Potential Analysis of Rainfall-Indexed Insurance in Romania

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Abstract

One of the key factors affecting the crop output is the rainfall volume. For this reason, insurance plans based on the rainfall deviation of the mean have been advanced. This paper provides prospects of rainfall-indexed insurance in Romania considering the tradeoff between moral hazard and basis risks. The reasonability of rainfall-indexed insurance will be judged first. The basic parameters will then be determined and the effectiveness will be measured. Finally, microfinance programs combined with indexed insurance will be advanced to deal with the basis risk problems, which also are the goals for further study.

Background and Introduction

As shown in Figure 1, Romania is situated in the central-southern of Europe and is exposed to main influences of the climate's continental domains: the oceanic climate, which covers the west and the central of the country; the continental climate that covers the east and south-east of the country; the Mediterranean climate covers south-western Romania and the northern (Baltic) climate in north of the territory. The climatic anomalies can trigger natural risk. In a 100 years series, three years are extremely drought, 58 years are drought, 24 years are rainy and 15 are very rainy.

According to the analysis of the data, most dramatic and time extended droughts were reported in south and south-eastern regions of the country. In this area, the influence of the continental anticyclones is bigger. The precipitation may lack during a month or two or even longer periods of time. The possible time intervals of droughts may cover 60-70 days. The most prolonged period of drought during a year cover the late summer and the beginning of the fall.

In southern Romania, the drought affected more than 4500 ha which need irritations. The study area shown by fgure2 is located in southern Romania which include five judets (Tulcea, Constanta, Buzau, Galati, Braila), which are often facing the most serious drought. After 1990, the irrigation facilities were partially abandoned. Reconstruction and the development of the irrigation net can be one of the choices to cover the necessities during the dry period of the year. But the high expenditures have become too heavy a burden for a developing country. The innovation of weather-indexed insurance may provide a cheaper solution.

Rainfall is a highly correlated factor affecting the yearly output of most corps. Such case is also true for the maize in Romania, which will be used the typical crop for our study. The daily rainfall data as well as the yearly maize output data from 1968 to 2000 in the study area were analyzed. The maize output in Romania change greatly from year to year. That means the farmers will face great output risks and consequent income negative shock. This article will first analyze the effect of rainfall on maize output and the risk will be identified. Because there is no financial market based on weather index, farmer cannot use contract in professional writing to hedge the rainfall risk. Some appropriately designed insurance plan is one of the remaining choices.

Traditional Crop Insurance and Rainfall-Indexed Insurance

To deal with the output-risk the farmer will face, maybe the direct response is to provide the insurance on the basis of yield. But the farms in Romania are usually small-sized, traditional crop insurance can be very expensive to administer. Providing individual crop insurance requires significant monitoring and some form of farm level inspection to verify crop losses farm level inspection of small plots of land is cost prohibitive for a private firm. Adverse selection and moral hazard are more serious problems in providing such traditional output insurance, which adds to the cost of crop insurance. Actually, there are no examples of successful crop insurance programs without heavy reliance on government subsidies.

Many literatures has illustrated that the rainfall-indexed insurance could replace traditional crop insurance (Skees 1999; Martin 2001). A key advantage of this kind of insurance is that the trigger event such as a rainfall shortage can be independently verified, and not subject to the same possibilities of manipulation that are present when insurance payments are linked to actual farm losses. Since the contracts and indemnity payments are the same for all buyers per unit of insurance, the usual problems of moral hazard and adverse selection associated with public output insurance are lessened. Additionally, the insurance would be easy to administer, since there are no individual contracts to write, no on-farm inspection, and no individual loss assessments. This can help the insurance remain affordable to a broad range of people. Such people can be agricultural traders, shopkeepers and landless workers whose incomes are also affected by the insured events. More participants into the insurance programs can contribute greatly to the further development of the insurance market.

In all, rainfall-indexed insurance plan could meet the following requirements (Skees 2002):

1) It is affordable to all kinds of rural people

2) It compensates for the rainfall-caused income loss to protect consumption and debt repayment capacity

3) It is practical to implement given the limited kinds of data available

4) It is market-oriented, no need for government subsidies.

5) It avoids the moral hazard and adverse selection problems.

