

## INSURANCE AS A TOOL FOR STEADY DEVELOPMENT OF AGRICULTURE

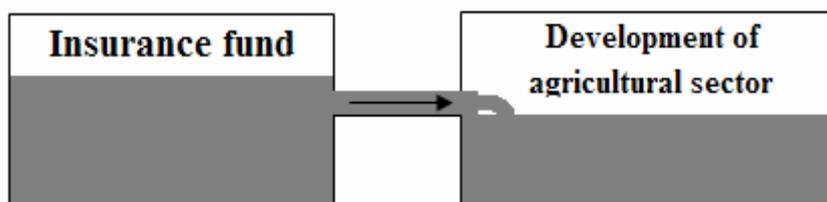
Konstantin Didenko, Vladimir Janson, Vitalijs Jurenoks  
Technical University – Riga, Latvia

### ABSTRACT

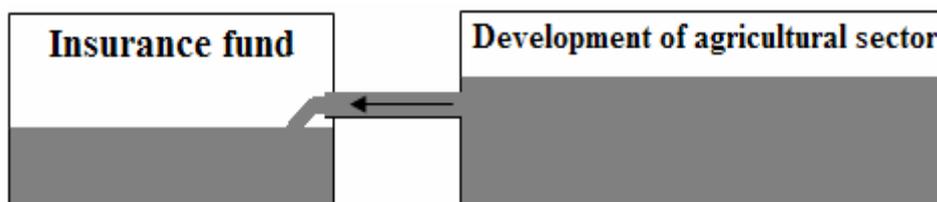
The research of development of agriculture over the last years has shown the necessity to develop stabilizing mechanisms ensuring constant and stable development of agriculture. The authors of the research offer to use risk insurance of agricultural operations as one of the stabilisation mechanisms. The research demonstrates, by a specific example, the effectiveness of application of the Monte-Carlo statistical method for calculating basic insurance parameters, such as insurance coverage, insurance premium, and insurance indemnity. By using average agricultural performance indicators for the state, the authors have established specific insurance parameters. The recommended use of information technologies is simple and frequently allows to avoid complicated theoretical calculations as well as allows to obtain sufficiently accurate practical results for taking appropriate decisions and thus enhancing the effectiveness of the performance of agricultural enterprises.

In order to ensure steady growth of agricultural production, especially in the private sector, it is necessary to introduce insurance products with regard

to operation of agricultural enterprises (see fig. 1 and 2).



**Figure 1. In unfavourable years the insurance fund allows to stabilize the agricultural sector**



**Figure 2. In favourable years the insurance fund can be increased using funds from the agricultural sector**

Insurance products with regard to operation of agricultural enterprises comprise a specific type of insurance services/products which, according to the classical insurance classification, fall within the scope of property insurance. Property insurance is further subdivided into two subgroups, i.e., real estate insurance and movable property insurance. The movable property part comprises several subgroups: insurance of property, domestic animals, and insurance of gardens and sowings.

Each insurance service/product, whether it is property insurance, or transportation vehicle insurance, or insurance of cereal sowings is characterised by three main phases of formation of the product:

- appraisal of insurance coverage;

- establishment of insurance tariff;
- calculation of losses.

When developing an agricultural risk insurance service/product, it is necessary to define the insurance object. Within the context of EU agricultural risk insurance problems the following insurance objects are considered:

Crop insurance, price insurance, insurance of incomes, profit insurance, and insurance of losses due to catastrophes, that could cover all types of agricultural production. The research also considers the possibilities of using modelling to evaluate the size of tariff and stability of the insurance portfolio. The case referred to illustrates the insurance of one of the agricultural risks – insurance of cereal sowings,

using real data in Latvia. According to the classical theory of insurance of cereal sowings, the insurance object is insurance of revenues from cereal crops. The classical theory offers the methodology of formation of the service, according to which it is possible to use statistical loss indicators.

The international practice of agricultural risks insurance shows that calculations of formation of insurance services use several options of obtaining statistical data, where data are split into three data groups, according to the phases of development of the service, as follows:

- statistical data for establishing the insurance coverage;
- statistical data for calculating the insurance premium;
- statistical data for calculating insurance indemnity.

