Maintaining the economic safety of environmental activities in agriculture

Yu Krasovska, T Kuznetsova, V Kostrychenko and O Lesniak
National University of Water and Environmental Engineering, Rivne, Soborna str. 11, Ukraine
E-mail: y.v.krasovska@nuwm.edu.ua

Abstract. This article is devoted to the study of directions to ensure a sufficient level of economic safety of farms. The multifactorial nature of threats to the external environment and internal factors determining various aspects of economic safety of agricultural enterprises is determined by their wide range and complexity of influence. The high level of risk that results from such influence, on the one hand, makes the activities of such enterprises economically vulnerable but, on the other hand, makes this business attractive. Calculations on the basis of empirical agricultural data confirm that from 40 to 60% of income (depending on location and weather conditions) they can lose from inappropriate groundwater table and not sufficient meliorative state of soils. To substantially reduce this figure and to increase the level of economic safety, it is proposed to optimise the parameters of drainage systems and achieve land reclamation improvement by constructing a water discharge justification model as a key factor for achieving necessary drainage rates. In addition, the use of crop diversification model within justified crop rotations will allow to significantly increase the level of economic safety of farms by optimizing price risks.

1. Introduction
Economic decision-making in today's economy takes place under conditions of risk. This is due to the complexity of market environment, the variety of forms of ownership, areas of activity, quick capital and information transfer. The complexity of factors affecting the business activities highlights the actuality of protecting businesses against possible negative factors affecting them. The detailed consideration of economic safety will theoretically allow the researcher to make practical recommendations to achieve the steady, protected from threats sustainable development.

2. Materials and methods
The study of scientific literature and governmental normative documents shows that in economic theory and practice there is no unambiguous interpretation in determining the essence of economic safety of the enterprise. The concepts of "danger", "threat", "risk" and even "economic safety" itself are not always clearly defined. However, they all differ significantly in content and volume and have different meanings in the system of economic categories.

Indeed, the definition of safety at first indicates ideological foundation for safety theory and only then is implemented in practice. There are many definitions in scientific sources that explore the problems of safety, both the concept of safety itself and the economic safety of enterprises in particular.
Each of these definitions certainly has the right to exist and is, in fact, the most concentrated expression of each author's views on the concept of safety, as well as on protection activities.

The conceptual foundations of the vision of both the category of economic safety and the theoretical and methodological foundations of its assessment are laid in the works of such famous researchers as O Chernyak [1, 2], V Heets [2], T Vasiltiv [3], J Kitching [4]. In the publications of Joseph J. Spengler safety consists in freedom from the incidence of events that tend to produce harm and damage, or at least from the harm and damage [5]. According to V Onyshchenko and O Bondarevska, safety is interpreted as state of economic security based on the analysis of the system of indicators [6]. Y Lysenko interpreted safety as the state of an economic entity, in which the vital components of the structure and activity of the enterprise are characterized by a high degree of protection against undesirable changes [7].

In our opinion, economic safety [8] should be understood as such a state of the socio-technical system of the enterprise that makes it possible to avoid external threats and to counteract internal factors of disorganization with the help of available resources, entrepreneurial abilities of the staff, enterprise departments and management.

The protection of the enterprise system against internal and external threats is ensured by using a system of tools: technical, organizational, informational, financial, legal and managerial.

In general, it can be noted that entrepreneurial activity itself implies a certain level of risk and uncertainty. Moreover, some studies point to the relationship between the level of risk and the level of profitability of the enterprise. If the economic effect is the result of economic activity, expressed in cost indicators, then in the same indicators we should try to assess the risk. Then the basic principles of calculation of economic effect also concern and economic assessment of risks: consideration of the factor of time; consideration of threats during life cycle; use of the system approach in calculations; optimization of alternative decisions; maintenance of a multivariative decision-making both technical as well as organizational.

3. Theoretical framework

Risk theory has developed a classic algorithm for risk assessment, which varies depending on the number of steps and their complexity [2, 6, 9, 10, 11]. Generalizing these approaches, we can identify the following sequence of steps in the process of risk assessment: 1 – maximum possible consideration of all factors affecting the occurrence of risk; 2 – determination of the probability of risk for each factor; 3 – determination of possible losses (financial, material, labor, moral) due to each of the factors; 4 – calculation of risk level.