Risk Identification

Taking the historical yearly output in the Judet of Briala from 1980 to 2000 as an example, it shows the yield varies greatly year by year from 1831 to 5433 thousand tons, which bring income risk to farmers. The existence of the correlated risks can not be ignored among these five Judets either. It is necessary to calculate the correlation between the outputs in these five Judets. If there are high correlations, the five Judet's outputs share great correlated risks. The further reinsurance plan may be needed to share such risk. Reinsurance plans are often provided by the international institutional such as World Bank, which shares the local risk by portfoliolizing the reinsurance plan worldwide. From the table1, except for the Braila area, there is high correlation between all the other four areas. The correlated risk shows the necessity of reinsurance.

Basic Terms and Principle for Rainfall-Indexed Insurance Plan

Rainfall-indexed insurance provides an effective policy alternative for it protect farmers from drought which is characterized as widespread and positively correlated. The key advantage of such insurance is the trigger events (rainfall shortage in our case) can be independently verified. The basic terms of a rainfall-indexed insurance contract are listed as follows:

Strike: the predetermined rainfall level where an indemnity occurs

Liability: the largest indemnity amount

Limit: the baseline of rainfall level

Tick: the indemnity amount per unit of rainfall, which is the ratio of liability to the strike.

Stop loss: the largest amount that the insurance plan can cover. The reinsurance plan or other plan can cover the remaining part.

CV: coefficient of variation equal to the ratio of standard deviation to the mean of some variable, which measures relative risk.

Indemnity: shown by formula as $\begin{bmatrix} 0 & if\ : rain > strike \\ strike - rain & if\ : rain \le strike \end{bmatrix} \times tick$

In the following process, the risk reduction effect of rainfall-indexed insurance will be shown which assumes the insurance plan run non-profit which means the premium $\overline{p}$ it collects will be used to pay all the indemnity I.

That is $N * \overline{p} = \sum_{i=1}^{n} I_i$, N is the number of the plan taker.

The output each year is Y_i. Theoretically, the relative risk without risk is

$$CV_1 = \frac{Std.Dev.(Y_i)}{Mean(Y_i)}$$

Under the insurance plan, the farm each year pays the fixed premium each year $\bar{p}$, and receives the indemnity each year I_i:

$$CV_2 = \frac{Std.Dev.(Y_i - \overline{p} + I_i)}{Mean(Y_i - \overline{p} + I_i)} = \frac{Std.Dev.(Y_i + I_i)}{Mean(Y_i)}$$

Because Y_i and I_i is always higher negative correlated (we can imagine the higher output means lower indemnity, vice versa) and the indemnity is relatively stable,

$$Std.\ Dev.\ (Y_i + I_i) < Std.\ Dev.\ (Y_i)$$

Thus $CV_2 < CV_{1,}$ the output and income variation has been reduced after the insurance program.

Indexed Insurance Based on Key Season's Rainfall

It is a known that there are several very "sensitive" periods along the growth cycle of a crop, in which the total rainfall has much more effect on the yearly output than other periods. Such critical periods may include the blossoming period and the harvesting period. The first insurance plan is based on the local rainfall in these critical periods to capture their greater influence on the change of output. For their significant effects on the output, they would be the most risky period. Therefore, it is necessary to identify the critical period first in which the cumulative rain has great effect on the yearly output. The regression of the yearly output on the seasonal rainfall can be used. If the coefficients of some season's rain are significant, we know they affect the yearly output greatly. According to the biological growth cycle of maize in Romania, total rain in every season from April 1 to August 31 can be used as the explaining variable for the change of the yearly output. The general regression of the following form was developed as:

$$\boldsymbol{Y} = \boldsymbol{C} + \sum_{i=1}^{15} b_i \cdot R_i$$

R_i is the seasonally accumulative rain; Y is the yearly yield.

The regression result is shown as in Table2. We can see the critical period is the second season of Aril and the first season of July. The coefficients of the seasonal rain tells that holding all the other variable constant, one mm increase of the seasonally cumulative rain can lead to the change of the yearly output.

The average for key season's rain R_i along the 20 year must be calculated to get the average rain. $\overline{R}$. Strike level can be designed as 0.75 of the average rain, which depends on the willingness of the insurer. The coefficient of the rain can be worked as the tick, which is the ratio of marginal yield to marginal Rainfall. Each year's indemnity can be calculated as: I_i = Max (S – R_i, 0)* Tick

The calculation result about the risks with and without such insurance plan can be compared in the following table3. The result from the table3 shows: with the key seasonal insurance plan, all the relative risks have been decreased but just by very little. This may be because that only the critical period's rainfall changes are selected to reflect all the risk variation of output. Such effect can be very small. To reflect the effect of all the rainfalls in one crop's growth cycle on the output, it is necessary to include more periods' rainfall for consideration.