In the example of the establishment of insurance coverage, calculation of insurance premium, and calculation of insurance indemnity, the authors have used average agricultural performance indicators for the state, i.e. average indicators for Latvia.

The calculation of insurance premium is based on the concept of expected loss

$Z_{\text{loss}}$ , which can be calculated according to the formula:

$$Z_{\text{loss}} = \sum p_i x_i \quad (1)$$

where

$x_i$  is possible loss  $i$  with the probability  $p_i$ .

In a real agricultural risk insurance process it is necessary to divide the insurance object into separate homogeneous groups of approximately equal insurance objects. Knowing the unit price of each agricultural product and the losses in the previous time period it is possible to calculate the expected loss  $Z_{\text{loss}}$ , using loss coefficients  $K_{i,\text{loss}}$  instead of probability  $p_i$ .

In this research the loss coefficient is calculated by using empirical data according to the formula, which reminds the classical probability formula:

$$K_{i,\text{loss}} = N_{i,\text{loss}}/N, \quad (2)$$

where

$N_{i,\text{loss}}$  - the number of events in which loss  $i$  set in;

$N$  - number of insured agricultural objects in one group.

Loss coefficients are calculated for each homogeneous group, where we put numbers  $D$ , which are calculated by the formula:

$$\Delta = \begin{cases} \text{Limit} - \text{Real Product}, & \text{if } \text{Real Product} - \text{Limit} < 0; \\ 0, & \text{if } \text{Real Product} - \text{Limit} \geq 0 \end{cases} \quad (3)$$

According to the classical insurance theory, actuary (net) insurance premiums have to fully cover the possible losses, then

$$\sum P_i = \sum Z_k, \quad (4)$$

where

$P_i$  – insurance premiums;

$Z_k$  – possible losses.

In such a case, in order to calculate the insurance premium, we can use the calculated losses and loss coefficients.

Loss indemnity is calculated using the following formula:

$$\text{Loss indemnity} = D * \text{Price}.$$

### Modelling scheme

#### Modelling goal:

- in cereal sowings insurance to establish the insurance coverage for the sowing area;
- to calculate insurance tariffs and the insurance premium;
- to develop a cereal sowings insurance service model;
- to model the insurance fund and to examine the stability of the fund under different conditions.

Let us consider the modelling scheme of the agricultural insurance fund, which later will allow us to model the process of developing the model and to establish the minimum amount of the insurance fund  $U$  (without a state subsidy). The minimum fund amount  $U$  guarantees that with a certainty  $\gamma$  (probability  $\gamma$ ) agricultural losses will be compensated.

For modelling the insurance fund, we will use the simplest individual risk modelling scheme. Let us assume that the insurance fund is satisfactory, given the following conditions:

The number of registered farms in the fund is constant;

Risks of individual farms are independent;

Payment of premiums is effected at the beginning of the period;

The loss distribution function is equal for all farms.

Let us designate that:

$n$  – number of agreements in the fund;

$j$  – ordinal number of the farm;

$p$  – probability of setting in of the insurance event;

$Y_j$  – possible losses of the farm  $j$ . Value  $Y_j$  has probability distribution function  $F(x)$ ;

$X_j$  – satisfied loss of the farm  $j$ .  $X_j = \text{Ind}_j * Y_j$ ;

$\text{Ind}_j$  – binary index of the insurance event of the farm  $j$ ;

$$\text{Ind}_j = \begin{cases} 1 & p \\ 0 & 1-p \end{cases} \quad (5)$$

The "0" value of index  $Ind_j$  shows that for the farm  $j$  an insurance event does not set in and that the farm  $j$  does not have losses. The insurance index is distributed evenly for all farms and is presented in the following table with a probability distribution:

Probability distribution table of index $Ind$		
$Ind$	0	1
probability	$1 - p$	$p$

By using variable  $Ind$ , we can calculate total number  $N$  of farms incurring losses:

$$N = \sum_{j=1}^n Ind_j \tag{6}$$

Total amount of losses is:

$$Z = X_1 + X_2 + \dots + X_n \tag{7}$$

Or by using indices of setting in of the events:

$$Z = Ind_1 \cdot Y_1 + Ind_2 \cdot Y_2 + \dots + Ind_n \cdot Y_n = \sum_{j=1}^n Ind_j \cdot Y_j \tag{8}$$

Figure 3 shows that total losses are formed in  $n$  farms during one time period.