In this regard, we can formulate the following basic requirements to the methodology of risk assessment: clear definition of the areas of risk manifestation, specification of the limits of risk research; establishment (selection) of risk indicators in order to prevent inconsistency of calculation results; application of special and general risk assessment methods taking into account the specific nature of risk, including probability theory; alternative approach to identifying favorable and adverse effects of risk events; consistency in risk assessment, movement from local assessments to integrative ones. However, it is advisable to use mathematical modelling techniques to ensure the selection and justification of a decision with an optimal level of risk [6, 12]. The purpose of such modelling is to select such design parameters or solutions that require compliance with the four basic principles of optimality: 1) under the specific conditions of decision-making, the results of activity should be achieved at the lowest cost; 2) specific tactical decisions should be selected and taken within an optimal time frame; 3) the qualitative aspect of decision implementation should be considered; 4) combined with the above mentioned elements, the maximum probability of achieving the goal under these specific conditions should be maximized. In general terms, methodological approaches to model building provide for selection of such system parameters, at which enterprise activity would give maximum expected effect and at the same time the level of economic risk would be minimal [12].
If we assume that $x_1, x_2, ..., x_n$ are quantitative parameters describing a set of key factors for the safe operation of the enterprise (established through analytical methods), then the model will have the following form:

$$
D = f(x_1, x_2, ..., x_n) \to \text{max}
$$

$$
v_1x_1 + v_2x_2 + \cdots + v_nx_n \leq z
$$

$$
x_1 \geq 0, x_2 \geq 0, ..., x_n \geq 0
$$

The optimal solution can be obtained either by applying Lagrange multipliers:

$$
\frac{\partial y}{\partial x_1} = 0, \frac{\partial y}{\partial x_2} = 0, \ldots, \frac{\partial y}{\partial x_n} = 0
$$

Risk will be calculated on the basis of the inability to achieve optimal parameters due to a number of external factors (e.g. inability to set an optimal price for a product due to an unfavorable market situation):

$$
R = g(x_1 - X_1, x_2 - X_2, ..., x_n - X_n, p_1, p_2, ..., p_n) \to \text{min}
$$

where $X_1, X_2, ..., X_n$ – limiting values of the model parameters due to the influence of external factors are set with the help of analytical methods and methods of cost-effectiveness), $p_1, p_2, ..., p_n$ - probabilities of deviations of the accepted values of parameters from the limits (set either with a combination of decision tree methods and statistical methods, or with the help of heuristic methods).

In the context of risk assessment and modelling in the area of agricultural environmental management, the same principles and methodological approaches should be followed. Specific here is the significant influence of weather and environmental factors on the level of system safety [13, 14]. The situation is more complicated for those objects, where in the process of nature management the transformation of natural processes took place by means of artificial intervention in the natural environment (first of all, land reclamation). Under modern conditions, as a result of various types of land reclamation for agricultural production, the effect of weather factors is not manifested in pure form, but only through the mechanism of response of the artificially transformed resources set to the action of these factors. This has formed a complex of economic and ecological risks in this sector of activity, extremely affecting the level of economic safety of such facilities [15, 16, 17, 18]. However, the above methodology makes it possible to assess the key factors that affect the level of economic safety and to build an optimization model of decision-making for managing these factors. In particular, the studies carried out on the basis of the data of meteorological station in Sarny in the region of Rivne (Ukraine) and statistical data of individual farms provide an opportunity to illustrate the application of these methodological approaches [12]. Agricultural enterprises carrying out agrarian nature management in conditions of drainage were chosen as objects of research. The whole complex set of economic and ecological risks was decomposed into components and the following were identified as the key factors (which can be optimized by means of economic decisions): unsatisfactory soil water-air regime, deterioration of land reclamation state and costs from unfavorable market conditions.

