EMU's have the same simulation results for the potential situation. In the **water-limited** situation soil moisture determines whether the crop growth is limited by drought stress. In both, the potential and water limited, situations optimal supply of nutrients is assumed.

For each situation, dry matter per hectare of above-ground biomass and storage organs such as grains and roots (potatoes and sugar beets) are simulated from sowing to maturity or harvest on the basis of physiological processes as determined by the crop's response to daily weather, soil moisture status and management practices (i.e. sowing density, planting date, etc.). The required inputs for WOFOST per simulation unit are daily weather data, soil characteristics, crop parameters and management practices.

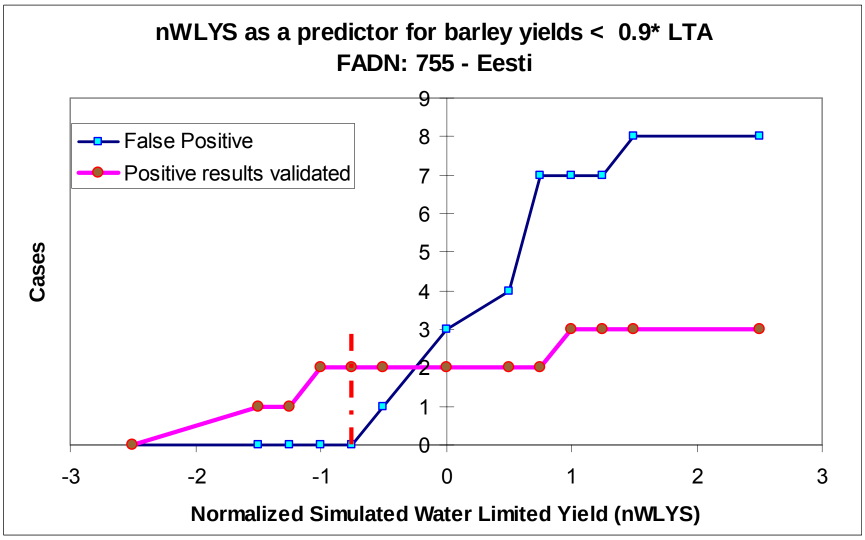
The parameter which is closest to actual yields is the "water-limited storage organs weight". However, sometimes a re-calibration based on observed data is needed. This can be explained by the fact that the model assumes as constant or as not influencing biotic and a-biotic limiting factors, such as pests and diseases, micronutrients deficiencies. This explains why simulated storage organ does not completely explain plant yield. The quality of the re-calibration versus observed time series of yields becomes of course dependent as well on the quality of the reference data. Besides this, it does not integrate the technological development (a more efficient agriculture, best variety selection), that can be strongly variable, both in time and space. Thus, a time series analysis is often necessary to account for the presence of trend factors in interannual yield variations.

4.4.5. Analysis of minimal thresholds for normalised indices

The objective of this section is to explore the possibilities of finding a threshold for each indicator which is able to point out bad years. So, these analyses do not to intend to provide a loss assessment based on an indicator, but to see if there is a threshold able to point out all bad years or, in a less severe test, most of the bad years. Conventionally, we defined as "bad year" a year with yield below -10% of the mean of detrended yields for all available years.

With this objective, we make tests analysing the number of positive results (the indicator points out a bad year when there is a bad year), of negative results (the indicator shows it is not bad year and there is not), of false positives (the indicators shows that it is a bad year but it is not) and the false negatives (the indicator does not reflect a bad year but it is). Due to the fact that a “bad year” may be determined by weather conditions unrelated with the considered indicator (e.g. a drought indicator will not account for the years with frost damages), at this step, it was not an objective the reduction of the number of “false negative” years. The indicators considered are: WLSOW (in the figures called water limited yield simulated WLYS), cumulated RSM between beginning of tillering and mid of grain filling and the TWC. In order to compare the thresholds for different FADN regions the values of the three considered indicators were normalised.

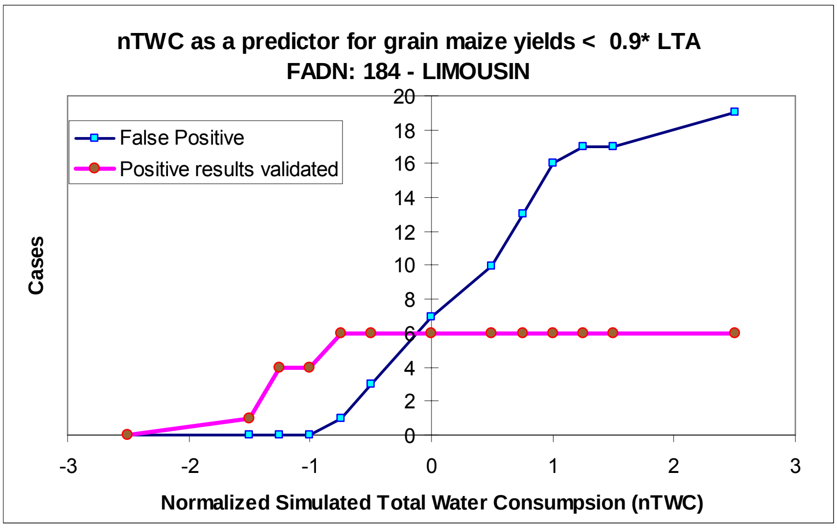
Figure 21 shows that a threshold of -0.75 of the normalized simulated water limited grain yield (WLSOW) of barley in Estonia is able to select 2 “bad years” out of 3.



Source: Authors calculations from Eurostat data and CGMS data

Figure 21. WLSOW and Eurostat yields for grain maize in Pays de La Loire (France)

Figure 22 gives an example (Limousin –France, grain maize) of a threshold of -1 for the normalized TWC. With this threshold, it is possible to separate 4 “bad years” out of 6. With a threshold of -0.75 all the “bad years” are pointed out but there appears also a false positive.



Source: Authors calculations from Eurostat data and CGMS data

Figure 22. WLSOW and Eurostat yields for grain maize in Pays de La Loire (France)

This approach can be developed in order to introduce automatic selection of the thresholds, automatic calculation of the kappa index for the confusion matrix (good-bad, years), introduction of new indicators (including aggregate indicators) and selection of a second (upper) threshold for supra-optimal effects.

4.5. Parameters from satellite images

4.5.1. The satellite images and the MVC NDVI

We will use an index quite similar to the one used by the Spanish insurance for pastures (section 9.4.4.2). However, we will not use information from the meteorological NOAA AVHRR satellite but from the SPOT-VEGETATION (SPOT-VGT) satellite. The more recent SPOT-VGT sensor is optimized for the purpose of evaluating the vegetation canopy almost every day, with nearly the same spatial resolution as the NOAA AVHRR (1 km), although with finer optical bands, and more stability so that images from one day to another have only a difference of 300 meters.

The data under goes several pre-processing steps, which are performed by the Flemish Institute for Technological Research (VITO). The steps comprise a sensor calibration, geometrical and atmospheric corrections as well as compositing from daily to ten-daily values (decades). For the latter one, we used the Maximum Value Compositing approach, which is employed for the Spanish insurance too (MVC NDVI, see section 3.4.4). NDVI original values are between -1 and 1. In order to avoid negative numbers, rescaling is done according to the equation: NDVI=(NDVIoriginal/0.004)-0.08, so that NDVI I scaled between 0 and 250.

A curve of decadal MVC NDVI is obtained for every pixel. This evolution curve is smoothed in order to eliminate the residual noise. For this, we use an algorithm of the type modified SWETS (Klisch et al. 2006, Swets 1999,), instead of "Double 4253H" used in the Spanish pasture insurance. The reference curves built from the MVC NDVI are defined as beginning on the first decade of October and finalized on the last decade of September of the next calendar year. The data series available extend from October 1998 to September 2007. Whenever information is not available for a particular period, a linear interpolation method is used to fill the missing gaps[10].

4.5.2. The masks

We want to be able to prove whether there exists or not a correlation between NDVI and yield at FADN regional level. To do so we must consider that crop yield data, either official numbers or forecast, are always expressed per "region", while NDVI is expressed per pixel. The gap between both approaches can however be bridged by the computation of the regional means of certain image values. In this way the CNDVI method developed by Genovese et al. (2001) computes regional NDVI means. Besides, it goes one step further as the values are weighted according to each pixel's acreage occupied by the land cover type of interest (a specific crop or group of crops). This CNDVI is based on the dimension of FADN regions.

The masks that can be used are the following:

1- The Corine Land Cover (CLC-2000) whose previous version was used in the Spanish pastures insurance. It has a resolution of 100m. CLC refers only to Europe, while there is a Global Land Cover (GLC-2000) mask which contains information of the entire world. GLC resolution is 1,000m. CLC is useful to discriminate between areas with pastures, crops, forest lands, etc. It differentiates irrigated and non-irrigated crops, but it does not discriminate between the different crops in arable land.

2- CAPRI mask. CAPRI accounts for Common Agricultural Policy Regional Impact. The mask has a resolution of 1000 m. It is crop specific but there is no differentiation between non-irrigated and irrigated land.

3- GLOBCOVER: Global land cover, based on ENVISAT-ESA's MERIS. MERIS is a programmable, medium-spectral resolution, imaging spectrometer operating in the solar reflective spectral range. It has a resolution of 300m.

Since the acreage can vary over space and time, and the existing masks doe not imply a yearly update, they are a major limiting factor for the correct retrieving of optimal NDVI based indicators.

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[10] In case of decades without valid information, the value will be calculated by interpolation of the values of the previous and the following decade, if and only if the number of missing decades will be lower or equal to four.

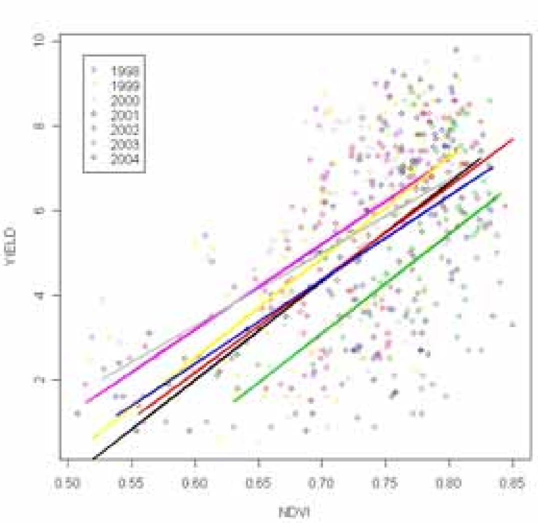
4.5.3. A first approach

As a preliminary analysis, we have a look at the correlation between the NDVI and the yield of wheat. A first approach considers the possibilities of using the maximum NDVI as an index for hedging yield risk. For the NDVI, we have used the max-NDVI per pixel of 1km2, averaged at FADN regional level and we applied some masks: Corinne Land Cover with constrains of >50% arable land and the CAPRI mask with constrain of wheat >50%. We have used the Eurostat-REGIO yield data, at FADN region level. Table 15 and Figure 23 show for every year the correlation between yield of wheat and max-NDVI masked. Annual average correlation values are between 0.45 and 0.70.

Table 15. Correlation for wheat: YIELD – maxNDVI

Year	Eurostat yield-maxNDVI correlation
1998	0.6024
1999	0.6602
2000	0.4525
2001	0.6612
2002	0.701
2003	0.4786
2004	0.5469
All	0.5474

Source: Elaborated by authors from Eurostat data and MARS NDVI data



Source: Elaborated by authors from MARS data and Eurostat REGIO data

Figure 23. Correlation of maxNDVI with Eurostat-Regio wheat yield

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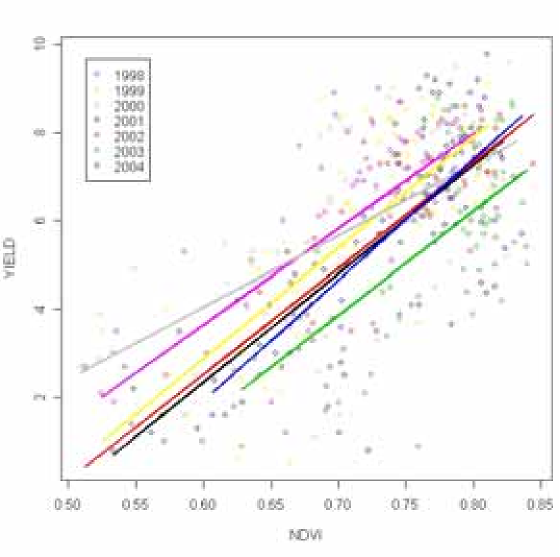
In the case that an area lacks more than 4 decade data or the last decade data is missing, the values will are decided through the analyses of the neighbouring areas of the same type.

The index based on max-NDVI could be improved in order to reach a higher correlation with yields. As second approach, instead of the max-NDVI of the year we could use the maximum NDVI in the period the crop is more sensible to risks and input (nutrients, water, etc) shortages. In particular, for wheat, the maximum NDVI during flowering and grain filling could be used. In order to see if this change could improve the correlations, we have made an experiment: we have eliminated from the database all the maximums which do not take place during the period of highest sensibility of winter wheat (stages of crop development: 80-150). As can be observed in Table 16 and Figure 24, correlations are higher, between 0.63 and 0.80. Figure 24 shows that the number of observations in the right-bottom decreases. The decrease of observations in the right-bottom and top-left corners indicates that there are fewer cases when a yield loss is not associated to an index loss and viceversa. This indicates that the change of max-NDVI used could improve correlation.

Table 16. Correlation for wheat: YIELD – max MVCNDVI eliminating the values in which max-NDVI does not take place during winter wheat development stages 80-150

Year	Eurostat yield-maxNDVI' correlation
1998	0.7196
1999	0.7395
2000	0.6349
2001	0.7733
2002	0.804
2003	0.5989
2004	0.7677
All	0.6803

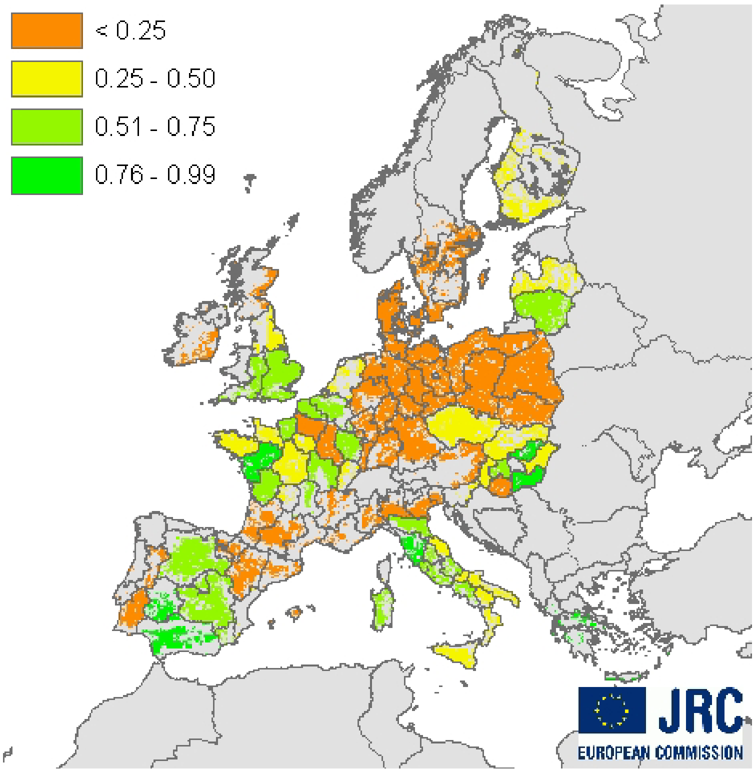
Source: Elaborated by authors from Eurostat data MARS data



Source: Elaborated by authors from MARS data and Eurostat REGIO data

Figure 24. max-NDVI correlation with Eurostat-Regio wheat yield eliminating the values in which max-NDVI does not take place during winter wheat development stages 80-150

Figure 25 shows the correlations per region. From the figure we can see that correlation is extremely low in most of central Europe (Poland, Germany, Denmark, Austria, Portugal, etc.) It shows highest values in more arid or dry areas, such as centre-south of Spain, some western regions of Italy, Greece, Hungary and also other regions with non-arid climate such as a north west of France or England. There is a factor influencing negatively in these correlations: the small number of years available (only 7).



Source: Elaborated by authors from Eurostat REGIO data and MARS data.

Figure 25. Correlation between max-CNDVI and Eurostat REGIO yield on FADN level.

Even if the maxCNDVI index limited to the period of more sensitivity of the plant is not everywhere correlated with wheat yields, we have calculated the potential losses based on this index. The NDVI deductible closest on average to the FADN yield with 30% deductible is 4.5%. The risk levels for this deductible are shown in Table 17.

Table 17. maxNDVI risk with different deductibles

FADN code	FADN region	5%	10%
260	Emilia-Romagna	3.82%	0.00%
270	Toscana	0.00%	0.00%
281	Marche	4.81%	0.00%
282	Umbria	0.00%	0.00%
291	Lazio	0.00%	0.00%
292	Abruzzo	0.23%	0.00%
301	Molise	0.09%	0.00%
302	Campania	0.00%	0.00%
303	Calabria	0.00%	0.00%
311	Puglia	0.00%	0.00%
312	Basilicata	1.87%	0.00%
320	Sicilia	0.00%	0.00%
330	Sardegna	0.00%	0.00%
460	Ipiros-Peloponissos	1.91%	0.00%
545	Castilla y Leon	2.19%	0.00%
550	Madrid	4.62%	2.14%
555	Castilla-La Mancha	0.00%	0.00%
560	Comunidad Valenciana	0.00%	0.00%
565	Murcia	0.00%	0.00%
570	Extremadura	3.72%	0.90%

Source: Elaborated by authors from MARS data

4.6. Conclusions

The analysis of feasibility of index insurance in the EU should take into account some general previous considerations, mainly:

- Index products are useful for systemic risk, at the aggregated level, so they are more adapted to reinsurance and catastrophic risks.
- Index-based products are best suited for homogeneous areas, where all farms have correlated yields. Given the heterogeneity of climates and geography in many European countries, index products efficiency will be probably lower than in the large homogeneous areas of the USA (for example, the corn belt).
- Insurance can be properly designed when there are yield time-series available (or losses time series). In Europe time series are only available at NUTS2 (region) level. Some of these regions (like Andalucia or Castilla y Leon in Spain) are very big and heterogeneous, what makes it difficult

to create an index that can be useful for all farmers in the region. Thus, the use of yield data at a more disaggregated level would be advisable or even necessary.

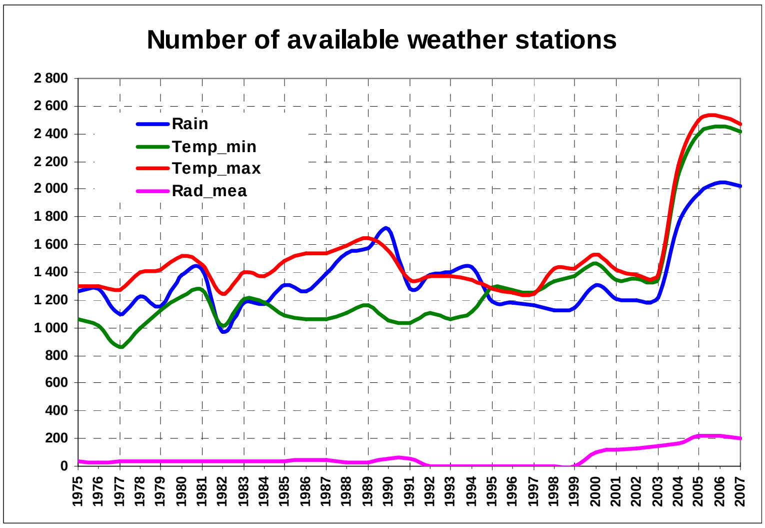
- If index insurance was to be subsidized within the CAP frame, it should fall under the WTO Green Box. As Paragraph 7 of the WTO Agreement refers to programs addressing directly income losses, index insurance seems to fit better in Paragraph 8, because indexes are intended to reproduce yield or production risks. However, it is not clear that index insurance by its nature can be considered under the Green Box, given that its nature is not to compensate by the actual loss of an individual, but by the loss indicated by a parameter (a farmer that did not suffer from a loss could potentially benefit from compensations). There is also the possibility of conflict with the need of a formal recognition by the Governmental authorities that when the index is below a certain threshold, it corresponds to a situation of natural or like disaster for all those who bought insurance and are thus entitled for the payment.

Once analysed these aspects and limitations and other technical issues, we have analysed several parameters or indicators which could be potentially used for crop insurances: regional yields which could be the basis for area yield insurance (Regional Yield Insurance RYI); some meteorological and agro-meteorological parameters; and last, an index from satellite images (NDVI).

RYI was designed for FADN regions and a number of arable crops. The area index used is Eurostat-REGIO yield. The fair premium rates for RYI with a trigger of 30% and no deductible oscillate for wheat from 0 to 14%, with average of 1.1%. The premium with a 30% deductible was also calculated. In this case, the maximum would reach 6.48% and the average 0.25%. With a 15% trigger wheat premiums reach the 15.7%. This shows that premium rates are very sensitive to the deductibles and trigger levels. The total premium amount can be multiplied by 2 or even up to 6 when reducing the trigger from 30% to 15%. The country average fair premiums per hectare oscillate between €4.17 and €9.17 for most arable crops, but reach €30,70/ha for potato. The final cost or commercial premiums are also estimated under certain assumptions. For RYI with a 30% trigger and a 50% market penetration (and assuming there is no adverse selection), the total EU-25 cost could be around of €77.6M for potato, €79.5M for barley and €69.8M for wheat, of which € 54.67M, €56M and €49.1 M respectively are the pure premiums.

Some meteorological indicators were analysed following the model of the area yield-tailored insurance from several indicators. An insurance product could be thus designed for each region on the most relevant parameter or combination of parameters according to the results. However, these combinations of indicators do not explain yields optimally, as the Multiple R-Squared is only 30%. Perhaps other indicators should be explored. Besides, it is also possible that there is too much heterogeneity within each NUTS2 region and a meteorological yield-tailored index could only have a good explanation capacity at a more disaggregate level. The meteorological indices analysis is useful to underline that the index risk can differ very much from one European region to another. The example shown in Chapter 4.3 aims to explain the level of vulnerability of the same crop, at the same development stage can vary as function of climatic conditions. The results of the late frost study expresses the need of analyse the climatic risk under many points of view, accounting with many physiological aspects related to the crop and many other expertise are needed to aggregate one data with another in order to reach robust outputs.

The agro-meteorological indices chosen and analysed in this chapter can be useful to give hints for the design of an index insurance product. The data availability it is not always sufficient, for instance the Eurostat Regio data series for eastern European countries starts only in 1994; this makes the range of calculation for the correlation coefficient of those countries, not possible to be extended for more than 10 years, with a certain impacts on the results. It has to be clarifyed that the quality of the meteorological data received and collected in the MARS database improved very much in the last period. The graph below shows the increase of available weather stations number.



Source: JRC Mars database

Figure 26. Meteorological weather station transmitting data to MARS database.

In general, as the analysis is made on a large scale (EU27), surely the results are not excellent because the domain of observations is very wide. Another aspect to consider is the climatic differences in Europe. Certain areas suffer lack of water, on the contrary other regions face problems of excessive rainfall, so this means that is sometimes tricky to analyse the same index on areas with different problematic. A step further could be the division of Europe into climatic zones; this could help to refine the outputs of the analyses and to determine which index can represent better the yield variability for each zone and each crop. At present, the results suggest many directions that could be taken to comprehend how far an index can serve to assess losses due to climatic event or to prevent income losses through an insurance scheme based on agro-meteorological indices.

Analyses for NDVI show that the maximum NDVI appears as a poor indicator of crop yield risk. We have looked at the correlations in each FADN region and we have found that the index and yields are not correlated. There is a factor influencing negatively in these correlations: the small number of years available (only 7). However, results improved when taking into account only those maximum NDVI which fall in the period when the crop is more sensitive to nutrients and water stresses. This means that the capacity of NDVI for explaining yields could be improved by using the maxNDVI of this sensitivity period. On the other hand, ongoing activities within the Agriculture Unit of the JRC have proved that the correlation between the indicators derived from NDVI and yield is dependent on different regions. A study in Spain showed that the max NDVI but also cumulated NDVI values for different periods of the growing season are significant. Further analysis could include indicators such as the start NDVI or the end NDVI of the growing season; the cumulated NDVI during the length of growing season; and cumulated NDVI between start and max NDVI, or between max NDVI and end NDVI of the season.

5. Cross validation of indirect index insurance with FADN data

5.1. Introduction

The objective of this chapter is to contrast the index insurances analysed with individual farm data from the Farm Accountancy Data Network (FADN). With this objective we first analyse (section 5.2) the individual farm yield risk (5.2.1) and income risk (5.2.2) at FADN region level. In a second step (section 5.3) we analyse again farm risk but assuming that all farms buy an index insurance (RYI). The decrease of the farm risk gives an indication of the efficiency of the index insurance.

FADN yield and income risk

The Farm Accountancy Data Network (FADN) is the best available source of data at single farm level[11]. In this chapter we quantify the risk of yield or income loss. The concept of risk is the expectation of the loss compared to the "normal" yield or income; in other words the risk is the loss averaged on time.

A "normal" yield or income is often considered the long term trend of the yield or the income of the farm. In order to calculate the long term trend, data provided by a time series is needed. Given that the FADN data do not contain information on the same farm for a big number of years, that is, we do not dispose of time series at individual farm level, we need to look for some alternative method to calculate farm risk. An alternative option is presented in this section, which attempts to make more flexible the concept of "constant sample": it is what we call the "2-year constant sample" method. It consists on a procedure to indirectly estimate the variation compared to the trend without estimating the trend for the farm. The procedure is model-based and consequently its validity depends on the acceptation of the model, but we consider it is reasonable enough and it allows to exploit the data of a farm whenever data are available for that far on two consecutive years. This methodology is explained in detail in Annex 5A (section 1.1) and results are shown in subsection 5.2.1.1.

On the other hand, the WTO agreements implicitly define the normal income or yield as a moving average of three preceding years. More specifically, the WTO green box conditions for aids to yield (and similarly for income) losses specify: "*a production loss which exceeds 30 per cent of the average of production in the preceding three-year period or a three-year average based on the preceding five-year period, excluding the highest and the lowest entry*". Limiting the sample to the farms that are kept for 4 years reduce the sample to less than 30% of the total sample, and the sample would be tiny in

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[11] The FADN database is described in Annex 5B (section 9.11)

many regions if we only consider farms with data on 6 consecutive years[12]. However, we have performed also this analysis and results are shown in subsection 5.2.2.

The analyses are restricted to EU-15 and for barley, grain maize, sunflower and wheat because of data availability. For the FADN loss risk assessment long time series are required, and are not available for the new MS. Income indicators based on FADN data are analysed since 1994.

Cross-validation for wheat area yield insurance

Next, the efficiency of RYI is validated with the FADN farm data. In order to attain this objective, we simulate the effects of RYI on each farm revenue, so that we obtain a new sample of farm revenues with insurance. The comparison of the risk on this second sample with the risk on the non-insurance sample allows to quantify the potential effects of the insurance on the average risk of the farms.

5.2. Quantitative assessment of the loss risk on the basis of FADN data

5.2.1. Risk of yield reduction at farm level

5.2.1.1. Risk of yield reduction from a trend: “2-year constant sample” method

The risk of yield reduction has been calculated using the 2-year constant sample method for a number of crops (barley, grain maize, sunflower and wheat). The risk of yield reduction is what is known in actuarial terms as fair premium or pure risk premium, and it corresponds to the risk that is undertaken by the insurer (expected compensation to be paid to the farmer) of a multi-risk yield insurance.

For every farm i of region k we observed production q_{it} and area S_{it} for crop c in the year t and the yield is $Z_{ti} = q_{it} / S_{it}$. The regional trends used in the method have been calculated according to the process described in the Annex 3C (section 9.12).

The FADN total sample is described in Annex 5B (Section 9.11), Table 40. The number of farms with observations in two consecutive years is shown in Table 42 in the same Annex, and the percentage of these farms on the average of all farms in each pair of years is Table 43. We have calculated the risks with a 30% trigger, according to WTO constraints, and with no deductible.

Figure 64 shows the results for wheat and barley for each FADN region. The results for the other crops are shown in Annex 5D (section 9.13.1). Table 18 below shows the average values per country. The computation has been carried out only for the regions for which the crop is sufficiently important to have a large enough sample size in FADN for a reliable estimate. Eastern European countries do not appear in the results as there was not enough available data.

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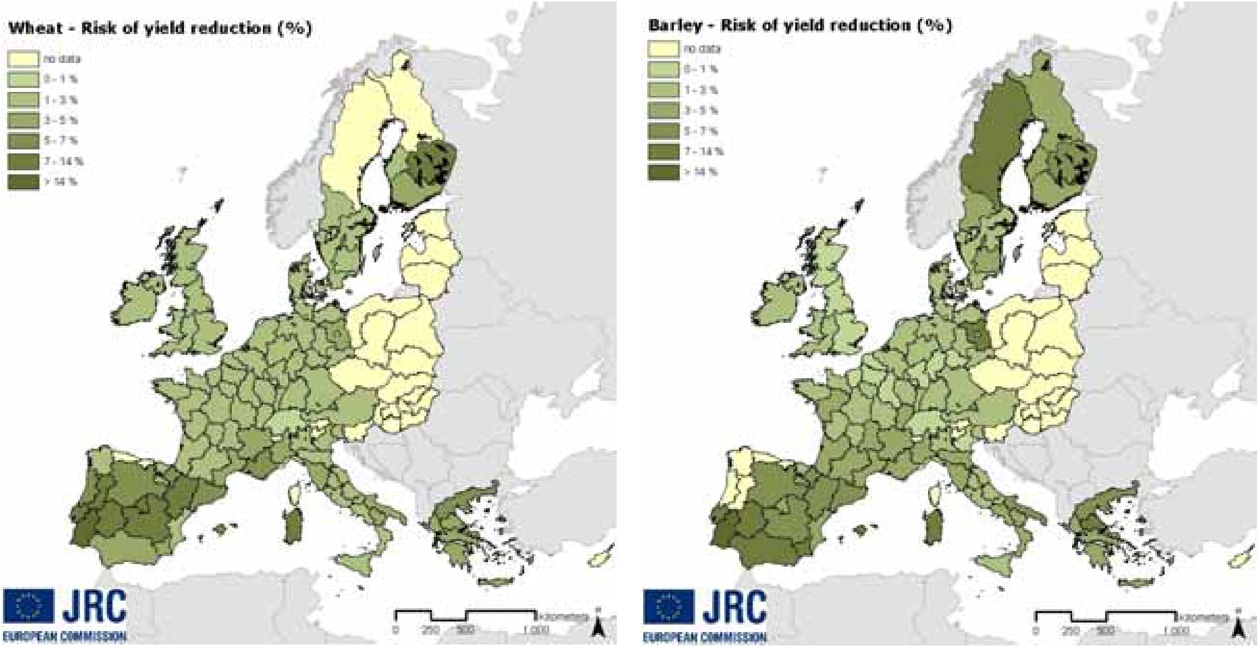
[12] The actual application of this rule would require an individual record of yearly production for each farm, but



Source: Elaborated by authors from FADN data

Figure 27. Farm yield risk (losses from trend with 30% trigger) for wheat and barley with "2-year constant sample" method

Table 18. Farm yield risk (losses % from trend with 30% trigger) "2-year constant sample" method

%	Wheat	Barley	Grain maize	Sunflower
AT	1.51	2.73	4.28	2.91
BE	0.52	1.19	4.35	
DE	1.19	1.71	5.00	6.64
DK	1.00	2.66		
ES	5.44	5.96	2.73	10.37
FI	6.26	4.78		
FR	1.59	2.34	3.06	3.55
GR	4.79	5.09	0.88	8.91
IE	0.75	2.38		
IT	2.76	3.37	3.38	4.90
LU	0.83	1.42		
NL	1.38	2.31	17.78	
PT	10.53	14.47	11.65	19.60
SE	1.34	4.94		
UK	0.90	1.11		
All	2.96	3.47	4.12	6.18

Source: Elaborated by authors from FADN yields

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such system does not exist in most European countries.

As explained in section 2.3, the risk rate of yield reduction in percentage is equivalent to the actuarially fair premium rate calculated for the RYI. In both cases, risks are expressed as a rate, that is, a percentage of the average or expected yield. It can be observed that these farm yield risks are on average higher than those represented by the fair premiums of RYI. Given that in some of the regions farm risks are quite high and an individual yield insurance policy could results unaffordable for the farmer, a RYI could be proposed in these cases.

5.2.1.2. Risk of yield reduction from a moving average: WTO method

If we follow the WTO indications on allowed aids in case of a disaster or calamity on production (see section 9.3 and also section 4.1.2 for a more in-depth analysis on the topic), the trigger and also the maximum amount of indemnities and payments should refer to one of these moving averages: "*the average in the preceding three-year period or a three-year average based on the preceding five year period, excluding the highest and the lowest entry*".

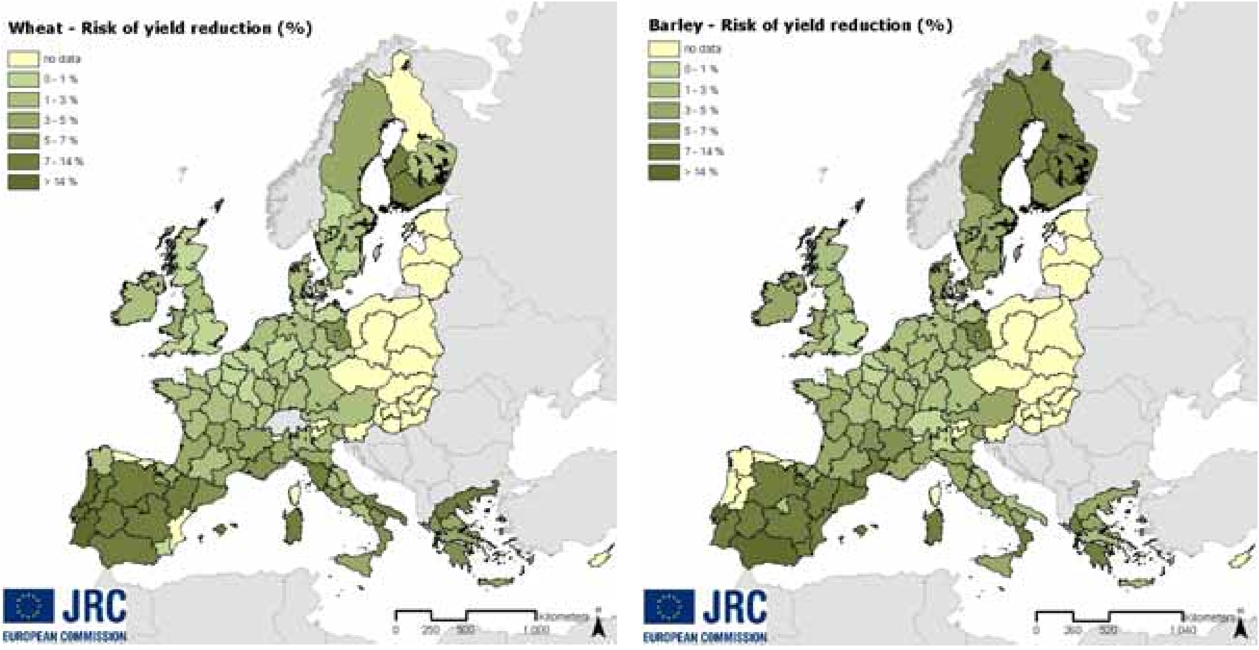
The yield loss in year t would be given by: $1-\gamma_{ti}$ with $\gamma_{ti} = \dfrac{3Z_{ti}}{Z_{it-1}+Z_{it-2}+Z_{it-3}}$

If applying a deductible d: $h_{ti} = \begin{cases} 0 & if \quad \gamma_{ti} > (1-d) \\ (1-d)-\gamma_{ti} & otherwise \end{cases}$

For region k, the relative loss for the insurer is $L_{tk} = E(h_{ti} / i \in k)$

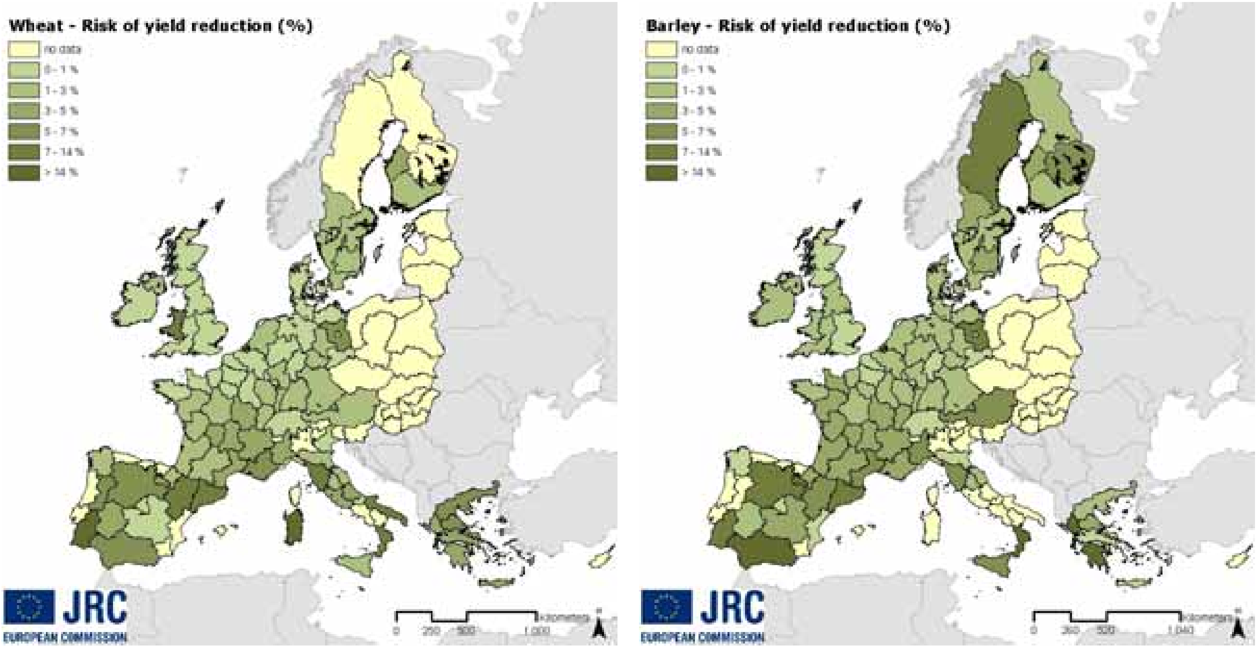
In order to perform these calculations, we need 4-year constant sample yields for each individual farm or 6-year constant samples in the second case. The analysis of FADN yields shows that 4-year constant samples are available for some farms and years (see Table 44 in Annex 4B) at least in the most important producing regions, but the number decreases for 6-year constant samples (Table 45).

