REGIONAL YIELD INSURANCE FOR ARABLE CROPS IN EU-27

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Regional Yield Insurance for Arable Crops in EU-27

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Abstract— **The paper looks at a hypothetical area yield insurance at the level of Farm Accountancy Data Network (FADN) regions: Regional Yield Insurance (RYI). Total premium cost is evaluated for each MS and EU-27 assuming that the whole crop surface for each single arable crop is insured. In order to check the efficiency of RYI for smoothing the farmers' income, we calculate the farmers' yield variability from a sample of individual farm FADN income data for two scenarios. The first scenario is the current one without RYI, and the second one is with RYI under the hypothesis of 100% market penetration. These analyses enable us to evaluate the potential of RYI as a farmers' income stabilizer. Moreover, they provide an insight of the potential of other kinds of index products in the heterogeneous European landscape. Results show that the risk reduction capacity of RYI is not very high for the case analyzed (wheat). However, there are some exceptions where the risk can be significantly reduced.**

Keywords— **Area yield insurance, index insurance, yield risk**

I. 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 speaking, weather derivatives are financial instruments that allow to trade weather related risks. According to Turvey [1], "the weather derivative can be brokered as an insurance contract or as an over-the-counter traded option".

Weather-index insurance contracts 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. This index or parameter can be either some area measure or some objective weather event such as temperature or rainfall. Thus, 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 based on weather events, which we will call indirect index insurance, and they can also be referred to as index-based weather insurance or climatic index insurance. The indexes in this second group can be based on weather indicators, agro-meteorological indicators or satellite imagery indicators.

Skees and Hartell [2] give a clear overview on what an index insurance scheme is and how it works. Index insurance seeks to protect the agricultural production sector from widespread, positively correlated, crop-yield losses (e.g., drought). 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.
2. No adverse selection.
3. Higher coverage levels. Since 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 [2].
4. Low administrative costs.
5. Standardized and transparent structure.
6. Availability and negotiability: Index insurance policies can easily be traded in secondary (future) markets.
7. Reinsurance function: Unlike most insurance where independent risk is a precondition, the precondition

for index insurance to work best for the individual farmer is correlated risk. 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. [3].

Index Insurance has also several disadvantages, listed below:

1. Basis Risk: Without sufficient correlation of the insured losses, "basis risk" results in index insurance not being an effective risk management tool.
2. Requirement of diffusion of measurements in a well-timed way and secure from altering.
3. Requirement of precision in modelling and sufficient historical data.
4. 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.

There are several examples of area index insurance in the world. In the USA there are four area index insurance programs [4]. They are described in Annex A.

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 an 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 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 [5].

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 [6]. 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. 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. [7].

One particular area or group insurance exists in Mongolia. It consists on an index-based livestock insurance (IBLI) pilot experience supported by the World Bank. 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). This scheme was never made before, and it is possible because Mongolia performs a complete census of every species each year [8].

Area yield insurance (AYI) does not currently exist in Europe. The objective of this article is to analyse the potential of AYI insurance for Europe. The AYI would apply at the level of Farm Accountancy Data Network (FADN) regions, so we will call it Regional Yield Insurance (RYI). The yield data from Eurostat-REGIO are detrended for each crop and region using the best-fitting function type (logarithmic, quadratic and linear). The premiums rates are calculated for a 10% deductible. Total premium cost is evaluated for each MS and EU-27 assuming that the whole crop surface for each single arable crop is insured. In order to check the efficiency of RYI for smoothing the farmers' income, we calculate the farmers' income variability from a sample of individual farm FADN income data for two scenarios. The first scenario is the current one without RYI, and the second one is with

RYI under the hypothesis of 100% market penetration. The following section explains the methodology used and section fourth shows the results. Both sections are subdivided in three parts: one focusing on the RYI, the second one on the farm yield risk, and the third one, on the comparison of risks with and without insurance.

II. METHODOLOGY AND DATA.

A. The regional yield insurance

The proposed design of this insurance scheme is a simple one. It is similar to the USA GRP (see Annex A). 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:

$$Indemnity = \max(0, Guaranteedyield - indexyield) \times price \times k$$

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*)). The deductible is set at 10%., given that a lower deductible would imply higher premium rates that sometimes could not be affordable by the farmers. The price considered is the average of national prices from 2002 to 2006 published by Eurostat. *K* is the product of the scale and the crop surface of the farm. The scale is also chosen by the producer, depending on how is his individual expected yield in relation with the regional yield, and it can vary from 50% to 150%[1]. 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.

The index is 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 two to four 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. 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 means that Eurostat data in some cases are applied at NUTS2 level, in other at NUTS1 and in the small countries at NUTS0. This means a more homogeneous geographic distribution, this also permits to have data series of an adequate length for some countries such as Germany, and it has the further advantage that it will facilitate comparison with FADN data for the analysis of farm yield risk and insurance. So, we have used Eurostat data, but aggregating it at FADN-region level.