4. Results

Table 1 presents the calculations of the specified risk parameters for two agricultural enterprises, which are representatives of different natural zones – called Polissya-zone and forest-steppe-zone. A comparative characteristic of economic-ecological risk for farms, shows that this indicator is lower for the object-representative of the forest-steppe zone - 48.3%, than for the object-representative of the Polissya zone - 68.2%), which is explained by better natural-climatic conditions. This has a significant impact on production costs and significantly reduces the level of economic risk. However, factors related to the negative meliorative condition of the drained lands also have a considerable impact (41.5% and 43.2%, respectively).
Table 1. Comparative characteristics of farms in different natural-climatic zones in terms of economic and ecological risk.

| Risk factor                                      | Relative risk, % |
|--------------------------------------------------|------------------|
|                                                  | Polissya zone    | Forest-steppe zone |
| Insufficient lowering of the groundwater table (GWL) in spring | 3,5              | 0,4               |
| Insufficient lowering of GWL in summer           | 6,3              | 4,3               |
| Excessive reduction of GWL in spring             | 3,9              | 4,4               |
| Excessive reduction of GWL in summer             | 3,9              | 2,1               |
| Deterioration of the ameliorative condition of soils | 43,2             | 41,5             |
| Market (price) factors                           | 16,4             | 1,1               |
| Economic and ecological risk total               | 68,2             | 48,3             |

The specified risk indicator can be significantly reduced, thereby increasing the level of economic safety of the subject: first, through reconstruction of drainage systems, reclamation improvement of drained lands and influencing the consequences of the weather risk component, which requires using optimization modeling when choosing new parameters of such systems; second, through applying the optimization model for diversification of price risks.

Within the framework of solution of the first aspect of increasing the level of economic safety, it is proposed to model such parameters of drainage system under which agricultural land use within its limits and zone of active impact would give maximum expected effect and at the same time the level of economic and ecological risk would be minimal.

At the first stage of modeling, using statistical material, a curve of pre-seeding runoff distribution is constructed for the drainage area for a number of years. In doing so, in the case of multi-year observation data, one can apply the central limit theorem, which says that "the probability distribution law of a random variable $\xi$ will be close to normal and with an unlimited increase of n ($\xi_1, \xi_2, \ldots, \xi_n$) will indefinitely approximate to normal. Having a normal distribution of the quantity $Q$, we can determine the probability of $Q$ falling into the interval $Q_p' \leq Q \leq Q_p$ by the Laplace function (p1) (equations 6-8):

$$F(Q) = \frac{1}{\sqrt{2\pi}} \int e^{-\frac{z^2}{2}} dZ$$

$$Z = \frac{Q-\bar{Q}}{\sigma}$$

$$P(Q_p' \leq Q \leq Q_p) = F(Q_p) - F(Q_p')$$

where $\bar{Q}$ – the average level of the variation series; $F(Q)$ – a function of the variation of pre-sprouting runoff for the drainage area; $Q_p', Q_p$ – the upper and lower limit of runoff, respectively, must be set aside to ensure the conditions for normal crop development; $\sigma$ - standard deviation.

In the same way, the probability of not falling within a given interval can also be determined: $p_2$ ($Q>Q_p$) and $p_3$ ($Q<Q_p$).

If no observational data are available, the analogy method is used or a field study with an appropriate distribution function is carried out.
In the process of modelling, we can distinguish three possible cases of the drainage system operation, each of which will correspond to the probability of occurrence:

- **case one** - our predicted parameter (design water consumption $Q_p$) will be the basis for operation of the drainage system and will ensure achievement of the drainage norm, the probability of this case $p_1$ stands with the design flow probability;

- **case two** - as a result of operation of the system, the parameter $Q_p$ will not ensure full removal of excessive moisture, and the probability of that is $p_2$;

- **case three** - as a result of system operation based on $Q_p$ parameter there is land desiccation with probability $p_3$. From the above, we can see that the second and third cases are risky.

The aim of the optimization is to justify $Q_p$ in such a way as to maximize the expected effect of agrarian nature management on the drained lands. Since, according to the conditions of the model, it directly depends on their reclamation condition, at the same time the economic and ecological risk is minimized.