We have first calculated the risk of yield reduction with a 3 year moving average for the 4-year constant sample. Figure 28 shows the mapping of the results for wheat and barley per FADN region. The results for the other crops are shown in Annex 5D (section 9.13.2). Table 19 shows the averages per country. In a second step, we have done the same for the three-year average of the previous five years disregarding the maximum and the minimum, from the 6-year constant simple. The mapping of the results per FADN regions is shown in Figure 29 for wheat barley and in annex 5D for the other crops. The average risk ratios per country are shown in Table 20.



Source: Elaborated by authors from FADN data

Figure 28. Risks of yield reduction ('3 year' moving average- 30% trigger) for wheat



Source: Elaborated by authors from FADN data

Figure 29. Risks of yield reduction ('5 year –minmax' moving average - 30% trigger) for wheat and barley

Table 19. Risk of yield reduction (‘3 year’ moving average with 30% trigger)

	Wheat	Barley	Grain maize	Sunflower
AT	2.08	3.95	5.86	3.09
BE	0.68	1.39	4.45	
DE	1.65	2.60	4.18	7.65
DK	1.45	4.11		
ES	6.17	8.48	3.23	11.99
FI	6.14	7.49		
FR	2.19	2.96	3.24	4.25
GR	5.54	4.30	1.00	7.94
IE	2.34	3.82		
IT	4.12	4.07	4.37	2.90
LU	1.21	1.79		
NL	1.03	2.22	14.04	
PT	15.46	14.80	10.12	27.49
SE	2.14	6.27		
UK	1.32	2.01		
All	3.82	4.50	4.10	6.56

Source: Elaborated by authors from FADN yields

Table 20. Risk of yield reduction (‘5 year –minmax’ moving average - 30% trigger)

	Wheat	Barley	Grain maize	Sunflower
AT	2.39	5.25	6.30	3.40
BE	0.43	1.15	4.30	
DE	1.53	2.24	3.64	9.30
DK	0.67	1.43		
ES	4.70	7.95	2.13	9.87
FI	3.06	3.39		
FR	2.17	2.98	3.61	4.19
GR	4.51	7.07	0.61	6.38
IE	0.80	1.47		
IT	5.33	9.21	2.32	6.48
LU	0.87	1.39		
NL	1.08	1.40		
PT	10.87	8.76	7.35	13.09
SE	1.74	4.30		
UK	2.26	1.33		
All	3.18	4.19	3.29	6.19

Source: Elaborated by authors from FADN yields

From the comparison of all the yield results we can observe several things. First, regarding, the amount of data, we see that the use of a 3 year moving average involves that data are not available any longer for some regions. But the effect is much more evident on comparing the results of the average of the 5 previous years minus the minimum and the maximum (for example South of Italy and Sardegna, part of Portugal, for wheat and also Slovenia and north-east of Italy for Barley).

The 3 years moving average show risk levels which on average are considerably higher than the "2-year constant sample" method. In fact, the 3 year moving average usually shows higher risks than any of the other two methods, but mainly for wheat and barley. The effect is smaller for sunflower and grain maize. In some cases the risk remains similar or with a slight decrease, and in very exceptional cases it decreases (for example: sunflower in Italy from 4.90% to 2.90%). This could lead to think that this moving average in general would not be restricting for aids given on the basis of the trend, but of course it should be checked on a case by case basis.

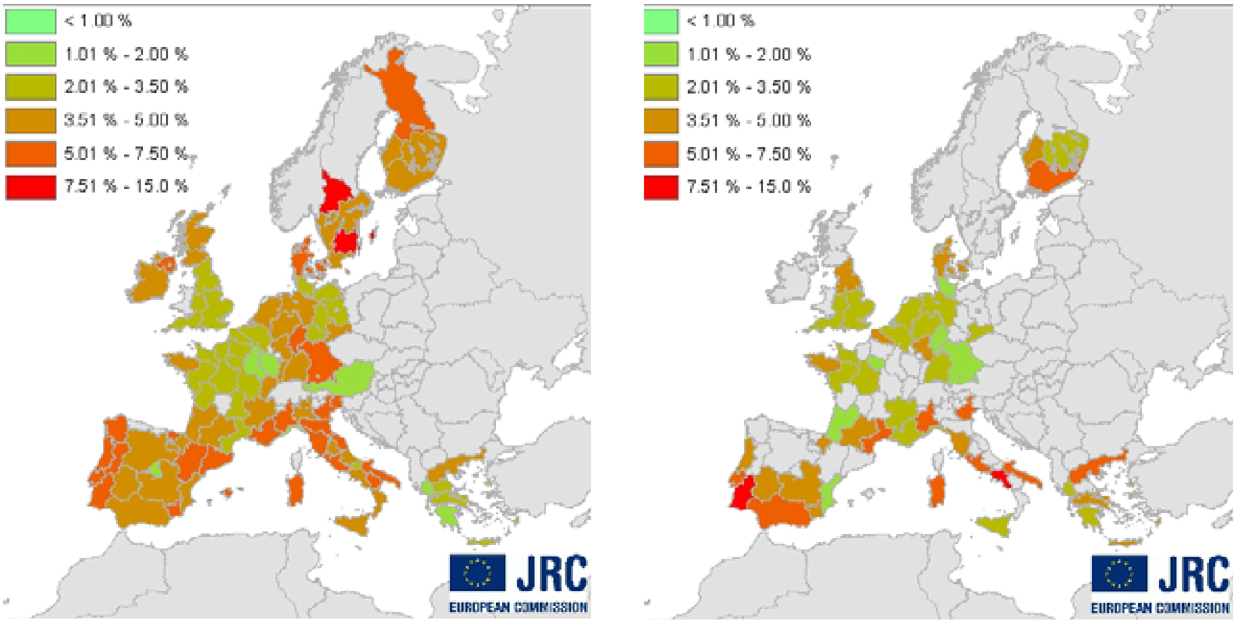
If we compare the levels of risk shown by the two moving averages, the risk with the 3-year is usually higher than the one with the 5-year. This can be explained because crop yields generally have a positive trend. This suggests that in most cases a moving average based on the last 3-years will be higher than a moving average based on the 5 previous years, so that the risk of yields below the obtained average is higher. At the same time, a moving average is oscillating, so its intrinsic risk is higher that the trend risk. This could have a potential implication at the political level. Given that the WTO definitions permit to compare the losses with the 3-year moving average and that risks with this method are on average bigger than with the other ones for winter cereals, it means that in these cases WTO rules would not be restrictive on average with respect to the trend loss calculation.

5.2.2. Risk of income and revenue reduction

The income reduction has been estimated from Farm Net Value Added (FNVA) data. The FNVA trends have been estimated in a similar way as the ones for yields (see Annex 4C, section 9.12). However, they have not been estimated from the Eurostat database, because it does not provide data on farm income. Instead, the weighted averages of farm FADN data per region, year and farm type have been used. The types of trends found for the different types of farms are shown in the same Annex 4C (Figure 62 and Figure 63).

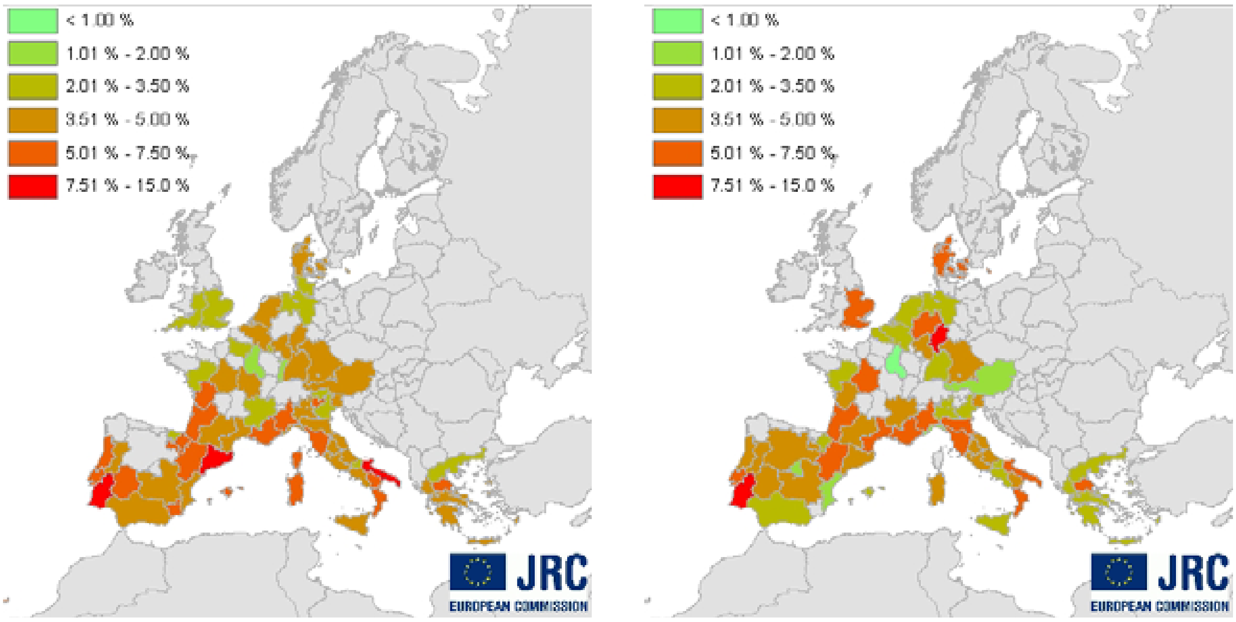
Applying the "2-year constant sample" method to the FNVA presents some additional difficulty because the behaviour of FNVA is more irregular than the behaviour of the yield. In particular negative values can appear and the meaning of $\frac{\gamma_{ti}}{\gamma_{t-1,i}} = \frac{Z_{ti}}{Z_{t-1,i}} \frac{g_{t-1,i}}{g_{ti}}$ needs some adaptation. As a provisional way to go ahead, we have limited the values of the ratio to the interval [0.1 – 10]. Values outside this interval are artificially pushed to 0.1 if they correspond to a decrease of FNVA or to 10 if it corresponds to an increase. In Annex 4C, Table 46, the special cases with FNVA values below 0.1 are listed. The rule that has been applied generally introduces a moderate underestimation of the risk.

We represent in Figure 30 and Figure 31 the calculated risk or pure premium rate (in %) of a hypothetical FNVA insurance with a 30% deductible. The choice of a 30% deductible is justified by the WTO constraints on public compensations for income losses. Pure premiums are above 7.5% in several regions (south of Sweden and Portugal, Campania and Puglia in Italy, Catalonia in Spain and central Germany). There are also large areas all around Europe with premium rates above 5%. We can observe that the risks are not lower than the yield risks seen before with the “2-year constant sample” method, even though here a deductible is applied, and so the expected risk should be lower. We can deduce from this that income risks are higher than farm yield risks.



Source: Elaborated by authors from FADN data

Figure 30. Risk (30% deductible) of Farm Net Value Added (FNVA) for specialists field crop and specialists horticulture



Source: Elaborated by authors from FADN data

Figure 31. Risk (30% deductible) of Farm Net Value Added (FNVA) for specialists permanent crops and mixed crops

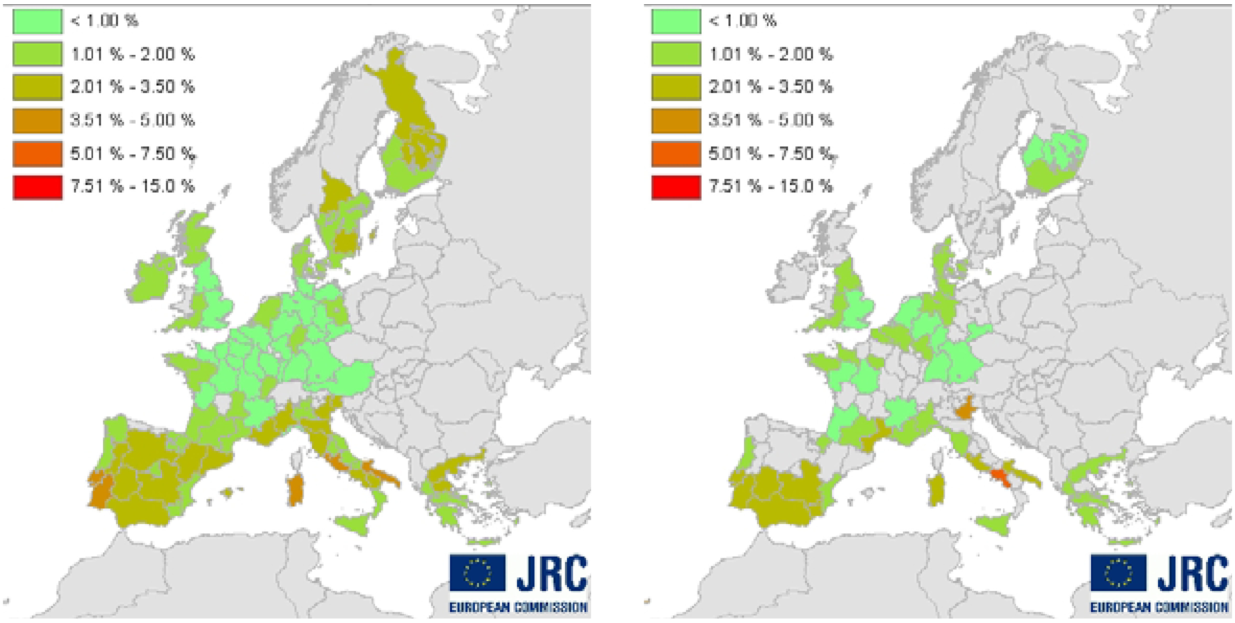
Table 21 summarizes the average pure premiums per country. The lowest premium rates are found in Austria and Belgium. The average premiums for all Europe are around 4%, much higher than yield averages, which were between 1 and 2.5%. This means that the main farm risks are not exclusively due to yield oscillations, but can be due to price risks or financial risks as well.

FNVA shows negative values and risks which differ much from yields. Given that this can be influenced by financial factors and other factors not directly related to the farming activity, we will analyse another FADN variable: the Value of Production (VP). This does not represent farmer's income but farmer's revenue, and thus, would not be linked to Paragraph 7 nor to Paragraph 8 of the Annex 2 of the WTO agreement on agriculture. However, this indicates us whether farmer's income risks are mostly due to price and production variability, or whether they are due to other factors.

Table 21. Farm Net Value Added average risk levels (pure premiums with 30% deductible)

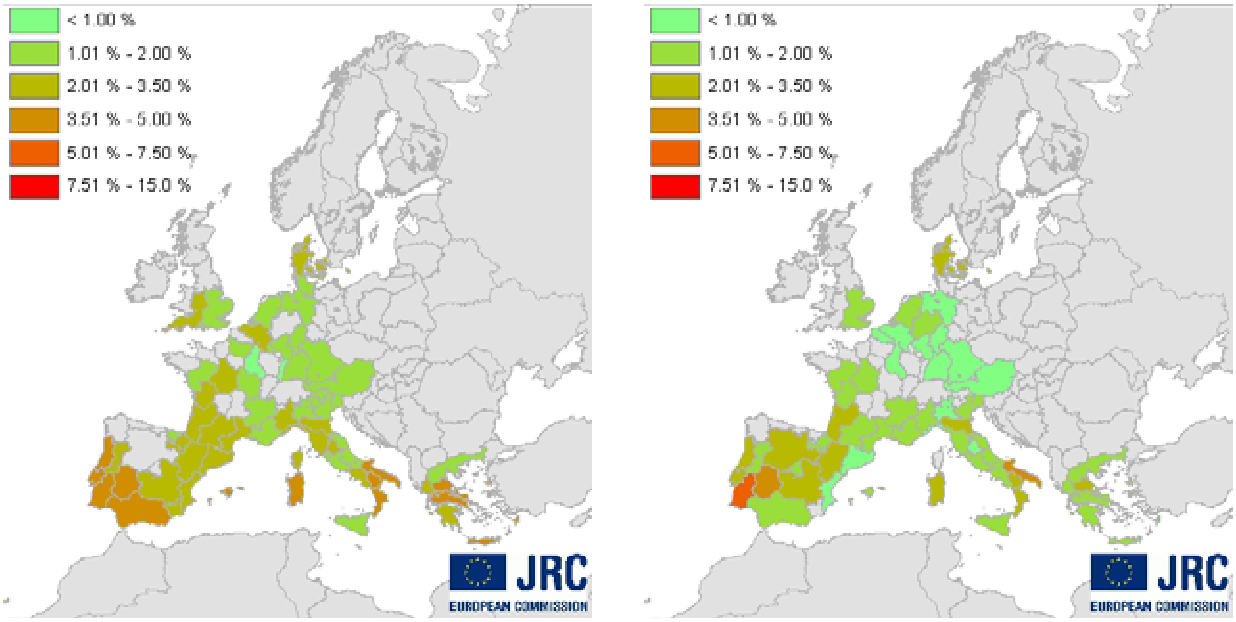
	Specialist field crop	Specialist horticulture	Specialist permanent crops	Mixed cropping
AT	1.994%		3.786%	1.881%
BE	2.153%	2.762%	4.585%	2.274%
DE	3.798%	2.272%	3.970%	4.879%
DK	6.708%	3.574%	4.759%	6.485%
ES	4.675%	4.254%	5.484%	3.530%
FI	4.402%	4.118%		
FR	3.242%	3.271%	3.912%	4.166%
GR	2.825%	4.140%	4.498%	3.559%
IE	3.602%			
IT	5.003%	5.433%	4.594%	4.212%
LU			3.084%	
NL	4.832%	3.344%	4.389%	3.420%
PT	6.167%	6.356%	6.526%	6.488%
SE	6.621%			
UK	4.134%	3.541%	3.287%	6.757%
All	4.235%	3.954%	4.629%	4.289%

Source: Elaborated by authors from FADN value of production



Source: Elaborated by authors from FADN data

Figure 32. Risk (30% deductible) of FADN Value of Production (VP) for specialists field crop and specialists horticulture



Source: Elaborated by authors from FADN data

Figure 33. Risk (30% deductible) of FADN Value of Production (VP) for specialists permanent crops and mixed crops

Table 22. Value of production average risk levels (pure premiums with 30% deductible)

	Specialist field crop	Specialist horticulture	Specialist permanent crops	Mixed cropping
AT	0.639%		1.573%	0.747%
BE	0.751%	1.001%	2.390%	0.823%
DE	0.779%	0.867%	1.544%	0.863%
DK	1.259%	1.460%	2.910%	2.629%
ES	1.941%	2.318%	2.932%	1.869%
FI	1.986%	0.926%		
FR	0.923%	1.139%	1.844%	1.341%
GR	1.838%	1.522%	2.931%	1.808%
IE	1.300%			
IT	2.219%	2.707%	2.535%	1.708%
LU			1.042%	
NL	1.102%	0.986%	1.674%	1.604%
PT	2.997%	2.800%	3.662%	2.931%
SE	1.971%			
UK	1.179%	1.016%	2.083%	1.255%
All	1.558%	1.653%	2.431%	1.675%

Source: Elaborated by authors from FADN value of production

From comparing the maps of VP (Figure 32 and Figure 33) with those of FNVA (Figure 30 and Figure 31) we see that while in some regions the level of risk remain unchanged, for most regions and crops, the level or risk undergoes an important increase. The increase, however, is not proportional, given that in some cases it goes from the lowest levels to the highest levels. For example, Hessen in Germany for mixed crops, or Catalonia in Spain for specialists permanent (>1% in VP, >7.5% in FNVA).

We see that the average risks shown in Table 22 for all countries are between 1.5 and 2.4, so the levels are closer to yield risks than to income risks. This means that the price and the production risk account only for a part of the income risks, being far from explaining most of the farm risk.

5.3. Cross-validation for RYI for wheat

5.3.1. Methodology

In order to see the effects of the area yield insurance on the farm economic results, we will not take into account the whole farm income, given that previous analysis have shown that farm income risk is not very much related to farm production risk (section 5.2.2), because of the effect of other income components which often are not intrinsic to the farming activity. So, we will look directly at the effect of area insurance (RYI) on the farm crop revenue.

The RYI provides for each region *r* and each year *t* and indemnity in yield-equivalent (T/ha):

$I_{tr} = \max(0, \overline{Y}_r \times Cov - Y_{rt}) \times p$ where $\overline{Y}_r$ is the average crop revenue in region r, *Cov* is the coverage level of the insurance and Y_{tr} is the actual regional yield in year *t*.

The farmer has to pay every year a premium, which in the long term equals the indemnities:

$P_{rt} = E(I_{rt})$ where *E* is the mathematical expectation.

Thus, if the farm buys area insurance every year, the farm economic results are modified by the premium paid, and by the indemnity in the years the region yield is lower than the guaranteed yield. So, we could say that the revenue of farm *i* in region r, when there is not insurance (R_{i0}) is modified in this way by insurance.

$$R'_{irt} = R_{i0} + I_{rt} - P_{rt}$$

In this way, we obtain for each farm in the FADN database a new revenue R' for every year. For simplicity of calculations, we have assumed a unitary price, so we have used farm yields instead of farm production values. The indemnities and premiums were expressed in percentage of the regional yield, in order to adapt them to the yield level of the farm.

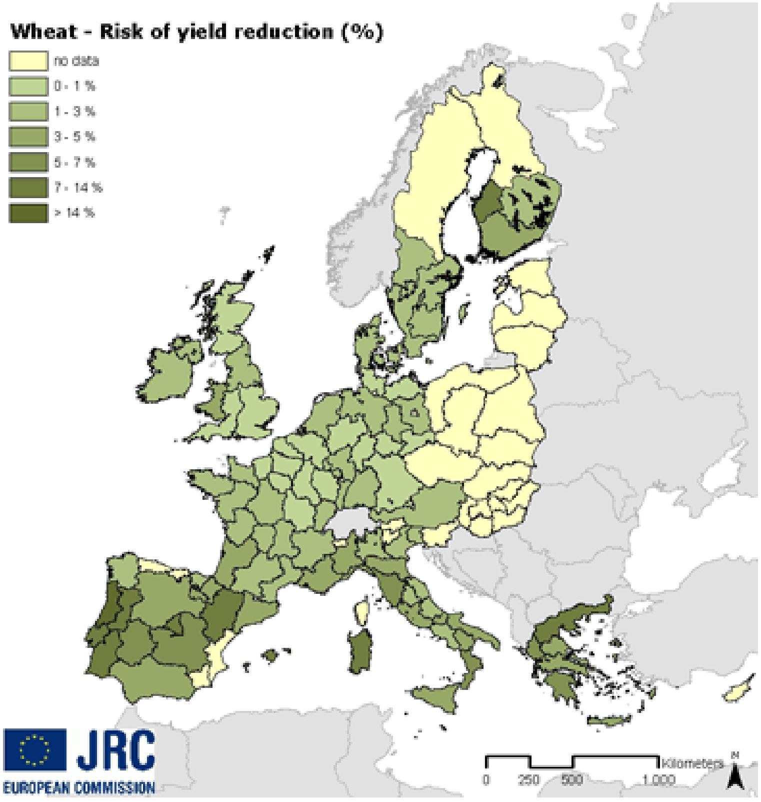
$$I_{rt}(\%) = \frac{\max(0, \bar{Y}_r \times Cov - Y_{rt})}{\bar{Y}_r}$$

$$P_{rt}(\%) = \frac{E(I_{rt})}{\bar{Y}_r}$$

However, given that the FADN farm sample is not constant, we could not use the average yield of the farm, but the actual yield, what makes the risk reduction effect of the insurance be much lower. Instead, the farm trend should have been used. Another option considered was to apply to all the farms of the region a fixed premium (and fixed indemnities) expressed in T/ha. We also tried this system, but the results did not differ much from the previous ones.

5.3.2. Results

Figure 34 shows the risk calculated with the "3 year moving average" method for the farms with insurance. The map for the same farm risk without insurance was shown in Figure 28.



Source: Elaborated by authors from FADN and Eurostat data

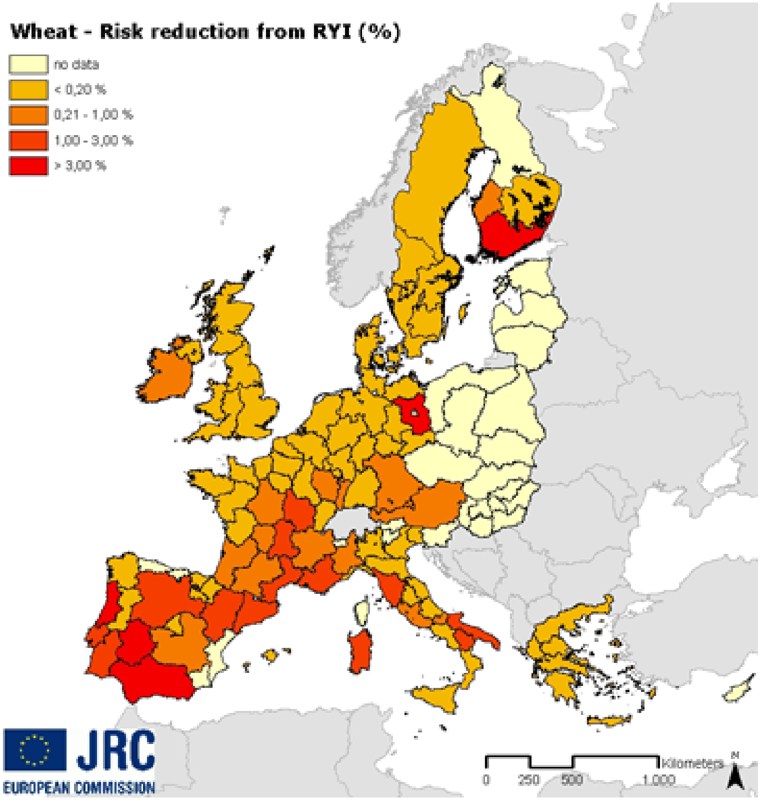
Figure 34. FADN production risk (30% deductible) with area yield insurance for wheat

If we compare both maps we can observe that the risk levels are very similar. However, we can see a significant decrease of the risk level in some regions: North-West of Portugal, south of Spain, East of

Germany, south of Finland. So, this decrease of the risk is observed mostly in Mediterranean areas, while in central and northern Europe the usually low risk levels remain unchanged.

Figure 35 shows the observed yield reductions. The yield reduction is largest:

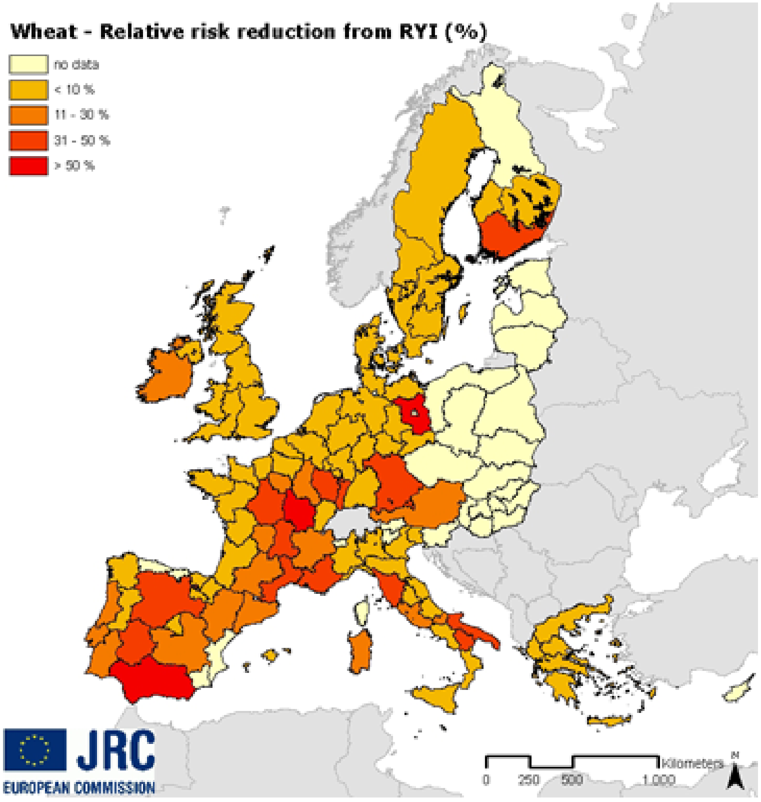
- in Spain: in Andalucia and Extremadura;
- in Portugal, in Entre Douro e Minho;
- in France, in Provence-Alpes-Cote d'Azur, Languedoc-Roussillon, Bourgogne and Auvergne;
- in Italy: Sardegna, Puglia, Toscana;
- in Germany: in Brandenburg
- in Finland: in Etela-Suomi.



Source: Elaborated by authors from FADN and Eurostat data

Figure 35. Wheat production risk reduction from area yield insurance

Figure 36 shows the decrease expressed as a percentage of the original risk. In most o the cases, the highest risk decreases correspond to a decrease of more than 50% of the risk, with a maximum of 68% in Brandenburg (Germany) and Bourgogne (France). Although the absolute risk reduction in Bourgogne is not high, the relative risk reduction is important. This means that in this region the RYI risk is quite efficient even if the original risk was not very high.



Source: Elaborated by authors from FADN and Eurostat data

Figure 36. Wheat production relative risk reduction from area yield insurance

The first results from this analysis show that:

- The effect of area yield insurance on the farm production risk is generally low.
- However, in some regions, the risk reduction is relevant.
- These results have to be considered cautiously, given that the quality of the data is not optimal. The correlations between Eurostat yields and FADN yield averages are often weak.

5.4. Conclusions

FADN data are used to compute and map the level of risk of yield reduction with a deductible 30% for major field crops at the level of the farm. The concept of risk used corresponds to the long term average payment by the insurer to the farmer. This is often labelled in the academic literature as “fair premium”, although in practice the premium is higher because of the management costs (including loss expertise) and the profit of the insurance company. Two different methodologies using FADN data have been used:

- One method based on the WTO-suggested approach that compares the yield each year with the average of previous years

- A newly developed method, that we have called “2-year constant sample”, that allows to use a higher number of FADN data and that takes into account the yield trend in each region.

The results show a geographic layout without any major surprise, but give a good indication of the quantitative level of risk. Preliminary results confirm that the risk level at the scale of the individual farm is much higher than the risk level using regional yield averages as trigger of a hypothetical index insurance.

Both approaches give results that are consistent with each other, but the two-year constant sample method gives in general slightly lower values for the risk than the 3-year moving average method for winter cereals. A possible explanation for this fact is that the WTO does not take into account the long term trend. We point out that the practical application of the WTO rule would require a farm-level register of yields going at least 3-5 years back; this does not seem to be available in most EU countries.

A spin-off of the study is the characterization of the regional yield trends with different functional shapes (linear, quadratic and logarithmic). This is a product that has a value as a tool to improve the current procedures of yield forecasting. However some additional work is necessary to collect time series of yields longer and more complete than the data available in the REGIO database.

The analysis of the income reduction risk is made by farm type instead of by crop. The application of the same methods to the income level measured through FNVA (Farm Net Value Added) is more problematic. We find a conceptual challenge in the application of the “30% deductible” when the average income in the previous year(s) is very low or even negative: What does it mean “a loss of more than 30% of the average income of the previous three years” when this average is negative? This inconvenient has been skipped by eliminating “awkward” ratios, but we have to warn that this may have a strong impact on the results, probably reducing the computed levels of risk. Even with this data cleaning implying a reduction of apparent risk, the risk levels computed for the income reduction are much higher than the risk of yield reduction. The reason for that is easy to understand: assuming relatively stable prices, a yield reduction of 30% correspond to an income reduction of much more than 30%, because the cost of production does not decrease with the yield. An alternative concept has been analysed: the value of production, or revenue, for which the estimated risk is much closer to the risk of yield reduction.

Cross-validation of wheat RYI

As could be expected, given that area yield indexes are more adequate for homogeneous regions, the risk reduction capacity of RYI is not very high for the example analysed. We can expect that the results do not depend from the crop type, but on the scale of the analysis. Besides, we have to take into account that it was underestimated due to the data constraints (the percentage indemnities were multiplied by actual farm yields and not by average or expected farm yields). However, there are some regions where the risk can be reduced up to a 68%.

The test for risk reduction capacity of other indexes could be done, however, it would be expected to be lower than the one from yield area index, given that theoretically regional yield area should describe the behaviour of farm yield better that other indexes at a regional scale.

6. General conclusions

6.1. Main conclusions on the index insurances

There is a debate on the nature on index insurances, because they are very close to financial derivative contracts. Also the pricing of index insurance is a complex issue: traditional methods for pricing financial derivatives have been used in most studies, but insurance or actuarial methods can be more adequate. From the literature review we can see that the market of agricultural weather derivatives is in the early stages. Also the agricultural index insurance markets quite new and is the object of study of the current literature. Due to the characteristics of indirect index insurance, that makes it more accessible and affordable than traditional crop insurance; many pilot programs have recently been implemented in developing countries. Some examples exist in Canada, the USA and only a few in Europe: mainly a pilot project in Austria of a weather index insurance based on meteorological data to cover yield from the risk of drought, and a satellite index insurance for fodder in Spain.

The literature review includes some studies that analyse area yield insurance, while all the rest refer to indirect insurances based on meteorological indicators. Among these, there are some examples of exogenous index insurance, and others of yield tailored insurances. A particular example which combines an exogenous standardised contract and yield-tailoring is the work by Torriani et al. (2007) in which the weather derivative which triggers the payment is exogenous but he proposes a yield-tailored combination of weather derivatives for the farmer.

The exogenous indexes can either have a fixed payment per unitary index decrease (for example a payment of 1€ per 1mm rainfall shortfall), or be proportional (a decrease of the rainfall of 50% would trigger a compensation of the 50% of the insured capital). The yield-tailored examples with multiple indicators adjust yield with the estimation of a model combining different indicators. Other yield-tailored indexes have only one indicator. They optimize the index-yield correlation by the application of weights for the different agronomic growth stages. The available examples are calculated for drought and use the cumulated precipitation. Their results show that a better correlation is achieved when the exogenous single indicator is weighted on the agronomic growth stages. Globally, most of the studies agree on the fact that the better or worse results from index products depend fundamentally on the correlation existing between the real loss of the farmers and the index analysed.

The analysis of feasibility of index insurance in the EU should take into account some general previous considerations, mainly:

- Index products are useful for systemic risk, at the aggregated level; consequently they are more adapted to reinsurance and catastrophic risks. As Woodard and Garcia (2007) state, limited potential efficacy of weather derivatives has been identified in hedging agricultural exposures. However, the potential for weather derivatives in agriculture may be greater than previously thought for aggregators of risk such as re/insurers.

- Index-based products are best suited for homogeneous areas, where all farms have highly correlated yields. Given the heterogeneity of climates and geography in many European countries, index products efficiency are lower than in the homogeneous areas of the USA (for example, in the corn belt).
- Insurance can be properly designed when yield time-series are available (or losses time series). In Europe time series are only available for relatively large regions. Some of these regions (like Andalucia or Castilla y Leon in Spain) are very big and heterogeneous. Thus it is difficult to create an index that can be useful for all farmers in the region: the use of yield data at a more disaggregated level would be advisable or even necessary.
- If insurance was to be considered within the CAP framework, the subsidies should comply with WTO green box criteria. Subsidies to index insurance could be considered as payments (made either directly or by way of government financial participation in crop insurance schemes) for relief from natural disasters (Paragraph 8 of Annex 2 of WTO Agreement on Agriculture), because indexes are intended to reproduce yield or production risks. However, it is not clear that index insurance by its nature can be considered under the Green Box, given that its nature is not to compensate the actual loss of an individual, but the loss indicated by a parameter (a farmer that did not suffer from a loss could potentially benefit from compensations). Practical difficulties would also arise from the requirement of a formal recognition by the Governmental authorities of natural disaster, as it would have to be linked to a certain threshold for the indexes used.

Once analysed these aspects and limitations and other technical issues, we have analysed several parameters or indicators which could be potentially used for crop insurances: regional yields which could be the basis for area yield insurance (Regional Yield Insurance RYI); some meteorological and agro-meteorological parameters; and last, an index from satellite images (NDVI).

RYI was designed for FADN regions and a number of arable crops. The area index used is Eurostat-REGIO yield. The fair premium rates for RYI with a trigger of 30% and no deductible oscillate for wheat from 0 to 14%, with average of 1.1%. The premium with a 30% deductible was also calculated. In this case, the maximum would reach 6.48% and the average 0.25%. With a 15% trigger wheat premiums reach the 15.7%. This shows that premium rates are very sensitive to the deductibles and trigger levels. The total premium amount can be multiplied by 2 or even up to 6 when reducing the trigger from 30% to 15%. The country average fair premiums per hectare oscillate between €4.17 and €9.17 for most arable crops, but reach €30,70/ha for potato.

