Petro Hrytsiuk
Dr. of Economics, Associate Professor, Professor of the Cybernetics Department, National University of Water and Environmental Engineering, Rivne
Tetiana Babych
Senior Lecturer of the Cybernetics Department, National University of Water and Environmental Engineering, Rivne

OPTIMIZATION OF CROP INDUSTRY STRUCTURE IN UKRANE TAKING INTO ACCOUNT RISKS

Abstract: The subject of this research is the optimization of crops and vegetables growing structure in Ukraine, taking into account the accompanying risks. Increasing the efficiency of production can be achieved by redistributing existing areas under crops. The paper considers Markowitz's optimal portfolio theory application to agro-production. The formulation of the problem finding the minimum risk with the established value of the crop production profitability, as well as the task of finding the maximum profitability at a limited level of risk is made. An effective set of agricultural crops sown area optimal portfolio of Ukraine has been formed. The maximal possible level of profitability and the minimum possible risk of the crop branch are determined. The technique of taking into account the combined effect of economic and weather-climatic risks on the crop production is developed. It has been shown that the main contribution to the overall crop risk is an economic risk.
Key words: crop production, profitability, risk, portfolio of agricultural crops.

Introduction. Crop production is the main branch of the Ukrainian agro-industrial complex. Grain and legumes occupy a special place in this field. In recent years, Ukraine has joined the main group of global exporters of grain. Export of grain in 2016 - 2017 marketing year brought to the treasury 6.1 billion USA dollars [1]. A steady increase in demand for grain crops there has been in the recent years. According to forecasts [2], the annual world demand for such crops as wheat, corn

and rice will amount to about 3.3 billion tons by 2050, which is 800 million tons more than the total harvest in 2014.

This opens up new opportunities and sets new challenges for Ukrainian agribusiness. The share of grain crops in 2016 amounted to 34% of the agrarian products gross output. The share of other most important crops in Ukraine is as follows: technical crops (27%), potatoes (7%) and vegetable crops (5%) [3].

The subject of this research is the Ukrainian crop production structure optimization, taking into account the accompanying risks. Land resources are limited. Therefore, increasing the efficiency of production can be achieved by redistributing existing areas under crops. Such redistribution should be well grounded by optimizing economic and mathematical modeling.

The research methodology in this paper relies on the classical theory of Markowitz portfolio. The subject of optimization in the classical financial portfolio theory is the redistribution of financial assets. The subject of agrarian portfolio optimization is the redistribution of areas allocated for different crops. Thus, using economic and mathematical modeling for optimizing the distribution of resources and proportions between crop sectors or crop species can become a tool for improving the agrarian production efficiency.

1. Analysis of recent research and publications. Von Neumann, Danzig, Glushkov, Nemchinov, Orlov and others devoted their works to the application of optimal planning methods at enterprises of various industries. Odintsov [4], Germanyuk [5], Dankevich [6], Tkachuk [7] devoted their research to problems of diversification in the agro-industrial complex.

Vitlinsky, Hrytsiuk [8] - [9], Zaburanna [10] studied the role of factors affecting the increase in profitability, as well as the mathematical modeling of grain production efficiency. The research on the dynamics of the main factors of grain production and its accompanying risks remains relevant due to the diversity of natural and climatic conditions in various regions of Ukraine, changes in economic conditions of production and climate change, which have been particularly intense in recent years.

This work is devoted to modeling crop production economic efficiency in Ukraine. The aim of the study is the optimization of the crops area structure of Ukraine's main crops, taking into account the accompanying risks.

2. Diversification as a tool to reduce financial and agrarian risks. The most important tool for risk reduction is diversification. For the first time, the method of diversification was used in the field of finance through the distribution of invested and borrowed cash capital between different investment objects in order to reduce the risk of potential capital loss or income from it [11] - [12, p.161].

In practice, diversification is most often realized through the creation of a financial assets portfolio. The main indicators of the financial portfolio quality are its expected return and risk. Among the main conceptual approaches to the portfolio formation are considered Markowitz, Sharp methods and the method of "quasi-Sharp" [13] - [15]. However, the principle of diversification can be extended to other sectors of the economy. The importance of diversification in agro-industrial sector is described in works [4] - [7], [16].

The main elements of the financial market are financial assets. When an investor decides to purchase an asset, he must be sure that, after a certain period of time, the market price will be greater than it is now. Therefore, it is necessary to have a certain mathematical apparatus to predict the future behavior of the financial asset market price [11]. Most often an investor is interested not in the future price of a financial asset, but in the expected change in prices for the future period of time (t, t + 1), or only in the price change expected direction.

The configuration of the financial system changes every minute due to changes in price, demand, supply. The configuration of the crop system is determined once a year - after the harvest and its realization. The main elements of the crop system are the area under crops with one or another crop.