Thus, the function of net income from the area $S$ will have the following form (formula 9):

$$
D = \begin{cases} 
Y_1 \cdot d \cdot \frac{Q}{q_p} + Y_3 \cdot d \cdot \left( \frac{Q_p}{q_p} - \frac{Q}{q_p} \right) + g(Q) \cdot \left( S - \frac{Q_p}{q_p} \right) , & Q_p \leq Q_p , \quad p_1 \\
Y_2 \cdot d \cdot \frac{Q_p}{q_p} + g(Q) \cdot \left( S - \frac{Q_p}{q_p} \right) , & Q > Q_p , \quad p_2 \\
Y_3 \cdot d \cdot \frac{Q_p}{q_p} + g(Q) \cdot \left( S - \frac{Q_p}{q_p} \right) , & Q < Q'_p , \quad p_3 
\end{cases}
$$

where $\frac{Q}{q_p}$ – the area of drained land on which the projected drainage rate has been achieved, ha;

$\frac{Q_p}{q_p}$ – the area of drained land, total, ha; $\left( \frac{Q_p}{q_p} - \frac{Q}{q_p} \right)$ – is the area of partially over-drained land, ha;

$\left( S - \frac{Q_p}{q_p} \right)$ – the area of the active drainage impact zone, ha; $g(Q)$ – the net income from 1 ha of the active impact area (depending on the direction of use and the level of groundwater drawdown).

Thus, the average annual net income per area $S$ will be determined as follows

$$
M_Q(D) = \left[ Y_1 \cdot c \cdot \frac{Q}{q_p} + Y_3 \cdot c \cdot \left( \frac{Q_p}{q_p} - \frac{Q}{q_p} \right) + g(Q) \cdot \left( S - \frac{Q_p}{q_p} \right) \right] \cdot p_1 +
+ \left[ Y_2 \cdot c \cdot \frac{Q_p}{q_p} + g(Q) \cdot \left( S - \frac{Q_p}{q_p} \right) \right] \cdot p_2 +
+ \left[ Y_3 \cdot c \cdot \frac{Q_p}{q_p} + g(Q) \cdot \left( S - \frac{Q_p}{q_p} \right) \right] \cdot p_3 \rightarrow \text{max} 
$$

The optimal solution $Q_p$ for maximizing $M_Q(E)$ can be obtained either by applying Lagrange multipliers or graphically. The resulting parameters will be the design water flow of the system and the probability that the actual flow will not exceed this figure. Using the same model, it is not difficult to calculate the possible losses (economic and ecological risk $R$) in case of such exceedance (or reduction) (formulae 11 and 12):

$$
R_1 = \left[ Y_1 \cdot d \cdot \frac{Q}{q_p} + Y_3 \cdot d \cdot \left( \frac{Q_p}{q_p} - \frac{Q}{q_p} \right) + g(Q) \cdot \left( S - \frac{Q_p}{q_p} \right) \right] - \left[ Y_2 \cdot d \cdot \frac{Q_p}{q_p} + g(Q) \cdot \left( S - \frac{Q_p}{q_p} \right) \right] 
$$

$$
R_2 = \left[ Y_1 \cdot d \cdot \frac{Q}{q_p} + Y_3 \cdot d \cdot \left( \frac{Q_p}{q_p} - \frac{Q}{q_p} \right) + g(Q) \cdot \left( S - \frac{Q_p}{q_p} \right) \right] - \left[ Y_3 \cdot d \cdot \frac{Q_p}{q_p} + g(Q) \cdot \left( S - \frac{Q_p}{q_p} \right) \right]
$$
If condition of model (10) is achieved, these indicators are minimized, and consequently the reconstruction project provides reduction of economic-ecological risk level and improvement of land reclamation state. The given model was used for substantiation of the best variant of carrying out the reconstruction of drainage system in conditions of Polissya. The Pechalivka drainage system in Kostopil district of region Rivne was chosen as a representative object. The modeling is based on long-term hydrological observation data from the Zulnia river, which is a water recipient of the system (based to governmental data) [12, p. 151-162]. According to the modelling results, the optimal design of a simple drainage system according to the criteria of maximum income and minimum risk is to design on the basis of a 50% flow assurance; for designing a system with mechanical water supply (according to the same criteria) - to design for the very water assurance - 1%, when calculating the model with consideration of efficiency of capital investments reconstruction - the optimal variant of designing parameters of polder system is recommended to focus on 5% of flow assurance.