The final cost or commercial premiums are also estimated under certain assumptions. For RYI with a 30% trigger and a 50% market penetration (and assuming there is no adverse selection), the total EU-25 cost could be around of €77.6M for potato, €79.5M for barley and €69.8M for wheat, of which

€54.67M, €56M and €49.1 M respectively are the pure premiums. We have assumed here an overhead of 42% for management costs, profit, reinsurance, etc.

Some meteorological indicators were analysed following the model of the area yield-tailored insurance from several indicators. An insurance product could be thus designed for each region on the most relevant parameter or combination of parameters according to the results. However, these combinations of indicators do not explain yields optimally, as the Multiple R-Squared is only 30%. Perhaps other indicators should be explored. Besides, it is also possible that there is too much heterogeneity within each NUTS2 region and a meteorological yield-tailored index could only have a good explanation capacity at a more disaggregate level. The meteorological indices analysis is useful to underline that the index risk can differ very much from one European region to another. The example shown in Chapter 4.3 aims to explain the level of vulnerability of the same crop, at the same development stage can vary as function of climatic conditions. The results of the late frost study expresses the need to analyse the climatic risk under many points of view, accounting better for physiological aspects related to the crop and additional expertise is needed to aggregate data to reach more accurate results.

The analysis of the agro-meteorological indices is made on a large scale (EU 27); this factor limits the quality of the results, because the domain of observations is very wide. There is a wide range of climatic differences in Europe. Certain areas suffer lack of water, while other areas face problems due to excessive rain, kill frost, etc. This means that is sometimes inappropriate to analyse the same index on areas with different limiting factors. Dividing Europe into climatic zones could represent an improvement for the analysis; this could help to refine the outputs and to determine which index can represent better the yield variability for each zone and each crop. At present, the results suggest many directions that could be taken to comprehend how far an index can serve to assess losses due to climatic event or to prevent income losses through an insurance scheme based on agro-meteorological indices.

Analyses for NDVI (Normalised Difference Vegetation Index) computed on SPOT-VEGETATION images, show that the maximum NDVI is a poor indicator of crop yield risk. We have looked at the correlations in each FADN region and we have found that the index and yields are not correlated. There is a factor influencing negatively in these correlations: the small number of years available (only 7). However, results improved when taking into account only those maximum NDVI which fall in the period when the crop is more sensitive to nutrients and water stresses. This means that the capacity of NDVI for explaining yields could be improved by using the maxNDVI of this sensitivity period. On the other hand, ongoing activities within the Agriculture Unit of the JRC have proved that the correlation between the indicators derived from NDVI and yield is dependent on different regions. A study in Spain showed that the max NDVI but also cumulated NDVI values for different periods of the growing season are significant. Further analysis could include indicators such as the start NDVI or the end NDVI of the growing season; the cumulated NDVI during the length of growing season; and cumulated NDVI between start and max NDVI, or between max NDVI and end NDVI of the season.

6.2. Main conclusions on the cross-validation

FADN data are used to compute and map the level of risk of yield reduction with a 30% trigger for major field crops at the level of the farm. The concept of risk used corresponds to the long term average payment by the insurer to the farmer. This is often labelled in the academic literature as “fair premium”, although in practice the commercial premium is higher because of the management costs (including loss expertise) and the profit of the insurance company. Two different methodologies using FADN data have been used:

- One method based on the WTO-suggested approach that compares the yield each year with the average of previous years
- A newly developed method, that we have called “2-year constant sample”, that allows to use a higher number of FADN data and that takes into account the yield trend in each region.

The results show a geographic layout without any major surprise, but give a good indication of the quantitative level of risk. Preliminary results confirm that the risk level at the scale of the individual farm is much higher than the risk level using regional yield averages as trigger of a hypothetical index insurance.

Both approaches give results that are consistent with each other, but the two-year constant sample method gives in general slightly lower values for the risk than the 3-year moving average method for winter cereals. A possible explanation for this fact is that the WTO does not take into account the long term trend. We point out that the practical application of the WTO rule would require a farm-level register of yields going at least 3-5 years back; this does not seem to be available in most EU countries.

A spin-off of the study is the characterization of the regional yield trends with different functional shapes (linear, quadratic and logarithmic). This is a product that has a value as a tool to improve the current procedures of yield forecasting. However some additional work is necessary to collect time series of yields longer and more complete than the data available in the REGIO database.

The analysis of the income reduction risk is made by farm type instead of by crop. The application of the same methods to the income level measured through FNVA (Farm Net Value Added) is more problematic. We find a conceptual challenge in the application of the “30% deductible” when the average income in the previous year(s) is very low or even negative: What does it mean “a loss of more than 30% of the average income of the previous three years” when this average is negative? This inconvenient has been skipped by eliminating “awkward” ratios, but we have to warn that this may have a strong impact on the results, probably reducing the computed levels of risk. Even with this data cleaning implying a reduction of apparent risk, the risk levels computed for the income reduction are much higher than the risk of yield reduction. The reason for that is easy to understand: assuming relatively stable prices, a yield reduction of 30% correspond to an income reduction of much more than 30%, because the cost of production does not decrease with the yield. An alternative concept has been analysed: the value of production, or revenue, for which the estimated risk is much closer to the risk of yield reduction.

The cross validation of area yield insurance with FADN data showed, as could be expected, that the risk reduction capacity of yield area index is not very high for the case analysed. We can expect that the results do not depend from the crop type, but on the scale of the analysis. Besides, we have to take into account that it was underestimated due to the data constraints (the percentage indemnities were multiplied by actual farm yields and not by average or expected farm yields). However, there are some regions where the risk can be reduced up to a 68%. These results have to be considered cautiously, given that the correlations between Eurostat yields and FADN yield averages are often weak.

The test for risk reduction capacity of other indexes could be done. However, it would be expected to be lower than the one from yield area index, given that theoretically regional yield area should describe the behaviour of farm yield better than other indexes at a regional scale.

7. References

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8. List of acronyms

AIDA	Agricultural Income Disaster Assistance-Canada
AGR	Adjusted Gross Revenue
APH	Actual Production History
AWU	Annual Work Unit
B	Billion
CAIS	Canadian Agricultural Income Stabilization
CAP	Common Agricultural Policy
CHU	Corn Heat Unit
CGMS	Crop Growth Monitoring System
CRC	Crop Revenue Coverage
CRMG	Commodity Risk Management Group
MVC NDVI	Maximum Value Composite NDVI
DG-AGRI	Commission’s Directorate General for Agriculture and Rural Development
EC	European Community
ENSO	El Nino-Southern Oscillation
ERHT	Excessive Rain at Harvest Time
ESU	European Standard Unit
EU	European Union
FADN	Farm Accounting Data Network
FCDD	Factores Climaticos Dañinos Diarios
FNVA	Farm Net Value Added
FWC	Financial weather contracts
GRP	Group Risk Plan (USA)
GRIP	Group Risk Income Protection (USA)
GRIP	Gross Revenue Insurance Plan (Canadian)
HDD	Heating Degree Days

ICICI	Industrial Credit and Investment Corporation of India
IFC	International Finance Corporation
IP	Income Protection
JRC	Joint Research Centre (European Commission)
LGM	Livestock Gross Margin
LRP	Livestock Risk Protection
M	Million
MVC NDVI	Maximum Value Composite NDVI
MS	European Union’s Member State
NDVI	Normalised Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
NUTS	Nomenclature des Unités Territoriales Statistiques
RA	Revenue Assurance
RSM	Relative Soil Moisture
RYI	Regional Yield Insurance
SADC	Southern Africa Development Community
SGM	Standard Gross Margin
SI	Satellite Imagery
SHR	Selyaninov Hydrothermal Ratio
T	Metric ton
TWC	Total Water Consumption
USA / US	United States of America
UK	United Kingdom
VP	Value of Production
WB	World Bank
WD	Weather derivatives
WI	Weather index insurance contract
WLSOW	Water Limited Storage Organs Weight
WTO	Word Trade Organisation

Countries acronyms

FADN			**Eursotat**	
BEL	Belgium		AT	Austria
CYP	Cyprus		BE	Belgium
CZE	Czech Republic		CY	Cyprus
DAN	Denmark		CZ	Czech Republic
DEU	Germany		DE	Germany
ELL	Greece		DK	Denmark
ESP	Spain		EE	Estonia
EST	Estonia		ES	Spain
FRA	France		FI	Finland
HUN	Hungary		FR	France
IRE	Ireland		GR	Greece
ITA	Italy		HU	Hungary
LTU	Lithuania		IE	Ireland
LUX	Luxembourg		IT	Italy
LVA	Latvia		LT	Lithuania
NED	Netherlands		LU	Luxembourg
OST	Austria		LV	Latvia
POL	Poland		NL	Netherlands
POR	Portugal		PL	Poland
SUO	Finland		PT	Portugal
SVE	Sweden		SE	Sweden
SVK	Slovak Republic		SI	Slovenia
SVN	Slovenia		SK	Slovak Republic
UKI	United Kingdom		UK	United Kingdom

9. Annexes

9.1. Annex 2A. Summary of the report on Agricultural Insurance Systems (AGRINSUR-I)

As mentioned above, this study is a continuation of the study on “Agricultural Insurance Schemes” (AGRINSUR-I), by Bielza et al. (2006). The main points and conclusions from the study were:

The economic situation of farms has a strong variability for several reasons:

- Policy reforms: trade agreements and market liberalisation (reduction of prices).
- An unbalances relationship with retailers better organised to put pressure on prices.
- Risk of animal diseases
- Climate change: There is a general perception that the frequency and intensity of extreme meteorological events is growing.

The AGRINSUR-I study makes a review of the agricultural risks management systems in Europe (EU-27) with a special focus on agricultural insurance. The role of Governments is analyzed for every country: offering or subsidizing insurances and providing aid ex-post. Most information comes from fact sheets collected from experts or consultants in the different countries.

The definition of crisis and disasters is rather generic. More precise definitions can be found for the authorisation of state aids in case of disaster or adverse climatic conditions. The positions of Member States in authorising these aids are analysed and compared with the “Community guidelines for State Aid in the Agriculture Sector” (EC, 2006b) and with the Regulation on the same topic (EC, 2006a).

Aid is sometimes given on an ad-hoc basis through compensation schemes, or finds, partially financed by the agricultural sector (on a voluntary or compulsory basis). Mutual funds, calamity funds and ad-hoc payments existing in European countries are summarised.

Agricultural insurances are fostered in a number of countries, where the law forbids that ad-hoc measures or disaster funds compensate damages that could have been insured. The levels of ad-hoc payments per country are compared.

The different types of agricultural insurance systems in Europe and key figures in each country are analysed. Some technicalities are described, such as reinsurance, triggers and deductibles.

The relationship between Government involvement and insurance development is highlighted. Usually private companies insure only hail and fire, and the government subsidies and public reinsurance are needed to make possible the insurance of agricultural systemic risks.

One conclusion is that the risk management tools available in the Member States (MS) could be further developed. However, given the heterogeneous situation in the MS, the interest of a harmonised EU-wide system of agricultural insurances is debatable. Conditions for a feasible EU-wide insurance scheme are analysed and classified into a) decisions of the policy makers (political criteria); b) decisions of the private sector: insurers, re-insurers and farmers (socio-economic); and c) technical conditions.

The existing insurance level is generally insufficient to smooth significant income reduction in bad years. The possible amount of costs of an EU-supported insurance system has been roughly quantified for a few hypothetical scenarios, under given assumptions. The feasibility of control systems and the technical aspects are analysed.

9.2. Annex 2B. The Income Stabilization project

Within the 6th Framework Program for the Research and Technological Development (RTD), there was a horizontal activity called "Scientific Support to Policies". It was in the frame of the call of proposals of this activity in October 2003 that a project on risk management was selected under the Task "Crisis/risk management tools". The full name of the project was: "Design and economic impact of risk management tools for European agriculture", but it is better known by its acronym "Income Stabilization". It started mid-2005 and finished in March 2008.

The Income Stabilisation Project, with 7 partners from 5 countries, was co-ordinated by the University of Wageningen. It was structured in 7 work packages (additional to WP1, management). It has the particularity that it had several potential overlaps and complementary aspects with the AGRINSUR-I project, so contacts were established and several meetings scheduled to ensure synergy between both projects. Especially Work Package 4 was particularly similar to the AGRINSUR-I project, although there are major differences: The AGRINSUR-I project was more specifically focused on EU-27 and on insurances, rather than generic risk management strategies. Another difference is that the AGRINSUR-I project had an additional target of exploring methods to map the variability of yield that can endanger a suitable farm income.

The aim of the Income Stabilisation project (Meuwissen et al. 2008) was to analyse the opportunities that risk management tools offer for stabilising farm incomes in the European Union in the contemporary context of new agricultural risks, an enlarged European Union, changing views about eligible forms of income support and disaster relief, and on-going developments at international risk management markets. Results present a representative cross-section of European farming, i.e. risk exposure, risk perception and economic impact issues have been studied in depth for 5 member states, i.e. Germany, Hungary, the Netherlands, Poland and Spain.

The project had three pillars: (1) a detailed analysis of farmers' *risk exposure* in the past and projected risks in the future; (2) a review of *risk management experience and farmers' perceptions of risk*; and (3) the *economic impact of and policy options for viable risk management instruments*.

(1) Risk exposure

Past risk exposure. This component of the project thoroughly analysed farm-level data from the Farm Accountancy Data Network (FADN) in order to provide insight into the volatility of farmers' risk exposure and into the chances of facing catastrophically low production, price or income levels. Specific research objectives included: (i) to provide insight into farm-level production, price and income distributions, including downside risk; (ii) to make a clear distinction between normal income fluctuations and income crises; and (iii) to discuss the usefulness of FADN data for measuring farmers' income (crisis) risk. Its main conclusion: *Data from FADN can partly provide insight into the wide range of on-farm risks.*

Future risk exposure*: what can we expect in the next ten years?* Since risks are constantly changing, data from the past generally tell only *part* of the story. This component of the project provided insight into the impact of future World Trade Organisation (WTO) and CAP scenarios on farmers' risk exposure and risk management opportunities. Research objectives were (i) to define likely future CAP and WTO scenarios with their implications for price, production and farm income; (ii) to analyse the impact of these scenarios on price, production and income probability distributions of farmers in the European Union; and (iii) to analyse the impact of these scenarios on the chances of catastrophically low incomes. Its main conclusion: *Increasing levels of liberalisation do not seem to lead to widespread negative effects on the stability of farm-incomes in the EU, although vulnerability differs significantly across farm types and member states.*

(2) Risk management experience and perception

Review of the international risk management arena*.* This part of the project reviewed historical, current and developing risk management instruments, both within the European Union and in non-EU countries. Research objectives were (i) to report on successful and unsuccessful risk management instruments; and (ii) to analyse the major characteristics of these schemes (e.g. the risks covered and the underwriting criteria applied), and their performance and economic impact. Its main conclusion: *There is an increasing variety of risk management instruments, including tools to capture the problem of asymmetric information. Public sector involvement can (still) lead to undesired incentives.*

Risk and risk management perception*.* Risk analyses by scientists do not necessarily correspond to the perception of risks by farmers. Also, what may be perceived as theoretically promising risk management instruments may not work well for farmers. Research objectives of this component of the project were: (i) to analyse farmers' perceptions of (crisis) risk and (crisis) risk management; and (ii) to analyse farmers' perceptions of the role of various possible risk financing partners, ranging from their own role to that of national and European governments. Its main conclusion: *Risk perception varies considerably across member states. Price and weather risk however is generally perceived to be most threatening.*

(3) Economic impact and policy options

The economics of risk management instruments*.* Theoretically ideal concepts may not work well at the farm level, or may just be too costly. This component of the project modelled the economic impact of potential risk management instruments for the European Union. Research objectives included: (i) to select promising risk management instruments, including purely private instruments, public-private partnership instruments and entirely public risk management instruments; (ii) to develop a whole-farm optimisation model and to analyse the economic impact of potential risk management instruments at farm level, including their impact on production decisions and on the level of (crisis) risk; and (iii) to analyse the budgetary impact of potential risk management instruments. Its main conclusion: *Despite application of a portfolio of prospective risk management instruments, substantial on-farm income volatility remains. Also, on-farm diversification seems to have its limitations.*

Policy options for risk management. The various themes of the project, i.e. risk exposure, risk management experience, risk perception and the economic impact of various schemes, were brought together in the final component of the project. The main research objective was to synthesise all previous project components in order to come up with policy options for (crisis) risk management that are feasible from a design and budgetary point of view, legitimate in CAP and WTO frameworks, and interesting for farmers. Its main conclusion: *For normal on-farm enterprise risk, infrastructural improvements are needed. For crisis risk, rules need to be set at EU level, but premium subsidies should be avoided.*

General conclusions from the project include:

(1) There is not sufficient data to accurately and instantly assess farmers' income risk. FADN data are worthwhile for farm-level risks, but only partly and retrospectively. Off-farm *income* data are largely lacking.

(2) Income risk measures and methods used throughout the analyses (i.e. income variation at individual farm level, shortfall risk and whole-farm modelling), provide insight into the wide variety of income risks faced by EU farmers.

(3) Eastern EU finetuning among stakeholders disclosed that there is not a commonly shared risk management perception, knowledge and view on the prospects of (innovative) risk management solutions.

(4) Due to established differences among EU-farming, both in risk exposure, risk perception and whole-farm consequences, risk management solutions need to be "tailor-made". However, from an analytical perspective, premium subsidies are nowhere to be preferred. Moreover, all risk management instruments require careful and proper design.

From the experiences from the project, also a number of issues for further research have been identified:

(1) Public sector involvement in on-farm risk management. If, from a political perspective, this option is considered, further research is needed to transparently set the rules for support and design. Rules should aim at public involvement leading to "crowding *in* private markets" instead of "crowding *out*" these markets.

(2) Crisis risk assessment. As FADN data did not fully allow to analyse farm-level effects of crisis risk, further analyses should be directed towards specific risks such as liability risk and disruptions through environmental damages.

The project as a whole seems to us a very complete and interdisciplinary analysis on the risk management current debate. Moreover, it combines the inputs of academics and scientific experts with those of the main actors of risk management: mainly famers and also insurance companies. We found a big strength of the project in the open discussions, which were not only limited to the project partners but also counted with the collaboration of many external agents and experts in the risk management field. Overall, our general impression of the project is very positive even if we found that some of its final statements stay unclear to us; for instance the conclusion on avoiding subsidies to insurance, whose motivation does not seem sufficiently explained.

9.3. Annex 2C. WTO Uruguay Round Agreements on Agriculture (Annex 2)

7. Government financial participation in income insurance and income safety-net programmes

(a) Eligibility for such payments shall be determined by an income loss, taking into account only income derived from agriculture, which exceeds 30 per cent of average gross income or the equivalent in net income terms (excluding any payments from the same or similar schemes) in the preceding three-year period or a three-year average based on the preceding five-year period, excluding the highest and the lowest entry. Any producer meeting this condition shall be eligible to receive the payments.

(b) The amount of such payments shall compensate for less than 70 per cent f the producer's income loss in the year the producer becomes eligible to receive this assistance.

(c) The amount of any such payments shall relate solely to income; it shall not relate to the type or volume of production (including livestock units) undertaken by the producer; or to the prices, domestic or international, applying to such production; or to the factors of production employed.

(d) Where a producer receives in the same year payments under this paragraph and under paragraph 8 (relief from natural disasters), the total of such payments shall be less than 100 per cent of the producer's total loss.

8. Payments (made either directly or by way of government financial participation in crop insurance schemes) for relief from natural disasters

(a) Eligibility for such payments shall arise only following a formal recognition by government authorities that a natural or like disaster (including disease outbreaks, pest infestations, nuclear accidents, and war on the territory of the Member concerned) has occurred or is occurring; and shall be determined by a production loss which exceeds 30 per cent of the average of production in the preceding three-year period or a three-year average based on the preceding five-year period, excluding the highest and the lowest entry.

(b) Payments made following a disaster shall be applied only in respect of losses of income, livestock (including payments in connection with the veterinary treatment of animals), land or other production factors due to the natural disaster in question.

(c) Payments shall compensate for not more than the total cost of replacing such losses and shall not require or specify the type or quantity of future production.

(d) Payments made during a disaster shall not exceed the level required to prevent or alleviate further loss as defined in criterion (b) above.

(e) Where a producer receives in the same year payments under this paragraph and under paragraph 7 (income insurance and income safety-net programmes), the total of such payments shall be less than 100 per cent of the producer's total loss.

9.4. Annex 3A. Examples of index insurances per countries

9.4.1. Examples of area index insurances

9.4.1.1. Europe (Sweden and United Kingdom)

In the 50’s, Sweden was managing an insurance program based on the yield and revenue of geographic areas (Skees and Hartell, 2004).

In the United Kingdom an area revenue insurance programme was launched in 1998 based upon the yield statistics of the Home Grown Cereals Authority and upon the LIFFE commodity futures prices. The cover provided indemnity for a 10% fall in yield and a 5% fall in price. Premium rates varied depending of the region from 1.10% to 3.5%. Take up was minimal and the product offering was cancelled in the following season.

9.4.1.2. India

In India, in 2004 a pilot program was introduced by the public insurance company AIC(Agriculture Insurance Company of India Limited). It is called “Farm Income Insurance Scheme” (FIIS) and is a area revenue insurance product. Indemnities are calculated as the difference between guaranteed revenue and actual revenue. Guaranteed revenue results from a basic price times the 7 year average yield of the district. The area actual revenue is calculated from district yields and a weighted average price provided by several local “Agricultural Produce Market Committees” at district or at state level. It applies for rice and wheat, and losses due to bad yields are covered when they are due to the following perils: flood, inundation, storm, cyclone, hailstorm, landslide, drought, dry spells, and large-scale outbreak of pests/diseases. The scheme is compulsory for loanee farmers and voluntary for non-loanee farmers. It is subsidized in a 75% for small and marginal farmers and 50% for other farmers. Given that appropriate rating methodology is not available at this stage, and that the guarantee price is completely independent from market price, the Government has the compromise to bear the claims above the year’s collected premiums. In Parbhani district of Maharashtra state for wheat crop during the rabi (spring) season 2003-2004, 981 wheat growers participated, and the loss ratio for the district was 1.34 (Bhise et al. 2007).

9.4.1.3. Mongolia

One particular case has been included in the area indices: it is the case of Mongolia. In the last years, Mongolia’s shepherds have suffered important losses due to weather calamities such as the winter thunderstorms. Given the nature of highly correlated death rates for animals in Mongolia, an index-based livestock insurance (IBLI) product was proposed and in May 2005, and the World Bank approved a loan to Mongolia to finance the Index-Based Livestock Insurance Project.. The major objective of the pilot program is to determine the viability of IBLI including testing herders' willingness to pay for the IBLI product. The index is based on area mortality rates by species and by province (number of adult animals dead divided by the number of total animals censed in the area at the beginning of the year). Indemnities would be triggered when the mortality rate is above a certain threshold. The indemnity would be function of the mortality rate multiplied by the protection value (or insured value) bought by the shepherd. This scheme was never made before, and it is possible because Mongolia performs a complete census of every species each year (Skees et al. 2005). Elaborate systems are in place to assure the quality of the data.

A traditional insurance on animal mortality would be hindered by several factors. The width of the territory in which shepherds take more than 30 million animals to pasture results in that the insurance of single heads would not work; even the most simple question, which is the identification of the propriety of the heads would demand very high transaction costs; besides, there are multiple possibilities of fraud and abuses and the monitoring costs needed to avoid them would be high (Skees & Hartell, 2004).

The project will support continued research to strengthen the mortality index by incorporating other indexes, for example, the Normalized Difference Vegetation Index (NDVI), as a means of establishing a more secure index for paying losses. (WB, 2005).

Mongolia's insurance market is a nascent market with extremely limited access to global risk-shifting markets, so significant financial exposure for this market remains among the largest challenges. Given concerns about financing extreme losses, the pilot design involves a syndicate pooling arrangement for companies. Herder premiums go directly into a prepaid indemnity pool. In the short term, the government of Mongolia will offer a 105 percent stop-loss on the pooled risk of the insurance companies. Once the reinsurance pool is exhausted, the government of Mongolia can call upon the contingent debt to pay for any remaining losses. In the long-term vision, the syndicate will be well positioned to find risk-sharing partners in the global community quickly. Reinsurers might be willing to provide capital and enter quotashare arrangements on that risk (WB, 2005).

9.4.1.4. Morocco

Drought insurance has been offered in Morocco since 1995-96. This scheme was implemented (private but Government subsidized) following the recommendations of the report ARML (1993). This insurance scheme has three guarantee levels, each of which has a different threshold and provides a different fixed indemnity. Of course, there are three different premiums according to the levels. In order for the insurance scheme to begin making indemnity payments, an official drought declaration must be made. At Level 1 (the lowest coverage level), the insurance pay-out is based on the realized average area yield for the rural commune. For the other two levels, the pay-out is based on assessments of the individual farm's realized yield. The formula for indemnification is non-proportional:

Indemnification/ha= Insured level/ha – Unit Price x Yield

For further information on the Moroccan drought insurance scheme see Skees et al. (2001).

9.4.1.5. USA

While the price component of existing USA revenue insurance products is based on an index, the insurance products GRP, GRIP, LRP and LGM are the only current Federal Crop Insurance Program (FCIP) products that base indemnities completely on the realized value of an underlying index (Barnett, 2004).

The Group Risk Plan or GRP has been offered since 1993. For the U.S. GRP program, indemnities are calculated as follows:

$Indemnity = \max\left(0, \frac{Guaranteedlevel - indexlevel}{Guaranteedlevel}\right) \times insuredvalue$ where the "index level" is the effective yield of the county where the farm is located (Skees, Black and Barnett, 1997), and the "guaranteed level" is the product of the coverage level selected by he policy buyer and the official estimate of the county's expected unitary yield. The choice of coverage level can be from 70% to 90%. The county's expected unitary yield is estimated from a detrended series of 45 years county yield data. The "insured value" is the product of the county's expected yield, the official estimate of the price, the coverage level, the scale and the crop surface in the farm. The scale is also chosen by the producer, depending on how is his individual expected yield in relation with the county yield, and it can vary from 90% to 150%.

The GRP type of contract is also defined as "proportional" because the yield reduction is measured as a percentage of the guaranteed level. An interesting characteristic of proportional contracts is that they have a "disappearing deductible": as the index becomes closer to zero, the indemnity tends to 100% of the insured value, with independence of the coverage level chosen (Skees & Hartell, 2004). Barnett et al. (2005) compare risk reduction from MPCI and GRP crop insurance contracts. The analysis is based on the actual GRP indemnity function rather than the area-yield indemnity function commonly used in the literature. Even with a number of conservative assumptions favouring MPCI relative to GFtP, results indicate that at least for some crops and regions GRP is a viable alternative to MPCI.

Later, a similar policy was developed and commercialised: Group Risk Income Protection (GRIP). In this program, the index is an "area revenue", that is, the product of the area yield times the price of the specific product. In 2004, both area yield and area revenue policies accounted for 7.4 % of total acreage insured but less than 3 % of total premiums. The average loss rate (indemnities/premiums) of GRP on its activity period prior to 2004 was 90%.

Barnett (2004) reviews GRP and GRIP, and compare them with the USA's traditional farm-level crop insurance product known as Actual Production History (APH) multiple-peril crop insurance. Besides, he discusses the new livestock index insurance products, which are in fact price insurance products: Livestock Gross Margin (LGM) and Livestock Risk Protection (LRP). Livestock Risk Protection (LRP) protects against decreases in the market value of insured cattle or swine. Livestock Gross Margin (LGM), which is available only for swine, protects against decreases in the margin between the market value of the animal and the cost of feed inputs. Both are index insurance products because indemnities are based not on actual prices received and/or paid by the producer but rather on changes in futures market prices (the index) for the animal (in the case of LRP) or the animal and feed inputs (in the case of LGM) during the life of the insurance policy. Thus, both products are, in essence, derivatives based on exchange-traded futures contracts. When comparing LRP and LGM to GRP and GRIP, it is important to note that price risk (for livestock and major crops) tends to be much more systemic than crop production risk. Crop production shortfalls in one region of the U.S. do not necessarily imply crop production shortfalls in other regions. In contrast, price increases or decreases are much more likely to affect all producers, regardless of where their farms are located. This means that, in general, one would expect less basis risk for index insurance products such as LRP and LGM that provide price risk protection, compared to products like GRP (GRIP) that protect against yield (revenue) risk (Barnett, 2004).

9.4.2. Examples of weather index insurances

9.4.2.1. Austria

In Austria an index is applied for the coverage of drought in yield insurance since 2007.

9.4.2.2. Canada

In 2000, after a serious drought, Ontario has introduced an index insurance based on rainfall. It was developed by the State agricultural insurance corporation, Agricorp. 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 (Stoppa and Hess, 2003).

AFSC also developed for Alberta a 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 payments. In 2002, around 4,000 livestock farmers have bought this contract.

Last, corn producers in Alberta can use a temperature index to insure their losses of silage. The Agriculture Financial Services Corp. (AFSC), the Canadian financial crown corporation of Alberta, has been offering Corn Heat Unit insurance program, a weather index-based insurance product offered to protect farmers against the financial impact of negative variations in yield for irrigated grain and silage corn. The contract is designed to insure against lack of Corn Heat Units (CHU) over the growing season. It has been offered on a pilot basis since 2000 and was planned to last until 2005. The program is scheduled for a thorough evaluation to assess its impact over the year 2006.

The CHU index falls into the *Growing Degree Day* category, and represents the energy available for the development of corn. Given the small window for agricultural production in Canada, the availability of sufficient solar energy is vital for the development of this crop. The index has been designed to indemnify the policyholder against an annual CHU below Threshold Corn Heat Unit (TCHU) level at the specified weather station. The CHU is estimated from daily maximum and minimum temperature, beginning on May 15 each year. The Celsius-based formula used to calculate daily CHUs is defined as follows (Brown and Bootsma, 1993):

$$CHU = 0.5 \times Y_{\min} + 0.5 \times Y_{\max} \tag{1}$$

$$Y_{\min} = 9/5 \times \left[T_{\min} - 4.4 \right] \tag{2}$$

$$Y_{\max} = 3.33 \times \left[T_{\max} - 10.0 \right] - 0.084 \times \left[T_{\max} - 10 \right]^2 \tag{3}$$

where T_{min} and T_{max} are the daily minimum and maximum temperatures, respectively.

The daily CHU values are calculated from these temperatures. The daytime relationship involving T_{max}, uses 10°C as the base temperature (if T_{max} is less than 10, its value is set at 10) and 30°C as the optimum temperature, as warm-season crops do not develop when daytime temperatures fall below 10°C and develop at a maximum rate at around 30°C. The nighttime relationship involving T_{min} uses 4.4°C as the base temperature below which daily crop development stops. (If T_{min} is less than 4.4, its value is set at 4.4.). The CHU value is calculated by taking into account the functional relationship between daytime and nighttime temperatures and the daily rate of crop development, as shown in Brown and Bootsma (1993). The accumulation of CHU stops on the first day on which a minimum temperature of minus two degrees Celsius or less is recorded, after 700 CHU have been accumulated. This means the accumulation continues until the first killing frost hits the crop. An early frost setback is also built into the AFSC calculation (WB, 2005)

The weather data for settlement of the contracts are provided by the federal and provincial weather stations and compiled by the Irrigation Branch of the Alberta Government. Contract end users can select a weather station for the settlement from the federal and provincial stations available, choosing the station that best represents the temperatures on their farms. Weather stations used for CHU insurance are divided into three groups based on similar historical heat accumulations. Weather stations within each group have similar threshold options, premium rates, and loss payment functions. When buying the insurance policy, farmers must elect the dollar coverage per acre, select the weather station for settlement purposes, and indicate if they prefer a hail endorsement to the contract or the variable price benefit.

The farmer must insure all the seeded acres of eligible corn and must insure a minimum of five acres for each crop: grain and silage crops are considered separate for the purposes of referring to a specific insurance contract.

Since the lack of heat units affects grain corn more than it does silage corn, the table of premium and payment rates differs for the two types of crop. The actual premium and payment rates are not available for public disclosure. The formula to calculate the indemnity for each insurable crop is given by the following equation:

Indemnity = Dollar coverage per acre x Payment rate x Number of Insured Acres

If a farmer chose to insure one hundred acres at $225 per acre, for example, and the accumulated CHU payment rate was 30 percent of the expected level, a claim of $6,750 dollars would result. The maximum indemnity payable is 100 percent of the Dollar Coverage per Acre (including the additional dollar coverage if a Variable Price Benefit is activated) multiplied by the number of insured acres. Claims are based on accumulated CHUs calculated using the temperature data recorded at the selected weather station. CHUs accumulated before the killing frost are compared to the threshold chosen by the producer at the weather station. If the annual CHUs are less than a chosen threshold, the insurance program starts to make payments according to a predetermined table. The further the annual CHUs are below the threshold, the greater the insurance payment. Producers can choose between two deductibles or threshold options: High and Low “Trigger”, which are approximately the 95 and 90% of the long-term normal CHU. Payments begin sooner under the high threshold option, so this choice has a higher cost than the low threshold option.

The main peril for producers is lack of heat during the growing season, but this insurance plan also includes a provision for late spring frost. A late spring frost can set back corn plant growth and affect production. To trigger this provision, a temperature of less than zero degrees Celsius must be recorded on or after June 1 and prior to the recording of 700 CHUs at the weather station. If both these conditions are met, 50 CHUs will be deducted from the accumulated total CHUs at the end of the year for the first day and an additional 15 CHUs will be deducted for every other day between June 1 and the day the frost in question occurred.

It is important to point out that the CHU contract with the hail endorsement is designed to protect corn against two major perils: lack of heat and hail. The grain and silage corn farmers are also eligible for traditional crop insurance contracts based on individual records; nevertheless, the premiums are lower for the CHU contract because of AFSC’s reduced transaction costs. It should also be noted that the premiums paid by the farmers for the CHU contract are subsidized by approximately 55 percent, so the farmer pays only 45 percent of the cost of the contract. The subsidy is 40 percent for the hail endorsement. The federal and provincial governments coshare the financial burden of the program, and they subsidize all AFSC’s administration costs (WB, 2005).

9.4.2.3. Ethiopia

To address the drought and food-insecurity situation in Ethiopia, two agricultural risk management structures were being considered in 2005 (WB, 2005): one at the farmer or microlevel and the other at the government or macrolevel. Both at the macro and the micro level, the scarcity of weather data in the country limits the scope of the project in its first years.

At the microlevel, the state-owned Ethiopia Insurance Corporation (EIC) planned to launch a small pilot program (for which it receives technical support from the World Bank). It was due to start in April 2006, and it consists on a weather insurance program for wheat and pepper farmers in southern Ethiopia, in the woreda (district) of Alaba. The products would be similar in concept to the products offered to farmers in India, but it will be sold at the group rather than individual level (to ‘kebeles’ or small groups of farmers and to farming cooperatives)

At the macrolevel, lack of rainfall in the critical months of August and September is the dominant, immediate cause triggering emergency relief operations in Ethiopia. The macrolevel structure consists on an index-based weather insurance as a reliable, timely and cost-effective way of funding emergency operations. Risks would be passed to the international reinsurance market. It does not aim to serve the food-insecure population, but the 35% of the population above the chronically food-insecure who are fully vulnerable to become so in the case of a drought as such the one in 1984.

The scheme was under study by the World Bank and the United Nations World Food Programme (WFP). WFP launched a pilot experience, by putting in place a small hedge for Ethiopia’s 2006 agricultural season from March to October 2006. The aim was to demonstrate the possibility of indexing and transferring the weather risks of least-developed countries and facilitating price discovery for Ethiopian drought risk in international financial markets. The index must be based on a weighted average, or “basket”, of as many stations as possible to capture the macrolevel nature of the risk the Government faces. So, the 2006 index pilot was based on a basket of 26 weather stations distributed throughout the agricultural producing areas of the country. The correlation (R^2) of the WFP drought index and the number of food aid beneficiaries between 1994 and 2004 was around 80%. (Hess et al. 2006). In the pilot stage of the program, the WFP was the counterparty to any commercial transaction with the international risk market, and donors would pay for the premium associated to the risk transfer. The ultimate aim of the initiative would be for the Government to go directly to the market and take responsibility for the risk management program as part of its overall long-term poverty reduction strategy.

Let’s have a look at the design of the insurance (WFP, 2006). After a selection of the weather stations with the most complete datasets (42 from the 600 available), spatial analysis techniques were used to assign woredas (districts), and hence rural populations, to the 42 selected rainfall stations. The objective was to find woredas whose normalized vegetation index[13] (NDVI) patterns correlated with rainfall recorded at each of the 42 stations. For a more detailed information on spatial analysis see

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[13] For insurance products based on NDVI see next section on satellite imagery index insurances

WFP 2006. After the spatial analysis, only 26 of the 42 stations initially considered were finally selected for the pilot project.

In Ethiopia there are two main rainfall periods: (i) the kiremt, associated with the meher main growing season accounting for 95 percent of national production, and (ii) the belg, the minor rainfall and growing season that accounts for 5 percent of national production, but whose rains are important in vulnerable areas and vital for pasture regeneration, water supply and planting of long-cycle crops. The FAO Water Requirement Satisfaction Index (WRSI) established how production of the dominant crops grown in each micro-climate can be indexed to rainfall amount and distribution. The pilot project uses the USGS/FEWS-NET WRSI (Senay and Verdin 2003), a modified version of the FAO WRSI (Frere and Popov (1986) to index crop yield to rainfall variability. There are many more robust and data-intensive physically-based crop models available, but the FAO WRSI model has the advantages of its limited data requirements and simplicity in operational use. It has been successfully tested Senay and Verdin made it an operational model with some modifications in the algorithm.