The data have been detrended using the trends (g_{tk}) calculated from logarithmic, quadratic or linear regressions adjusted for each region and each crop as explained in annex B. If the regional yield for a year *t* and a region *k* is y_{tk} and the trend yield for the same year is g_{tk}, then the detrended yield $y_{tk}^{\det}$ for year t has been calculated as:

$$y_{tk}^{\det} = y_{tk} \frac{g_{2005k}}{g_{tk}}$$

, as we assume that the expected yield for our insurance is the trend yield of the last year for which there is data available g_{2005k}. 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 above, with the two deductibles. Then, we have calculated the premium as the average of the indemnities, and the premium rate as the average 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,

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

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 1 Crop prices used for the premium calculations

Crop	Price €/T	Crop	Price €/T
Barley	104.7	Rapeseed	306.1
Wheat	113.2	Sunflower	206.1
Grain maize	115	Potato	188.1
		Sugar beet	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.

B. Estimation of the risk at farm level: the "2-year constant sample method"

For the estimation of the risk at farm level we have used FADN data. 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 for these countries.

Usually, the risk of the individual farm (either yield, revenue or income risk) could be calculated from a trend built from time-series data. 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.

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 with a certain crop. Farm *i* has a weight W_{ti} for extrapolation in FADN.

Our target variable, the yield of a certain crop, is noted y_{ti} for farm i and y_{tk} for category k. y_{tk} can be estimated as $\hat{y}_{tk} = \bar{y}_{ti}\}_{i\in k}$

We call g_{tk} the trend of y_{tk}. The computation of the trend, selecting a constant, linear, quadratic or logarithmic function, is described in annex B. 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 y_{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 $t \neq t'$.

$$y_{ti} = A_i\,\delta_{tk}\, g_{tk}\,\varepsilon_{ti} = A_i\, y_{tk}\,\varepsilon_{ti} = g_{ti}\delta_{tk}\varepsilon_{ti}$$

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. $y_{tk} = \delta_{tk} g_{tk}$

The attempt now is exploiting the data of a farm as soon as we have two consecutive observations for that farm[2]. 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}

[2] In the FADN dataset, the number of records available is 620,331, with an average of 38,700 records/year. The exploitable dataset with two consecutive year observations per farm is reduced to 433,851 records (29,000 per year on average)

Thus we will use as data for the estimation of the risk: $\Delta y_{ti} = \frac{y_{ti}}{y_{t-1,i}} = \frac{g_{tk}}{g_{t-1,k}} \frac{\delta_{tk}\ \varepsilon_{ti}}{\delta_{t-1,k}\ \varepsilon_{t-1,i}}$. 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: $h(y_{ti}) = \begin{cases} 0 & if \quad y_{ti} > (1-d)g_{ti} \\ (1-d)g_{ti} - y_{ti} & otherwise \end{cases}$

This corresponds to the loss compensated by an insurance with a straight deductible *d*.

We can write $(1-d)g_{ti} - y_{ti} = g_{ti} \times ((1-d) - \delta_{tk}\varepsilon_{ti})$

Therefore we want to estimate the risk $E[h(y_{ti})]$, 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 y_{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 $\frac{\gamma_{ti}}{\gamma_{t-1,i}} = \frac{y_{ti}}{y_{t-1,i}} \frac{g_{t-1,i}}{g_{ti}}$ 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.

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 (see annex B), 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:

$$F(\varphi) = \frac{\sum_{\varphi_{it} \le \varphi} f(\varphi_{it})}{\sum f(\varphi_{it})}$$

The distribution function of $\gamma_{ti} = \delta_{tk}\varepsilon_{ti}$ was derived from $F(\varphi)$.

C. Methodology of the cross-validation

The objective of this section is to validate the efficiency of area yield insurance with the FADN farm data. 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, 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 on the farm revenue from the crop. In order to attain this objective we proceed in the following way. We part form the FADN farm revenues, whose risk is calculated with the "2-year constant sample" method. By simulating the effects of area yield insurance on the farms, we can obtain a new sample of farm revenues with insurance. The calculation of the risk on this second sample with the aforesaid method will allow quantifying the potential effects of the insurance on the average risk of the farms, by comparing it with the risk on the non-insurance sample.