Under the conditions of this study, in order to improve economic safety of agricultural enterprises, a model of diversification of cultivation of several crops in a scientifically grounded crop rotation, whose yields depend differently on the influence of weather and environmental factors and whose prices have different phases of fluctuations, is proposed. Let us introduce the variables: \(X_1, X_2, ..., X_n\) are the areas devoted to growing the first, second, etc. crops respectively, \(h_1, h_2, ..., h_n\) are the shares of corresponding areas in the total \(h_1 + h_2 + ... + h_n = 1\). Using statistical data on the yield of each of these crops on the lands being drained, statistical series are constructed. Using these data, the average long-term yield of \(\bar{Y}_1, \bar{Y}_2, ..., \bar{Y}_n\) and the average yield deviation: \(\sigma_1, \sigma_2, ..., \sigma_n\) for each crop are determined.

Costs per hectare of crops are calculated for individual crops \(bt_1, bt_2, ..., bt_n\).

An important indicator for the model is product prices: \(P_1, P_2, ..., P_n\). To consider the risk of price fluctuations, these values are also determined using statistical methods, namely by first constructing a trend series for each of the selected crops. Then a trend is constructed for the price series for each crop, depending on the nature of the changes, and a forecast value of the corresponding price for each crop is determined: \(\hat{P}_{t+1} = f(t + 1)\). From this we get a series: \(\hat{P}_1, \hat{P}_2, ..., \hat{P}_n\). In addition, we calculate the standard deviation of the price fluctuations: \(\sigma_1^p, \sigma_2^p, ..., \sigma_n^p\).

This model does not take into account the risk of fluctuating product costs, as the composition of costs for all crops is almost identical. Only their distribution changes slightly. This means that crop diversification will have almost no effect on the risk of fluctuating costs.

In order to ensure that this diversification model is implemented, a risk efficiency indicator should be introduced, which is defined as the ratio of expected income to the amount of risk:

\[
D(X) = D/(\sigma_{port} \cdot \sigma_{port}^{m}), \text{UAH/UAH} \quad (13)
\]

The expected income will be:

\[
D = (\bar{Y}_1 \cdot X_1 \cdot \hat{P}_1 - bt_1 \cdot X_1) + (\bar{Y}_2 \cdot X_2 \cdot \hat{P}_2 - bt_2 \cdot X_2) + \cdots + (\bar{Y}_n \cdot X_n \cdot \hat{P}_n - bt_n \cdot X_n) \quad (14)
\]

Portfolio risk of yield fluctuations:

\[
\sigma_{port} = \sqrt{\sum_{i=1}^{n} \sigma_i^2 \cdot X_i^2 + n \cdot R \cdot \prod_{i=1}^{n} \sigma_i \cdot \prod_{i=1}^{n} X_i}, \text{center} \quad (15)
\]

Portfolio risk of prices fluctuations:

\[
\sigma_{port}^u = \sqrt{\sum_{i=1}^{n} \sigma_i^{u2} \cdot h_i^2 + n \cdot R^u \cdot \prod_{i=1}^{n} \sigma_i^{u} \cdot \prod_{i=1}^{n} h_i}, \text{UAH/center} \quad (16)
\]

The diversification model takes the following form. Target function:
D(x) = \left( \overline{y}_1*+\overline{x}_1*+\overline{p}_1-\overline{b}_1*+\overline{x}_1* \right) + \left( \overline{y}_2*+\overline{x}_2*+\overline{p}_2-\overline{b}_2*+\overline{x}_2* \right) + \cdots + \left( \overline{y}_n*+\overline{x}_n*+\overline{p}_n-\overline{b}_n*+\overline{x}_n* \right) \\
\sum_{i=1}^{n} \sigma_i^2 x_i^2 + n \sum_{i=1}^{n} \sigma_i \Pi_{i=1}^{n} x_i = \sum_{i=1}^{n} \sigma_i^2 h_i^2 + n \sum_{i=1}^{n} \sigma_i \Pi_{i=1}^{n} h_i \\
\rightarrow \max \quad (17)

\begin{align*}
\text{Limitations:} \\
bt * X_1 + bt2 * X_2 + \cdots + bxn * Xn \leq B_{\text{max}}; \\
X_1 + X_2 + \cdots + Xn = S; \\
X_1 \geq 0, X_2 \geq 0, \ldots, Xn \geq 0
\end{align*} \quad (18)

As a result, the enterprise will have an allocation of areas between different crops that maximizes profitability while minimizing risk, i.e. the main objective of diversification will be achieved.