Indexed Insurance Based on Rainfall along the Crop Growth Cycle

As shown before, all the rainfall along the crop growth cycles should be included to reflect the variation of output. But the weight with different season has different effect on the output. How to design the weight is the first consideration. After the process to find the weight, the basic parameters such as strike, liability and tick should be determined. A complete insurance plan and reinsurance plan and even the profit for an insurer can be finally determined.

The algorithm to determine the weight of each season is to select the weight that can reduce the risk of the maize production in these five judets to the largest extent. That is:

Maximize: $CV_2 - CV_1$

Subject to: $1 \le W_{ij} \le 1 and \sum_{j=1}^{18} W_{ij} = 1$

Or:

$$\underset{W_{ij}}{Max}: \frac{SE\left\{Y_i + Max\left[\frac{\sum_{j=1}^{20} W_{ij} R_j}{20} - R_j, 0\right] \times \frac{\sum_{i=1}^{20} Y_i}{\sum_{i=1}^{20} R_i} - Mean\left[Max\left[\frac{\sum_{j=1}^{20} W_{ij} R_j}{20} - R_j, 0\right] \times \frac{\sum_{i=1}^{20} Y_i}{\sum_{i=1}^{20} R_i}\right]\right\}}{Mean\left\{Y_i + Max\left[\frac{\sum_{j=1}^{20} W_{ij} R_j}{20} - R_j, 0\right] \times \frac{\sum_{i=1}^{20} Y_i}{\sum_{i=1}^{20} R_i} - Mean\left[Max\left[\frac{\sum_{j=1}^{20} W_{ij} R_j}{20} - R_j, 0\right] \times \frac{\sum_{i=1}^{20} Y_i}{\sum_{i=1}^{20} R_i}\right]\right\}}$$

$$- \frac{SE(Y_i)}{Mean(Y_i)}$$

Subject to: $1 \leq W_{ij} \leq 1;$

$$\sum_{j=1}^{18} W_{ij} = 1;$$

The specific determination process for the weight and parameters are shown in the Appdix2. After the weight for each season has been determined, the according parameters such as tick, liability and strike can be solved. The optimal weights for the different periods appear in Table4.

Besides the parameters above for each judet, it is important to determine the loading rate. “A common loading procedure is to expand the loads on the standard deviation of the payout series. Generally, a loaded of 33% of the standard deviation is added to the pure premium insurance” (Skees, 2002). Then, all insurance plans can be designed by following procedures, which can also be expressed by the flow chart in figure3 and appendix 3.

The reduced risk after the insurance plan is shown in table5. It is obvious that the insurance programs in Constanta is most effective, which can reduce the output variation by 45.2 percentage. In other areas, it still functions to reduce the output variation from almost 10 percent to 20 percent.

Conclusion and Further Study:

In southern Romania, rainfall account for about 90 percent of crop loss in the last twenty years. High correlation of output loss with rainfall make the rainfall based insurance a worthwhile experiment in those areas. This article analyzes the rainfall risks' effect on the corn outputs in five judets of southern Romania. To deal with the risk, two insurance plans based on rainfall have been advanced. By the test of data, 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. In the process of determining the parameters of insurance plan, two statistics mean and standard error of rain and output were used to calculate the expectation and to measure risk.

By the comparison between pre- and post- insurance program, it is obvious that the rainfall-indexed insurance program can reduce the output variations that originate from the rainfall shortage in. Therefore, there could be potential demand for the rainfall-indexed insurance. In the area like Constanta, the demand can be expected to be urgently for it functions well to smooth the output and according income greatly. Although the rainfall indexed insurance has many advantages over other insurance such as: it has data with much better quality; it can reduce the moral hazard problems, it still faces a great challenge of basis risk which occurs when an insured has a loss but does not receive enough payment to cover the loss or occurs when the indemnity he receives exceeds the loss. Since an individual's output can not be fully correlated with the rainfall index, there exists always basis risk. Microfinance programs combined with the index insurance have been advanced to reduce the basis risks (Skees, 2003). The end users of such programs are the rural financial entity or microfinance group. Within the mircrofiance group, members usually live in neighborhood and have knowledge about each other. "Peer monitoring" among members can reduce the moral hazard problems and reduce the transaction costs. They can use many informal mechanisms to pool risk and assist individuals when some members met bad shocks. Thus idiosyncratic risks faced by each rural household would be dealt with within group members. However, such microfinance groups are lack of capacity to deal with major disasters such as drought, which adversely affect all members at the same time or form a systematic risk for the groups. As shown in our study, the index insurance can reduced the correlated risk effectively. The microfinance groups can purchase the index insurance contracts from a global writer such as World Bank and cope with the great loss that every member suffers at the same time. The institutional designation of the microfinance programs and quantification of their effect will be the goal of further studies.