WRSI is an indicator of crop performance based on water availability during the growing season, calculated using a crop water balance model. Studies by FAO have shown that WRSI can be related to crop production using a linear yield-reduction function specific to the crop in question (FAO, 1986). WRSI is defined as the ratio of seasonal actual evapotranspiration experienced by a crop to the crop's seasonal water requirement; hence it monitors water deficits throughout the growing season, taking into account the phenological stages of a crop's evolution and the periods when water is most critical to growth. The WRSI model was initially developed for use with weather station data to monitor the supply and demand of water for a rain-fed crop during the growing season. The model currently is used by FEWS-NET as one of the operational remote-sensing products to monitor agricultural areas around the world for signs of drought on a near-real-time, spatial and continuous basis using a combination of satellite-derivative rainfall estimates and rain-gauge data from the GTS to compute WRSI values (Senay and Verdin, 2003).

The inputs and data sources required to calibrate the WRSI model for an area and a crop during a growing season include:

i) cumulative decade rainfall (mm) for the 26 rainfall stations

ii) average decade potential evapo-transpiration (PET) (mm) for the 26 rainfall stations

iii) the water-holding capacity (WHC) (mm) of the soil

iv) crop coefficients (Kc) for each crop; Kc values define the water-use pattern and are defined for each of the critical phenological points of a crop's evolution

v) maximum crop root depth (m) and the allowable depletion fraction

vi) seasonal yield-response factors (Ky) for each crop to convert WRSI values to yield estimates

WRSI can be related to crop production or yield estimate by using the following linear yield-reduction function:

Actual Yield (AY)=1-(1-WSRI)*Seasonal Ky*Maximum Yield

The study was performed for the staple crops in Ethiopia: maize, teff, and sorghum, together with millet, wheat and barley. These crops were given weights based on their average-area-planted ratios (α_{crop}) for each woreda, and thus constituted a *staple crop basket*. Production per hectare for the *staple crop basket* of each woreda, Y_w, is therefore defined as follows:

$$Y_w=\alpha_{Maize}AY_{Maize}+\alpha_{Sorghum}AY_{Sorghum}+\alpha_{Millet}AY_{Millet}+\alpha_{Teff}AY_{Teff}+\alpha_{Wheat}AY_{Wheat}+\alpha_{Barley}AY_{Barley}$$

and

$$\alpha_{Maize}+\alpha_{Sorghum}+\alpha_{Millet}+\alpha_{Teff}+\alpha_{Wheat}+\alpha_{Barley}=1$$

Indexing the staple crop production in this way established an objective indicator for household production per unit area cultivated for each woreda. For more details on the model see WFP 2006.

Vulnerable or at-risk households were characterised for each woreda: number, size, income, income sources, asset (mainly livestock) holdings and farm choices. Income from agricultural production was estimated to average 68 percent of total income (*HI*) for vulnerable households. The impact of production variations in the staple-crop basket on at-risk household in each woreda was modelled. The following relationship was assumed between deviations in production per unit area, measured by the staple-crop basket WRSI, and agricultural income losses per at-risk household:

Drought-related agricultural income loss per at-risk household = expected at-risk household agricultural income under normal (non-drought) conditions x *% deviation of* Y_w *from median*

Last, household purchasing power is reduced as a result from increased market prices associated with extreme drought. So, a market-price inflation factor was added to the model to ensure that income losses are adjusted upwards to compensate for reduced household purchasing power. A simple price-inflation factor was calculated for each woreda by considering the staple-crop basket for the woreda and multiplying the proportion of each crop in the basket by the approximate price increase observed for it in 2002, Ethiopia's last extreme drought year. These price increases were 200% for maize, and between 115 and 150% for the rest of the crops.

The final index of livelihood losses for at-risk beneficiaries is defined as follows:

Index =sum of livelihood losses in the woredas associated to the 26 weather stations

$$Index = \sum N_w \times p_w \times HAI_w \times \max\left(0, {(X_w Y_{median} - Y_w)}\big/{Y_{median}}\right)$$

Where N_w is the number of at-risk households in each woreda, p_w is the price inflation factor, HAI_w=0.68HI_w, HI_w being the expected household income from the 2000 Welfare Monitoring Survey[14], Y_w and Y_{median} are respectively the actual and the median crop production per hectare of the staple-

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[14] Central Statistical Authority 2000

crop basket for that woreda, and X_w is the woreda-specific income-loss trigger level adjustment factor, which is defined as follows: $X_w = \min\left(1, {}^{12.2}\!\big/\, Y_{median}\right)$

9.4.2.4. India

India has an application of insurance microfinance. Studies had indicated that rainfall variation accounts for more than 50 percent of variability in crop yields (Bhise et al. 2007). The Government asked the Agricultural Insurance Corporation (AIC) to start a weather-based crop insurance scheme on a pilot basis in some states, in consultation with the Governments concerned, as an alternative to the indemnity-based National Agricultural Insurance Scheme (NAIS) (Roth et al. 2007). In 2003, the *Icici Lombard General Insurance Company* started two pilot insurance programs, one of which covers against shortage of rainfall, and the other against excess of rainfall. These policies were offered through different banks. These index policies have the advantages of providing the indemnities within a shorter delay than the current agricultural insurance system in India. Weather index insurance has since developed, as can be appreciated in Table 23, which shows all the weather insurance products in India. Reinsurance is made mostly in the international reinsurance market. It is estimated that during 2005, 250,000 farmers bought weather insurance throughout the country (WB, 2005).

Table 23. Weather index insurance in India

Name **Index**	**Crop covered**	**Years**	**Promoter / seller**	**Region**	**Buyer**	**Maximum demand**
I1-ICICI Rainfall Deficit rainfall	Khariff groundnut Castor	2003 -	CRMG / ICICI Lombard directly and through BASIX (KBS & BSFL)	(At the beginning Andra Pradesh)	Farmers (borrowers and non borrowers)	(2005) 6.703 farmers 7.685 policies
I1- ICICI Rainfall Excessive rainfall	Groundnut Castor	2003 -	CRMG / ICICI directly & through BASIX	Since 2005 7 States	Farmers (borrowers and non borrowers)	(2005 all ICICI's?) 100000 farmers
I1-ICICI rainfall Deficit rainfall	Cotton	2004 -	CRMG / ICICI through BASIX		Farmers (borrowers and non borrowers)	
Deficit rainfall	Soya	2003 -	ICICI Lombard through KBS	Madhya Pradesh	Borrower farmers (embedded in loan price)	
Excessive rainfall	Soya Rice	2003-	ICICI	Madhya Pradesh Uttar Pradesh	Farmers	(2003) 1500 soya farmers
Various	Crop lending portfolio	2004 -	CRMG / ICICI Lombard		BSFL-BASIX	
I2- Deficit rainfall	Orange (Khariff) Coriander (Rabi)	2004 -	ICICI and regional Government through banks and ICICI agents	Rajasthan	Farmers	(2004) 783 orange farmers 1036 coriander farmers

I3-Barish Bima Yojana Rainfall (drought)	Monsoon crops	2004 -	IFFCO-Tokio	Gujarat, Maharashtra, Andhra Pradesh and Karnataka	Farmers	(2005) 16000 contracts
I4- AIC Varsha Bima Yojana Deficit rainfall	Khariff crops	2004	AIC or NAIC	10 states	Farmers	(2005) Options I & II: 107977 farmers, 77693 has. Option III: 17476 farmers, 19945 has.
I5- AIC Sookha Suraksha Kavach Drought protection shield)	All major khariff crops: sorghum, pearl millet, maize, groundnut, soya-bean, cluster bean.	2004	AIC or NAIC	Rajasthan	Farmers	
I6- AIC coffee rainfall index	Coffee		AIC or NAIC	Karnataka	Farmers	
?		2005 -	HDFC Chubb in association with Mayhco & WRMS	Maharashtra	Farmers	50,000 farmers

Source: Self-made from information in WB (2005), Kelkar (2006), and http://www.weather-risk.com/Clients.aspx

Legend:

CRMG: Crop Risk Management Group of the World Bank

BASIX: Microfinance institution

KBS: Krashi Bima Samruddhi local area bank of BASIX

BSFL: Bharatiya Samraddhi Finance Ltd., the non-banking finance arm of the BASIX group

ICICI-Lombard: Subsidiary of ICICI Bank

IFFCO-Tokio: Joint venture insurance company (the Indian insurance arm of the Millea Group)

NAIC: National Agricultural Insurance Company responsible for the government-sponsored area-yield indexed crop insurance scheme

AIC: Agricultural Insurance Corporation

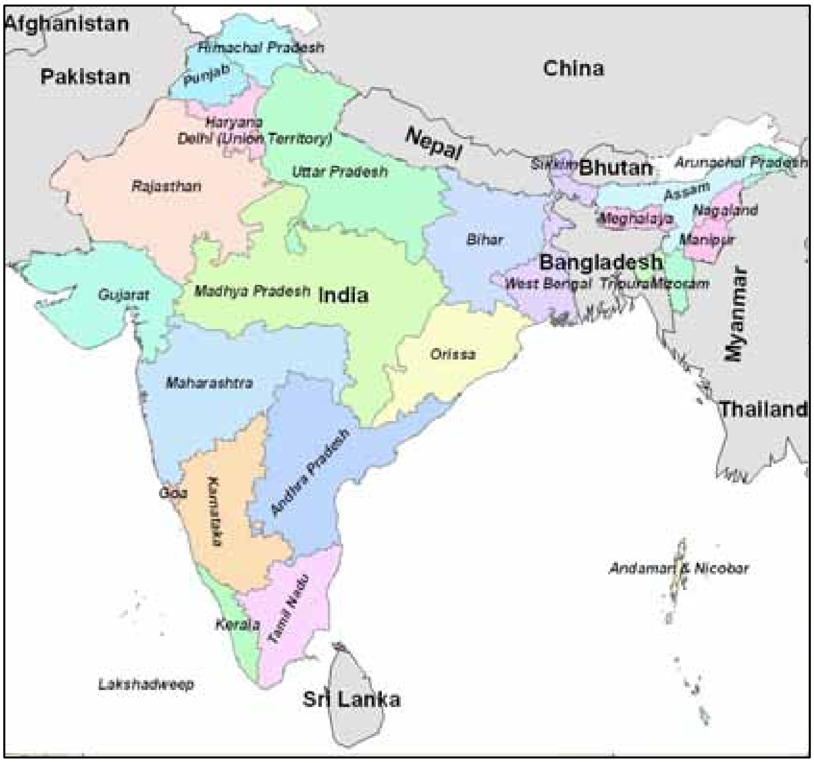
HDFC Chubb HDFC Chubb General Insurance Company Limited is a joint venture between HDFC, India's premier financial services company and Chubb Corporation.

Mayhco An Indian seed company partially owned by Monsanto

WRMS Weather Risk (www.weather-risk.com)

Khariff: Autumn crop, Monsoon season, from June to September. The Kharif crop is the autumn harvest (also known as the summer or monsoon crop) in India and Pakistan. Kharif crops are usually sown with the beginning of the first rains in July, during the south-west monsoon season. The term Kharif means "autumn" in Arabic. Major Kharif crops: Millets (Bajra and Jowar), Paddy, Maize, Moong (Pulses), Groundnut, Red Chillies, Cotton, Soyabean (from http://en.wikipedia.org/wiki/Kharif_crop)

Rabi: Spring crop. The Rabi crop is the spring harvest (also known as the "winter crop") in India and Pakistan. The term Rabi means "spring" in Arabic, which is reflected in two months of the Islamic lunar calendar, Rabi' al-awwal and Rabi' al-thani (which usually span mid/late April to mid/late June), when the crop is harvested. Major Rabi crops: Wheat, Barley, Mustard, Sesame (from http://en.wikipedia.org/wiki/Rabi_crops)



Source: Made by Oscar Rojas for this report

Figure 37. States in India

Technical characteristics of the indexes:

I1[15]- The weather insurance contracts designed for the castor and groundnut farmers are based on of rainfall collected and recorded at different weather stations and rain gauges in Andra Pradesh.

The initial product (2003) was based on a weighted rainfall index. High-yield rainfall correlations were measured for khariff crops in the area; nevertheless agronomic information was used to enhance and strengthen the yield-rainfall relationship for the contract structures. In the case of groundnut, for example, the most critical periods—when groundnut is most vulnerable to low rainfall and therefore water stress—are the emergence periods immediately after sowing and the flowering and podfilling phase two to three months after emergence (Narahari Rao et al. 2000). On the basis of farmer interviews, agrometeorological studies (Gadgil et al. 2002), local yield information, and models such as the United Nations Food and Agriculture Organization (FAO) water satisfaction index (UNFAO 2005), a groundnut-specific rainfall index was developed. The index was defined as a weighted sum of cumulative rainfall during the period from May 11 to

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[15] See Table 23 for the identification of the insurance

October 17, the average calendar dates for the groundnut growing season. Individual weights were assigned to consecutive ten-day periods (decades) of the growing season, so the index gave more weight to the critical periods during the crop's evolution when groundnut is most vulnerable to rainfall variability. Furthermore, a decade cap on rainfall of 200 mm was introduced to the index because excessive rain does not contribute to plant growth. The individual weights were determined by groundnut water requirements, as advised by local agrometeorologists that maximized correlation between district groundnut yields and the rainfall index but defined homogenous rainfall periods, making the contract understandable and more marketable to the farmers and less susceptible to basis risk. More information on the index construction can be found in Hess (2003). The average or reference weighted index value for groundnut and castor were determined to be 653mm and 439mm, respectively. These reference-weighted index values represent the expected growing conditions that produce satisfactory yields for farmers of these crops in the region. The weather insurance contracts were designed so that payouts started at 95 percent of this reference level. The initial pilot limited how much insurance a farmer could purchase by offering three different fixed contracts depending on the size holding of the farmer wanting to buy the insurance. Sums insured are fixed by landholding size: for groundnut farmers: small (less than 2.5 acres); medium (2.5 to 5 acres); and large (more than 5 acres); and for castor farmers, small (less than 2.5) and medium (more than 2.5 acres). The premium rates relative to sum insured are 3.2%, 3.0% and 3.0% respectively fro groundnut farmers, and 3.2% and 2.2% respectively for castor farmers (WB, 2005 and Kelkar, 2006). The payout schedule as a function of index is not a linear relationship (more details in WB, 2005). The weighted rainfall indices for Khariff 2003 were calculated to be 516 mm for groundnut, and 490 mm for castor, triggering a payout for groundnut farmers and no payout for castor farmers. The net incurred claims were 70.3 % of the net premium earned for groundnut, and 53.3% for the total insurance.

The second pilot program in khariff 2004 introduced significant changes to the 2003 design. In light of the farmer feedback from khariff 2003, the drought protection products for 2004 were structured by dividing the groundnut and castor growing seasons into three phases each, corresponding to the plants' three critical growing periods: (1) establishment and vegetative growth, (2) flowering and pod formation, and (3) pod filling and maturity. With a departure from the weighted index design, the new contracts specified a cumulative rainfall trigger for each of the three phases, with an individual payout rate and limit for each phase. Trigger levels and payout rates were determined in consultation with local agrometeorologists and farmers and with reference to local yield data as in 2003. Premiums and threshold levels vary by weather station, depending on the risk profile of each individual location. This simplified design was introduced to give clarity to the recovery process by clearly associating each critical growth phase with an individual deficit rainfall protection structure. In a further departure from the 2003 pilot, the contracts were designed to be sold per acre. A farmer could buy as many acres of protection as he wished, provided he actually cultivated that many acres of the crop to be insured. The premium associated with Groundnut Weather Insurance for Narayanpet Mandal, for example, was 4.17% of the sum insured.

New contracts were also offered for cotton farmers, and an excess rainfall product for harvest was offered to all castor and groundnut farmers. This product covered from excess rainfall between September1st and October 10th and the index is based on the number of consecutive days with rainfall greater than or equal to 10 mm rainfall. The premium was 3.3% of the maximum liability, which would correspond to more than seven consecutive days with more than 100mm/acre rainfall, and the minimum indemnity corresponds to 4 consecutive days.

The new policies feature a dynamic contract start date and they are "monsoon failure" policies meaning that they are area-specific rather than crop-specific products, targeting general livelihood losses rather than losses associated with yield variations of a specific crop.

I2- Perils covered for oranges (Kelkar, 2006):

a- Lack of effective shower to initiate flowering (Premium 16.6%)

b- Dry spell during flowering (Premium 12.6%)

Premiums are on insured amount. Small and marginal farmers can have a 50 discount on the premiums.

I3- Weather insurance contracts similar to the ICICI deficit rainfall contract of 2003 (I-1).

I4 – The scheme was initially introduced in 27 districts of 4 states from the Rabi 2004 season. Later on it was extended to 142 districts in 10 states.. AIC has been providing three options under this insurance scheme (not all in all states) (Bhise et al. 2007):

- Option 1: Seasonal Rainfall Insurance
- Option 2: Rainfall Distribution Index
- Option 3: Sowing failure

Premium rates have been optimized between 4% and 6% by adjusting benefits. The sum insured ranges between the cost of production and the value of production and farmers can buy insurance till the onset of the monsoon (Kelkar, 2006).

I5 – Premium rates have been optimized between 5% and 8% by adjusting benefits. The sum insured ranges between the cost of production and the value of production and farmers can buy insurance till the onset of the monsoon (Kelkar, 2006).

I6 – It blends rainfall index and yield parameters. Nearly two-thirds of the payout is decided on the basis of coffee yield at harvest time. Premium rates are flexible, with coffee growers allowed to choose benefits on the basis of their premium affordability. AIC announces that it was likely to introduce short period covers insuring coffee against deficit rainfall during 'blossom showers' and backing showers'.

Within the evaluation by Kelkar (2006), we find that "Through personal communication with ICICI Lombard, it was learnt that the company made profits in two ventures – insurance of rice crop against excess rainfall and insurance of oranges in Rajasthan. However it did not make a profit in insurance of groundnut crop against deficit rain in Andra Pradesh, which was implemented by BASIX. The basic problem was that of high administration costs of selling the insurance to individual farmers. ICICI Lombard found it uneconomical to seek out each farmer, but would instead prefer to sell insurance cover to state governments.

9.4.2.5. Malawi

At the microlevel, a pilot study by the World Bank proposed a crop production index constructed from weather data recorded at the airport weather station in Lilongwe (Malawi's capital). All that is needed is for demand to be aggregated at product distribution channels (WB, 2005).

At the meso level, index insurance has been proposed to reduce loans risk, by packaging it with the loans into a single product. Banks would increase interest rates to pay the premiums, and borrowers would pay only a fraction of the usual loan due in case of a severe drought impacting crop yields. Weather insurance products have been designed to secure credit for groundnut farmers (WB, 2005). Bundled loan and insurance contracts were offered in four pilot areas. These pilot areas were chosen because the National Smallholder Farmers Association of Malawi (NASFAM) had farmer clubs located near meteorological stations with reliable precipitation data. Additionally, the relatively good rain patterns for Malawi standards made the pilot scheme more feasible there. The most vulnerable Malawian farmers, located in more drought-prone areas are currently excluded from this scheme (Osgood et al. 2008).

The insurance contracts were designed to pay out if the rainfall data from the nearest meteorological station showed a deficit at one or more critical stages of the growing season. Each contract had a 'no-sow' clause that would pay out if insufficient rain fell during the early part of the season, from mid-November to early January. This was followed by clauses specifying the different levels of rainfall that would trigger payments during the three major phenological stages of establishment, flowering, and maturation. (Hellmuth et al. 2007)

Malawi's leading insurance companies are participating as a consortium, the Insurance Association of Malawi, to aid learning during the project's pilot phase. Once the insurance scheme and the mechanisms for administering it have been developed and tested, the companies will operate individually, in competition with one another. (Hellmuth et al. 2007). The cost of the insurance premium, currently about 7.5% of the loan, is likely to remain a barrier for the poorest farmers, who often live in the areas at greatest risk of drought. Competition may create some scope for reducing this cost, but affordability for poor farmers will doubtless remain an issue as the program expands.

892 policies were sold (to banks) in October 2005 for the 2005/2006 groundnut growing season (Osgood et al. 2008). The season unfolded with rainfall recorded at the meteorological stations close to normal levels for the various production areas. In three of the four pilot locations adequate rainfall was received to avoid payouts, but farmers in the Kasungu area received a small payout of US$ 0.68 each. (Hellmuth et al. 2007). A total of 2536 farmers joined the scheme in October and November

2006. A household survey in the first pilot showed that 86% of subjects wanted to join the scheme again the following season, and 67% said they had encouraged other farmers to join in (Osgood et al. 2008). One concern expressed by the farmers was that the rainfall data used to determine payouts were from a single rainfall station that could be up to 20 km away. As a result some farmers were winners and others losers, as rainfall on their farms differed from that at the station. This is one of the major challenges facing the design and implementation of index insurance in heterogeneous rainfed environments. (Hellmuth et al. 2007).

At the macro level, a specific nationwide maize production index for the entire country could form the basis of an index-based insurance policy or operate as an objective trigger to a contingent credit line for the government in the event of food emergencies that put pressure on government budgets. Applying the Lilongwe maize farmer index approach to the macrolevel situation, a Malawi Maize Production Index (MMPI) can be defined as the weighted average of farmer maize indexes measured at weather stations located throughout the country, with each station's contribution weighted by the corresponding average or expected maize production in that location. Given the objective nature of the MMPI and the quality of weather data from the Malawi Meteorological Office, such a structure could be placed in the weather risk reinsurance market. Analysis shows that Malawi could need up to US$70 million per year to financially compensate the government in case of an extreme food emergency. The estimated premium for such a product would be of US$6.96 million or the insurance rate of 10 percent (WB, 2005).

The MMPI indicator analysed by the World Bank turned out to be relatively poorly linked with crop yields. This is the reason why an agro-meteorological indicator was later developed (see next subsection 3.4.3 on agro-meteorological indicators).

9.4.2.6. Mexico

Mexico is the first developing country in stipulating a reinsurance agreement based on a bunch of weather indexes. In fact, weather indexes are used in reinsurance, in mutual insurance and hydrological-resources markets (Skees and Hartell, 2004).

The progressive diffusion of meteorological derivatives or weather derivatives has provided the possibility of using these tools to manage the risks relative to the effects of natural calamities on agriculture. The society for agricultural insurance in Mexico, Agroasemex, is a Mexican government-owned company operating exclusively in agricultural insurance. Among its roles, there is the reinsurance of Mexican insurance companies, mutual insurance societies and insurance funds. Agroasemex relies heavily on the traditional reinsurance market to protect its agricultural portfolio from inordinate losses. As a result of a 70 percent increase in the retrocession rates of 2001, Agroasemex's search for new alternatives led it to analyze the comparative efficiency of the weather derivatives market. As a result, in 2001, Agroasemex has used the weather markets to reinsure a part of their insurance programs' coverage. By using weather indexes based on temperature and rainfall measures in the mean production areas, a weather index was created which shows a very high correlation with the historical series of insurance indemnities in agriculture. This method of reinsurance proved to be more efficient than traditional reinsurance.

According to a publication by the World Bank (WB, 2005), there are two agricultural production cycles in Mexico: spring-summer and autumn-winter. The former is primarily a rain-fed production cycle, while the latter is generally irrigated. The Agroasemex weather risk transfer program was specifically designed for the autumn-winter cycle of 2001 to 2002. The main weather risks for agriculture during this cycle were potentially large negative deviations in temperature and excess rainfall. For some areas, where irrigation was not used, lack of rainfall was also an important risk. The index was based on a total liability of Agroasemex computed for five states and five crops (tobacco, maize, sorghum, chickpeas and beans. The crop and weather risks were selected according to several factors (their relative importance in the portfolio, the availability of consistent and high-quality weather data, etc.). This total liability represents approximately 10 percent of the risk in the entire portfolio of Agroasemex in 2001-2002 (US$269 million). The total expected traditional reinsurance premium for the entire Agroasemex portfolio was estimated to be US$1.9 million. The following method was used to establish the relationship between weather indices and the expected indemnities of the Agroasemex agricultural portfolio. First, a severity index was created for each crop in the portfolio in order to understand, at the portfolio level, how important this crop risk would be when a given weather phenomenon, as captured by an index, occurred. A very simple severity index (SI) is defined as follows:

$SI = (Indemnities/Total\ Liability)_{ti}$

t=1991/92, 1992/93, … 1999/2000; autumn-winter cycles

i= Crop

Once the severity index was calculated for each crop, the next step was to find a mathematical relationship between the SI and the weather index most relevant to the crop. Agroasemex performed linear least square regressions for each crop severity index to establish the SI–weather-index relationship:

$$y_t = m_0 + m_1 x_t + \varepsilon_t$$

where $y_t = (Indemnities/Total\ Liability)_t$

and $x_t = FCDD_t$

where FCDD (Factores Climaticos Dañinos Diarios) represent the index that captures the critical weather risk of each crop in the portfolio; ε_t is a normally distributed noise term; and the estimators for the linear gradient and intercept, m_1 and m_0, were calculated using a least squares regression method. The gradient estimator for m_1, in particular, is very important, as it establishes the relationship between the individual severity indices and the relevant weather indices. Once all the linear regressions for each crop are performed and all the linear estimators are calculated, the expected indemnities (in monetary terms) for each severity index, given a certain weather index (FCDD) and total liability, can be calculated as follows:

$(Indemnities)_t=(Total\ Liability)_t \times FCDD_t \times m_1$

The FCDD term for each crop represents the weather index or indices that best capture the weather risk for that crop. If we are analyzing the exposure of beans to low temperatures, for example, the FCDD index could be defined as the number of days that the daily minimum temperature drops below a specified daily threshold during the growing season. It is important to note that even though each severity index (SI) is a seasonal aggregate, the types of risks relevant for an agricultural portfolio of crops can occur over very short periods of time; for example, crop damage due to frost can occur in just one day. Therefore the selection of the individual weather indices for each crop was based on two criteria: first, and primarily, on the agronomical surveys and experience of the technical personnel of Agroasemex, and second, on the strength of the mathematical relationship obtained when comparing the available data on indemnities for the crop in question, with the weather index - this was done both on a daily basis (data on indemnities were available in daily resolution) and on a seasonal basis.

In total, eleven independent FCDDs were designed to represent the exposure of the crops and risks selected. The FCDD calculation methodologies using daily weather data are presented in Table 3 for all crops in the portfolio. To understand how each individual FCDD was estimated, consider the example for the weather index chosen for tobacco in Nayarit: DDD-12. Low temperature is the greatest risk for tobacco crops in Nayarit; when the daily minimum temperature drops below 12°C, the expected tobacco yields will be below average. Hence 12°C is the minimum temperature threshold level for tobacco crop damage: DDD-12 represents Damage Degree Days with a 12°C threshold. The DDD-12 index is defined as follows:

$$DDD-12=\sum \max(0,12-T_{\min})$$

where the DDD-12 summation is over each day in the growing period of tobacco: November 1 to March 31 of the following year. The data are aggregated at a seasonal level. The DDD-12 estimation is consistent with the El Niño, as the worst year recorded of cold temperatures affecting the tobacco-producing area.

Table 24. The eleven FCDD indices

Crop	FCDD	Calculation methodology (in mm and degree Celsius)	Calculation period
Tobacco	DDD-12	DDD-12 = Sum Daily [max (0, 12 – Tmin)]	Dec 1–Mar 31
	EMNF	EMNF = Sum Daily [Rainfall Station 1] + Sum Daily [Rainfall Station 2]	Nov 1–Feb 28
	EMMA	EMNF = Sum Daily [Rainfall Station 1] + Sum Daily [Rainfall Station 2]	Mar 1–Apr 30
Beans	DDD-5	DDD-5 = Sum Daily [max (0, 5 – Tmin)]	Oct 1–Apr 30
	DDD-3	DDD-3 = Sum Daily [max (0, 3 – Tmin)]	Dec 1–Dec 31
	EMF	EMF = Sum Daily [Rainfall Station 1] + Sum Daily [Rainfall Station 2] + Sum Daily[Rainfall Station 3]	Nov 1–Mar 31
	MAX-5	MAX-5 = max (MP - 200, 0); MP=max(Sum5-dayD3)-max rainfall for a consecutive period of 5 days, where D3 = Daily Rainfall Station 1 + Daily Rainfall Station 2 + Daily Rainfall Station 3	Nov 1–Mar 31
Chickpeas	EMG	EMG = Sum [max (Daily Rainfall – 55, 0)]	Nov 1–Apr 15
Sorghum	MAXPS	PS = Sum [max (250 – CMP1, 0)] + 2 ∗ Sum [max (250 – CMP2, 0)]; CMP1 = Monthly Cum. Rainfall Station 1 CMP2 = Monthly Cum. Rainfall Station 2	Oct 1–May 31
Maize	DDD-5	DDD-5 = max [D5 – 22, 0]; D5 = Sum Daily [max (0,5-Tmin)]	Oct 1–Apr 30
	DDD-3	DDD-3=Sum Daily [max(0,3-Tmin)]	Dec 1–Dec 31

Source: WB (2005)

FCDD indices are converted into expected indemnities in monetary terms using the equations established above. The strength of the approach outlined above was back-tested by using annual historical indemnity and total liability information from the Agroasemex direct insurance operations from 1990 to 2001. The values of the severity index for each crop were calculated using both the historical and the modelled data for comparison. By combining the information from the different crops, the basket of all the expected indemnity indices was used to replicate the overall weather exposure of the agricultural portfolio. This “combined index”—essentially the sum of all the expected crop indemnity indices—was used as an underlying proxy and therefore hedge for the weather exposure of a portfolio. The results demonstrate that the combined weather index model explains about 93 percent of the variability demonstrated by the empirical data. A derivative structure based on this combined index, such as a call option, is therefore conceptually the same as a stop-loss reinsurance strategy for the portfolio, as weather is the greatest risk to Agroasemex.

The original analysis performed by Agroasemex focused on four possible call option derivative structures, which varied in the strike price and limit of payout that could be used as an alternative to a traditional stop-loss reinsurance contract to manage the portfolio risk (Table 25). The historical results and the stochastic analysis (Monte-Carlo simulation) for the actuarial fair value of risk for each call option structure (average and standard deviation) are summarized in Table 25. In addition to the actuarial fair value of risk, the market premium was calculated. The market premium charged combined the expected or fair value of the risk— the pure risk premium—with an additional risk margin. Considering market standards at the time, the following risk loadings above the expected value were considered:

- Loading Based on Standard Deviation: Market standards 20 to 40 percent. An intermediate loading of 30 percent was considered by Agroasemex.
- Loading Based on the Uncertainty due to Gaps in the Historical Weather Data (for more information see WB, 2005)
- Loading for Administrative Expenses: A margin of 15 percent was added.

Table 25 shows the estimated commercial premium (full price) - calculated as the expected value plus risk margin - for the four weather derivative structures.

Table 25. Estimated Commercial Premium for Weather Derivative Structures (in US$)

Call option structure	**A**	**B**	**C**	**D**
Strike price	**1,000,000**	**1,100,000**	**1,200,000**	**1,300,000**
Payout limit	**1,200,000**	**1,100,000**	**1,000,000**	**900,000**
Premiums				
Last Ten-Year HBA				
Pure Risk Premium	181,447	151,447	121,447	91,447
Standard Deviation Loading	83,372	69,669	55,987	42,347
15% Margin	46,733	39,020	31,312	23,611
Full Price	311,552	232,229	186,622	141,157
Simulation Analysis				
Pure Risk Premium	133,460	104,291	80,252	60,528
Standard Deviation Loading	80,241	70,226	60,638	51,634
Data Uncertainty Loading	31,750	27,584	23,693	20,136
15% Margin	43,315	30,797	24,863	19,793
Full Price	288,766	232,898	189,447	152,091

Source: WB (2005)

Despite the risk loading, Agroasemex eventually bought structure D from the market (for more information see WB, 2005).

Besides using weather indexes for reinsurance, Agroasemex has started a cooperation with mutual insurance funds, composed of small trading agricultural companies. The objective of this cooperation is to allow to the mutual funds to buy insurance indexed on meteorological parameters and, so, to decide which kind of products to offer to their own members. These programs are at the moment in an initial development stadium. (Skees and Hartell, 2004).

Agroasemex technicians are also evaluating the possibility of using the index insurance to develop links with the water resources markets. Based on this approach, when the water availability is lower than an agreed level, the institution controlling water for irrigation would guarantee an indemnity to the users. (Skees and Hartell, 2004)

Last, the greatest interest generated by the 2001 transaction was from the Mexican government regarding their catastrophic weather exposure: since 2001, Agroasemex has sold weather index insurance to three Mexican states to cover the states' catastrophic exposure related to agriculture. In turn, Agroasemex has bought protection for this risk, on a quota share basis, in the international weather derivatives market. The three transactions together have an approximate notional value of US$15 million, with several other states in the coverage pipeline. There are unofficial reports that the international market has also closed several transactions with the private industry in Mexico as a result of this first weather derivative transaction. (WB, 2005).

9.4.2.7. Morocco

In Morocco, given the limitations of the Drought program (see the Moroccan yield insurance scheme in the previous section), the Government agreed to participate in a World Bank research project aimed at exploring the feasibility of weather-based insurance. The product proposed was a rainfall index insurance contract that would indemnify cereal producers when the rainfall index in a given area fell below a specified threshold. The indexes were developed by local agronomists together with farmer's representatives. They were not just cumulative measures of rainfall but included specific weights for different plant growth phases and a "capping" procedure to take into account the loss of water in excess of storage capacity and hence unavailability to contribute to plant growth. This process allowed the indexes developed to reach correlation values of over 90 percent (Stoppa and Hess 2003). The implementation of the planned pilot program in Morocco did not take place. The main reason for this failure was that rainfall precipitation in the selected areas showed a downward trend, and the reinsurance company involved in the deal made the cost of the insurance prohibitive for producers. The experience developed through this study, however, generated expertise that led to the realization of other WB-facilitated deals (for example India) and of other independent programs (for example, in Colombia).

9.4.2.8. Nicaragua

In the case of Nicaragua, Hazell and Skees provided the first feasibility study in 1998. Subsequently, Skees and Miranda (1998) examined the issue in more detail and made specific recommendations about insufficient and excess rainfall insurance in the major cereal production. After Hurricane Mitch arrived in October 1998, the World Bank developed an aggregate weather index that would provide disaster financing to the Government during severe weather events. The index was even priced in the global reinsurance markets. However, the Government rejected the idea considered it unnecessary because "they could depend on the global community for assistance when major catastrophes occurred" In 2004, the World Bank responded to the interest of INISER (Instituto Nicaraguense de Seguros y Reaseguros) in developing a local weather index insurance market for agriculture. The World Bank provided technical assistance to analyze potential markets for a pilot project in 2005 and decided to secure lending for the groundnut (mani) sector. Final contracts have been designed and priced by reinsurers. The pilot project was expected to begin operations in the summer of 2006. (WB, 2005). According to the Nicaraguan diary "La Prensa" (21st December 2006), it is already available and it covers groundnut from deficit and excess rainfall during growth period, and from excess rainfall during harvesting (http://www-ni.laprensa.com.ni/archivo/2006/diciembre/21/noticias/economia/163423.shtml).

9.4.2.9. Peru

In Peru agricultural weather insurance is under study. The feasibility study focuses in the following crops: rice, mango, yellow maize, potato, coffee, cotton and asparagus (WB, 2005).

9.4.2.10. SADC: Proposal for reinsurance in SADC

The Southern African Development Community (SADC) is composed by 14 Southern African countries. If index insurance such the one proposed for Malawi was applied in the other SADC countries, the WB (2005) proposed the following strategy as the most efficient way to manage the risk. It would be to layer risk as follows:

- SADC Fund: The size of the SADC fund could be set at US$80 million, the average financial impact of four average droughts in the region, with each member contributing its share according to an actuarially fair assessment of the expected claim of each country. The SADC fund approach would reduce insurance costs by 22 percent for Malawi due to risk pooling effects.

- Reinsurance and/or contingent credit lines: SADC wide events incurring a financial loss of, say, US$80 million to $350 million could be transferred to the weather-risk reinsurance / professional investor market. Alternatively, in such situations, the SADC members could have access to a World Bank contingent credit line.

- Securitization: The final and extreme layer of risk, such as drought in ten countries, occurring 1 percent of the time, could be securitized and issued as a CAT bond (investors lose the principal if the event occurs in exchange for a higher coupon) in the capital markets. The advantage of capital markets for this risk transfer is the immense financial capacity of these markets and also the longer tenure of CAT bonds: up to three years and possibly longer. (WB, 2005)

9.4.2.11. Ukraine

Regarding Ukraine, a pilot project (Appendix 2 in WB 2005) was developed by the World Bank, for winter wheat producers in the Kherson oblast[16], in the south of Ukraine. This pilot was sold by the insurance company Kiev-based Credo Classic. However, the regulator only approved weather index insurance as an insurance product in April 2005, and so only a few weather insurance policies were sold to farmers during the brief marketing period of the first pilot of 2005.

The most significant weather risks for growing winter wheat in the Kherson oblast are (1) winterkill during the crop's hibernation period from December to March, and (2) water deficit during the vegetative growth period from mid-April to June. Informal interviews with farmers in the oblast indicate that farmers are less concerned with winterkill risk than with drought risk, even though it can potentially cause complete damage, because of the potential to resow. The following drought index insurance was suggested for Kherson in 2005.