5. Conclusions
Given that the main parameters of economic safety are the expected effectiveness of the system and the level of risk associated with its operation, the application of the above approaches can significantly improve it in the enterprise. In particular, the use of a model for optimizing the parameters of the reclamation system can reduce the risk of crop losses several times due to the unfavorable reclamation condition of soils. The proposed model of diversification will reduce the level of dependence of agricultural enterprises on the risk of price fluctuations. In doing so, the above approaches are the scientific basis for the choice of risk handling method: risk retention, risk transfer or risk prevention.

References
[1] Chernyak O and Zaharchenko P 2016 Actual Problems of Forecasting of Complex Social-Economic Systems Behavior (Berdyansk: Publisher Tkachuk OV) p 512
[2] Heets V M, Klebanova T S, Chernyak O I, Ivanov V V., Dubrovina N A and Stavytskyy A V 2008 Models and Methods of Social and Economic Forecasting (Kharkiv: VD "Inzhek") p 396
[3] Vasylytsiv T and Voloshyn, V. 2007 Economic security of entrepreneurship in the conditions of European integration of Ukraine Problems of developing foreign economic ties and attracting foreign investment: regional aspect 1639-1644
[4] Kitching J, Blackburn R, Smallbone D and Dixon S 2009 Business Strategies and Performance during Difficult Economic Conditions. (London, U.K.: Department for Business Innovation and Skills) p 77
[5] Spengler, Joseph J 1968 The Economics of Safety Law and Contemporary Problems 33, 619-638
[6] Onyshchenko V and Bondarevskva, O 2018 Principles of assessing the economic security of the region Baltic Journal of Economic Studies 4(3) 189-197
[7] Lysenko Y G 2002 Mechanisms of economic safety management (Donetsk, DonNU) p 178
[8] Goncharov S, Kuznietsova T and Lesniak O 2012 Basics of economic safety (Kyiv: Kondor) p 216
[9] Bakr A F, El Hagla K, Nayer A and Rawash A 2012 Heuristic approach for risk assessment modelling: EPCCM application (Engineer Procure Construct Contract Management) Alexandria Engineering Journal (51) 305–323
[10] Fekete A 2012 Safety and security target levels: Opportunities and challenges for risk management and risk communication International Journal of Disaster Risk Reduction. (2) 67–76
[11] Moore P 1983 The business of risk (Cambridge University Press) p 375
[12] Krasovska Y and Kostrichenko V 2011 Assessing the economic and ecological risks of using drained land (Rivne: NUWEE) p 254
[13] Kovshun N, Savina N, Diallo M, Kushnir N, Zhiwei D and ZoshchukV. 2021 Principles of creating a system of sustainable water use in Ukraine. E3S Web of Conferences 280 10007 https://doi.org/10.1051/e3sconf/202128010007
[14] Mikhno I, Koval V, Shvets G, Garmatiuk O and Tamošiūnienė R. 2021 Green economy in sustainable development and improvement of resource efficiency. Cent. Eu. R. Bus. Rev. 10(1) 99–113

[15] Koval V, Kovshun N, Plekhanova O, Kvitka S and Haran, O 2019. The role of interactive marketing in agricultural investment attraction. SGEM2019 19(5.3) 877-884

[16] Kvasha S, Pankratova L, Koval V and Tamošićiūnienė R 2019 Illicit financial flows in export operations with agricultural products. Intel. Econ. 13(2) 195-209

[17] Belinska Y, Matvejciuk L, Shmygo, N, Pulina T. and Antoniuk D 2021 EU agricultural policy and its role in smoothing the sustainable development of the EU’s agricultural areas. IOP Conf. S.: Ear. and Envir. Sci. 628(1) 012030

[18] Nazarova K, Mysiuk V, Gordopolov V, Koval V, Danilevičienė I. 2020. Preventional audit: Implementation of sox control to prevent fraud. Verslas Teor. Prakt. 21(1) 293-301. https://doi.org/10.3846/btp.2020.11647