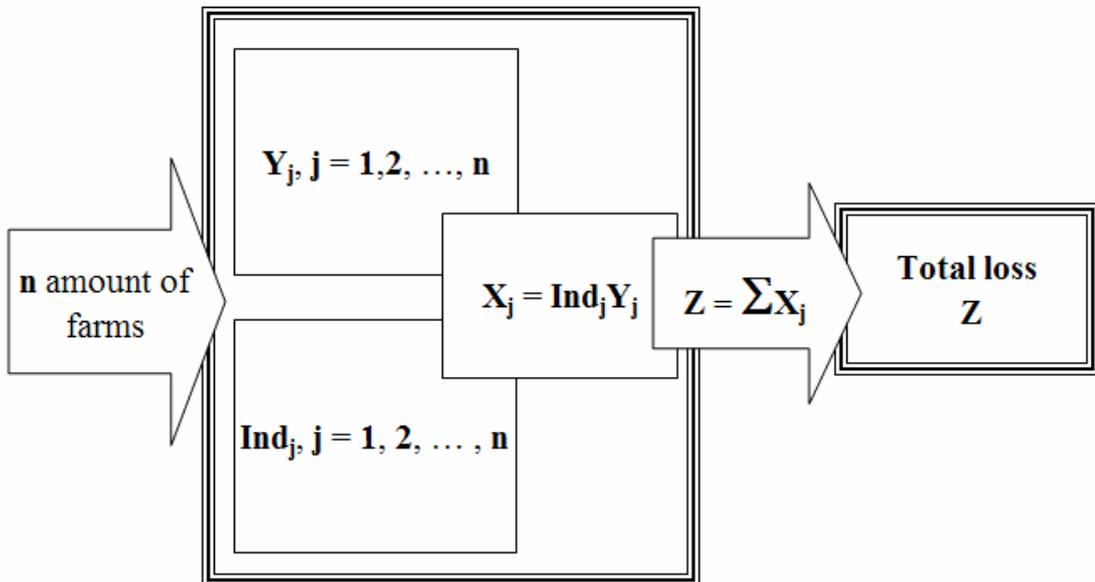


Figure 3. Illustration of process of loss formation

We are to compensate losses to farms with a certainty  $g$  and are to ensure the required operation of the fund with cash funds  $L$ . It means that the

amount of the fund after compensations must be positive with a certainty  $\gamma$  (see fig. 4).

$$P(U - Z \geq 0) = \gamma$$

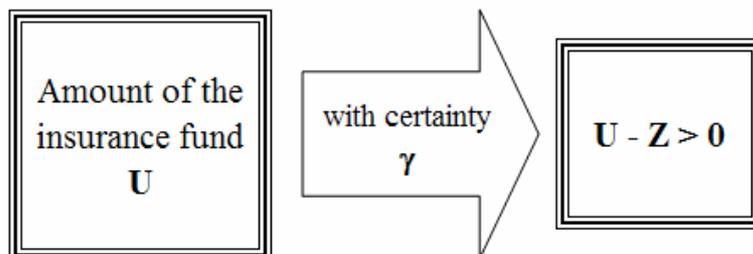


Figure 4. Illustration of the amount of the insurance fund  $U$ , losses  $Z$ , and parameter  $\gamma$

The degree of risk (stability) of the insurance fund can be established by the variation coefficient:

$$K_{\text{var}}(Z) = \frac{\sigma(Z)}{E(Z)} = \frac{\sqrt{D(Z)}}{E(Z)} \quad (9)$$

where

$\sigma(Z)$  - standard deviation from the amount  $Z$  (standard error);

$E(Z)$  - mathematical expectation of value  $Z$ , which in practice is measured with average value of  $Z$ ;

$D(Z)$  - variation of value  $Z$ .