In the absence of reliable yield data, expert assessment and the results of a report by the Ukranian Hydrometeorological Center were used as the basis for constructing an appropriate weather index for winter wheat in Kherson. Agricultural drought can take two forms: air drought and soil drought. Air drought, characterized by a long rainless period, high air temperature, and low air humidity, is often described using the Selyaninov Hydrothermal Ratio (SHR). For the vegetative growth period for winter wheat in Kherson, April 15 to June 30, the SHR is defined as follows:

$$SHR = \sum_{15\,April-June} DailyRain.fall \Big/ \left(0.1 \times \sum_{15\,April-June} AverageDailyTemperature\right)$$

It holds for periods when daily average temperatures are consistently above +10°C. This period, on average, begins on April 15 in the Kherson oblast. Daily rainfall was capped to avoid for too much rainfall that is not useful for the crop, so that

Capped Daily Rainfall =min(50, Daily Rainfall Total in mm)

The SHR does not always serve as a reliable criterion of agricultural drought because it does not account for soil moisture, but because soil dryness, unlike rainfall and average temperature, is generally not an observed variable, the SHR is the only objective indicator that can be used to capture drought risk during the vegetative period. Conditions for obtaining the best harvest are when the SHR

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[16] Oblast: a political subdivision of Imperial Russia or a republic of the Union of Soviet Socialist Republics or of the Russian Federation

is between 1.0 and 1.4. When the SHR is greater than or equal to 1.6, plant yields will be depressed by excessive moisture. When the SHR is less than or equal to 0.6, plants are depressed by drought conditions. In general, the isoline SHR = 0.5 coincides with regions of semidesert climate conditions. Results from the UHC crop model that suggest the impact on yields of SHR during the vegetative growth stage between April 15and June 30 are defined in Table 26.

Table 26. Relationship Between SHR and Winter Wheat Yields During the Vegetative Growth Phase of Plant Development

SHR	Description	Yield loss (%)
1.6	Excessive humidity	30+
1.3-1.6	Damp	-
1.0-1.2	Sufficient humidity	-
0.7-0.9	Dry	-
<0.7	Drought conditions	-
0.5-0.6	Medium drought	20
0.4-0.5	Severe drought	20-50
<0.4	Extreme drought	50+

Source: Hess et al. (2005)

The SHR can therefore be used as an index to monitor the impact of air drought on winter wheat crop yields. The payouts – SHR correspondence is shown in Table 27, the payouts expressed in percentage of the insured amount. The insured amount can be chosen by the farmer, with a maximum which equals the maximum production and input costs the farmer can have per hectare.

Table 27. Relationship Between SHR and Financial Losses Associated with Winter Wheat Yield Fluctuations

SHR	Payout per hectare (% of max. loss)
0.51-0.60	20 %
0.46-0.50	30 %
0.41-0.45	40 %
0.36-0.4	50 %
0.31-0.35	60 %
0.26-0.3	70 %
0.21-0.25	80 %
0.16-0.2	90 %
<0.15	100 %

Source: Hess et al. (2005)

The payout of a SHR index insurance contract is determined by the following equation:

$$Payout = \min\left(M, \max\left(0, K - SHR\right) \times X\right)$$

where *M* is the limit of the contract (maximum liability), *K* is the strike, SHR is the SHR index measured during the calculation period, and *X* is the payout rate, determined by the structure of the contract. The final premium will be the expected payout E(P) plus an additional risk margin the provider will charge for taking the weather risk from the end user, that is,

Premium= E(P)+ Risk Margin

There are many methods for measuring risk and hence for determining a risk taker's risk margin. Two examples of simple methods that have been suggested (Henderson et al. 2002) for the weather market are the Sharpe Ratio and the Return on Value at Risk (VaR); both measure expected excess return in terms of some measure of risk and hence determine the "cost of risk" for the contract seller.

Sharp Ratio[17] α: $$\Pr emium = E(P) + \alpha \times \sigma(P)$$

Return on VaR(99%)[18] β $$\Pr emium = E(P) + \beta \times \left[VaR_{99}(P) - E(P)\right]$$

In both methods outlined above, α and β quantify the risk loading appropriate for the risk preferences of the provider. Reasonable estimates for α and β, given prices in the weather market, are α = 15–30% and β = 5–10%. It was assumed that α = 25% and β = 5%. By simply taking the thirty years of payouts for a weather insurance contract with a strike level of SHR = 0.4, the payout statistics result: E(SHR) = UAH 70, σ(SHR) = UAH 220 and VaR_{97}(SHR)=UAH 800. A first-order estimate of an appropriate premium to charge a farmer for an insurance contract with a strike level of SHR = 0.4 at Behtery Weather Station, therefore, is between UAH 110 and 125 per hectare for a sum insured of UAH 1000. (WB 2005).

After the 2005 experience, the insurance company leading the pilot in Kherson was already providing consultations to other markets players in Ukraine on designing index-based products in-house and drafting the insurance rules for these new products. There were also plans to scale up weather insurance activities to cover more crops and regions in 2006. (WB 2005).

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[17] The Sharpe Ratio uses standard deviation as the underlying measure of risk; therefore α represents the "cost of standard deviation" as determined by the seller's risk preferences. One of the benefits of relating risk to the standard deviation of payouts is that it constitutes an easy parameter for estimating; however, it is a symmetric measure of risk capturing the mean width of the payout distribution, and, for traditional risk exchange products, the payout distribution is often not symmetric but has a long tail. (WB 2005, Appendix 1)

[18] The Return on VaR method uses VaR(99%) as the underlying measure of risk and therefore b represents the "cost of VaR." Value-at-Risk (VaR) is a term that has become widely used by insurers, corporate treasurers, and financial institutions to summarize the total risk of portfolios. The advantage of VaR99 is that it is computed from the loss side of the payout distribution, where loss is defined with respect to the expected payout E(P), and therefore captures the potential financial loss to the seller. Using the Return on VaR method is more appropriate for pricing structures that protect against low-frequency/ high-severity risk, which have highly asymmetric payout distributions. VaR99 is a harder parameter to estimate, however, particularly for strike levels set far away from the mean, and it is usually established through Monte Carlo simulation. The worst-case recorded historically can often be used as a crosscheck for VaR. (WB 2005, Appendix 1)

The World Bank has also performed a feasibility study on how to develop weather index insurance in the country. The World Bank advises that the Government cooperates in two fields: one, the acquisition, installation and maintenance of automated weather stations. Two, the performance of a reinsuring role. This role could be implemented in this way, in order to achieve cheap access to the international reinsurance market: risk layers representing relatively frequent but mild adverse events would be insured by a Government risk fund. Intermediate risk layers (for example events happening less than once in twenty years) could be transferred to a Government's Backstop Facility. The catastrophic risk layer (once in a hundred years events) could be transferred to international reinsurance markets (WB, 2005).

9.4.3. Examples of agro-meteorological index insurances

9.4.3.1. Malawi

The indicator analysed by the World Bank (see above, in the section 9.4.2.5 on weather insurances in Malawi) turned out to be relatively poorly linked with crop yields. FAO proposed to use the tools included in the FAO AgroMetShell (AMS) software to derive an effective weather-based maize yield index (WYX, Weather Yield indeX) that could be used for crop insurance purposes in Malawi. The technical work and results of the technical cooperation programme between World Bank and FAO are collected in Chavula and Gommes (2006). AMS computes a crop specific water balance to derive value-added crop-weather variables that can be combined with other data (e.g. remote sensing inputs, farm inputs such as fertilizer use) and statistically related with crop yield using standard multiple regression techniques. "Value-added crop-weather variables" are variables such as actual evapotranspiration that are know to be more meaningful than raw meteorological variables. So, average maize yields were regressed against selected significant variables, mixing cross-sectional and time series data. Calculations were made geographically by Extension Planning Area (EPA) for two types of maize: local maize and hybrid maize. The final Malawi local maize forecasting equation is, for each pixel,

$$Yield=0.93*Yavg+1.81*DEFtot-0.17*WEXtot+2.36*ETAveg-26.50*DEFveg$$

Where:

Yield is the weather – based yield index for local maize

- Yavg is average yield for local maize
- DEFtot is total water deficit
- WEXtot is total water excess
- ETAveg is Evapotranspiration at vegetative stage
- DEFveg is water deficit at vegetative stage.

For hybrid maize, the following equation was derived:

$$Yield/Yavg=0.03Year-2E\text{-}05Year^2+0.01WRSIfin-0.008ETAtot+1.2E\text{-}05\ ETAtot^2$$

Where:

- Yield is the weather – based yield index for hybrid maize
- Yavg is average yield for hybrid maize
- Year is the year for which the calculations are done
- WRSIfin is the Water satisfaction index computed for the end of the crop cycle
- ETAtot is the total Evapotranspiration over the cycle.

9.4.4. Examples of satellite imagery index insurances

One of the satellite networks with more information available for these purposes comes from the NOAA satellite. It is the network used by the Canadian and Spanish pasture insurances. The NOAA satellite has blue, green, red, infrared, and thermal sensors and takes one image per day for every square kilometre of the earth's surface. The Normalized Difference Vegetation Index (NDVI) is a type of vegetative index based on the relationship between red light (visible) and near-infrared light. Healthy vegetation absorbs the red light from the sun and uses it for photosynthesis while reflecting near-infrared light from the sun. The formula used to calculate the NDVI is given by:

$$NDVI = (NIR - \text{"Red"})/(NIR + \text{"Red"})$$

where *NIR* is near-infrared light and *Red* is red light. The more red light is absorbed by the plants, the smaller the amount of red light is, in turn, reflected by the plant and recorded by the satellite, therefore the larger the NDVI value. An important disadvantage of this system is the alterations caused by the cloud-covered days, because the satellite cannot get the proper radiations from the crops. Another important input for the use of NDVI as index insurance is the design of an appropriate mask[19]. (WB, 2005).

9.4.4.1. Canada

In Canada, in the province of Alberta, the Agricultural Financial Service Corporation (AFSC) developed a Satellite Imagery Insurance in order to insure fodder production. The pilot was launched in 2001 and was limited to a geographical area of the province where pasture is the predominant land cover.

It is based on data from satellites that use specific wavelengths of light to estimate growth conditions on native pasture. An NDVI, scaled appropriately to reflect native pasture production, was calculated for each township in the pilot area and a Pasture Vegetation Index (PVI) was generated. The insurance compensates producers according to a predetermined payment schedule when the average accumulated *Pasture Vegetation Index* (PVI) in a township falls below a threshold value of 90% of the

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[19] A mask is simply a set of geo-referenced information identifying specific land features that can be laid over the satellite imagery information. The overlaying of this information allows some of the satellite imagery to be extracted from the information file prior to making production assessments.

township normal PVI value from previous years. The program was expanded slightly in 2002 to the portion of the province in which the square kilometre resolution of the NOAA satellite was considered practical for pasture[20]. The program has been running for several years (Stoppa & Hess 2003, WB 2005).

The mask used for the project selects only information known to be at least 85 percent native or improved pasture at a quarter section level (160 acres). In the pilot area, where satellite imagery insurance operated, a significant percentage of land, 80 to 90 percent, is native pasture. Areas of crop irrigation and some bush land also need to be extracted, or they significantly influence the program outcome. If a quarter section of land has irrigation, it is removed from the program dataset.

While ample data existed to calculate the PVI, little accurate “in-field” pasture information was available to judge whether the PVI actually correlated to pasture growth. In the past, however, AFSC had operated a cage clipping system (to avoid animal grazing) to measure forage production. This permitted to obtain estimates from 1991 to 1999 that permitted comparing historical PVI values to pasture production trends over time. Correlation was confirmed with farmers. To augment the information acquired by satellite imagery, AFSC developed research plots throughout the pilot pasture area to measure rainfall and the growth of pasture under cages and to note changing pasture conditions over the growing season throughout the pilot area (thirty in total). The correlations were improved substantially through this process.

Pasture insurance is sold in the spring of each year, but farmers must make their purchasing decisions by the end of February. Farmers must insure all the acres of pasture within the same category—native, improved, or bush pasture—but a lower than normal PVI value in one township is not offset by a higher than normal PVI in another. Coverage is derived by multiplying the pounds of pasture production expected in each forage risk area, as determined by AFSC, by 80 percent of one of the four price options available to the farmer. The premium rate for the 2003 native pasture insurance program was 21 percent, 60 percent of which is subsidized by the government (WB 2005).

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[20] The NOAA satellite system was used because historical satellite images were readily available. To be effective, however, any non-pasture land had to be excluded from the satellite images. With the square kilometer resolution of the satellite image, pastureland outside the pilot area is situated in smaller land parcels and within other crop and forested land. Moving beyond the pilot area, with this resolution, would dictate the exclusion of many pixels that do not meet the minimum pasture content criteria. Without a minimum number of pixel images, the sample size for a township production estimate is not credible.

9.4.4.2. Spain

General presentation

The parametric insurance scheme in Spain was engineered mainly to cover farmers from droughts affecting the pasture areas.

The product has been offered since 2001 for all the farms performing extensive livestock production, specifically cattle, sheep, horses, and goats. (MAPA, 2007)

The index (ENESA, 2007 and WB, 2005)

The index utilized is also the NDVI (estimated from NOAA images). In contrast to the previous case study, the insurable index is based only on pure imagery, that is, no verification with actual yields was performed. The satellite images are processed by the Remote sensing Laboratory from the University of Valladolid.

Images are obtained by the AVHRR sensor, on board of the satellites from the series NOAA. The images transferred by the satellite at its noon passing over the peninsula are calibrated and corrected from atmospheric effects and geometric distortions with an accuracy lower than a pixel (1km2).The vegetation activity indicator is NDVI, explained above, but in contrast to the weekly NDVI values, this scheme is based on a ten-day period NDVI index. NDVI is calculated daily and from these daily measures the **Maximum Value Composite (MVC NDVI)** index per ten-day period (decade) is obtained. It is the pastures activity indicator for each 'ten-day' in the year (in fact, three 'ten-days' are considered per natural month). In this way, the effects from clouds, as well as the discrepancies produced by the different light intensity and other perturbing effects are eliminated.

A curve of 'ten-day' MVC NDVI is obtained for every pixel. This evolution curve is smoothed with an algorithm of the type "Double 4253H" in order to eliminate the residual noise. This algorithm has the property of keeping constant the area below the curve. The reference curves built from the MVC NDVI are defined as beginning on the first decade of October and finalized on the last decade of September of the next calendar year. Whenever information is not available for a particular period, a linear interpolation method is used to fill the missing gaps[21].

The mask in this scheme is based on the Corine Land Cover (CLC-90), which is used to discriminate between areas with and without grassland production. A minimum of a 50% of the surface occupied by grass and pasture lands has been required to consider a pixel as an area with grassland production. Besides, areas (pixels) with more than 10% of the surface occupied by woods and forests have been dismissed.

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[21] In case of decades without valid information, the value will be calculated by interpolation of the values of the previous and the following decade, if and only if the number of missing decades will be lower or equal to four. In the case that an area lacks more than 4 decade data or the last decade data is missing, the values will are decided through the analyses of the neighbouring areas of the same type.

The MVC-NDVI (from now on Vegetation Index, VI) curves are obtained for the years 1987-2006, and the 'ten-day' average (AVI) and standard deviation (SDVI) are established for each 'ten-day' and each homogeneous pasture area.

How the insurance works

The description of the product is detailed in ENESA (2007) and MAPA (2007). The drought on pastures insurance is designed to cover the farmers experiencing more than thirty dry days (defined as based on the average historical information on pasture per 'ten-day').

There are two guarantee levels. So, there are two Guaranteed Vegetation Index (GVI), high (GVI_h) and low (GVI_l):

$$GVI_h = 0.98 \times (AVI - 0.7 \times SDVI)$$

$$GVI_l = 0.98 \times (AVI - 1.5 \times SDVI)$$

So, the coverage is 98% of the historic average VI for each area and 'ten-day', with an additional deductible of 0.7 or 1.25 of the standard deviations from the average VI.

The VI observed in a given 'ten-day' in year *t* is given by actual *VIt*.

The indemnity or compensation value (*CompVal*) for each decade is given by:

$$CompVal = \alpha \frac{InsVal}{36}$$

Where InsVal is the insured value, which is calculated as the product of the number of animals in the farm multiplied by the unitary price chosen.

And α is an indemnity coefficient, for each period of the year, risk region, and guarantee level. For example, the indemnity coefficients for the central area can be seen in Table 28.

Table 28. Indemnity coefficients for central Spain

	GVI-h *High guarantee level*		*GVI-l* *Low guarantee level*	
	Option A	Option B	Option A	Option B
December-February	10%	10%	20%	20%
March	30%	30%	80%	80%
April	40%	40%	110%	110%
May-June	50%	50%	150%	150%
July-September	-	10%	-	20%
October-November	30%	30%	70%	70%-

Source: Made by authors from data in MAPA (2007)

There are two main insurance options the farmer can choose[22] .

Option A[23]: The trigger for a compensation is that $VIt<GVI$ during at least three ‘ten-days’. The guarantee periods vary depending on the region.

Option B: The trigger for a compensation is that the Compensation Value in the whole period is above the 10% of the insured value $(CompVal_{total}>10\%InsVal)$, considering that there is a loss in any ‘ten-day’ for which $VIt<GVI$..

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[22] There is a minor third one covering only the months of October and November

[23] The third option (Option C) is similar to Option A but it applies only to October- November.

9.5. Annex 4A. Data available: CGMS and CGMS indicators

CGMS responds to Crop Growth Monitoring System. CGMS[24] has been developed within JRC (Joint Research Centre- European Commission). The mission of the “system” is to provide timely, consistent and reliable analysis at pan-European level on the status of the crops and on the harvest prospective. The information and the derived forecasts are used at CAP decision maker level especially to fill crop balance sheet estimates. For instance in 2003 the system contributed to assess the effect of the severe summer drought on the European crop productions. The system has started R&D in the late 80s and has become fully operational since 1999.

The MCYFS is called a system because several elements and independent modules are integrated to reach the final purpose, i.e. to monitor crop behaviour and produce crop yield forecasts. The MCYFS is run operationally on an area covering the whole European Continent, Maghreb and Turkey. The crops covered by system simulation models are: wheat, spring barley, grain maize, rape seed, sunflower, potato, sugar beet, field bean (pastures, rice, soy bean are in phase of study/evaluation). However, the crop parameters simulated can be extended to other crops or varieties belonging to the same class such as winter barley, durum wheat, and field peas. The main pillars of the system are:

- Observed meteorological data collection, processing and analysis
- Simulation of agro-meteorological crop growth parameters
- Low resolution satellite data analysis
- Statistical analysis and forecasts

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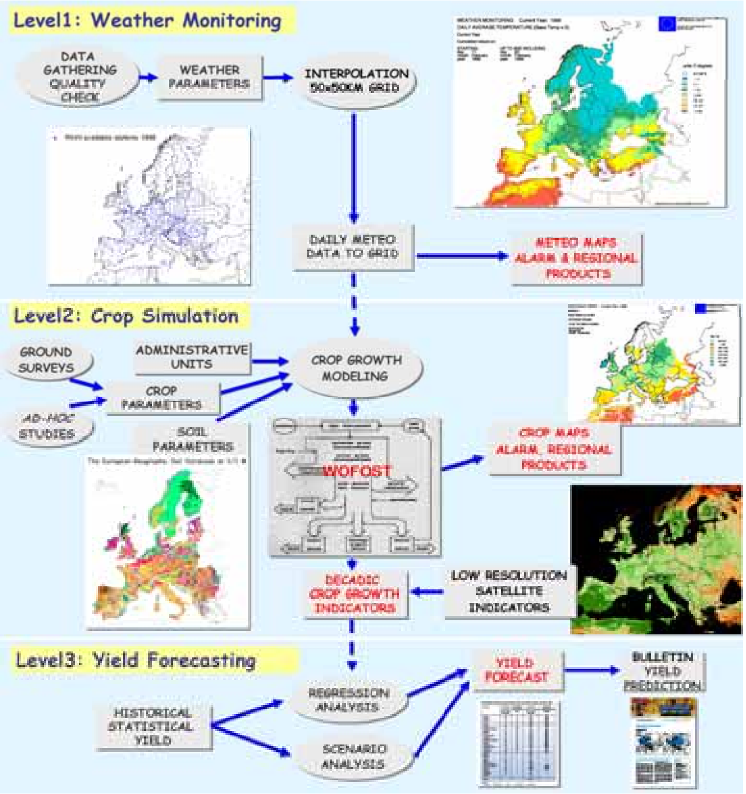
[24] CGMS has been developed by the Mars-Stat Action, Agriculture and Fisheries Unit, Institute for Protection and Security of the Citizen (Directorate General Joint Research Centre of the European Commission). CGMS is the kernel of the EC agro-meteorological system (MARS Crop Yield Forecasting System), that finds its legal basis in EU Parliament - Council Co-decision 1445/2000/CE for the period 1999-2003. This co-decision was recently renewed to cover the period 2004-2007 (Ref. PE/CONS 3661/1/03 OJ L 309 of 26.11.2003) and again in the FP6/JRC-Multi Annual Working Program (Action 1121: MARS-Stat period 2002-2006) for the related R&D activities.

Figure 38. Crop Growth Monitoring System (CGMS)



Source: Genovese (2004)

In CGMS, there are three levels of analysis (see Figure 1). The first one consists on analysis and aggregation (correction and interpolation) of meteorological data coming from a multitude of meteorological stations spread all over the EU area. At the second level, crop growth simulation takes place. In addition to weather data obtained at level 1, crop characteristics and soil information are added. At level 3, simulation results are aggregated at the national level, and yield is predicted through statistical regressions analysis.

The system is organized around 3 internal “infrastructures”, namely a Meteorological Monitoring Infrastructure (its main DB is the observed interpolated meteorological data since 1975), a Vegetation Monitoring Infrastructure (its main DB is the vegetation indicators based on low resolution satellite data since 1989), and Agrometeorological Infrastructure (its main DBs are crop parameters, crop calendars and phenology). The DB are exploited to run a main crop growth simulation model (CGMS-WOFOST) and a pasture model (CGMS-LINGRA).

The outputs of the system are threefold:

- dB and mapped outputs of agricultural season quality indicators. Examples: extreme temperatures maps at a given crop stage; simulated biomass and grain production, estimated actual soil moisture reserve, state of advancement of the development stage during a given month, differences from the long term average at a given decade or period within the growing season for any agro-meteorological indicator;
- Alarm and risk warning: Detection of abnormal weather conditions (during a given month, or cumulated since the start of the season).
- Calculated yield forecasts.

Each ten days meteorological and agro-meteorological maps are produced by the system and screened by analysts. The data are updated on the web site according and published in the MARS bulletin about 6-7 time a year as complete analysis and each 15 days as Climatic Updates during the main crop vegetative period.

A) European weather data (observed interpolated meteorological data since 1975)

There is a big amount of weather data available in the Mars-Stat meteorological data bases that could be used as indexes to monitor weather risks. The original data are obtained from meteo-stations all around Europe, and the composition of the database, calculation of indirect variables (i.e. ET0) and interpolation of data when needed, is performed. The main weather variables available are:

- Average daily temperature
- Longest heat wave period
- Number of heat waves
- Maximum daily temperature
- Minimum daily temperature
- Snow depth
- Temperature sum
- Global radiation
- Number of cold days
- Number of days with significant rain
- Precipitation
- Climatic water balance
- Potential evapotranspiration (ET0)
- Vapour pressure
- Wind speed

The suitability of these data to constitute a weather index useful for yield losses estimation shall be studied. Several types of insurance can be based on these data: drought insurance (see Skees 2001), excess of rain insurance, frost insurance, etc.

B) Crop simulation model.

Weather data are inserted together with the Agrometeorological Infrastructure Data (crop parameters, crop calendars, etc.) in the crop simulation model (WOFOST) to predict crop yields. WOFOST is based on a photosynthesis model. The outputs of the model are:

- Development stage
- Potential leaf area index
- Potential above ground biomass
- Potential storage organs
- Relative soil moisture
- Status of development stage
- Total water consumption
- Total water requirement
- Water limited leaf area index
- Water limited above ground biomass
- Water limited storage organs
-

Other values can be obtained through the model, which are indicatives of the stresses suffered by the crops. These could potentially constitute risk indexes:

- Longest heat wave period around crop development stage
- Number of heat waves around crop development stage
- Rain around crop development stage
- Rain around sowing
- Temperature around crop development stage

The following sections will explore the possibilities to use these variables as indexes.

9.6. Annex 4B. Comparison of losses calculated at farm level (FADN yields) and at regional level (Eurostat yields)

In order to understand the difference between the deductibles at farm and at regional level, we have compared the risks (expected losses from a trend[25]) for wheat yield calculated at farm level with the "2-year constant sample" method (like in section 5.2.1.1) with the risk calculated at regional level from Eurostat wheat yields. The two maps in Figure 39 show the risks with a 30% deductible at farm level from FADN data and at the level of FADN regions (NUTS2 or NUTS1) level from Eurostat data. Figure 40 shows the differences between the risks in the two maps of Figure 39. As can be observed in the map, most differences are positive, indicating that FADN or individual risks are higher than regional risks. The average difference is approximately of 1%. However, we find some exceptions in which the regional risk obtained is higher that the farm risk. This is the case of the south-east of Spain and some regions in the south of Italy.

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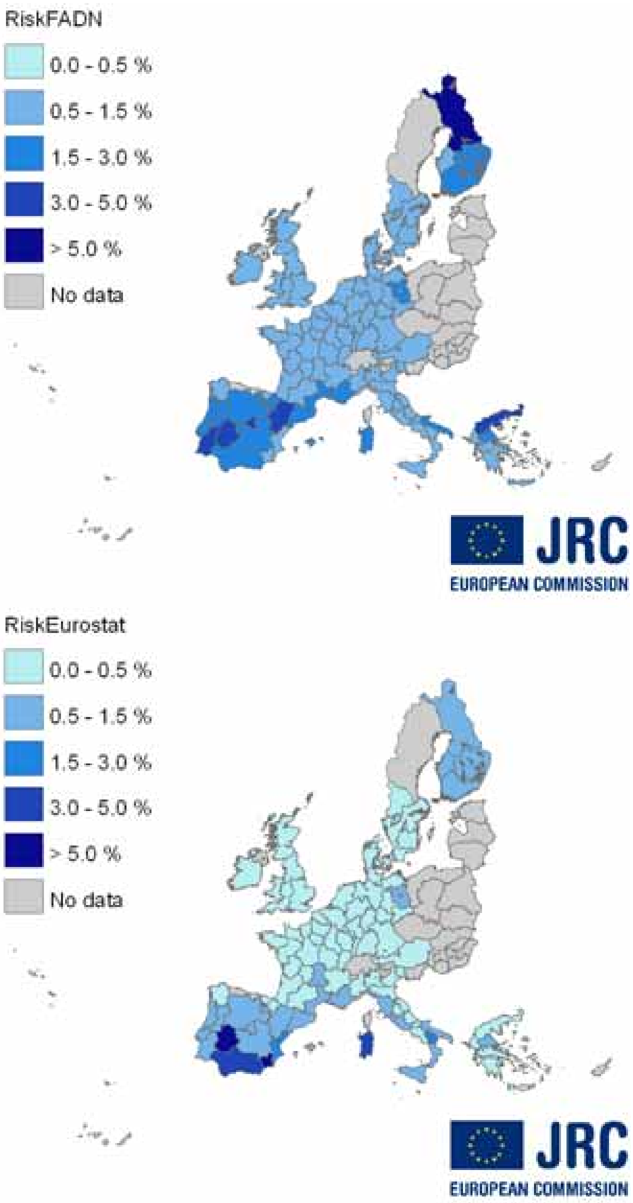
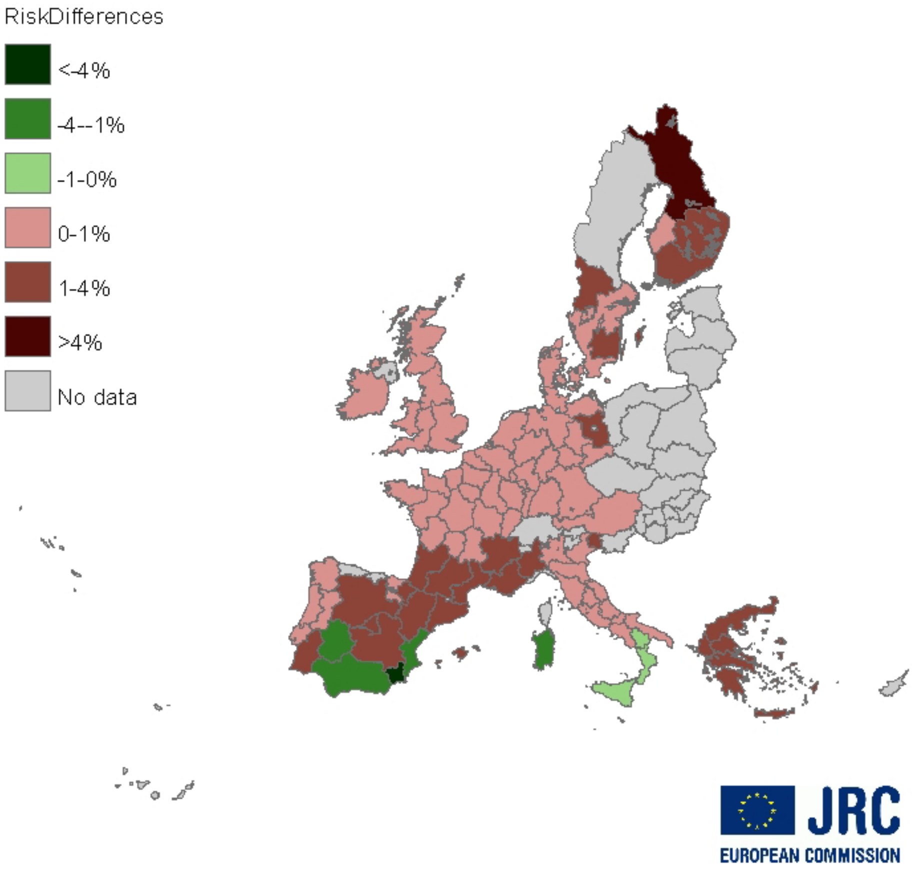
[25] See section 9.12 for the calculation of the trend.



Source: Elaborated by authors from Eurostat data and from FADN data.

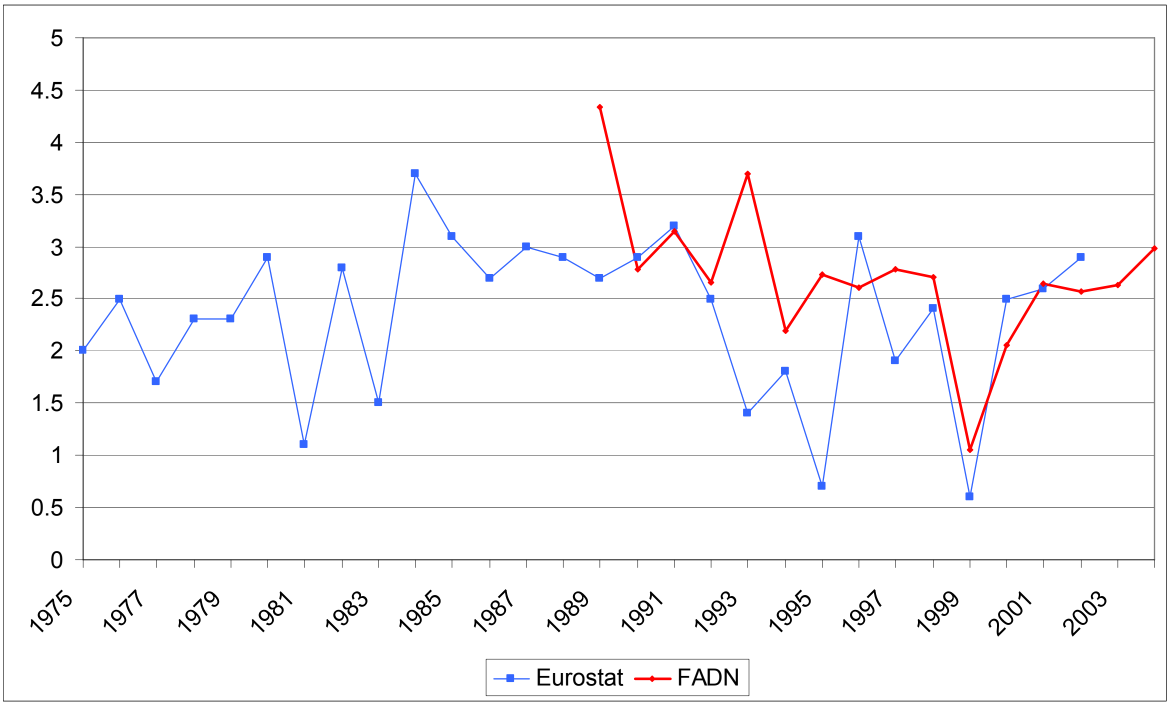
Figure 39. FADN yield risk and Eurostat yield risk for wheat with a 30% deductible



Source: Elaborated by authors from FADN and Eurostat data

Figure 40. Differences FADN risk -Eurostat risk for wheat yields with a 30% deductible

In order to understand the reason of these negative risk differences, we look at the FADN and Eurostat yields in the largest region showing this inconsistency, Andalusia. We can observe the Andalusia yield data in Figure 41. The correlation between Eurostat and FADN yields appears quite low (0.35), with only a similar loss in 1999. The losses registered by Eurostat in 1995 and 1993 are not registered by FADN data. Similar divergences exist in other regions, like Murcia. This poses a question on the quality of the data.



Source: Elaborated by authors from Eurostat and FADN data

Figure 41. Wheat yields in Andalucía (Spain). FADN average and Eurostat NUTS2

We have calculated the Eurostat yield risk at different straight deductibles for every region, in order to find out the straight deductible which results in a risk level similar to the average FADN risk with a 30% deductible. Table 29 shows the weighted averages (weighted with the crop surfaces) for both Eurostat and FADN yields. As can be seen in Table 29, the region deductible that would be equivalent to 30% farm deductible would be 18.7% for the average of all the regions. However, regional differences are very important, so that the equivalent deductible would change from one region to another. The last column refers to the differences of both risks in the regions (values shown are the average of the absolute values of the regional differences between both risks). The deductible that minimizes the regional differences is 22%. For this reason, for our future calculations we will assume that the 30% farm-level deductible is equivalent to a 19% deductible.

Table 29. Wheat yield farm and regional risks for FADN regions

Deductible	Area risk (Eurostat) Weighted average	Farm risk (FADN) Weighted average	Average of risk differences
30%	0.48%	1.19%	1.00%
22%	0.92%	1.19%	0.97%
18.70%	1.19%	1.19%	0.99%

Source: Elaborated by authors from FADN (1989-2004) and Eurostat (1975-2003) data

We had seen in the map in Figure 40 that some regions presented anomalies, showing higher risk at regional level than at farm level. If we eliminate these regions for the calculations, Table 29 would be modified as shown in Table 30. The region deductible which would be equivalent to a 30% farm deductible in this case would be 14.60%. The deductible which minimizes the differences is 17%, so in this case we can assume that the average region deductible equivalent to a 30% farm deductible would be around 15%.

Table 30. Wheat yield farm and regional risks for FADN regions without anomalous regions

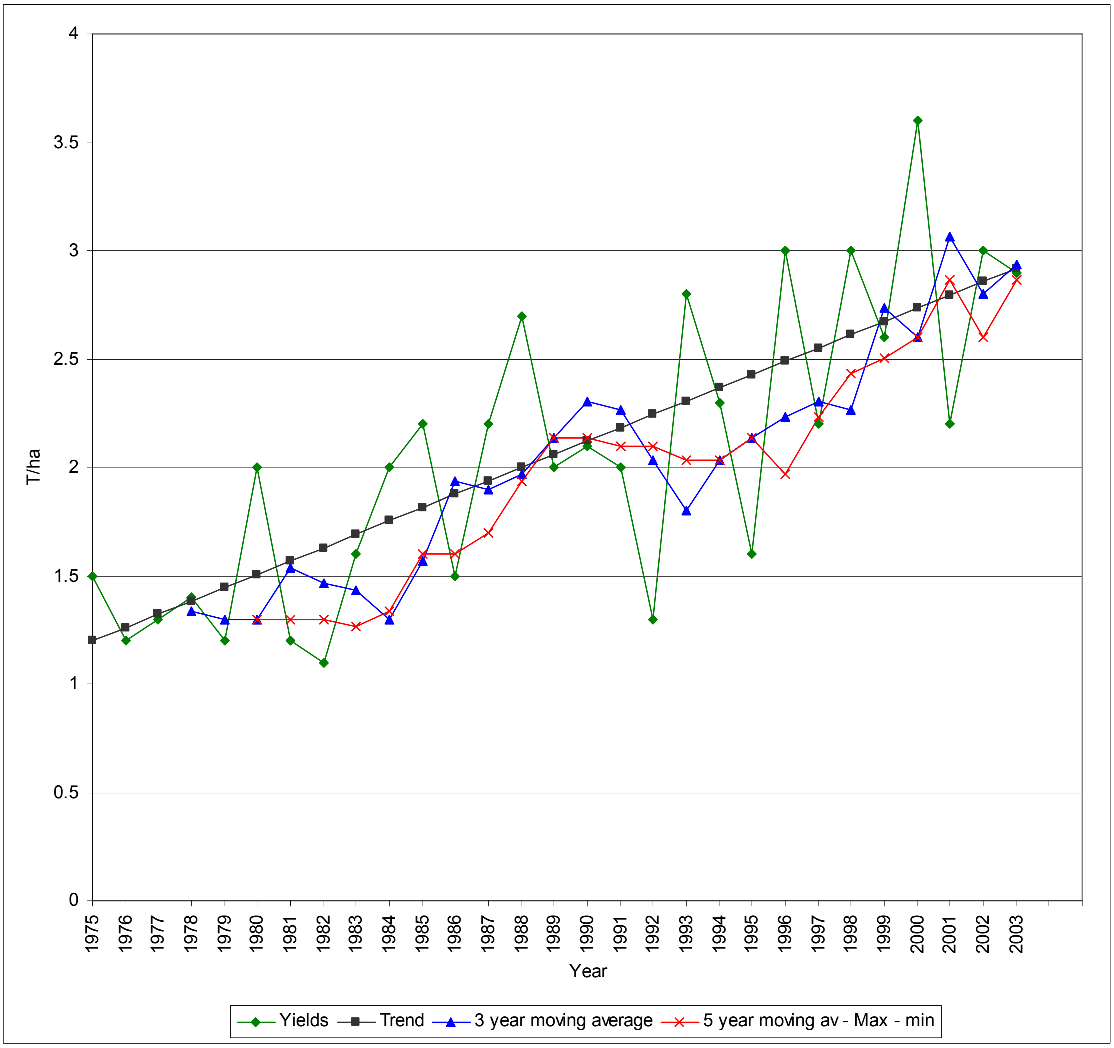
Deductible	Area risk (Eurostat) Weighted average	Farm risk (FADN) Weighted average	Average of risk differences
30%	0.24%	1.14%	0.96%
17%	0.92%	1.14%	0.68%
14.60%	1.14%	1.14%	0.69%

Source: Elaborated by authors from FADN (1989-2004) and Eurostat (1975-2003) data

In summary, from the previous analyses we can deduce that the equivalence between a regional deductible and a farm deductible will depend on the region considered (and probably also on the crop). For the case of wheat, we can establish that the average region deductible equivalent to a 30% farm deductible would be between 15% and 19%.