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Appendix 1

Figure1 Relief units of Romania

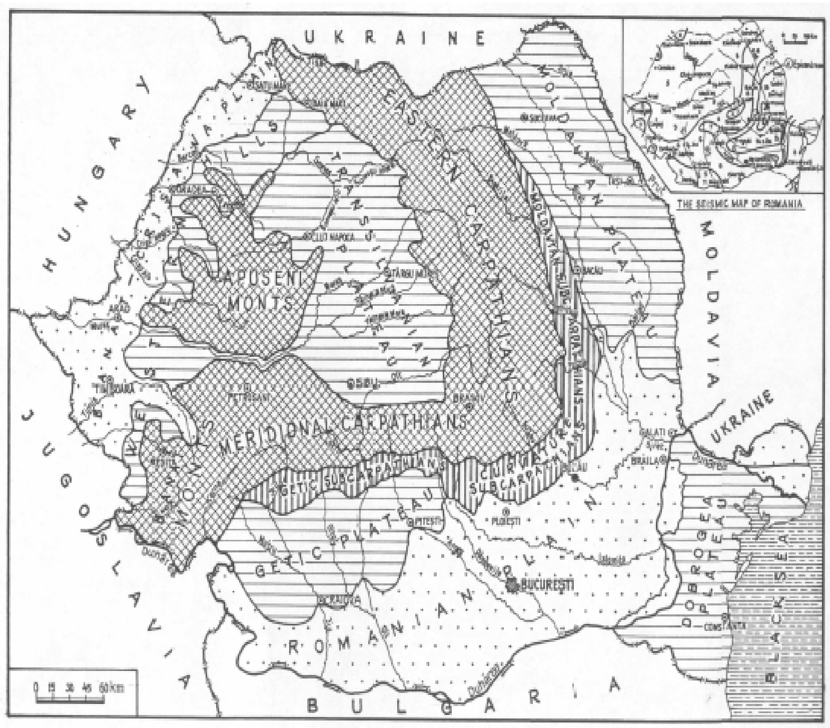

Figure2 Map of study area

Figure3 Flow chart of the designation of the insurance contract designation

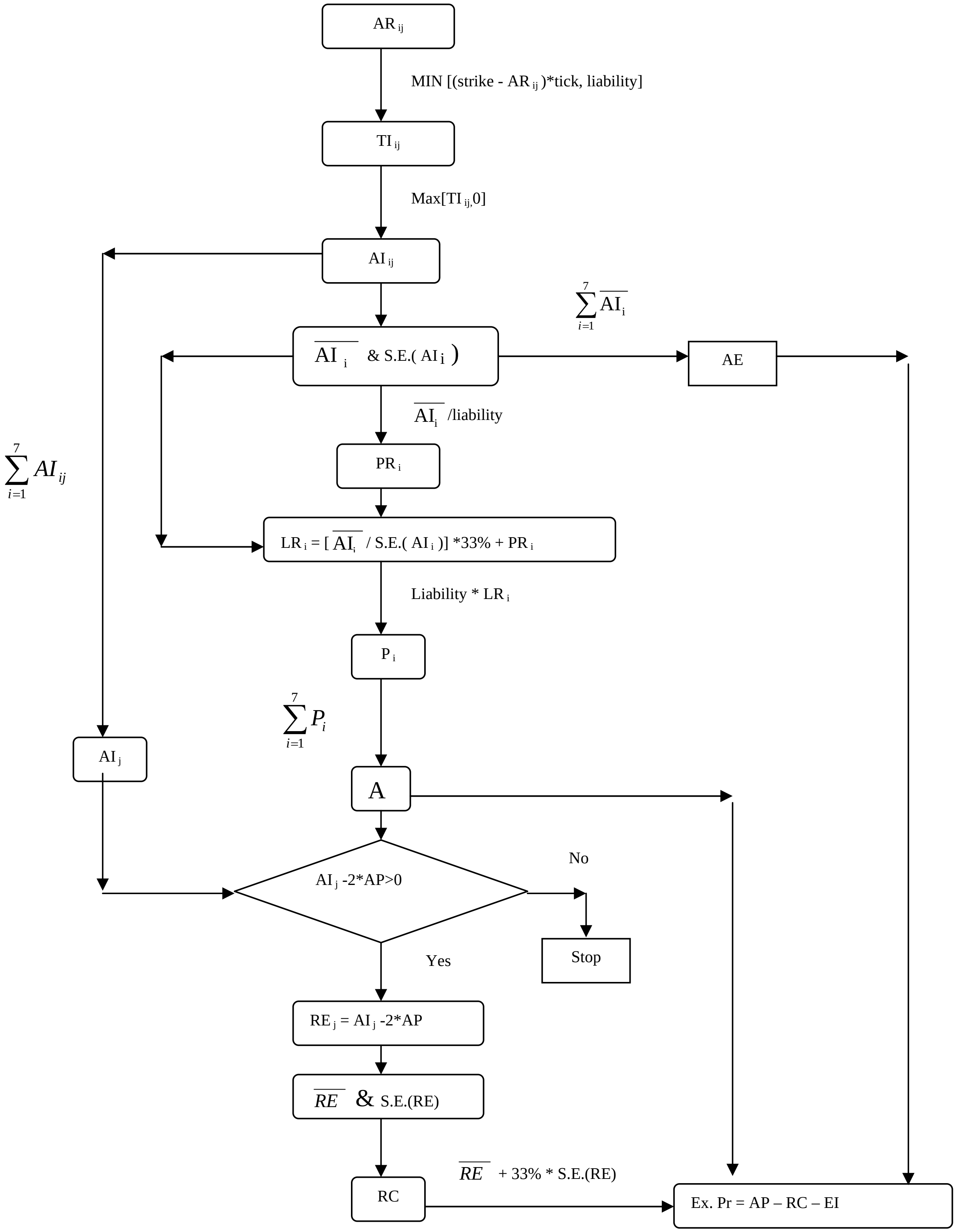

Table1 Output Correlation between Judet(1980-2000)

	Braila	Buzau	Calarasi	Galati	Tulcea
Braila	1	0.04	0.08	0.02	0.16
Buzau	0.04	1.00	0.63	0.57	0.82
Constanta	0.08	0.63	1.00	0.45	0.72
Galati	0.02	0.57	0.45	1.00	0.48
Tulcea	0.16	0.82	0.72	0.48	1

Table2 The regression result of yearly output on seasonal rain :

Variable	Coefficient	S.E.	T-value	P(t>T)
1-Apr	11.74	9.74	1.21	0.23
2-Apr	21.04	7.72	**2.72**	0.01
3-Apr	-9.84	10.66	-0.92	0.36
1-May	6.10	6.71	0.91	0.37
2-May	-3.69	8.63	-0.43	0.67
3-May	-9.06	6.11	-1.48	0.14
1-Jun	7.37	6.45	1.14	0.26
2-Jun	1.61	5.75	0.28	0.78
3-Jun	3.53	6.07	0.58	0.56
1-Jul	19.92	9.50	**2.10**	0.04
2-Jul	-2.72	7.93	-0.34	0.73
3-Jul	7.02	5.88	1.19	0.24
1-Aug	5.76	7.66	0.75	0.45
2-Aug	-1.92	10.53	-0.18	0.86
3-Aug	-8.16	8.49	-0.96	0.34
1-Sep	2.23	4.63	0.48	0.63
2-Sep	0.92	10.55	0.01	0.99
3-Sep	3.31	6.63	0.50	0.62
Constant	3088.16	441.34	7.00	0.00

Table3 Risk comparison with and without key season's rainfall-indexed insurance plan

	CV1	CV2
Braila	0.218	0.212
Buzau	0.204	0.198
Constanta	0.077	0.071
Galati	0.238	0.221
Tulcea	0.275	0.256