If variation coefficient  $K_{\text{var}} > 15\% - 20\%$ , it means that our fund becomes risky, since probable loss  $Z$  variation ( $\sigma^2$ ) become larger.

If the number of farms in the fund is big, it is possible to use the central marginal theorem and to establish value  $U$ . Let us consider the inequality:

$$U - Z \geq 0$$

which has to be valid under probability  $\gamma$ :

$$P(U - Z \geq 0) = \gamma$$

From the inequality  $U - Z \geq 0$  derives inequality  $Z \leq U$ , and after that inequality  $Z - E(Z) \leq U - E(Z)$ . Dividing it by a positive value  $\sigma(Z)$ , we obtain

$$\frac{Z - E(Z)}{\sigma(Z)} \leq \frac{U - E(Z)}{\sigma(Z)}$$

Value  $S = \frac{Z - E(Z)}{\sigma(Z)}$  normally distributed with

$E(S) = 0$  and  $\sigma(S) = 1$ . Then the following formula can be applied:

$$P(S \leq \alpha) = \int_{-\infty}^{\alpha} \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} dx \quad (10)$$

Thus we can write that

$$\begin{aligned} P(Z \leq U) &= P\left(\frac{Z - E(Z)}{\sigma(Z)} \leq \frac{U - E(Z)}{\sigma(Z)}\right) = \\ &= P\left(S \leq \frac{U - E(Z)}{\sigma(Z)}\right) \rightarrow \int_{-\infty}^{\frac{U - E(Z)}{\sigma(Z)}} \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} dx = \gamma \end{aligned}$$

By designating  $\frac{U - E(Z)}{\sigma(Z)} = \alpha(\gamma)$  it is possible

to find the value of  $\alpha(\gamma)$  from equation:

$$\int_{-\infty}^{\alpha(\gamma)} \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} dx = \gamma$$

And thus from the equation

$\frac{U - E(Z)}{\sigma(Z)} = \alpha(\gamma)$ , the required insurance fund

amount  $U$  is:

$$U = \alpha(\gamma) \sigma(Z) + E(Z) \quad (11)$$

The amount of the insurance coverage in cereal sowings insurance depends on the average amount of crop received by years, in which no relevant losses took place. The size of the insurance coverage can be established by the following formula:

$$\text{Average Productivity} * \text{Price} = \text{Limit}, \quad (12)$$

where

Average Productivity - average productivity of cereal sowings in the state 2000 /2005);

Price - for the purpose of simplifying calculations, the assumed average price of cereals in the state.

#### Analysis of average productivity of cereals

The calculations of the insurance model are based on the data on total cereal productivity in the state in the time period since 2000 until 2004. (Table 1.1)

**Table 1.1. Average productivity of cereals in Latvia by years (2000 /2004)**

	Year	Average productivity, cnt/ha
1.	2000	19.57
2.	2001	19.33
3.	2002	22.05
4.	2003	18.60
5.	2004	20.93

Source of data: Latvia Republic Central Statistical Board. Latvian agriculture 2000/2005 (10.11.12.13. 14.)

Before using these data it is necessary to evaluate credibility intervals of average productivity of cereals (fig. 5).

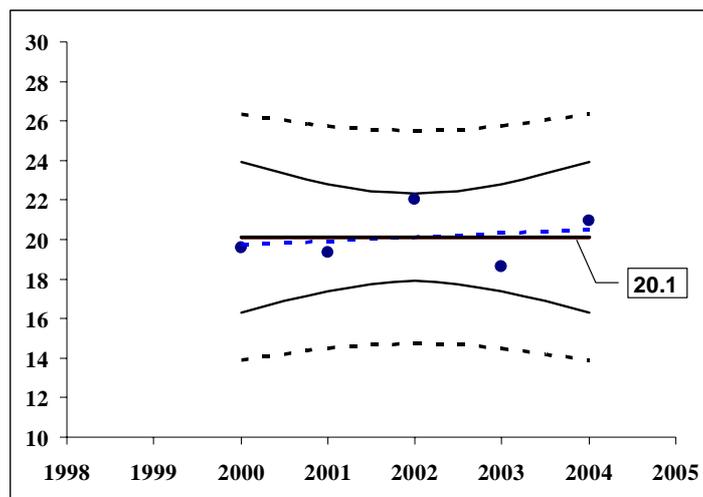


Figure 5. Linear average productivity (cnt/ha) model in Latvia with credibility intervals