9.7. Annex 4C. Comparison of losses triggered from a trend and from three year moving averages

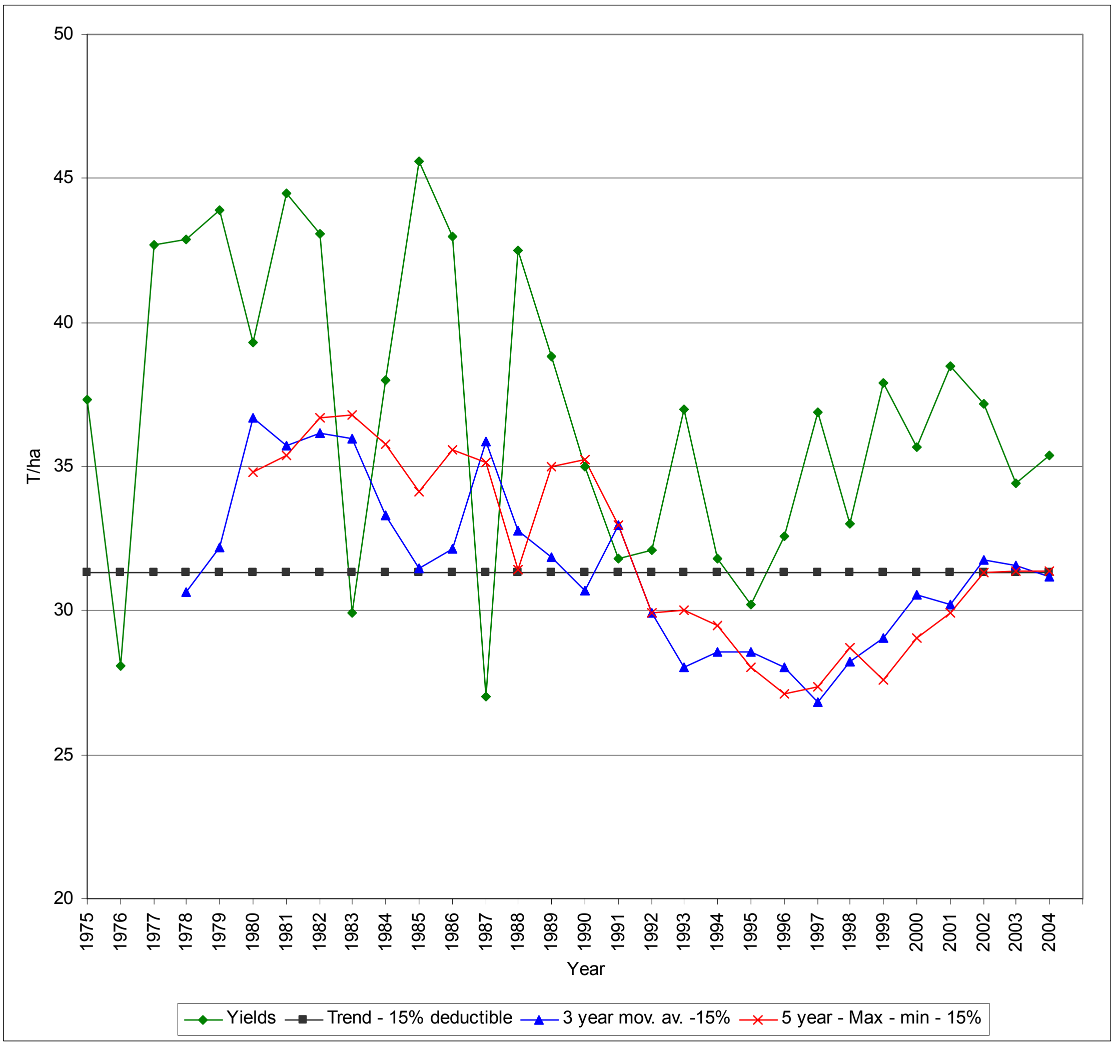
A first approach would indicate that insurers would prefer to base their insured amount in an expected production/income based on the average of a detrended time series, given that it is a more stable amount. A three-year moving average, for a region of high risks, can have big oscillations. Due to the lack of individual data, we will try to illustrate it with regional yield data. Figure 42 shows the regional wheat yields in Castilla y Leon (Spain), a detrended average line and the WTO-moving-average curves. It can be observed that the moving averages present big oscillations. For example, the 3 year moving average from the prior five years eliminating the maximum and minimum would result in an insured amount of 2.27T/ha in 1991, and only 1.80 T/ha two years later (1993), while the general trend is increasing.



Source: Elaborated by authors from Eurostat data

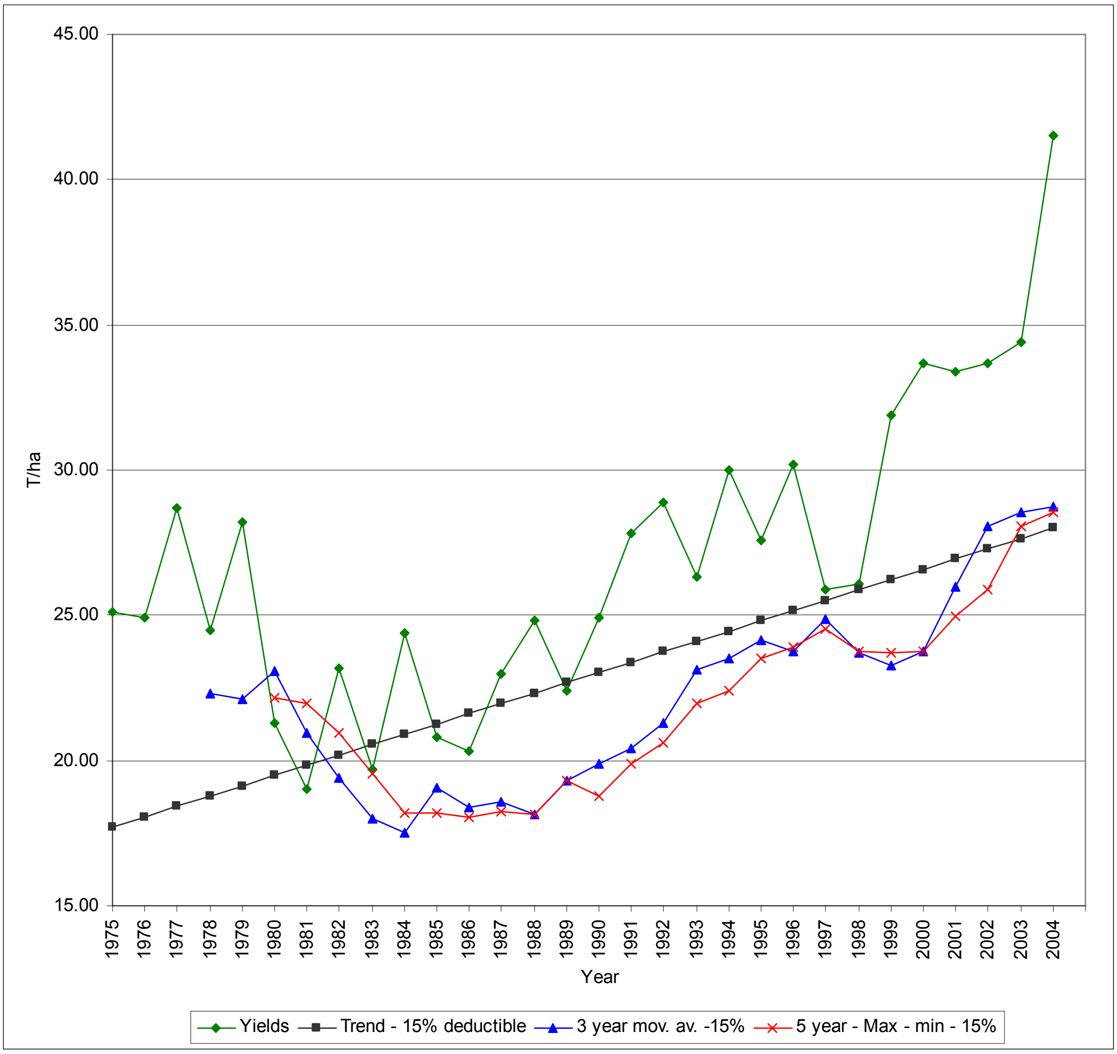
Figure 42. Trend and moving averages for wheat yields in Castilla y Leon (Spain)

In order to compare the eligible losses (losses above a threshold) for an insurance based on a detrended average with the losses allowed by the WTO moving averages criteria, we have performed an analysis on yields at regional level. Given that regional yields are expected to oscillate less than individual yields, we have used a 15% trigger, assuming that it could be equivalent to 30% trigger in individual yields (see Annex 5A, section 9.4). In fact, for Eurostat NUTS2 yields the eligible losses are almost always zero with a 30% trigger, showing that this trigger is too big for regional yields. Figure 43, Figure 44 and Figure 45 graph the region yields, the corresponding trend minus 15%, with the three years moving averages minus 15%.



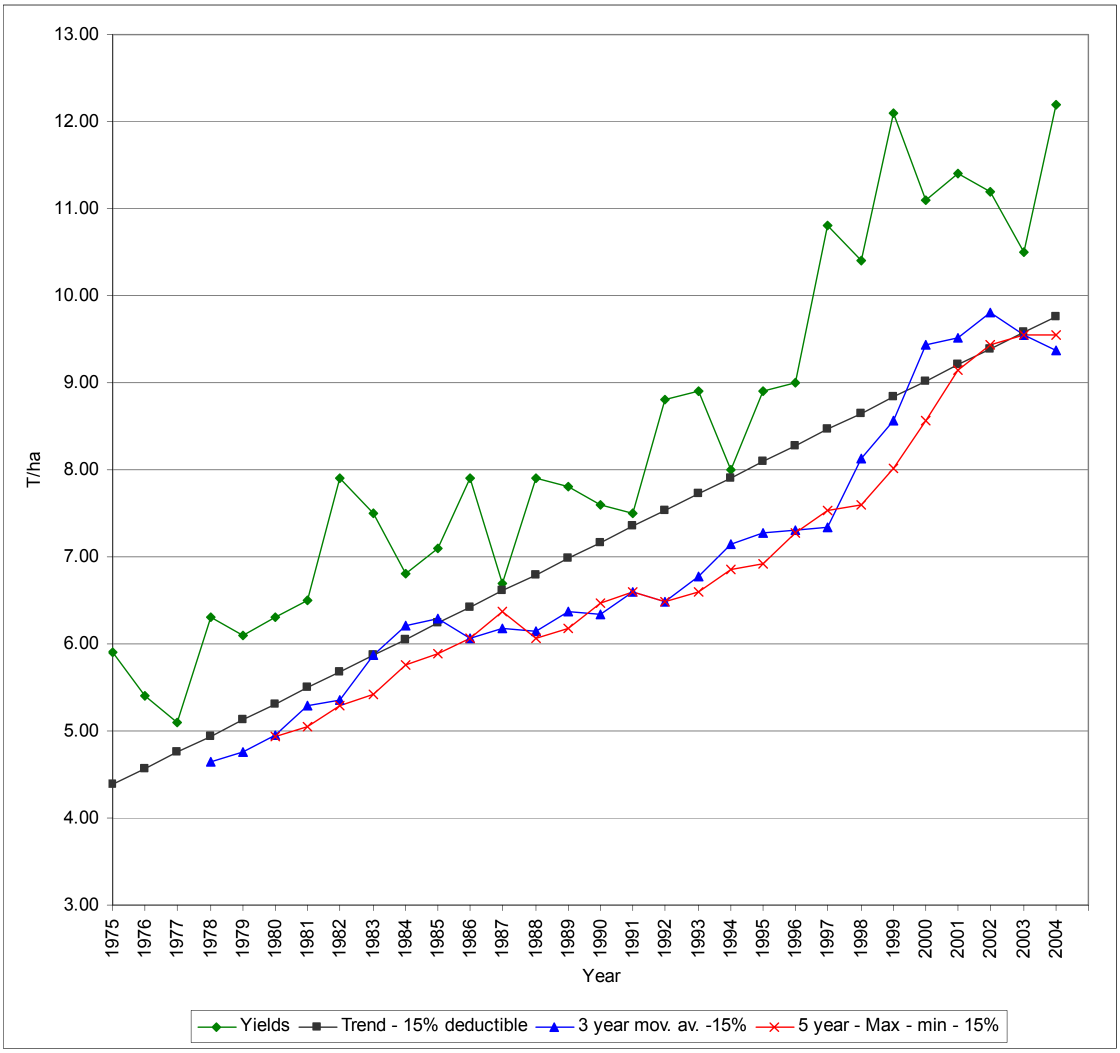
Source: Elaborated by authors from Eurostat data

Figure 43. Trend and moving averages minus 15% for green maize yields in Schleswig-Holstein (Germany)



Source: Elaborated by authors from Eurostat data

Figure 44. Trend and moving averages minus 15% for potato yields in Ireland



Source: Elaborated by authors from Eurostat data

Figure 45. Trend and moving averages minus 15% for grain maize yields in Belgium

Results show some interesting conclusions:

1- The trigger from the detrended average can either less constraining (year 1995 in Figure 43 and years 1983 and 1986 in Figure 44) or more constraining (year 1983 in Figure 43 and year 1981 in Figure 44) than losses from the moving averages.

2- The triggers from the two moving averages are more close to each other than the trigger from the detrended average.

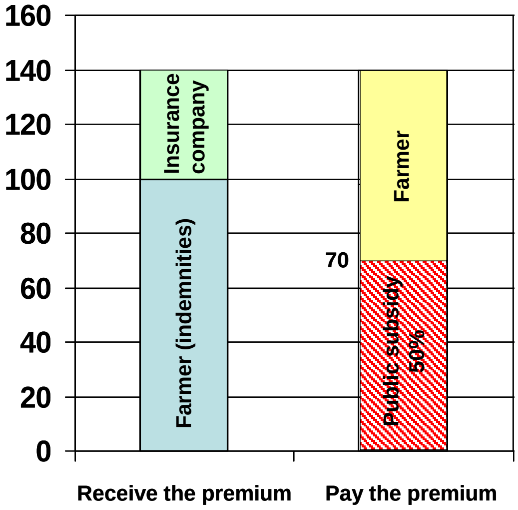
3- In general, when the trend is increasing, the lower values in the years before cause that the moving averages have on average lower values than the trend. So, when the trend is increasing, the WTO conditions would be constraining on average for an insurance based on a moving average (see Figure 44 and Figure 45).

4- Instead, when the trend is constant, such as in Figure 43, we can have some period when WTO criteria would be constraining (from 1992 to 2002, and particularly for the loss in 1995, where the actual yield is below the detrended average but above the moving averages), and some periods when they would allow aids (1979-1989). There would even be some cases when WTO would allow aids but payments are not triggered by the insurance (for example in 1991, where the actual yield is just above the trend but below the moving averages).

9.8. Annex 4D. Discussion on the deductibles and maximum subsidies allowed for income insurance by the Uruguay Round Agreement on Agriculture

Paragraph 7 of Annex 2 of the Uruguay Round Agreement on Agriculture permits a maximum subsidy to income losses equivalent to 70% of the losses. This would mean a 100% subsidy to an insurance with a 30% deductible. However, is the subsidy percentage is lower, the deductible could be smaller in order to reach this maximum compensation. In order to analyse the mutual effect of the deductibles and the subsidy percentage on the compliance with WTO criteria, we will put some examples.

Example 1: Let us assume that the expected indemnities of a farmer equal 100 monetary units. Then, the market premium of an insurance product with no deductible could amount to 140[26]. If the Government subsidizes the 50%, the money from the Government would be 70 (see Figure 46). If, as expected, the farmer has a loss of 100, he is receiving from the Government 70, so 70% of his loss which is the maximum admitted by WTO. This means that the insurance product would need a trigger of 30% but not a deductible of 30% when the Government subsidizes only 50% of the premiums.



Source: Elaborated by authors

Figure 46. Subsidies and WTO: Example 1

Example 2: We can propose another example. If the expected loss is still 100, and the Government's subsidy is 70% of the premium, then 98, we could say that the money from the Government has exceeded the 70% of the losses and that it does not comply with WTO (see Figure 47). However, it could also be argued that the Government is paying the Administrative costs of insurance, so 40, and that the farmer actually only receives the difference, 58. In fact,

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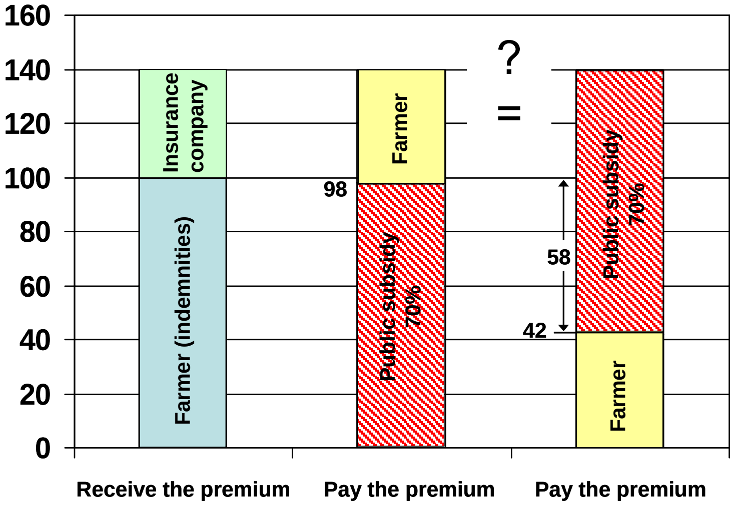
[26] Bielza et al. (2006) estimate that the average loss rate in Europe can be around 70%. This means that the expected indemnities are 0.7 for every euro of premium paid. As the fair premium is equivalent to the expected indemnities, we can consider that to a fair premium of 0.7 we have to add 0.3 for administrative costs, so, to increase it by 43%.

the farmer paid a premium of 140-98= 42 and received 100 as indemnities, so he only received net 58, so less than 70% of the loss.

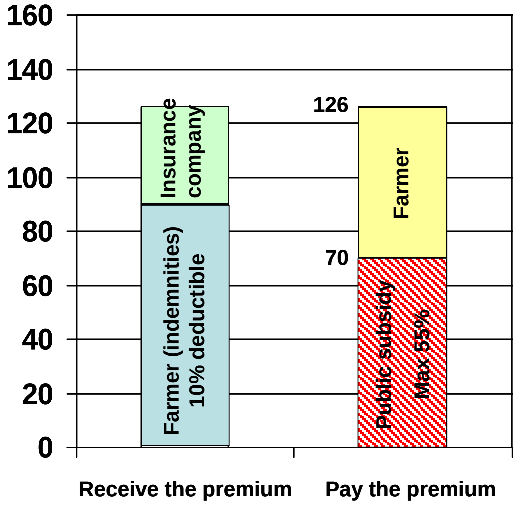


Source: Elaborated by authors

Figure 47. Subsidies and WTO: Example 2

These examples show that the insurance design would need to take into account the foreseen subsidy from the Government, or perhaps more simple, that the Government should take into account the deductibles of the insurance in order to fix the subsidy. These examples also lead to a question, developed in Example 3.

Example 3: If we assume the most restrictive situation, in which we would not accept that the subsidies from the Government pay the administrative costs, but that they are entirely paid to the producers, and we assume the most common minimum deductible of 10%, which would be the maximum subsidy possible in order to comply with WTO requirements? A 10% deductible would mean that the fair premium would decrease to 90, and the market premium to 126. The maximum subsidy allowed would be 70% of the loss, so 70 monetary units. In this way, it can be obtained by a simple calculation that the maximum subsidy possible would be 55% of the market premium (see Figure 48).



Source: Elaborated by authors

Figure 48. Subsidies and WTO: Example 3

9.9. Annex 4E: Premium rates for RYI

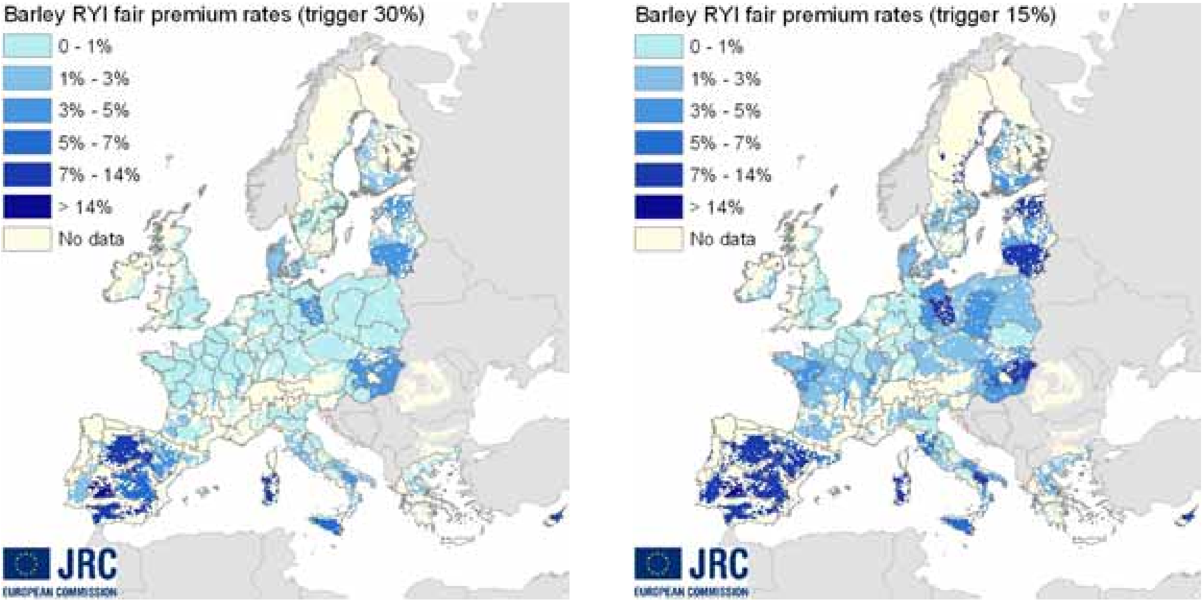
9.9.1. Premium rates for cereals

The premium rates for wheat are shown in section 4.2.4.

Table 31. Premium rates (%) for barley (premiums calculated at FADN-region level)

	Trigger 30%			Trigger 15%		
	Average	Maximum	Minimum	Average	Maximum	Minimum
AT	0.00%	0.00%	0.00%	1.94%	1.94%	1.94%
BE	0.00%	0.00%	0.00%	0.55%	0.55%	0.55%
CY	13.99%	13.99%	13.99%	13.99%	13.99%	13.99%
CZ	0.00%	0.00%	0.00%	1.55%	1.55%	1.55%
DE	0.32%	4.49%	0.00%	1.60%	7.84%	0.00%
DK	1.08%	1.08%	1.08%	1.92%	1.92%	1.92%
EE	3.85%	3.85%	3.85%	7.27%	7.27%	7.27%
ES	6.62%	15.74%	0.00%	8.94%	18.16%	2.99%
FI	1.69%	1.69%	1.69%	4.62%	4.62%	4.62%
FR	0.30%	1.81%	0.00%	1.98%	6.14%	0.00%
GR	0.56%	2.25%	0.00%	2.27%	4.92%	1.30%
HU	2.44%	4.13%	0.00%	5.05%	7.97%	1.62%
IE	0.00%	0.00%	0.00%	1.18%	1.18%	1.18%
IT	1.66%	8.48%	0.00%	3.09%	11.75%	0.00%
LT	4.27%	4.27%	4.27%	7.40%	7.40%	7.40%
LU	0.00%	0.00%	0.00%	1.88%	1.88%	1.88%
LV	2.29%	2.29%	2.29%	3.84%	3.84%	3.84%
NL	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
PL	0.00%	0.00%	0.00%	1.82%	3.36%	0.00%
PT	2.21%	2.21%	2.21%	10.84%	10.84%	10.84%
SE	0.82%	2.47%	0.00%	3.43%	7.23%	1.43%
SI	0.00%	0.00%	0.00%	2.25%	2.25%	2.25%
SK	3.83%	3.83%	3.83%	3.83%	3.83%	3.83%
UK	0.00%	0.00%	0.00%	0.83%	3.11%	0.00%
Europe	2.09%	15.74%	0.00%	4.15%	18.16%	0.00%

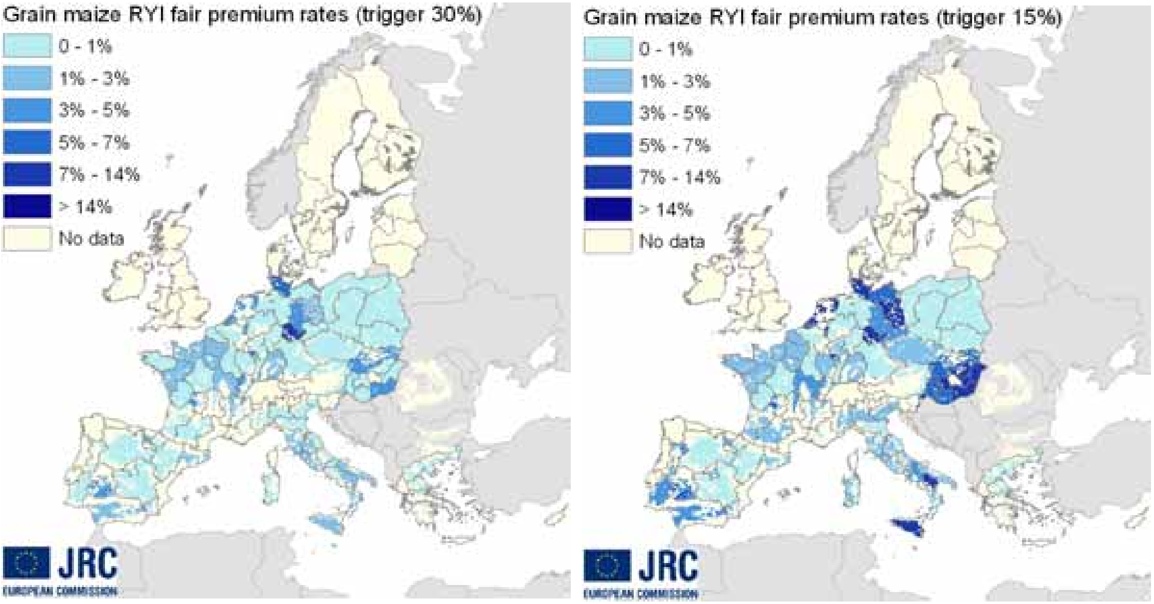
Source: Authors calculations from Eurostat data


Barley RYI fair premium rates (trigger 30%)

Barley RYI fair premium rates (trigger 15%)

Source: Elaborated by authors from Eurostat Source: Elaborated by authors from Eurostat data

Figure 49. Premium rates for RYI for barley (trigger 30% and 15%)


Grain maize RYI fair premium rates (trigger 30%)

Grain maize RYI fair premium rates (trigger 15%)

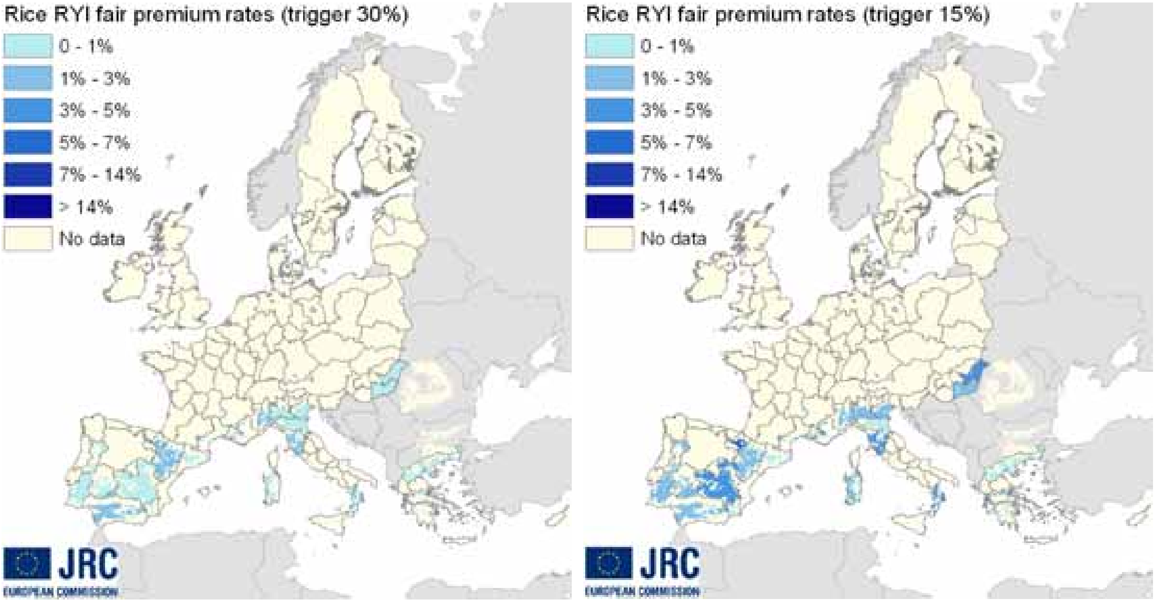
Source: Elaborated by authors from Eurostat data

Figure 50. Premium rates for RYI for grain maize (trigger 30% and 15%)

Table 32. Premium rates (%) for grain maize (premiums calculated at FADN-region level)

	Trigger 30%			Trigger 15%		
	Average	Maximum	Minimum	Average	Maximum	Minimum
AT	0.00%	0.00%	0.00%	0.76%	0.76%	0.76%
BE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CZ	0.00%	0.00%	0.00%	1.90%	1.90%	1.90%
DE	2.08%	7.51%	0.00%	3.95%	9.20%	0.00%
ES	0.98%	3.93%	0.00%	2.57%	7.84%	0.00%
FR	0.73%	3.43%	0.00%	2.02%	6.72%	0.00%
GR	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
HU	0.71%	4.24%	0.00%	8.07%	11.56%	5.36%
IT	0.64%	2.95%	0.00%	2.64%	7.95%	0.57%
NL	4.04%	4.04%	4.04%	9.54%	9.54%	9.54%
PL	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
PT	0.00%	0.00%	0.00%	4.67%	4.67%	4.67%
SI	2.92%	2.92%	2.92%	7.89%	7.89%	7.89%
SK	4.13%	4.13%	4.13%	6.11%	6.11%	6.11%
Europe	1.47%	7.51%	0.00%	4.56%	11.56%	0.00%

Source: Authors calculations from Eurostat data



Source: Elaborated by authors from Eurostat data

Figure 51. Premium rates for RYI for rice (trigger 30% and 15%)

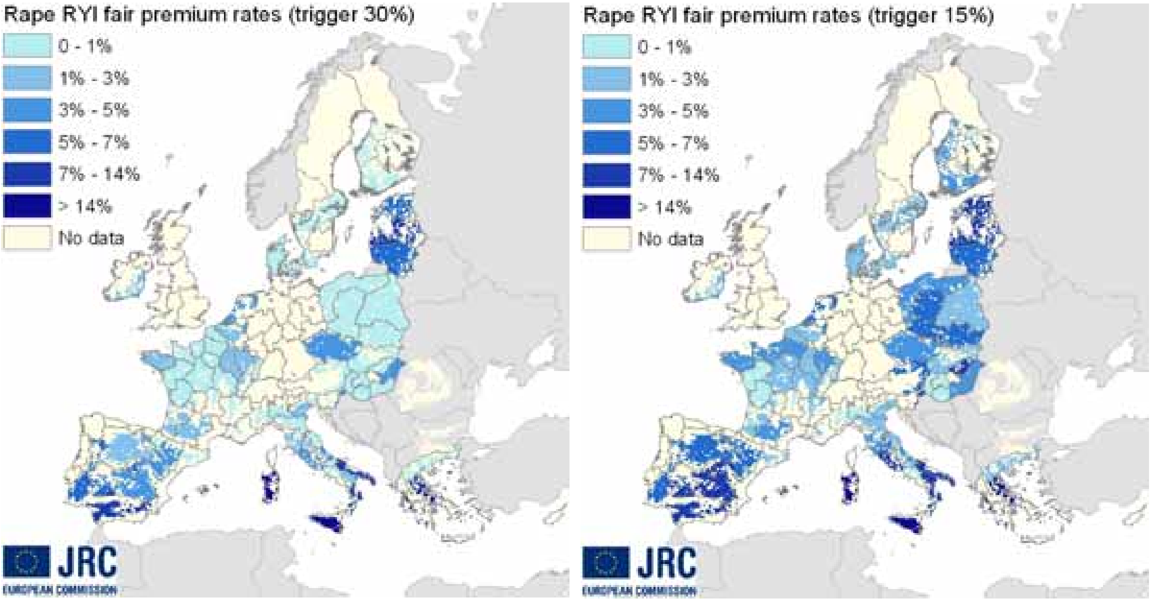
Table 33. Premium rates (%) for rice (premiums calculated at FADN-region level)

	Trigger 30%			Trigger 10%		
	Average	Maximum	Minimum	Average	Maximum	Minimum
ES	0.67%	2.56%	0.00%	2.05%	5.20%	0.00%
FR	1.37%	1.43%	1.30%	2.81%	3.32%	2.31%
GR	0.00%	0.00%	0.00%	1.07%	1.12%	0.97%
HU	0.00%	0.00%	0.00%	3.18%	3.99%	2.37%
IT	0.67%	2.18%	0.00%	2.13%	4.63%	0.61%
PT	0.00%	0.00%	0.00%	1.51%	1.51%	1.51%
Europe	0.45%	2.56%	0.00%	2.13%	5.20%	0.00%

Source: Authors calculations from Eurostat data

9.9.2. Premium rates for oilseeds: rapeseed, soybean and sunflower

The rapeseed calculations encountered several problems. In many cases, the yield variations where huge and with an unusual behaviour, which could be due to the variation in the cultivated surface. In fact, in many regions the crop progressively disappeared, with the last years showing a surface of one hectare or less per region. This can have an impact on average yields, with an increase/decrease of cropped rapeseed-suitable areas. These aspects where found for example in Italy, where we tried to combat these effects by artificially modifying the trend adapting it to the different periods observed. A similar case was found in Greece. In this case we did not manipulate the data, and consequently, the premiums rates resulted to be very high, as can be observed in Table 34. Anyway, it is not actuarially advisable to design an insurance product for a crop and regions which suffer from this kind of data problems.