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

$I_{tr} = \max(0, y_k \times Cov - y_{tk}) \times p$ where y_k is the average crop revenue in region *k*, *Cov* is the coverage level of the insurance and y_{tk} 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:

$P_{tk} = E(I_{tk})$ 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 *k*, when there is not insurance (R_{i0}) is modified in this way by insurance.

$$R'_{tik} = R_{0i} + I_{tk} - P_{tk}$$

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.

$$I_{tk}(\%) = \frac{\max(0, y_k \times Cov - y_{tk})}{y_k}$$

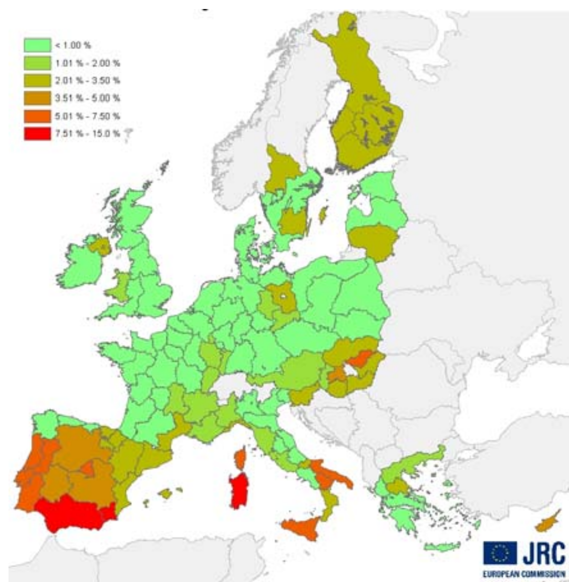
$$P_{tk}(\%) = \frac{E(I_{tk})}{\bar{Y}_k}$$

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.

III. RESULTS

A. Regional yield insurance (RYI)

In this section we present first the premium rates results and then, the estimation of the maximum total premium amounts. The results of the premium rates at FADN region level for wheat are shown in Fig. 1. The premiums rates aggregated at country level are shown in Table 2 to Table 4. These tables show the average, maximum and minimum premium rates for the considered 10% deductible.



Source: Elaborated by authors from Eurostat-REGIO data

Fig. 1. Premium rates for regional yield insurance for wheat (deductible 10%)

The rapeseed calculations encountered several problems. In many cases, the yield variations were 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. A similar case was found in Greece. In this case we did not manipulate the data, and consequently the premium rates resulted to be very high. Anyway, it is not actuarially advisable to design an insurance product for a crop and regions which suffer from this kind of data problems.

Table 1. Average premium rates (%) for grain maize with 10% deductible (FADN-region level)

	Average	Maximum	Minimum
AT	0.46%	0.46%	0.46%
BE	0.38%	0.38%	0.38%
CZ	1.51%	1.51%	1.51%
DE	2.77%	6.51%	0.10%
ES	1.82%	5.58%	0.00%
FR	1.33%	4.32%	0.13%
GR	0.07%	0.22%	0.00%
HU	4.73%	7.56%	3.36%
IT	2.58%	21.89%	0.37%
NL	6.06%	6.06%	6.06%
PL	0.09%	0.35%	0.00%
PT	2.85%	2.85%	2.85%
SI	5.16%	5.16%	5.16%
SK	4.11%	4.11%	4.11%
Europe	2.42%	21.89%	0.00%

Source: Authors calculations from Eurostat-REGIO data

Table 2 Average premium rates (%) for wheat with 10% deductible (FADN-region level)

	Average	Maximum	Minimum
AT	1.09%	1.09%	1.09%
BE	0.26%	0.26%	0.26%
CY	3.95%	3.95%	3.95%
CZ	0.09%	0.09%	0.09%
DE	0.77%	2.86%	0.12%
DK	0.40%	0.40%	0.40%
EE	0.68%	0.68%	0.68%
ES	5.66%	14.33%	0.72%
FI	3.42%	3.42%	3.42%
FR	1.08%	5.90%	0.26%
GR	1.35%	2.52%	0.74%
HU	3.21%	5.50%	1.82%
IE	0.58%	0.58%	0.58%
IT	2.44%	9.46%	0.12%
LT	2.39%	2.39%	2.39%
LU	1.38%	1.38%	1.38%
LV	0.95%	0.95%	0.95%
PL	0.21%	0.47%	0.06%
PT	6.33%	6.33%	6.33%
SE	1.08%	2.16%	0.00%
SI	2.00%	2.00%	2.00%
SK	2.75%	2.75%	2.75%
UK	0.79%	2.57%	0.05%
Europe	1.91%	14.33%	0.00%

Source: Authors calculations from Eurostat-REGIO data

Table 3 Average premium rates (%) for barley with 10% deductible (FADN-region level)