When using the Regression tool in programme MS Excel, it is possible to obtain a linear model of average productivity by years:

$$\text{Average Productivity} = 0.20 * \text{Year} + 19.496 \text{ (cnt/ha)} \quad (13)$$

When considering the results obtained by the Regression tool programme, the following conclusions can be made:

The model (13) with a 95% probability is not relevant, thus it can be concluded that average productivity tendency for the whole state is not relevant and in the model it can be assumed that average crop by years is constant.

Standard error of average productivity by years (SE) is 1.55 cnt/ha. Using this standard error, it is possible to approximately (95%) construct the average productivity credibility interval:

$$\text{Average productivity} - 2\text{SE} < \text{Real average productivity} < \text{Average productivity} + 2\text{SE}$$

$$\text{or } 16.396 \text{ cnt/ha} < \text{Real average productivity} < 22.596 \text{ cnt/ha.}$$

Average growth of average productivity in a year is  $a_1 = 0,200$  cnt/ha.

Determination coefficient  $R^2$  is 5.3%, which once again confirms that the model is not statistically relevant and in reality there are big fluctuations around the constant value  $C = 20,1$  cnt/ha, which is average crop for 5 years (see fig. 5).

The research, by using real data on productivity in Latvia, has dealt with evaluation of loss probabilities dependent on the category of farms and the level of guaranteed productivity.

The authors have considered three agriculture categories I, II, III and three levels (limits) of guaranteed productivity  $L - 80\%, 90\%, 100\%$ . By using the Monte-Carlo statistical modelling method, the authors have modelled different options of formation of the fund. For example, if

Number of farms in the fund	$n =$	100
Insurance event sets in with a probability	$p =$	0.05
Fund guarantee level	$\gamma =$	0.90
Insurance limit	$L =$	80%
Insured crop amount	$L_{\text{ins\_crops}} =$	500

statistical basic indicators for simulated fund are the following:

$E(X) =$	3646	Average value of losses
$V(X) =$	1582711	Variation of losses
$\sigma(X) =$	1258	Standart deviation of losses
$K_{\text{var}}(X) =$	34.51%	Variation coefficient of fund

The authors also have modelled insurance funds when losses set in when crop is lower than the previ-

ously established level  $L$ . In this case indices  $Ind_{crops}$  are used:

$$Ind_{crops} = \begin{cases} 0, & \text{if Real Product} > \text{Limit} \\ 1, & \text{if Real Product} < \text{Limit} \ \& \ (\text{Limit} - \text{Real Product})/\text{Limit} > 1 - L \end{cases} \quad (14)$$

which can characterise the amounts of losses.

### Conclusions.

The calculations show that very often variation coefficient  $K_{var}$  fluctuates within the range from 20% to 100%, which testifies to the fact that insurance fund is often not so stable and additional financing is required from the state.

In the age of up-to-date information technologies the application of the Monte-Carlo statistical method is simple and frequently allows to avoid from complicated theoretical calculations as well as allows to obtain sufficiently accurate practical results to take appropriate decisions on insurance parameters.

### References

1. Didenko K., Saulitis J. Conditions and Problems in the Economic Development of Latvia on the Eve of the 21st Century. // *Latvian Economy at the Turn of Centuries 1* (26). – Riga, University of Latvia, 2000.
2. Harrington S.E., Niehaus G.R. *Risk Management and Insurance*. – New York, 2003. – 672 p.
3. European Commission. *Risk Management Tools for EU Agriculture with a Special Focus on Insurance*. Working Document, January 2001. – 84 p.
4. Ray P.K. *A Practical Guide to Multi-risk Crop Insurance for Developing Countries* – U.S.A.: Science Publishers, Inc., 1991. – 162 p.
5. *Risk Management in Agriculture*, A discussion document prepared by the Economics and Statistics Group of the Ministry of Agriculture, Fishery and Food – UK, MAFF, January 2001. – 11 p.