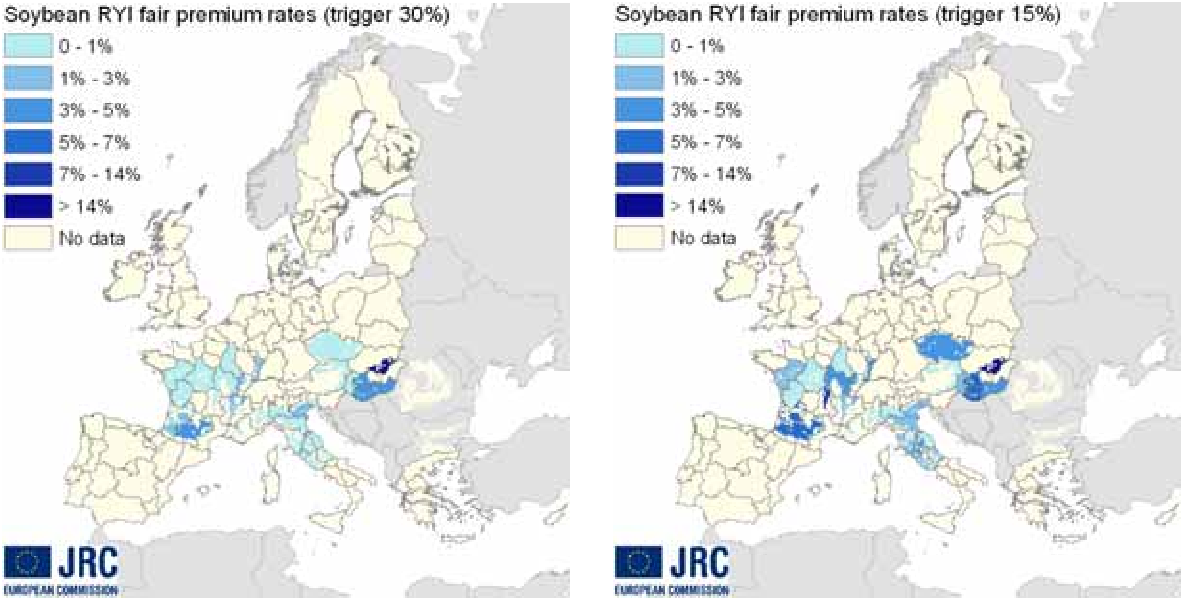
Source: Elaborated by authors from Eurostat data

Figure 52. Premium rates for RYI for rapeseed (trigger 30% and 15%)

Table 34. Premium rates (%) for rapeseed (premiums calculated at FADN-region level)

	Trigger 15%			Trigger 15%		
	Average	Maximum	Minimum	Average	Maximum	Minimum
AT	0.00%	0.00%	0.00%	6.89%	6.89%	6.89%
BE	1.53%	1.53%	1.53%	2.33%	2.33%	2.33%
CZ	3.72%	3.72%	3.72%	3.72%	3.72%	3.72%
DK	0.00%	0.00%	0.00%	1.88%	1.88%	1.88%
EE	5.41%	5.41%	5.41%	7.13%	7.13%	7.13%
ES	4.40%	11.51%	0.00%	7.54%	15.45%	2.04%
FI	0.00%	0.00%	0.00%	3.94%	3.94%	3.94%
FR	0.37%	1.59%	0.00%	2.41%	4.55%	0.00%
GR	11.51%	17.14%	0.00%	15.16%	20.80%	1.51%
HU	0.54%	3.23%	0.00%	2.46%	7.87%	0.00%
IE	1.56%	1.56%	1.56%	2.32%	2.32%	2.32%
IT	4.98%	26.76%	0.00%	7.07%	28.54%	0.79%
LT	5.04%	5.04%	5.04%	6.35%	6.35%	6.35%
LU	3.11%	3.11%	3.11%	5.99%	5.99%	5.99%
LV	9.47%	9.47%	9.47%	11.85%	11.85%	11.85%
NL	3.73%	3.73%	3.73%	6.08%	6.08%	6.08%
PL	0.00%	0.00%	0.00%	4.78%	6.75%	2.52%
PT	5.78%	5.78%	5.78%	6.67%	6.67%	6.67%
SE	0.00%	0.00%	0.00%	1.71%	1.71%	1.71%
SI	3.37%	3.37%	3.37%	7.86%	7.86%	7.86%
SK	0.00%	0.00%	0.00%	1.94%	1.94%	1.94%
Europe	3.07%	26.76%	0.00%	5.53%	28.54%	0.00%

Source: Authors calculations from Eurostat data



Soybean RYI fair premium rates (trigger 30%)

Soybean RYI fair premium rates (trigger 15%)

Source: Elaborated by authors from Eurostat data

Figure 53. Premium rates for RYI for soybean (trigger 30% and 15%)

Table 35. Premium rates (%) for soybean (premiums calculated at FADN-region level)

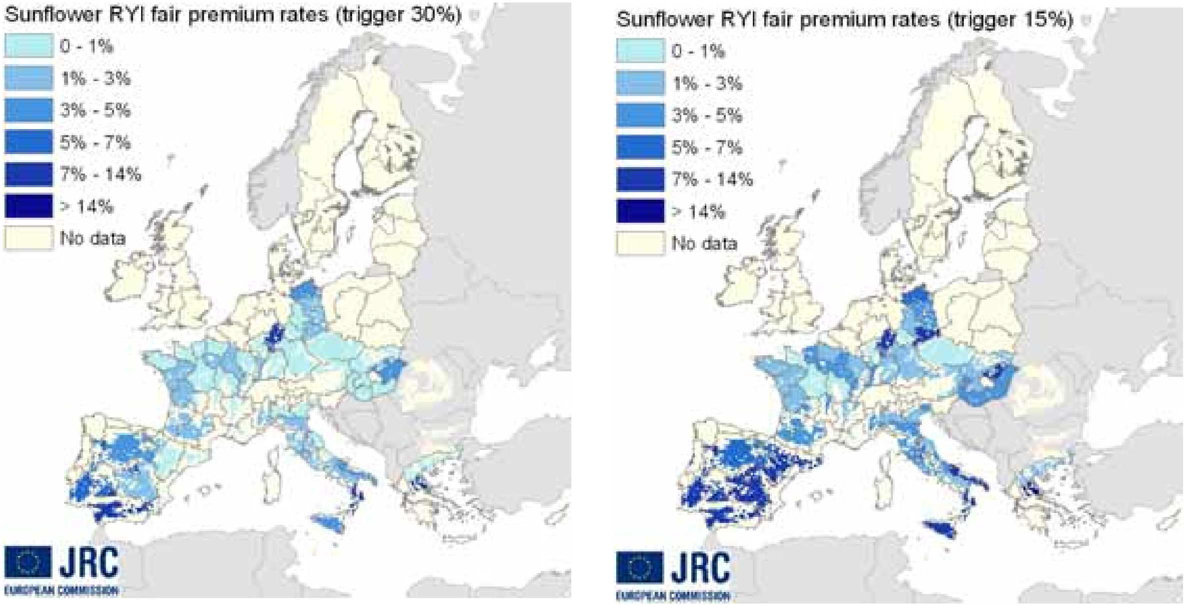
	Trigger 30%			Trigger 15%		
	Average	Maximum	Minimum	Average	Maximum	Minimum
AT	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CZ	0.00%	0.00%	0.00%	4.39%	4.39%	4.39%
FR	0.99%	3.40%	0.00%	2.89%	7.48%	0.00%
HU	4.99%	14.91%	0.00%	6.92%	16.73%	1.98%
IT	0.19%	1.87%	0.00%	1.45%	3.85%	0.00%
Europe	1.54%	14.91%	0.00%	3.91%	16.73%	0.00%

Source: Authors calculations from Eurostat data

Table 36. Premium rates (%) for sunflower (premiums calculated at FADN-region level)

	Trigger 30%			Trigger 15%		
	Average	Maximum	Minimum	Average	Maximum	Minimum
AT	0.00%	0.00%	0.00%	1.21%	1.21%	1.21%
DE	2.10%	8.19%	0.00%	4.18%	12.64%	0.00%
ES	3.44%	7.85%	0.00%	7.74%	11.80%	3.40%
FR	0.59%	2.13%	0.00%	2.48%	4.76%	0.00%
GR	4.54%	9.08%	0.00%	8.56%	14.97%	2.15%
HU	1.13%	3.40%	0.00%	4.07%	7.86%	1.64%
IT	1.95%	8.07%	0.00%	4.68%	10.18%	2.08%
PT	5.79%	5.79%	5.79%	9.34%	9.34%	9.34%
SK	0.00%	0.00%	0.00%	2.52%	2.52%	2.52%
Europe	2.17%	9.08%	0.00%	4.98%	14.97%	0.00%

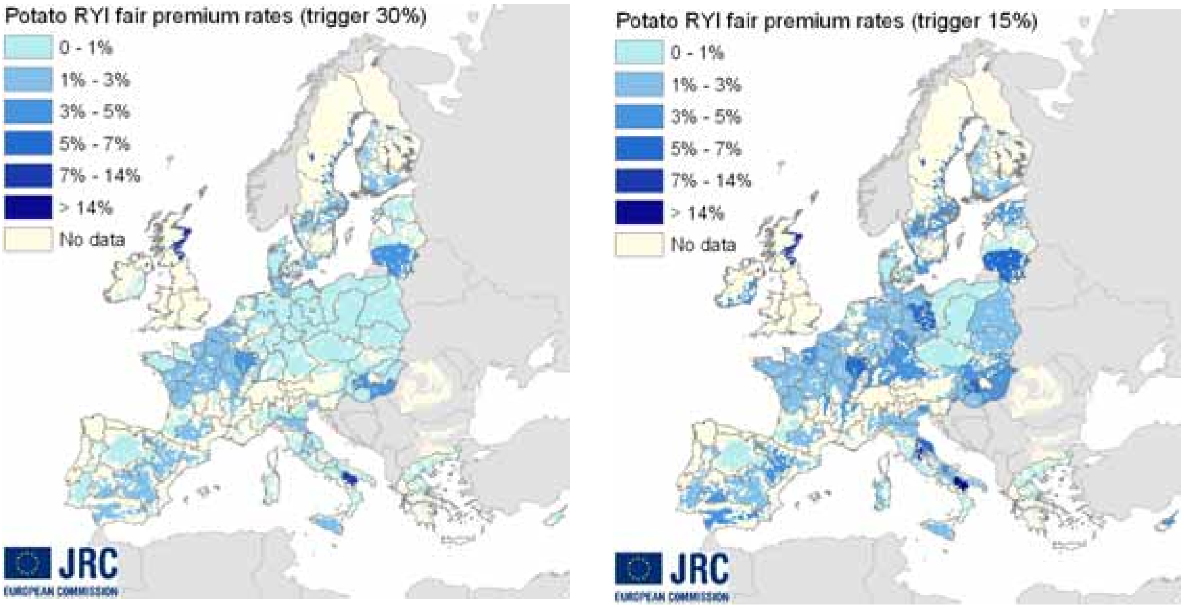
Source: Authors calculations from Eurostat data



Source: Elaborated by authors from Eurostat data

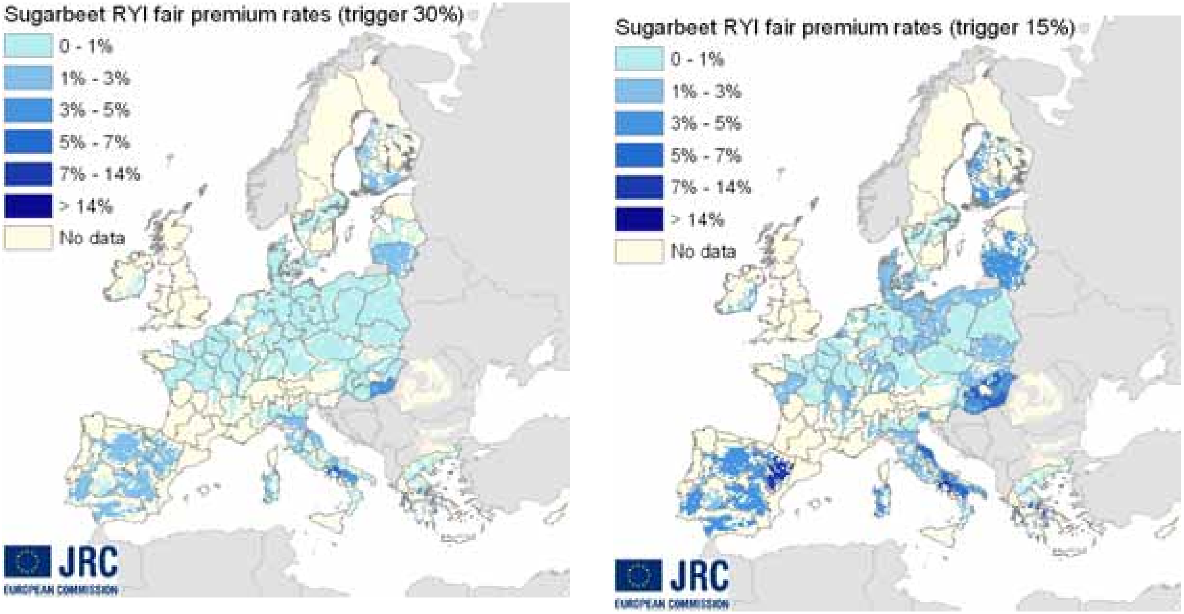
Figure 54. Premium rates for RYI for sunflower (trigger 30% and 15%)

9.9.3. Premium rates for tubers: potato and sugarbeet



Source: Elaborated by authors from Eurostat data

Figure 55. Premium rates for RYI for potato (trigger 30% and 10%)



Source: Elaborated by authors from Eurostat data

Figure 56. Premium rates for RYI for sugar beet (trigger 30% and 10%)

Table 37. Premium rates (%) for sugar beet (premiums calculated at FADN-region level)

	Trigger 30%			Trigger 15%		
	Average	Maximum	Minimum	Average	Maximum	Minimum
AT	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
BE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CZ	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
DE	0.00%	0.00%	0.00%	1.07%	2.32%	0.00%
DK	0.00%	0.00%	0.00%	1.04%	1.04%	1.04%
ES	1.01%	1.88%	0.00%	4.01%	8.71%	2.09%
FI	2.12%	2.12%	2.12%	3.90%	3.90%	3.90%
FR	0.07%	1.00%	0.00%	0.95%	2.20%	0.00%
GR	1.96%	3.92%	0.00%	3.06%	5.69%	0.00%
HU	0.50%	3.02%	0.00%	4.27%	6.86%	0.00%
IE	0.00%	0.00%	0.00%	1.93%	1.93%	1.93%
IT	1.11%	6.74%	0.00%	3.60%	10.57%	0.80%
LT	2.21%	2.21%	2.21%	3.51%	3.51%	3.51%
LV	0.00%	0.00%	0.00%	3.51%	3.51%	3.51%
NL	0.00%	0.00%	0.00%	1.13%	1.13%	1.13%
PL	0.00%	0.00%	0.00%	1.11%	2.67%	0.00%
PT	1.18%	1.18%	1.18%	3.22%	3.22%	3.22%
SI	0.00%	0.00%	0.00%	2.14%	2.14%	2.14%
SK	0.00%	0.00%	0.00%	2.18%	2.18%	2.18%
Europe	0.53%	6.74%	0.00%	2.14%	10.57%	0.00%

Source: Authors calculations from Eurostat data

Table 38. Premium rates (%) for potato (premiums calculated at FADN-region level)

	Trigger 30%			Trigger 15%		
	Average	Maximum	Minimum	Average	Maximum	Minimum
AT	0.00%	0.00%	0.00%	1.47%	1.47%	1.47%
BE	1.18%	1.18%	1.18%	2.36%	2.36%	2.36%
CY	0.00%	0.00%	0.00%	3.21%	3.21%	3.21%
CZ	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
DE	0.39%	3.80%	0.00%	2.93%	6.05%	1.09%
DK	0.00%	0.00%	0.00%	0.83%	0.83%	0.83%
EE	0.00%	0.00%	0.00%	3.79%	3.79%	3.79%
ES	2.44%	4.97%	0.00%	3.59%	6.59%	0.66%
FI	1.72%	1.72%	1.72%	2.50%	2.50%	2.50%
FR	1.29%	3.65%	0.00%	2.34%	5.02%	0.00%
GR	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
HU	1.16%	3.49%	0.00%	3.47%	5.15%	2.02%
IE	0.00%	0.00%	0.00%	3.03%	3.03%	3.03%
IT	1.42%	12.36%	0.00%	3.49%	14.30%	0.63%
LT	4.08%	4.08%	4.08%	5.70%	5.70%	5.70%
LU	2.87%	2.87%	2.87%	4.71%	4.71%	4.71%
LV	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MT	0.00%	0.00%	0.00%	2.39%	2.39%	2.39%
NL	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%
PL	0.00%	0.00%	0.00%	0.84%	1.73%	0.00%
PT	0.00%	0.00%	0.00%	2.05%	2.05%	2.05%
SE	2.61%	5.44%	0.00%	3.90%	6.65%	1.18%
SI	0.00%	0.00%	0.00%	3.30%	3.30%	3.30%
SK	0.00%	0.00%	0.00%	4.64%	4.64%	4.64%
UK	6.10%	7.41%	4.47%	6.54%	7.41%	5.15%
Europe	0.96%	12.36%	0.00%	2.93%	14.30%	0.00%

Source: Authors calculations from Eurostat data

9.10. Annex 5A: The “2-year constant sample” method.

We consider a generic farm *i* in a year *t*. Farm *i* belongs to a class of farms *k*. The class *k* can be defined as a FADN region or as the set of farms in the region of a certain-size or a certain-farm type. Farm *i* has a weight W_{ti} for extrapolation in FADN.

Our target variable (yield, income/AWU, Farm net value added) is noted Z_{ti} for farm i and Z_{tk} for category k. Z_{tk} can be estimated as $\hat{Z}_{tk} = \overline{Z}_{ti}\}_{i \in k}$

We call g_{tk} the trend of Z_{tk}. The computation of the trend, selecting a constant, linear, quadratic or logarithmic function, is described in section 9.12. The trend for farm *i* is called g_{ti}. We assume it is proportional to the trend for the class to which it belongs: $g_{ti} = A_i\, g_{tk}$. The coefficient $A_i > 1$ if the farm generally performs better than the average in the region. $A_i < 1$ if it performs worse. Some type of assumption is necessary to make up for the absence of a time series long enough to compute directly the trend g_{ti}.

The actual value of Z_{ti} differs from the trend g_{ti} for several reasons: the general goodness/badness of the year for that region, that we represent by δ_{tk} and a specific variation for to the farm i for year t due to a variety of reasons, that we collect in a residual term ε_{ti}. We assume that ε_{ti} and $\varepsilon_{t'i}$ are independent for $t \neq t'$.

$$Z_{ti} = A_i\, \delta_{tk} g_{tk}\, \varepsilon_{ti} = A_i\, Z_{tk}\, \varepsilon_{ti} = g_{ti} \delta_{tk} \varepsilon_{ti}$$

δ_{tk} indicates if the year t has been better or worse than the trend in region k. It can be estimated from the time series of the average data for the region *k*. $Z_{tk} = \delta_{tk} g_{tk}$

The attempt now is exploiting the data of a farm as soon as we have two consecutive observations for that farm. The ratio of the observations for consecutive years will give us an indication on the tendency to fluctuation represented by the terms δ_{tk} and ε_{ti}

Thus we will use as data for the estimation of the risk: $\Delta Z_{ti} = \dfrac{Z_{ti}}{Z_{t-1,i}} = \dfrac{g_{tk}}{g_{t-1,k}} \dfrac{\delta_{tk}\ \varepsilon_{ti}}{\delta_{t-1,k}\ \varepsilon_{t-1,i}}$. Using these ratios has the advantage of eliminating the term A_i, that we are unable to estimate properly due to scarce data for farm i.

We use a loss function:
$$h(Z_{ti}) = \begin{cases} 0 & if \quad Z_{ti} > (1-d)\, g_{ti} \\ (1-d)\, g_{ti} - Z_{ti} & otherwise \end{cases}$$

This corresponds to the loss compensated by an insurance with a straight deductible *d*.

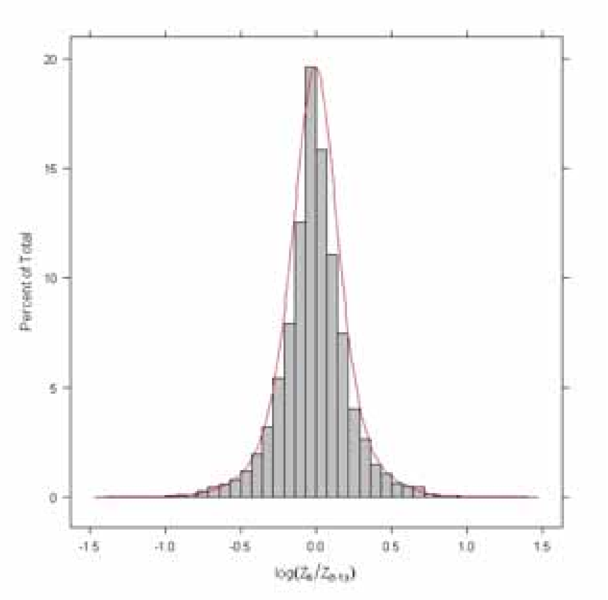
We can write $(1-d)g_{ti} - Z_{ti} = g_{ti} \times ((1-d) - \delta_{tk}\varepsilon_{ti})$

Therefore we want to estimate the risk $E[h(Z_{ti})]$, we need to estimate the distribution of $\delta_{tk}\varepsilon_{ti}$, more specifically the part of the distribution with values below $(1-d)$.

The term $\gamma_{ti} = \delta_{tk}\varepsilon_{ti}$ measures the ratio between the yield Z_{ti} obtained in a farm and the expected yield g_{ti} . It has two components: the general deviation in the region and the specific deviation of farm i in year t, excluding the long term difference A_i between the farm *i* and the class *k*.

From the data we can compute $\frac{\gamma_{ti}}{\gamma_{t-1,i}} = \frac{Z_{ti}}{Z_{t-1,i}} \frac{g_{t-1,i}}{g_{ti}}$ and hence derive an estimate of the distribution of $\varphi_t = \log(\gamma_t) - \log(\gamma_{t-1})$, that we can call φ for a generic year, assuming a stationary behaviour of risk. Under the hypothesis of stationary behaviour we can put together all the observed values for different years to estimate the distribution of φ.

The histograms of φ look approximately like a normal distribution, with means close to 0, but the Kolmogorov test rejects in most cases the normality. The main reason is that queues can be very long, compared to Gaussian densities (thicker than Gaussian far from the mean); this can be checked because the values of the kurtosis are often very high (see Figure 57 and Table 39).



Source: Elaborated by authors from FADN data

Figure 57. Histogram of $\log(\gamma_t) - \log(\gamma_{t-1})$ for the region of Bavaria

Table 39. Descriptive parameters of the distribution of $\log(\gamma_t)-\log(\gamma_{t-1})$ for the region Bavaria, showing that the apparently Gaussian distribution does not fit.

Distribution analysis	
Min	0.2664
1st Qu.	0.8850
Median	0.9923
3rd Qu.	1.1070
Max	3.7720
Mean	1.0145
Sd	0.2386
cv	0.2352
skewness	1.7134
kurtosis	9.1231
Normality test	
Kolmogorov-Smirnov	p-value<0.001

Source: Elaborated by authors from FADN data

If φ had followed a gaussian distribution $N(0,s^2)$, it would have been reasonable to assume that $\log(\gamma_t)$ and $\log(\gamma_{t-1})$ are independent random variables with a $N\left(0,{s^2}/{2}\right)$ distribution, i.e. they have the same distribution as $\frac{\varphi}{\sqrt{2}}$.

We now consider if it is reasonable to assume that $\log(\gamma_t)$ and $\log(\gamma_{t-1})$ have the same distribution as $\frac{\varphi}{\sqrt{2}}$ even if φ does not follow exactly a normal distribution. The question is: it is approximately true that φ follows the same probability distribution as the sum (or the difference) of two independent variables distributed as $\frac{\varphi}{\sqrt{2}}$? If so, we can estimate the distribution of $\log(\gamma_t)$ as the distribution of $\frac{\varphi}{\sqrt{2}}$.

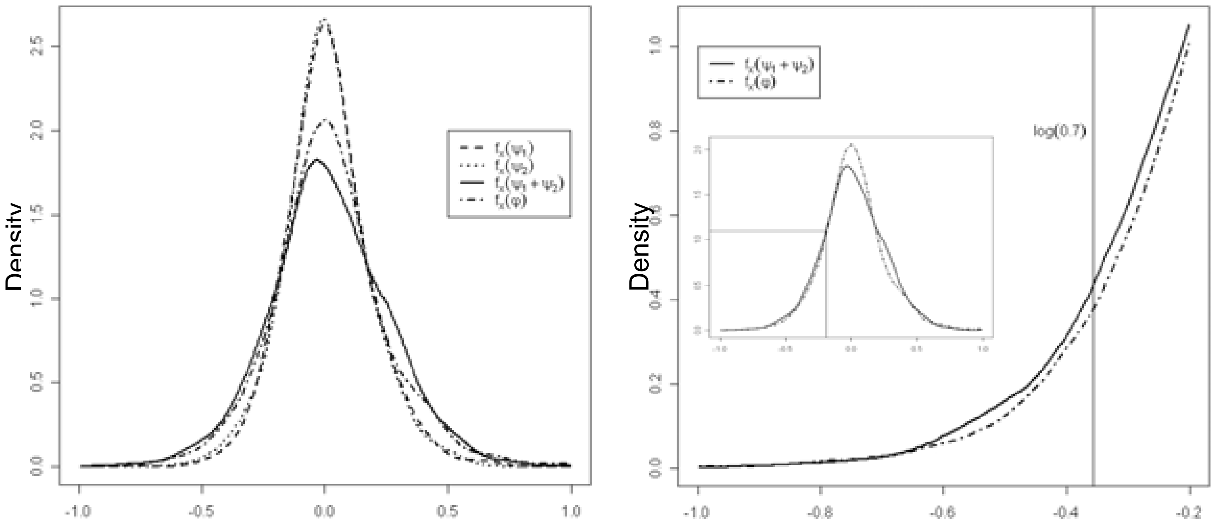
For the empirical application, once the regional trend g_{tk} has been calculated, to estimate the density of φ_t we have used the Kernel density estimator (Tapia and Thompson, 1978) with a bandwidth 0.05 and "triangular" smoothing.

The distribution function was estimated as:

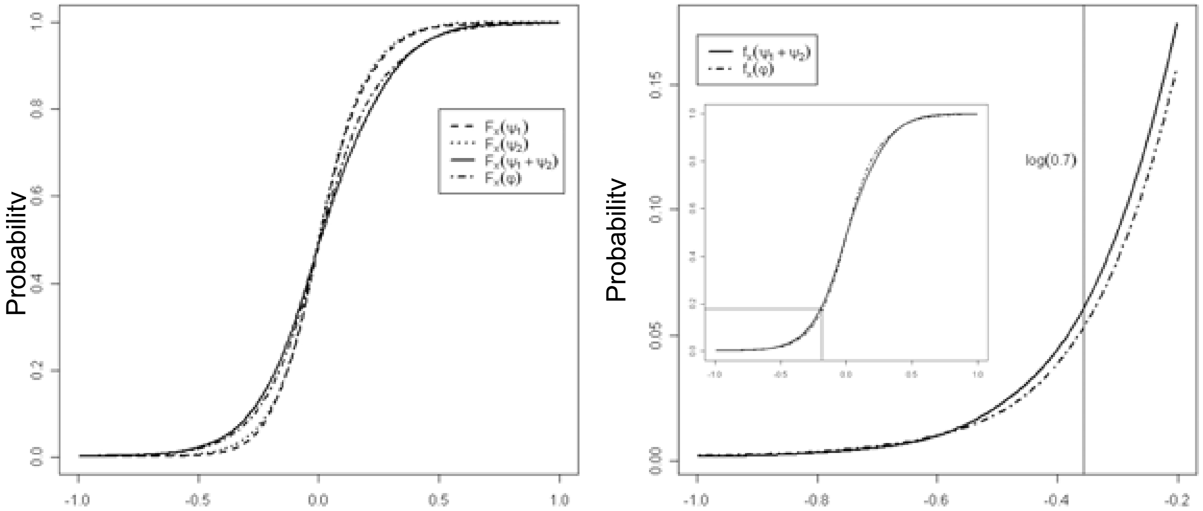
$$F(\varphi) = \frac{\sum\limits_{\varphi_{it} \leq \varphi} f(\varphi_{it})}{\sum f(\varphi_{it})}$$

The distribution function of $\gamma_{ti} = \delta_{tk}\varepsilon_{ti}$ was derived from $F(\varphi)$ by simple change of variable. As an example, the estimated functions for wheat yields in Lorraine are shown in Figure 58.

Density Function



Cumulative Distribution Function



Source: Elaborated by authors from FADN data

Figure 58. Density and distribution functions for wheat yields in Lorraine

9.11. Annex 5B: Description of the FADN data

FADN was launched in 1965. It is an annual survey carried out by the Member States of the European Union. The network collects every year accountancy data from a sample of the agricultural holdings in the European Union. Derived from national surveys, the FADN provides harmonised micro-economic data; the bookkeeping principles are the same in all countries. The survey does not cover all the agricultural holdings in the Union but only those that are large enough to be considered commercial. Too small farms are excluded (hobby or semi-subsistence farming).

The aim of the network is to gather accountancy data from farms for the determination of incomes and business analysis of agricultural holdings. Currently, the annual sample has approximately 80.000 holdings. They represent a population of about 5.000.000 farms in the 25 Member States, which cover approximately 90% of the total utilized agricultural area (UAA) and account for more than 90% of the total agricultural production of the Union. The information collected, for each sample farm, concerns approximately 1000 variables and is transmitted by National Liaison Agencies. These variables described in a Farm Return refer to:

- Physical and structural data, such as location, crop areas, livestock amount, labour force, etc.
- Economic and financial data, such as the value of production of the different crops, stocks, sales and purchases, production costs, assets, liabilities, production quotas and subsidies, including those connected with the application of CAP measures.

All individual data relating to individual farms received by the Commission are highly confidential. Only aggregated results for groups of farms are published.

To ensure that this sample reflects the heterogeneity of farming before the sample of farms, the field of observation is stratified according to 3 criteria: region, economic size and type of farming. A certain number of farms are selected in each stratum and an individual weight is applied to each farm in the sample, this corresponding to the number of farms in the 3-way stratification cell of the field of observations divided by the number of farms in the corresponding cell in the sample. This weighting system is used in the calculation of standard results and generally also for the estimations in specific studies.

The standard results are a set of statistics, calculated from the Farm Returns, which are periodically produced and published by the Commission. They describe in considerable detail the economic situation of farmers by different groups. The FADN survey covers the entire range of agricultural activities on farms. It also collects data on non-agricultural farming activities (such as tourism and forestry).

FADN provides in fact a unique source of data to analyse the income of farmers making the difference between different types of farms, size of the holding and regions. The data would allow simulating to a certain extent what would have happened without insurances; in particular the costs of insurances are collected for each farm of the sample. Unfortunately the compensations received by farmers in case of crisis are insufficiently detailed for a proper analysis.

Description of the data used for developing our analysis:

- **Period:**

  For EU-12, data are available for years 1989-2004; for Austria, Sweden and Finland, the data set starts in 1995, giving still a 10-year series that allows computing a trend. For new member states, only 2004 is available so it is not possible to use FADN data in the computation of risk indexes.

  Income indicators based on FADN data are analysed since 1994.

- **Variables available for each farm:**

  General information about the farm:

  - Less Favoured Area (LFA)
  - Altitude class
  - size in European Size Units (ESU),

  Classification of the farm: region, type of farm, size class, weight of the farm for extrapolation (number of farms in the population for each stratum divided number of farms in the sample).

  Productivity-related variables of main crops: Common wheat, Durum wheat, Barley, Grain maize, Sunflower, Rapeseed, Soya, Olives for oil:

  - Area
  - Production
  - production value

  Additional information:

  - expenditures in insurances
  - subsidies for insurances.

- **Subset:**

  Only farms with some area in one of the major crops mentioned above.

Table 40. Size sample of FADN yield data per country and year

ctry	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
BEL	708	683	656	664	671	677	691	690	667	674	633	692	663	708	715	713	10905
CYP																322	322
CZE																1128	1128
DAN	1934	2004	2006	1823	1835	1818	1852	1882	1811	1552	1537	1613	1637	1654	1574	1543	28075
DEU	3963	4063	3985	4021	4131	4033	4302	4265	4533	4238	4555	4703	4902	5032	4999	5005	70730
ELL	5440	5160	5120	5179	5076	4578	4382	4099	4033	3963	3819	3870	3598	3359	3547	3607	68830
ESP	4284	4081	3678	3567	3148	3359	3146	4391	4723	4569	4482	4771	4813	4402	4306	3962	65682
EST																371	371
FRA	5715	5698	5590	5790	5775	5871	5607	5680	5651	5741	5763	5696	5571	5619	5264	5234	90265
HUN																1611	1611
IRE	368	335	323	324	324	258	239	235	257	242	205	208	235	250	234	233	4270
ITA	14259	13864	13335	13227	12724	11407	10493	11396	10851	10508	10814	10313	11338	11561	9414	9079	184583
LTU																932	932
LUX	274	275	259	251	248	257	246	235	243	288	297	307	364	427	404	386	4761
LVA																572	572
NED	341	342	318	305	304	345	303	312	308	282	278	278	352	363	345	347	5123
OST							1556	1550	1520	1497	1451	1380	1338	1294	1247	1276	14109
POL																8867	8867
POR	1420	1375	1473	1515	1565	1500	1441	1338	1242	1162	1117	1046	908	906	895	907	19810
SUO							745	737	759	686	621	603	578	551	571	597	6448
SVE							517	586	677	767	758	786	770	722	718	756	7057
SVK																549	549
SVN																247	247
UKI	1857	1624	1625	1617	1514	1626	1669	1499	1812	1831	1747	1404	1188	1256	1472	1343	25084
Total	40563	39504	38368	38283	37315	35729	37189	38895	39087	38000	38077	37670	38255	38104	35705	49587	620331

Source: FADN data

Table 41. Size sample average for pairs of consecutive years

from	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	
to	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
BEL	696	670	660	668	674	684	691	679	671	654	663	678	686	712	714	10195
DAN	1969	2005	1915	1829	1827	1835	1867	1847	1682	1545	1575	1625	1646	1614	1559	26337
DEU	4013	4024	4003	4076	4082	4168	4284	4399	4386	4397	4629	4803	4967	5016	5002	66246
ELL	5300	5140	5150	5128	4827	4480	4241	4066	3998	3891	3845	3734	3479	3453	3577	64307
ESP	4183	3880	3623	3358	3254	3253	3769	4557	4646	4526	4627	4792	4608	4354	4134	61559
FRA	5707	5644	5690	5783	5823	5739	5644	5666	5696	5752	5730	5634	5595	5442	5249	84791
IRE	352	329	324	324	291	249	237	246	250	224	207	222	243	242	234	3970
ITA	14062	13600	13281	12976	12066	10950	10945	11124	10680	10661	10564	10826	11450	10488	9247	172914
LUX	275	267	255	250	253	252	241	239	266	293	302	336	396	416	395	4431
NED	342	330	312	305	325	324	308	310	295	280	278	315	358	354	346	4779
OST							1553	1535	1509	1474	1416	1359	1316	1271	1262	12693
POR	1398	1424	1494	1540	1533	1471	1390	1290	1202	1140	1082	977	907	901	901	18647
SUO							741	748	723	654	612	591	565	561	584	5777
SVE							552	632	722	763	772	778	746	720	737	6421
UKI	1741	1625	1621	1566	1570	1648	1584	1656	1822	1789	1576	1296	1222	1364	1408	23484
Total	40034	38936	38326	37799	36522	35050	38042	38991	38544	38039	37874	37963	38180	36905	35347	566548

Source: FADN data

Table 42. Number of observations that remain in the sample in consequent years

from	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	
to	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
BEL	593	581	559	570	589	599	618	612	616	589	592	598	596	639		8351
DAN	1449	1544	1382	1330	1289	1302	1334	1370	1186	1033	960	1128	1187	1145	1126	18765
DEU	3317	3248	2830	3395	3451	2583	2952	3179	3727	2233	3635	3816	4030	4422	4322	51140
ELL	4490	4455	4638	4399	3721	2802	3361	3539	3446	3379	3414	3122	2950	2816	3080	53612
ESP	2661	2910	2164	2494	2006	2050	2493	3837	3695	3604	3956	4360	4018	3738	3599	47585
FRA	4629	4520	4515	4757	4840	4729	4700	4744	4890	4968	5006	4822	4843	4706	4614	71283
IRE	282	267	270	236	210	193	180	152	177	95	167	173	195	197	197	2991
ITA	10295	10033	9332	8982	8455	7725	7373	7740	7661	8093	8166	7820	7784	1912	6825	118196
LUX	253	252	239	237	233	240	199	216	107	272	273	285	334	352	357	3849
NED	256	251	241	243	249	249	230	236	257	223	278	143	296	270	275	3697
OST							1433	1422	1392	1346	1302	1251	1196	1165	1122	11629
POR	1109	1169	1199	1234	1224	1137	1068	1016	984	917	897	781	728	676	735	14874
SUO							655	647	611	568	527	526	498	503	521	5056
SVE							444	483	583	521	677	698	652	640	627	5325
UKI	1315	1246	1297	1192	1188	1299	1232	1257	1552	1555	1241	233	842	1033	1016	17498
Total	30649	30476	28666	29069	27455	24908	28272	30450	30884	29396	31091	29756	30149	24214	28416	433851

Source: FADN data

Table 43. Observations that remain in consecutive years expressed as the percentage of the average number of observations in the pairs of consecutive years

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	
ctry	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
BEL	85.3	86.8	84.7	85.4	87.4	87.6	89.5	90.2	91.9	90.1	89.4	88.3	86.9	89.8	0.0	81.9
DAN	73.6	77.0	72.2	72.7	70.6	71.0	71.5	74.2	70.5	66.9	61.0	69.4	72.1	70.9	72.2	71.3
DEU	82.7	80.7	70.7	83.3	84.5	62.0	68.9	72.3	85.0	50.8	78.5	79.5	81.1	88.2	86.4	77.2
ELL	84.7	86.7	90.1	85.8	77.1	62.5	79.3	87.0	86.2	86.8	88.8	83.6	84.8	81.6	86.1	83.4
ESP	63.6	75.0	59.7	74.3	61.7	63.0	66.2	84.2	79.5	79.6	85.5	91.0	87.2	85.9	87.1	77.3
FRA	81.1	80.1	79.3	82.3	83.1	82.4	83.3	83.7	85.8	86.4	87.4	85.6	86.6	86.5	87.9	84.1
IRE	80.2	81.2	83.5	72.8	72.2	77.7	75.9	61.8	70.9	42.5	80.9	78.1	80.4	81.4	84.4	75.3
ITA	73.2	73.8	70.3	69.2	70.1	70.5	67.4	69.6	71.7	75.9	77.3	72.2	68.0	18.2	73.8	68.4
LUX	92.2	94.4	93.7	95.0	92.3	95.4	82.7	90.4	40.3	93.0	90.4	84.9	84.5	84.7	90.4	86.9
NED	75.0	76.1	77.4	79.8	76.7	76.9	74.8	76.1	87.1	79.6	100.0	45.4	82.8	76.3	79.5	77.4
OST							92.3	92.6	92.3	91.3	92.0	92.1	90.9	91.7	88.9	91.6
POR	79.4	82.1	80.3	80.1	79.9	77.3	76.9	78.8	81.9	80.5	82.9	79.9	80.3	75.1	81.6	79.8
SUO							88.4	86.5	84.6	86.9	86.1	89.1	88.2	89.7	89.2	87.5
SVE							80.5	76.5	80.7	68.3	87.7	89.7	87.4	88.9	85.1	82.9
UKI	75.6	76.7	80.0	76.1	75.7	78.8	77.8	75.9	85.2	86.9	78.8	18.0	68.9	75.7	72.2	74.5
Total	76.6	78.3	74.8	76.9	75.2	71.1	74.3	78.1	80.1	77.3	82.1	78.4	79.0	65.6	80.4	76.6

Source: FADN data

Table 44. Percentage of farms which have data for the prior 3 years (4-year constant sample)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
BEL	67.9%	67.2%	66.5%	67.3%	70.7%	74.1%	78.5%	81.4%	75.4%	76.5%	71.0%	70.9%	
DAN	47.3%	47.0%	44.0%	42.1%	41.2%	44.0%	45.1%	44.8%	35.0%	31.5%	33.6%	40.0%	44.3%
DEU	51.5%	50.3%	51.2%	43.9%	42.9%	35.8%	47.9%	32.7%	36.0%	32.1%	50.9%	59.2%	65.6%
ELL	69.5%	68.7%	61.9%	36.4%	32.8%	40.8%	61.4%	67.4%	68.1%	68.8%	68.2%	60.5%	60.2%
ESP	36.5%	48.8%	35.2%	38.6%	28.5%	34.7%	43.0%	56.5%	56.4%	63.3%	74.2%	75.7%	76.2%
FRA	53.2%	53.3%	55.1%	59.3%	59.2%	59.6%	60.0%	62.8%	66.5%	67.2%	67.0%	68.0%	69.5%
IRE	63.9%	54.6%	56.6%	59.0%	54.9%	40.5%	37.2%	31.2%	34.1%	30.2%	54.4%	56.8%	62.7%
ITA	37.3%	37.2%	34.8%	36.8%	32.6%	36.7%	33.9%	36.3%	41.9%	41.7%	38.1%	10.3%	5.7%
LUX	86.5%	89.9%	83.7%	85.8%	76.6%	75.3%	31.3%	32.3%	29.6%	65.4%	56.2%	58.7%	73.1%
NED	46.2%	49.3%	45.5%	48.2%	43.3%	45.8%	49.6%	56.8%	74.1%	31.0%	35.5%	32.8%	57.3%
OST							83.3%	83.8%	85.0%	85.2%	84.5%	84.4%	78.5%
POR	54.7%	54.1%	55.3%	55.9%	57.6%	57.4%	60.9%	64.9%	67.1%	66.3%	64.5%	56.6%	52.3%
SUO							74.1%	75.5%	75.1%	76.8%	76.8%	75.3%	71.7%
SVE							44.9%	43.3%	50.5%	55.8%	74.2%	76.3%	69.7%
UKI	50.6%	51.3%	49.8%	48.8%	50.2%	46.8%	50.8%	54.8%	68.8%	16.5%	14.3%	12.0%	38.9%
All	48.3%	49.3%	46.7%	41.0%	37.9%	39.8%	49.3%	50.8%	53.8%	51.8%	54.3%	48.3%	34.1%

Source: FADN data

Table 45. Percentage of farms which have data for the prior 5 years (6-year constant sample)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
BEL	54.4%	54.6%	55.4%	58.9%	62.8%	66.0%	65.5%	67.7%	64.1%	62.7%	
DAN	28.9%	28.3%	27.1%	27.4%	27.3%	25.5%	21.6%	21.5%	20.0%	19.6%	22.4%
DEU	38.1%	27.5%	24.9%	26.1%	30.5%	17.5%	20.1%	21.7%	24.1%	24.5%	42.9%
ELL	45.6%	25.8%	18.4%	16.7%	19.2%	28.1%	46.7%	51.4%	52.5%	48.7%	46.2%
ESP	25.1%	25.1%	17.9%	21.6%	22.7%	28.4%	33.6%	45.4%	51.5%	58.0%	65.7%
FRA	38.5%	38.9%	39.4%	42.0%	42.6%	44.6%	47.0%	49.0%	50.6%	52.3%	53.5%
IRE	45.3%	47.7%	43.4%	33.9%	27.7%	26.3%	25.5%	21.7%	22.8%	23.5%	47.6%
ITA	19.4%	17.5%	18.5%	18.4%	19.3%	17.9%	19.5%	21.6%	19.6%	6.6%	3.3%
LUX	76.3%	80.5%	70.6%	68.7%	27.4%	27.6%	25.1%	22.8%	18.7%	48.8%	53.1%
NED	22.3%	22.4%	20.8%	20.8%	22.0%	30.6%	38.8%	19.9%	24.5%	24.1%	30.5%
OST							77.7%	78.6%	77.9%	78.0%	73.1%
POR	38.9%	39.1%	40.1%	42.0%	46.0%	47.4%	51.6%	55.8%	53.0%	45.7%	44.0%
SUO							64.0%	64.7%	66.1%	64.6%	62.3%
SVE							28.4%	35.6%	44.5%	48.3%	58.7%
UKI	32.8%	33.6%	35.7%	30.2%	32.2%	37.9%	43.9%	11.5%	11.1%	10.3%	11.2%
All	31.7%	25.6%	23.8%	24.4%	25.6%	25.9%	34.3%	35.6%	35.9%	34.1%	25.4%

Source: FADN data

9.12. Annex 5C: Trend estimation

The trend estimation process is described for a generic regional variable Z_{tk} which can represent either regional yield, either regional Farm Net Value Added or regional Value of Production. In the case of yields, the regional trend has been estimated from Eurostat REGIO data for regional yields, because they can be considered more reliable. Instead, in the other two cases, FADN regional averages have been used to estimate the regional trends.