	Average	Maximum	Minimum
AT	0.96%	0.96%	0.96%
BE	0.25%	0.25%	0.25%
CY	11.13%	11.13%	11.13%
CZ	0.55%	0.55%	0.55%
DE	1.07%	5.17%	0.01%
DK	1.26%	1.26%	1.26%
EE	4.55%	4.55%	4.55%
ES	6.89%	14.62%	1.84%
FI	2.72%	2.72%	2.72%
FR	1.28%	4.38%	0.20%
GR	1.40%	3.01%	0.71%
HU	3.35%	4.97%	1.25%
IE	0.56%	0.56%	0.56%
IT	2.22%	8.30%	0.00%
LT	4.79%	4.79%	4.79%
LU	1.40%	1.40%	1.40%
LV	2.67%	2.67%	2.67%
NL	0.09%	0.09%	0.09%
PL	0.93%	1.76%	0.00%
PT	6.64%	6.64%	6.64%
SE	1.98%	4.32%	0.66%
SI	0.82%	0.82%	0.82%
SK	2.88%	2.88%	2.88%
UK	0.48%	1.39%	0.09%
Europe	2.62%	14.62%	0.00%

Source: Authors calculations from Eurostat-REGIO data

Table 4. Average premium rates (%) for sugar beet with 10% deductible (FADN-region level)

	Average	Maximum	Minimum
AT	0.38%	0.38%	0.38%
BE	0.14%	0.14%	0.14%
DE	0.57%	0.99%	0.11%
DK	0.52%	0.52%	0.52%
ES	2.64%	5.81%	1.31%
FI	2.47%	2.47%	2.47%
FR	0.62%	1.32%	0.16%
GR	1.88%	3.61%	0.02%
HU	2.57%	3.86%	1.21%
IE	1.17%	1.17%	1.17%
IT	2.36%	7.59%	0.68%
LT	2.17%	2.17%	2.17%
LV	2.24%	2.24%	2.24%
NL	0.54%	0.54%	0.54%
PL	0.83%	1.67%	0.42%
SI	1.96%	1.96%	1.96%
SK	1.18%	1.18%	1.18%
Europe	1.46%	7.59%	0.02%

Source: Authors calculations from Eurostat-REGIO data

Table 5. Average premium rates (%) for sunflower with 10% deductible (FADN-region level)

	Average	Maximum	Minimum
AT	0.66%	0.66%	0.66%
DE	2.82%	8.64%	0.11%
ES	5.11%	8.52%	2.26%
FR	1.66%	3.04%	0.20%
GR	5.51%	9.97%	1.06%
HU	2.29%	4.86%	0.89%
IT	2.97%	6.84%	1.15%
PT	6.64%	6.64%	6.64%
SK	2.01%	2.01%	2.01%
Europe	3.30%	9.97%	0.11%

Source: Authors calculations from Eurostat-REGIO data

Table 6. Average premium rates (%) for potato with 10% deductible (FADN-region level)

	Average	Maximum	Minimum
AT	0.86%	0.86%	0.86%
BE	1.36%	1.36%	1.36%
CY	1.55%	1.55%	1.55%
CZ	0.42%	0.42%	0.42%
DE	1.79%	4.30%	0.70%
DK	0.63%	0.63%	0.63%
EE	1.97%	1.97%	1.97%
ES	2.81%	5.57%	0.47%
FI	1.57%	1.57%	1.57%
FR	1.56%	3.36%	0.06%
GR	0.21%	0.47%	0.00%
HU	2.18%	3.15%	1.33%
IE	1.67%	1.67%	1.67%
IT	2.31%	10.55%	0.42%
LT	3.70%	3.70%	3.70%
LV	3.21%	3.21%	3.21%
NL	0.61%	0.61%	0.61%
PL	1.00%	1.00%	1.00%
PT	0.91%	0.91%	0.91%
SE	0.80%	1.11%	0.36%
SI	1.30%	1.30%	1.30%
SK	2.54%	4.63%	0.65%
UK	2.21%	2.21%	2.21%
Europe	2.64%	2.64%	2.64%

Source: Authors calculations from Eurostat-REGIO data

Table 7. Average premium rates (%) for rapeseed with 10% deductible (FADN-region level)

	Average	Maximum	Minimum
AT	3.61%	3.61%	3.61%
BE	1.92%	1.92%	1.92%
CZ	2.75%	2.75%	2.75%
DK	1.15%	1.15%	1.15%
EE	5.37%	5.37%	5.37%
ES	5.30%	10.60%	1.04%
FI	1.94%	1.94%	1.94%
FR	1.48%	2.70%	0.54%
GR	11.63%	15.80%	1.24%
HU	1.40%	3.87%	0.00%
IT	2.28%	7.38%	0.39%
LT	4.17%	4.17%	4.17%
LU	4.11%	4.11%	4.11%
LV	8.71%	8.71%	8.71%
NL	4.76%	4.76%	4.76%
PL	2.54%	3.75%	1.57%
PT	4.66%	4.66%	4.66%
SE	1.03%	1.03%	1.03%
SI	5.00%	5.00%	5.00%
SK	1.73%	1.73%	1.73%
Europe	3.81%	23.54%	0.00%

Source: Authors calculations from Eurostat-REGIO data

Table 8 shows the total fair premium that would be paid by farmers for yield insurance in the case of the total crop surface in the country being insured. A 50% market penetration would consequently mean a reduction by 50% of these quantities, and a subsidy of 50% would reduce them another 50%. 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.