Table4 Optimal weight for 20-day period rainfall for five Judets

	APR 1	APR 2	APR 3	MAY 1	MAY 2	MAY 3	JUN 1	JUN 2	JUN 3	JUL 1	JUL 2	JUL 3	AUG 1	AUG 2	AUG 3
Weights for 1986-2000															
Braila	0%	0%	0%	0%	0%	17%	0%	11%	5%	0%	26%	5%	6%	5%	25%
Buzau	0%	0%	0%	0%	0%	3%	0%	23%	15%	0%	21%	25%	0%	0%	13%
Constanta	7%	0%	20%	1%	1%	7%	5%	29%	0%	0%	13%	0%	0%	0%	17%
Galati	3%	0%	1%	11%	0%	24%	0%	0%	0%	11%	0%	0%	26%	3%	22%
Tulcea	0%	0%	7%	0%	0%	0%	0%	35%	24%	0%	10%	0%	0%	0%	23%
Weights for 1968-2000															
Braila	12%	0%	7%	5%	0%	15%	0%	22%	5%	0%	5%	0%	9%	7%	12%
Buzau	7%	3%	1%	0%	0%	0%	0%	16%	4%	0%	13%	27%	7%	0%	21%
Constanta	0%	1%	0%	7%	5%	17%	0%	16%	3%	0%	7%	18%	0%	3%	24%
Galati	12%	0%	4%	0%	0%	16%	14%	5%	0%	0%	12%	1%	4%	23%	10%
Tulcea	0%	0%	0%	0%	0%	0%	0%	12%	2%	0%	27%	3%	2%	11%	42%

Table 5 Reduced risk after indexed insurance plan based on rainfall along the crop growth cycle

Judet	Braila	Buzau	Constanta	Galati	Tulcea
(CV2-CV1)/CV2	0.24	0.105	0.452	0.156	0.116

Appendix2:

Weight determination for the insurance plan based on rainfall along the crop growth cycle

First, it is assumes some weight variables w_{ij} as for each year (i) and season (j)

Calculate the expected rainfall for each season along the growth cycle

$$\sum_{j=1}^{18} W_{ij} R_j = R_i$$

Get the average yearly rainfall $(\sum_{i=1}^{20} R_i) / 20 = \overline{R}$

The strike S could be 0.75* $\overline{R}$

Determine the mean and the standard error of the yearly yield:

$$\overline{Y} = \frac{\sum_{i=1}^{20} Y_i}{20}$$ And S.E(Y_i)

CV_1= S.E(Y_i)/ $\overline{Y}$

Tick T = ($\overline{Y}$ / $\overline{R}$)

The Indemnity each year(i) I_i = Max (($S - R_i$), 0)*T

Get the average Indemnity: $\overline{I}$

Liability L= T* S

Premium rate PR= $\overline{I}$ /L and calculate the premium P each year.

After the insurance plan the farmer get the actual output:

$A_i = Y_i + I_i - P$

CV_2= (S.E.(A_i))/Mean(A_i)

Appendix3

Designation of the insurance contract designation

A) Expected Indemnity and Premium

For each judet *i*, assume the actual rainfall in key period j is AR_{ij}

The theoretic indemnity amount $TI_{ij} = MIN\ [(strike - AR_{ij})*tick, liability]$

The actual indemnity amount $AI_{ij} = Max\ [TI_{ij}, 0]$

Calculate the mean and standard error for AI_{ij}: $\overline{\mathrm{AI_i}}$ and $S.E.(AI_i)$ for each judet i.

Premium Rate for judet I: $PR_i = \overline{\mathrm{AI_i}}/liability$

Load Rate for judet I: $LR_i = [\overline{\mathrm{AI_i}} / S.E.(AI_i)] *33\% + PR_i$

Expected Indemnity for all the judets: $EI = \sum_{i=1}^{7} \overline{\mathrm{AI_i}}$

Premium in judet i: $P_i = liability * LR_i$

B) Calculate the reinsurance Cost

Aggregate the premiums in all judets $AP = \sum_{i=1}^{7} P_i$

Aggregate all the liability in all judets $AL = \sum_{i=1}^{7} L_i$

Aggregate $\mathrm{AI_{ij}}$ for all judets: $AI_j = \sum_{i=1}^{7} AI_{ij}$

If we term $(AI_j - 2*AP)$ where $AI_j - 2AP>0$ as the risk exposure for the reinsurance part, it can be written as RE_j. Find the mean and standard error of RE_j: $\overline{RE}$ and $S.E.(RE)$

Reinsurance Cost:

$RC = \overline{RE} + 33\% * S.E.(RE)$

C) Expected Profit for an insurance company:

Ex. Pr = Total Premium – Reinsurance Cost – Expected Indemnity

$= AP - RC - EI$