The trend g_{tk} of the variable Z_{tk} is estimated as $g_{tk} = E(Z_{tk})$ with a simple model that can be logarithmic, quadratic, linear, or constant.

A *logarithmic trend* is given by a linear regression of Z_{tk} with the expression:

$$g_{tk} = \hat{\beta}_{0\log} + \hat{\beta}_{1\log} \log(t_k^* + 1)$$

where $t_k^* = t_k - t_{k\min}$, if the significance level of $\hat{\beta}_{1\log}$ is less then 20% and $\hat{\beta}_{1\log} > 0$;

a *quadratic trend* is given by:

$$g_{tk} = \hat{\beta}_{0quad} + \hat{\beta}_{1quad} x_k + \hat{\beta}_{2quad} x_k^2$$

where $x_{tk} = (t_k - \bar{t}_k)$ and $\bar{t}_k$ is the average of the years in which we have data for the region k. The quadratic trend is settled by a quadratic regression with restrictions if the conditions for a logarithmic trend are not satisfied, and the significance level of $\hat{\beta}_{2quad}$ is less than 20%, $\hat{\beta}_{2quad} < 0$ and $\hat{\beta}_{1quad} > 0$;

a *linear trend* is given by:

$$g_{tk} = \hat{\beta}_{0lin} + \hat{\beta}_{1lin} x_k$$

calculated by a linear regression if the conditions for a quadratic trend are not satisfied and the significance level of $\hat{\beta}_{1lin}$ is less than 20% and $\hat{\beta}_{1lin} > 0$;

a *constant trend* is given by:

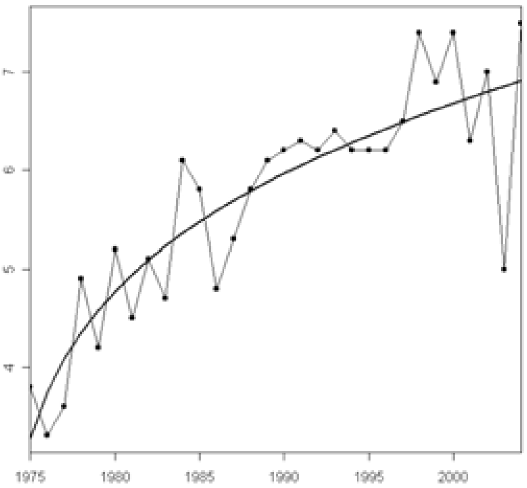
$$g_{tk} = \overline{Z}_{tk}$$

calculated by the average of Z_{tk} if the conditions for a logarithmic, quadratic and a linear model are not satisfied.

Figure 59 shows some examples of the different types of trends found for yield in European FADN regions.

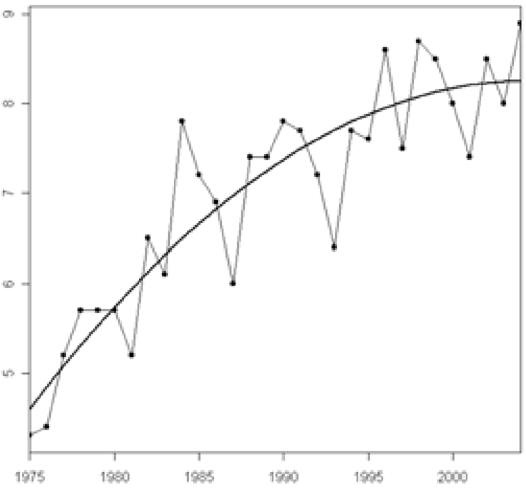
Logarithmic Trend

(Wheat - Bourgogne)



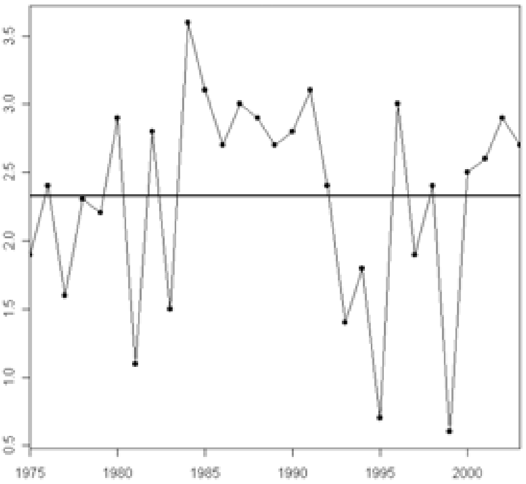
Quadratic Trend

(Wheat - Haute-Normandie)



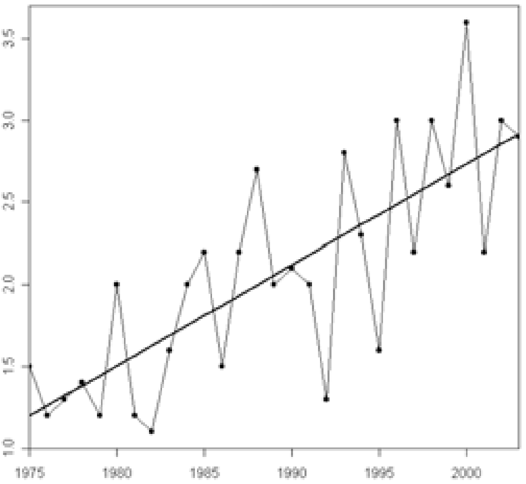
Constant Trend

(Wheat - Andalucia)



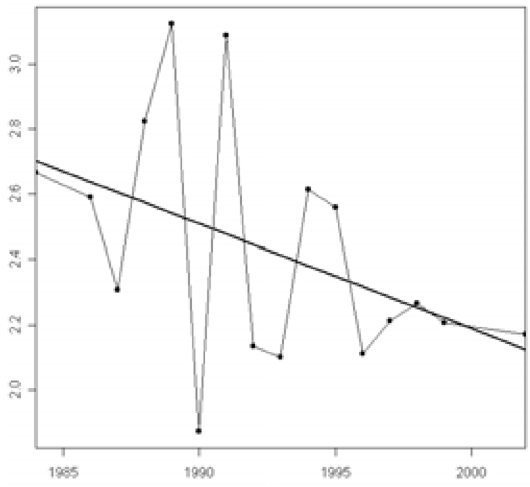
Linear Trend

(Wheat – Castilla Leon)



Negative Linear Trend

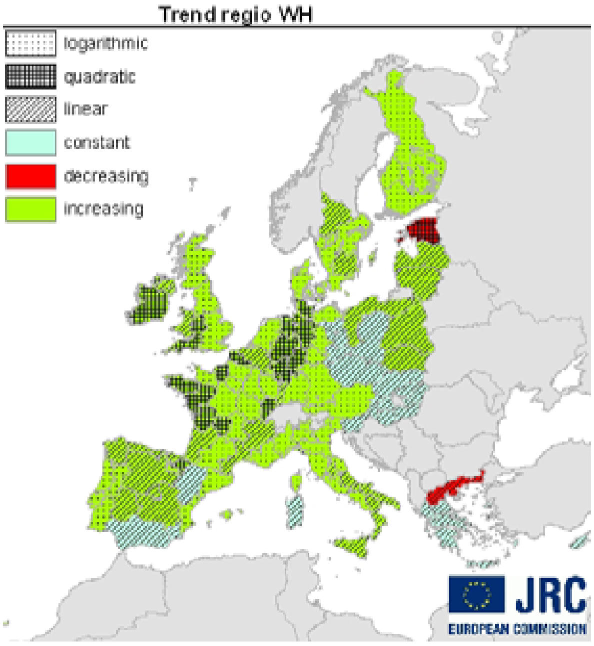
(Wheat - Makedonia-Thraki)



Source: Elaborated by authors from Eurostat data on FADN regions

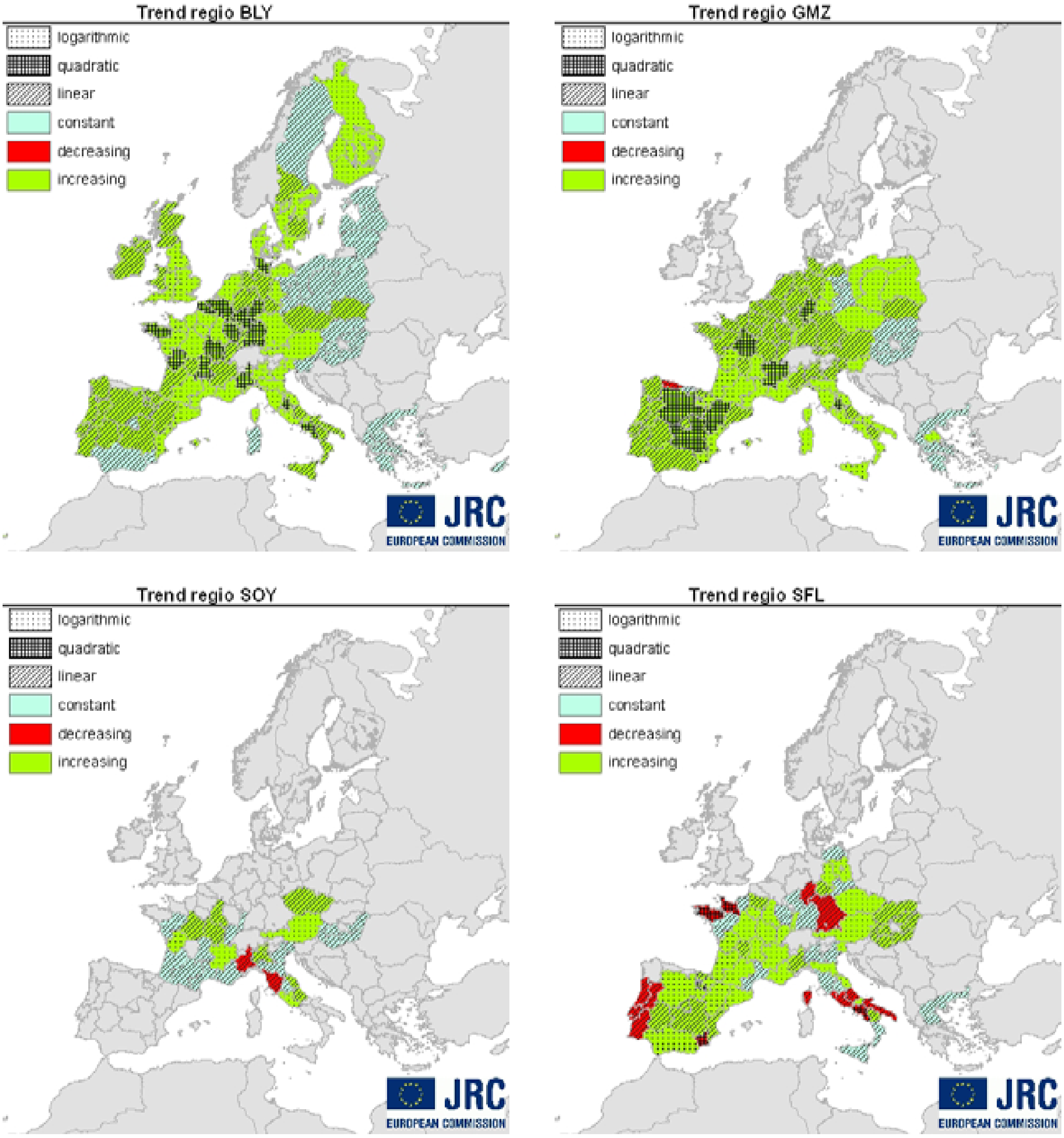
Figure 59. Examples of types of trends for wheat yields in different European regions

This analysis has been performed for several crops yields for all FADN regions in Europe. The types of trends that have been found are shown in Figure 61 and Figure 60. A similar analysis has been performed with FADN regional averages, for Farm Net Value Added and Value of Production. The types of trends found are shown in Figure 62 and Figure 63 respectively. In the calculation of the FNVA trend, we have encountered cases with negative values of this variable. These are reported in Table 46.



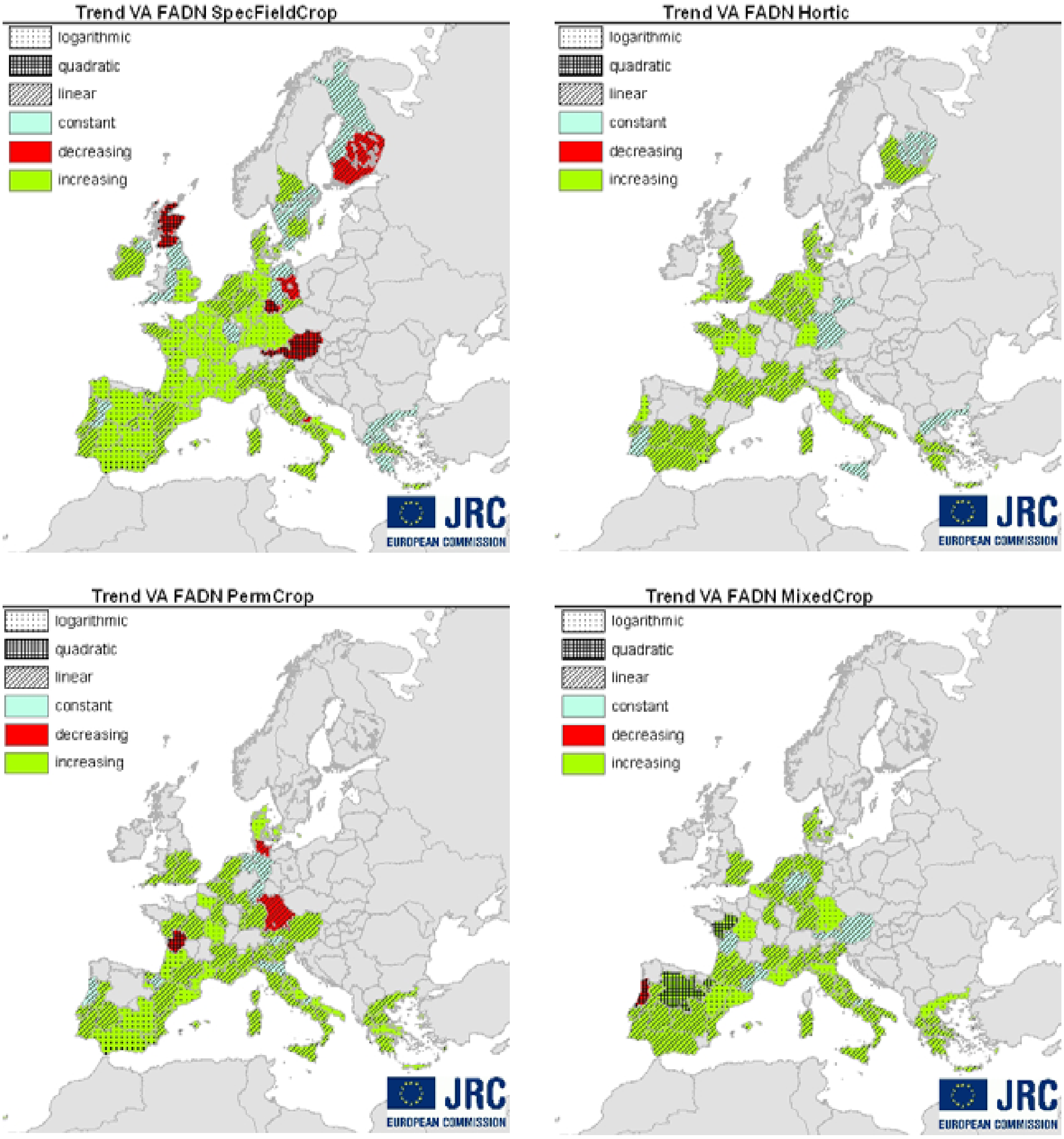
Source: Elaborated by authors from Eurostat-REGIO data

Figure 60. Types of trends for the yields of wheat



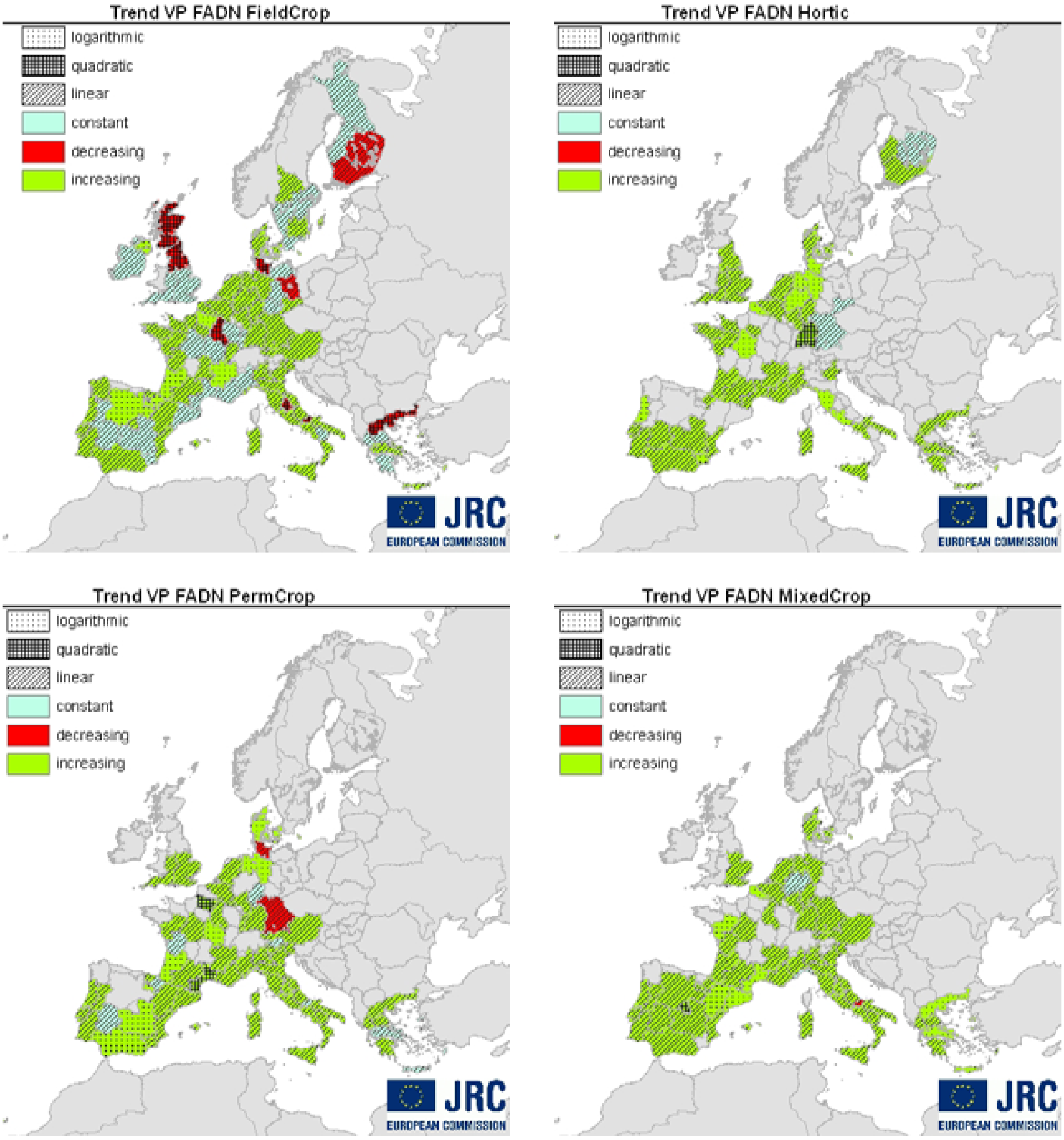
Source: Elaborated by authors from Eurostat-REGIO data

Figure 61. Types of trends for the yields of barley, grain maize, soybean and sunflower respectively



Source: Elaborated by authors from FADN data

Figure 62. Types of trend FADN Farm Net Value Added (FNVA) for specialists field crop, specialists horticulture, specialists permanent crops and mixed crops respectively



Source: Elaborated by authors from FADN data

Figure 63. Types of trend FADN production value (VP) for specialists field crop, specialists horticulture, specialists permanent crops and mixed crops respectively

Table 46. Special cases with negative FNVA values

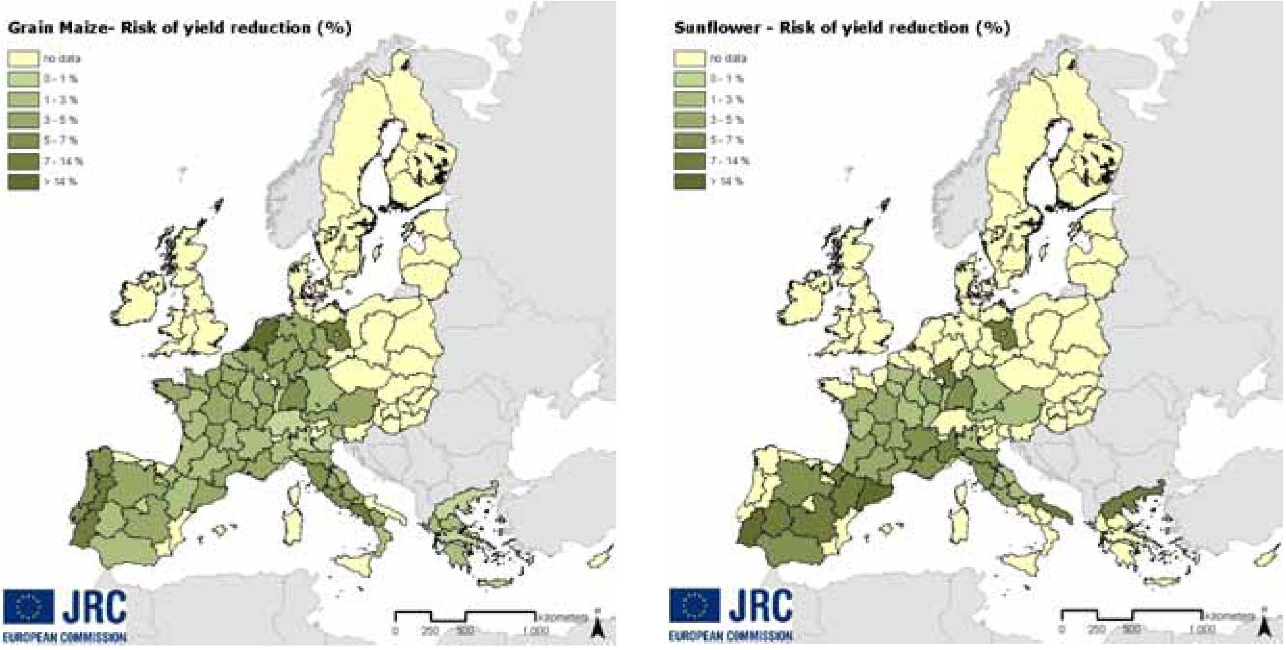
Region	Type of farm	Year	Mean value	Number of farms
Limousin	Specialist field crops	2003	-10166.0	2
Limousin	Specialist field crops	2005	-5949.3	2
Languedoc-Roussillon	Specialist field crops	1992	-1595.7	27
Luxembourg	Specialist field crops	1997	-1134.1	1
Galicia	Specialist field crops	1989	-705.3	33
Madrid	Specialist field crops	1991	-876.0	2
Canarias	Specialist field crops	1999	-1265.6	1
Canarias	Specialist field crops	2002	-9304.1	21
Tras-os-Montes/Beira	Specialist field crops	1997	-3080.7	7
Tras-os-Montes/Beira	Specialist field crops	2000	-2009.7	4
Azores e da Madeira	Specialist field crops	1991	-2790.3	1
Azores e da Madeira	Specialist field crops	1995	-82.7	8
Azores e da Madeira	Specialist field crops	1997	-52.5	6
Lan i norra	Specialist field crops	1995	-20614.5	1
Lan i norra	Specialist field crops	1996	-15919.4	1
Lan i norra	Specialist field crops	2000	-4205.5	12
Sachsen-Anhalt	Specialist horticulture	1996	-6473.9	5
Picardie	Specialist horticulture	1990	-214.8	1
Alsace	Specialist horticulture	1991	-2032.5	1
Auvergne	Specialist horticulture	1993	-3332.2	1
Auvergne	Specialist horticulture	2003	-1118.0	1
Marche	Specialist horticulture	2005	-22432.0	6
Scotland	Specialist horticulture	2004	-3340.2	1
Pais Vasco	Specialist horticulture	1996	-3607.7	1
Tras-os-Montes/Beira	Specialist horticulture	1995	-133.4	9
Tras-os-Montes/Beira	Specialist horticulture	1996	-129.0	14
Tras-os-Montes/Beira	Specialist horticulture	2005	-1180.9	44
Hessen	Specialist permanent crops	1995	-119823.2	2
Brandenburg	Specialist permanent crops	2000	-3652.8	1
Valle d'Aoste	Specialist permanent crops	1994	-133.2	7
Galicia	Specialist permanent crops	1989	-2145.6	12
Madrid	Specialist permanent crops	1990	-11267.2	3
Murcia	Specialist permanent crops	1992	-1115.9	15
Extremadura	Specialist permanent crops	1992	-2880.1	5
Pohjois-Suomi	Specialist permanent crops	2004	-34005.0	1
Pohjois-Suomi	Specialist permanent crops	2005	-8002.0	1
Saarland	Mixed cropping	2000	-5666.1	1
Corse	Mixed cropping	2001	-11718.0	1
Galicia	Mixed cropping	1989	-185.5	6
Galicia	Mixed cropping	2001	-933.9	12
Pais Vasco	Mixed cropping	2000	-9527.8	1
Extremadura	Mixed cropping	1992	-10787.1	13
Slattbygdslan	Specialist field crops	2004	-3870.2	5

Source: Elaborated by authors from FADN Farm Net Value Added data

9.13. Annex 5D: Farm yield risk (FADN data)

9.13.1. Farm yield risk with “2-year constant sample” method

The map for wheat and barley and the table summarising the average results per country are shown in section 5.2.1.1

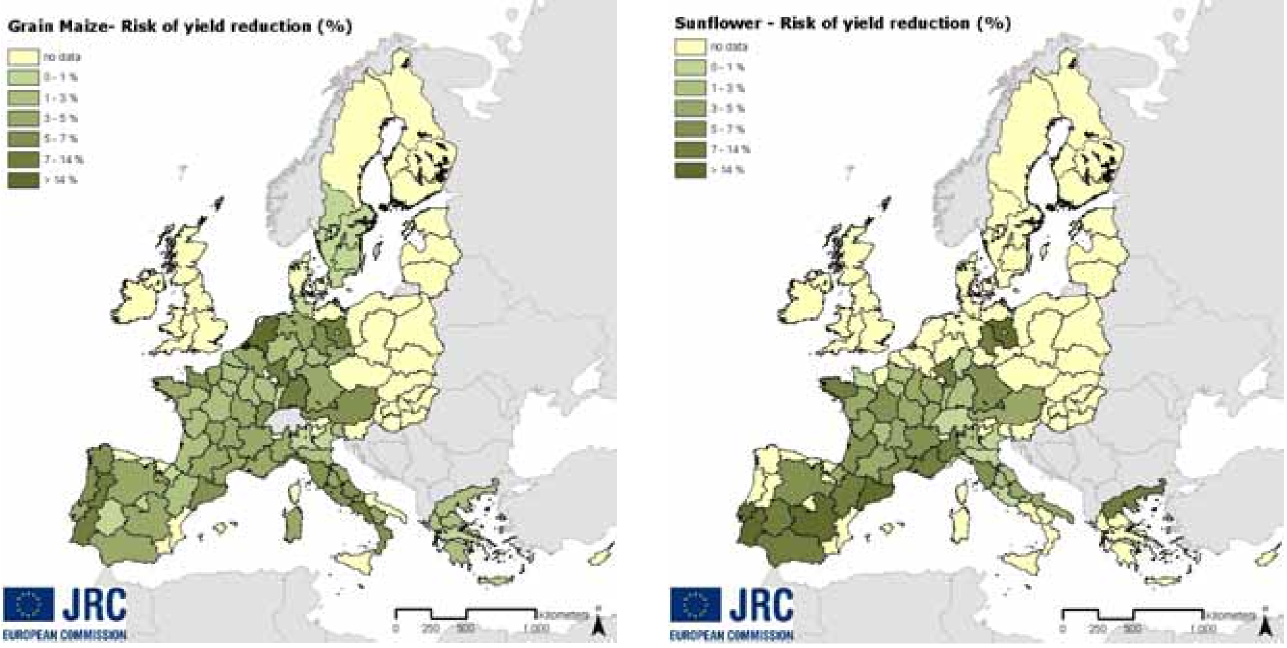


Source: Elaborated by authors from FADN data

Figure 64. Risks of yield reduction (trend -30% deductible) for grain maize and sunflower with “2-year constant sample” method

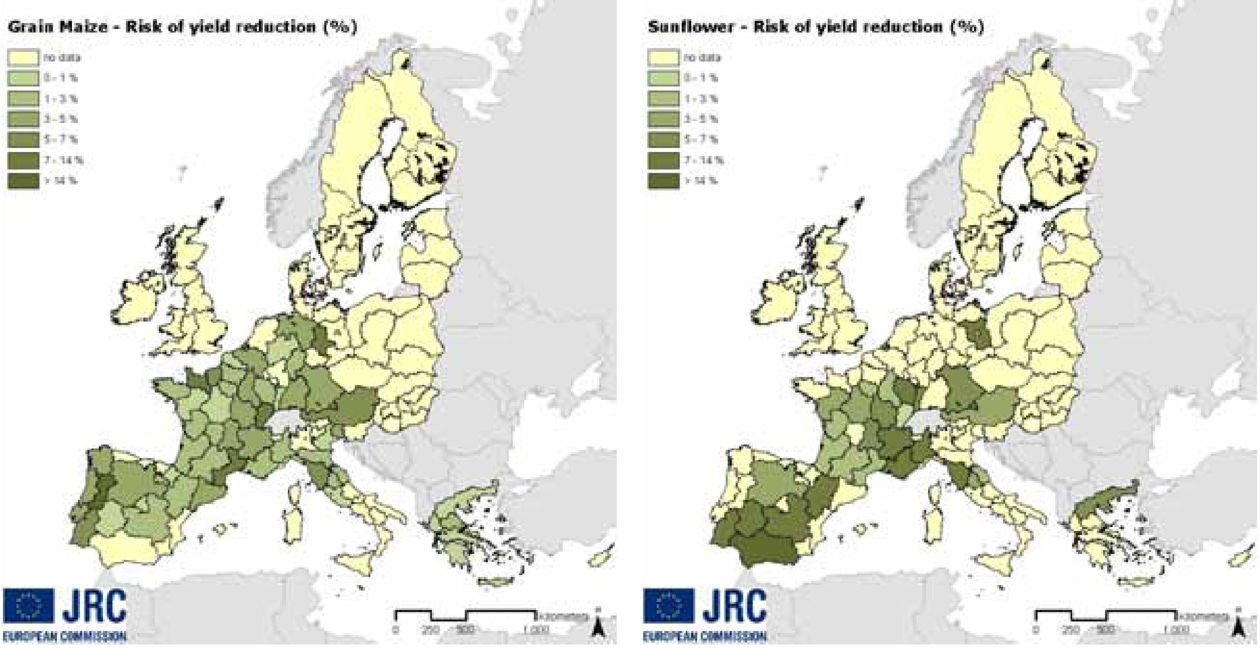
9.13.2. Farm yield risk with “WTO moving average” method

The maps for wheat and barley and the table summarising the average results per country are shown in section 5.2.1.2



Source: Elaborated by authors from FADN data

Figure 65. Risks of yield reduction (‘3 year’ moving average-30% trigger) for grain maize and sunflower



Source: Elaborated by authors from FADN data

Figure 66. Risks of yield reduction (‘5 year –minmax’ moving average - 30% trigger) for grain maize and sunflower

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Abstract

Index insurances, diversely from traditional agricultural insurances, do not refer to the actual farm losses but to the losses evaluated from an index. The study evaluates the feasibility of index insurances for EU and makes a cross-validation based on the yield loss risk calculated from FADN data. Premiums have been estimated for a Regional Yield Insurance (RYI) for FADN regions and a number of arable crops. Some meteorological, agro-meteorological and NDVI indicators were also analysed according to the model of the area yield-tailored insurance. From the statistical analysis the indicators do not explain yields optimally. Due to the strong heterogeneity within the EU regions, a meteorological yield-tailored index could have a better explanation capacity at a more disaggregated level.

FADN data are used to compute and map the risk of yield reduction for major field crops and of income reduction by farm type. The cross validation of area yield insurance consisted on the calculation of the risk with FADN data with and without insurance. Results show that the risk reduction capacity of yield area index for the case analysed is not very high, but in some regions the risk can be reduced up to a 68%. The risk reduction capacity of other indexes is expected to be lower than the yield area index.

Finally, the study shows that index products efficiency is relatively low at farm level due to the European heterogeneity of climates and geography and to the large geographical scale that had to be used in the study. So, index products could be more efficient for reinsurance that works at aggregated level.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.