Table 8. Total fair premium (000 €) for RYI with 10% deductible (premiums calculated at FADN region level)*

	Barley	Grain Maize	Potato	Rape	Sugar beet	Sunflower	Wheat
AT	1,379	976	1,784	1,947	470	56	1,799
BE	187	91	5,778	81	418		530
CY	1,254		493				49
CZ	1,312	656	1,116	7,024			384
DE	11,096	2,677	34,424		5,188	453	15,390
DK	7,307,172		1,784	1,588	837		1,386
EE	1,746		1,721	383			91
ES	71,884	6,948	31,221	22,867	12,039	13,199	46,107
FI	20,592		10,482	2,151	4,337		7,542
FR	13,117	18,324	20,361	20,176	4,943	5,839	24,122
GR	815	343	241	1,426	516	143	3,972
HU	3,657	33,303	3,781	5,498	3,172	4,335	14,222
IE	973		2,905	51	788		401
IT	2,393	10,663	7,311	6,455	8,210	1,536	25,117
LT	5,345		10,454	1,090	961		2,981
LU	120		172	66			82
LV	1,075		1,033	600	490		438
NL	29	727	12,618	497	1,592		
PL	3,822	291	33,828	9,904	3,421		2,787
PT	3,225	23,409	19,615	3,117	623	1,596	15,648
SE	1,417		3,424	499			220
SI	34	2,137	1,003	86	193		349
SK	2,227	3,245	2,245	1,711	712	606	4,886
UK	1,983		17,745				2,256
Total	157,000	103,797	225,626	87,225	48,919	27,766	170,771

Source: Authors calculations from Eurostat-REGIO data
* Missing data are due to not enough data for calculating the premium

These loadings, according to Bielza et al. [10], can increase the premiums amount by 42%[3]. The total cost for the commercial premiums with 50% penetration would then be:

- Sunflower €19.71M
- Sugar beet €34.73M
- Oilseed rape €61.93M
- Grain maize €73.70M
- Barley €111.47M
- Wheat €121.25M
- Potato €160.19M

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

[3] Bielza et al. [10] 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%.

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%.

B. Farm yield risk

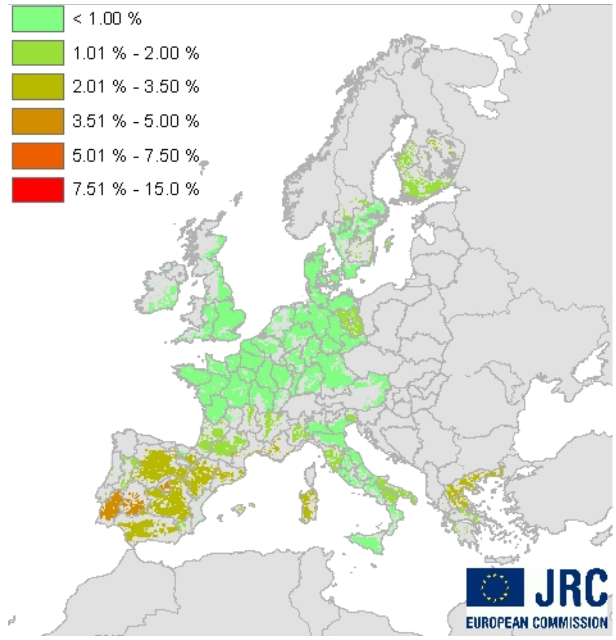
We assume that risks of losses smaller than 30% of the average can be considered normal farm risks. Thus, we analyse the crisis risk or big risks of the farms by looking only to those losses above 30% of the average yield. So, the crisis risk has been calculated using the 2-year constant sample method assuming a deductible=30%.

The risk has been calculated for a number of crops (barley, grain maize, sunflower and wheat). Fig. 2 shows the results for each FADN region for wheat. Table 9 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.

The risk levels reported are generally low, often below 1%. They are lower than the premium rates applied by insurers to a yield (multi-risk) insurance. One explanation for this fact can be that usually yield insurance has not a 30% deductible for all risks covered. An additional explanation can be that only farmers with a relatively high risk buy insurances. This also suggests that the average risk level of insured farmers would be lower with a higher penetration of the insurance.

C. Cross-validation: yield risk with insurance

Fig. 3 shows the risk calculated with the "2-year constant sample" method for the farms with insurance. The map for the same farms without insurance was shown in Fig. 2. 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: Andalucía, Aragon and Navarra (south and north-east of Spain), south of France, Sardinia, Puglia, Basilicata and Friuli-Venezia in Italy, and in Greece. So, this decrease of the risk is observed in Mediterranean areas, while in central and northern Europe the usually low risk levels remain unchanged. .



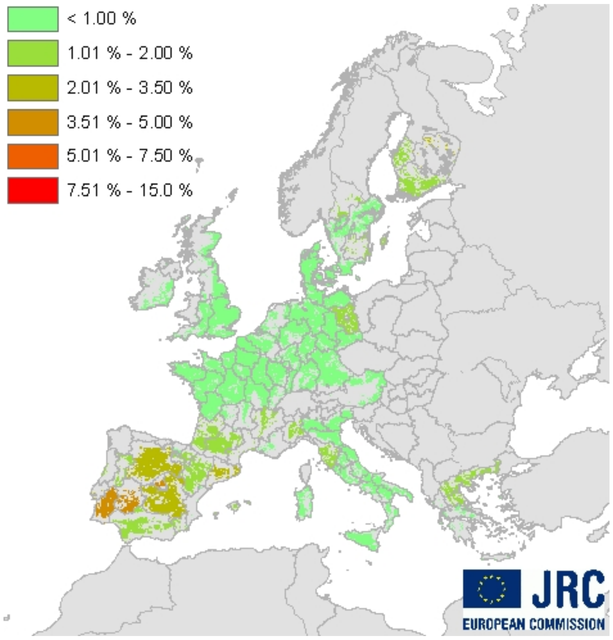
Source: Elaborated by authors from FADN data

Fig. 2. Risk of yield reduction (below 30% of the trend) for wheat

Table 9 Risk of yield reduction (below 30% of the trend) "2-year constant sample" method

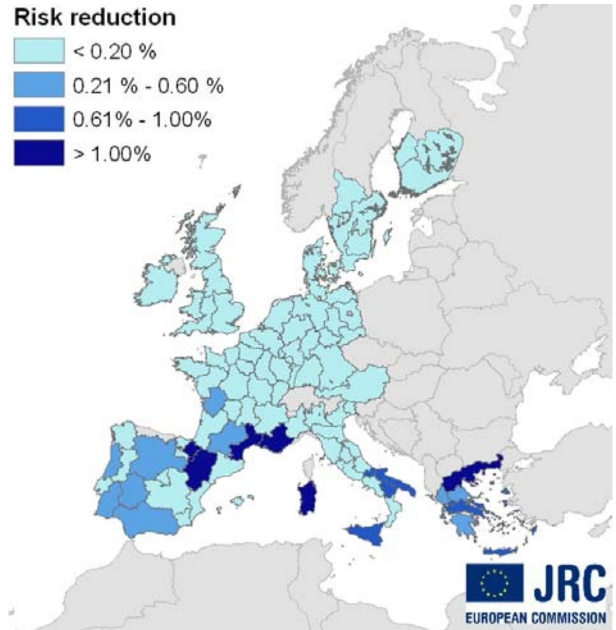
	Barley	Grain Maize	Sunflower	Wheat
AT	0.88%	1.31%	0.93%	0.57%
BE	0.44%	0.69%		0.35%
DE	0.56%	1.22%	2.53%	0.50%
DK	0.85%			0.50%
ES	2.58%	1.60%	3.58%	2.57%
FI	1.57%			3.26%
FR	0.74%	1.17%	1.24%	0.60%
GR	1.77%	0.28%	2.53%	2.37%
IE	0.88%			0.60%
IT	0.98%	0.69%	1.47%	0.91%
LU	0.50%			0.46%
NL	0.70%	0.53%		0.22%
PT	2.67%	1.24%	3.11%	2.70%
SE	1.39%			0.65%
UK	0.45%			0.35%
All	1.36%	1.09%	2.60%	1.19%

Source: Elaborated by authors from FADN yields



Source: Elaborated by authors from FADN and Eurostat-REGIO data

Fig. 3 FADN production risk (below 30% of the trend) with area yield insurance for wheat



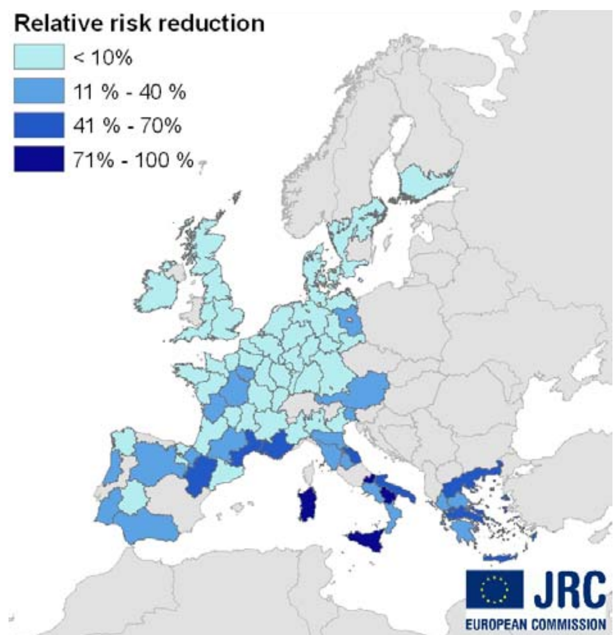
Source: Elaborated by authors from FADN and Eurostat-REGIO data

Fig. 4. Wheat production risk reduction from area yield insurance

Fig. 4 shows the observed yield reductions. The yield reduction is largest in Aragon and Navarra (Spain), Provence-Alpes-Cote d'Azur and Languedoc-Roussillon (France), Sardinia (Italy) and Makedonia-Thraki (Greece). The decrease is more than 50% in Puglia, Basilicata, Sicilia and Molise (Italy), Sterea Ellas-Nissi (Greece) and Alentejo e do Algarve (Portugal).

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 important. The maximums are around 1.5% points for Aragon and Sardinia, which accounts for 46% of the original FADN risk in the case of Aragon (Fig. 5), and 76% in the case of Sardinia. In Sicilia, the risk reduction from the original risk is 100% (see again Fig. 5).



Source: Elaborated by authors from FADN and Eurostat-REGIO data

Fig. 5. Wheat production relative risk reduction from area yield insurance

- 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.

IV. CONCLUSIONS

This article analyses an area area-index insurance based on regional average yields, Regional Yield Insurance (RYI), for arable crops in EU-27. The insurance design is similar to USA Group Risk Protection, but non-proportional. We have set a 10% deductible in order to obtain a premium level affordable for the farmers.

Premium rates at 10% deductible oscillate for wheat from 0% to 14.33% with average 1.91% while for barley they are higher on average (from 0% to 14.62% with average 2.62%). For grain maize, potato, and rapeseed, the averages oscillate between 2.42 % 3.81% (grain maize and rapeseed respectively).

Assuming a 50% market penetration (and assuming there is no adverse selection), RYI could have a total cost of €160M for potato, €121M for wheat, €11M for barley, of which € 113M, €85M and €78.5 M respectively are the pure premiums. The “fair premium” does not correspond to the final or commercial premium at which insurance is sold by insurance companies, since the “fair premium” does not take into account of management costs and profit of the insurance company.

In order to analyse the risk at farm level from FADN data, we have developed a methodology, the “2-year constant sample” method, which allows quantifying the risk when the data set has no time series at individual farm level. We have quantified the severe yield risks with and without insurance by assuming that a severe risk corresponds to a loss higher than 30% of the expected yield.

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 case analysed (wheat). Anyhow, 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 exceptions where the risk can be significantly reduced: these correspond mainly to regions with high risks.

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

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ANNEX A: 'USA FEDERAL CROP INSURANCE PROGRAM' INDEX INSURANCE PRODUCTS

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 [9], 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 [2]. Barnett et al. [11] 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 the "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 [4] 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).

ANNEX B: TREND ESTIMATION

We estimate the trend from Eurostat-REGIO data, considered more reliable. The technological trend for the yield of each crop is only computed for regions in which the crop is important enough. We excluded for each crop the regions for which the total area of the crop in the farms of the sample is less than 1000 ha in the average.

The trend g_{tk} of the yield 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:

$$g_{tk} = \hat{\beta}_{0lin} + \hat{\beta}_{1lin} x_k$$

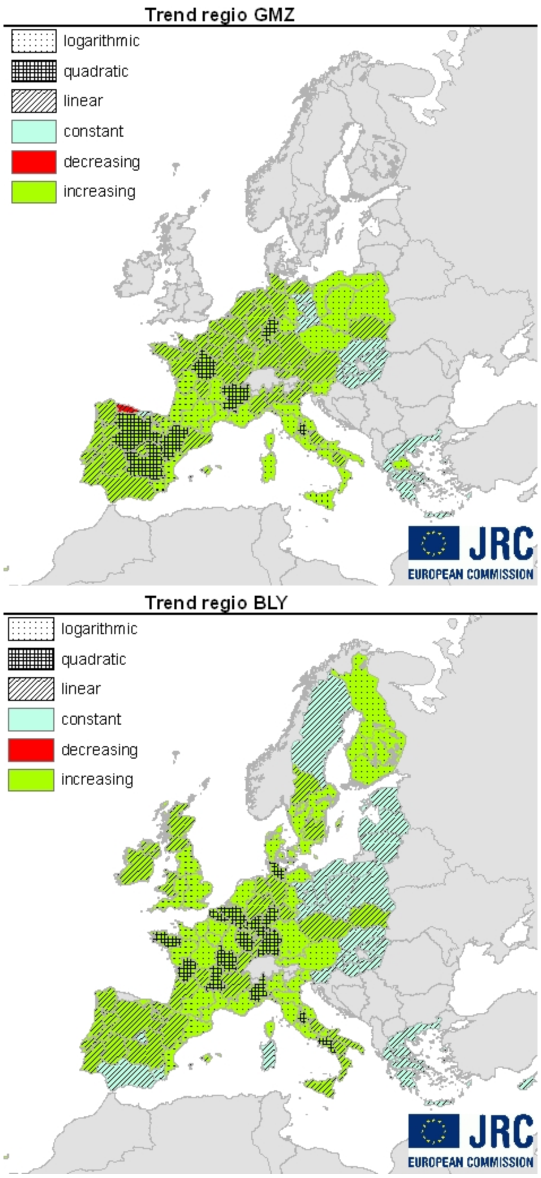
calculated by a linear regression if the conditions for a quadratic trend are not satisfied and the significance level of $\hat{\beta}_{1lin}$ is less than 20% and $\hat{\beta}_{1lin} > 0$;

a *constant trend* is given by:

$$g_{tk} = \overline{Z}_{tk}$$

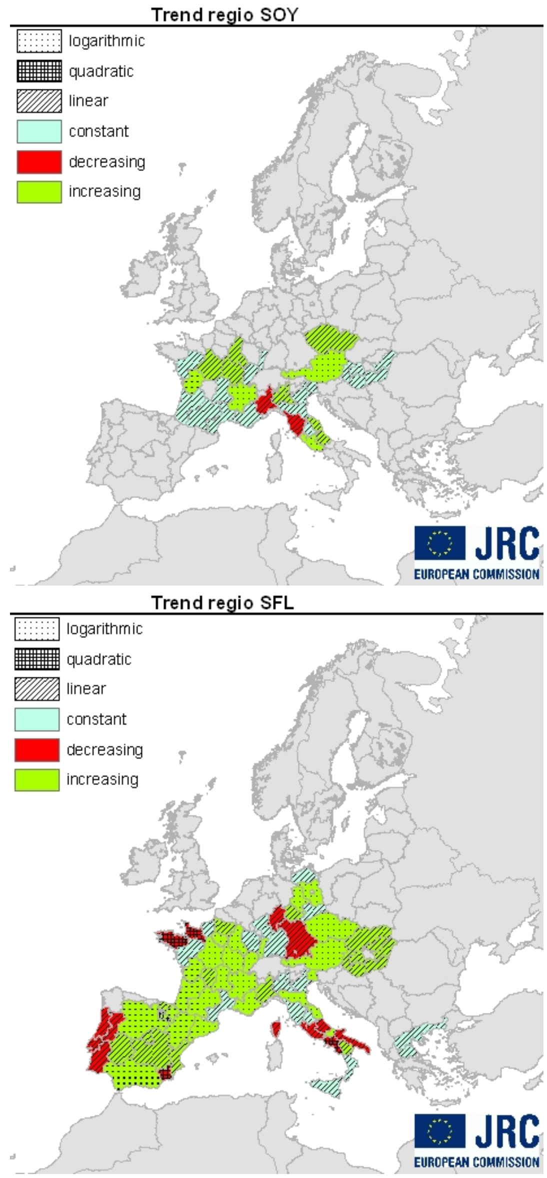
calculated by the average of the yields Z_{tk} if the conditions for a logarithmic, quadratic and a linear model are not satisfied.

We have performed this analysis for several crops for all FADN regions in Europe. In order to see the types of trends that have been found, see Fig. 8 to 8.



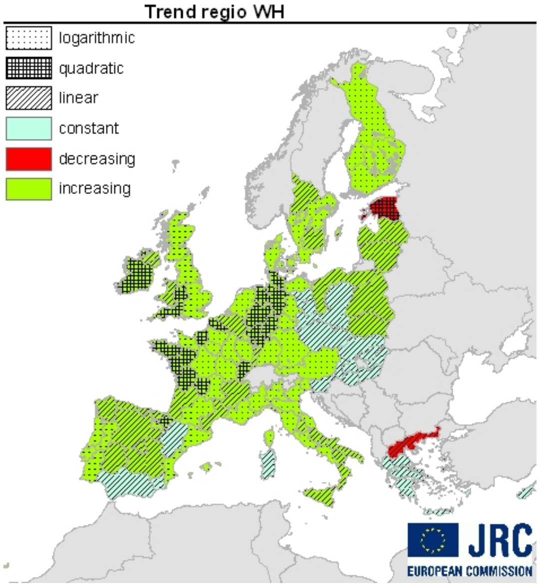
Source: Elaborated by authors from Eurostat-REGIO data

Fig. 6. Types of trends for the yields of barley and grain maize respectively



Source: Elaborated by authors from Eurostat-REGIO data

Fig. 7. Types of trends for the yields of soybean and sunflower respectively



Source: Elaborated by authors from Eurostat-REGIO data

Fig. 8. Types of trends for the yields of wheat