The main criterion for the agrarian production economic efficiency is profit P derived from one hectare of crop, or the crop production profitability R, which reflects the ratio of profits to incurred costs. These values are linked by a relationship:

$$P = (R+1) \cdot Z, \tag{1}$$

where Z - financial costs per 1 hectare of cultivated crop. The expression for the profitability of crop production has the form

$$R = P / Z - 1 = Y \cdot C / Z - 1. \quad (2)$$

Here P - the income (UAH / ha), Y - yield (c / ha), Z - expenses (UAH / ha), C - price of crop (UAH / c) [8].

3. Optimization of the crop sector structure. Main agricultural crops in Ukraine are potatoes, sugar beets, cereals, legumes and vegetables.

Let's put the task of optimizing the Ukrainian crop production structure taking into account the accompanying production risks by changing the areas under cultivated crops structure. Let us denote:

$S_i; i = 1..k$ - area under *i*-th crop (*k* - number of crops);

$S_0 = \sum_{i=1}^{k} S_i$ - the sum of all areas under crops;

$w_i = S_i / S_0; i = 1..k$ - share of the area S_i under *i*-th crop in relation to the total area under crops S_0;

$r_i; i = 1..k$ - profitability of the *i*-th crop.

The aggregate of all areas under crops can be considered as a portfolio that is characterized by its profitability. To optimize the portfolio, we will use average crop profitability $r_1, r_2, \ldots, r_k$ and a correlation matrix Σ based on the agricultural crops profitability time series

$$\mathbf{\Sigma} = \begin{pmatrix} \sigma_1^2 & \rho_{12} & \cdots & \rho_{1k} \\ \rho_{21} & \sigma_2^2 & \cdots & \rho_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ \rho_{k1} & \rho_{k2} & \cdots & \sigma_k^2 \end{pmatrix}. \quad (3)$$

We determine the profitability of a portfolio as a weighted sum of its component (weights) profitability:

$$R_P = \sum_{i=1}^{k} w_i r_i , \quad (4)$$

and portfolio risk by Markowitz methodology:

$$V_P = \sqrt{\sum_{i=1}^{k} \sum_{j=1}^{k} \left(w_i \times \sigma_i \times w_j \times \sigma_j \times \rho_{ij} \right)} . \quad (5)$$

Markowitz model of the optimization of the portfolio of financial assets is based on the following assumptions [17] - [18]:

- the return of securities (profitability of crops) is distributed according to the normal law;
- historical data used in the calculation of profitability and risk fully reflect future values of return.

By optimizing the areas under crops portfolio, we assumed that the value of production profitability was distributed according to the normal distribution law. There are two possible approaches to solving the problem of optimizing portfolio investments. The first approach (the direct task of Markowitz) aims to maximize the crops portfolio profitability for some given risk limitation. In order to increase the overall crop production profitability, it is possible to change the size of the area under each crop in accordance with its profitability and market needs. The mathematical model of the first optimization problem (task at maximum profitability) will have the form:

$$\begin{cases} R_P = \sum_{i=1}^{k} w_i \times r_i \to \max; \\ V_P = \sqrt{\sum_{i=1}^{k}\sum_{j=1}^{k}\left(w_i \times \sigma_i \times w_j \times \sigma_j \times \rho_{ij}\right)} \le V_0; \\ \sum_{i=1}^{k} w_i = 1; \quad w_i \ge 0; i = 1...k. \end{cases} \tag{6}$$

Here R_P - the total profitability of crop production in Ukraine (in terms of crops we have taken into account), w_i - relative share of i-th crop in the portfolio of land (weight of i-th asset), r_i - profitability of production i-th crop (average profitability according to data of 2008-2016), σ_i - the i-th risk asset calculated as its standard deviation for the period under research, V_0 - the maximum permissible value of risk, ρ_{ij} - the coefficient of linear correlation between two types of assets (time series of crop profitability). The first ratio of system (6) describes the target function, which involves maximizing the overall crop production profitability in the region by redeveloping the area under crops structure. The second ratio sets the permissible

level of risk. The third and fourth ratios describe the conditions of the areas n and the nonnegativity of the total area.

Since the crop production is an important component of the country's population food supply, the area under crops cannot be reduced below a certain minimum. In order to prevent abrupt changes in area under crop we added restriction to the model (6) of the following form

$$0.9w_{i0} \le w_i \le 1.1w_{i0}; i = 1..k. \quad (7)$$

Here w_{i0} - the current value of the area under i-th crop share prior to the start of optimization. Current values of area under crops were determined by averaging according to the data for 2011-2015.

The second approach (the return task of Markowitz) is to minimize risk while maintaining a certain guaranteed level of portfolio profitability. The mathematical description of the Markowitz model for a minimum risk problem will look like:

$$\begin{cases} V_P = \sqrt{\sum_{i=1}^{k}\sum_{j=1}^{k}\left(w_i \times \sigma_i \times w_j \times \sigma_j \times \rho_{ij}\right)} \to \min; \\ R_P = \sum_{i=1}^{k} w_i \times r_i \ge R_0; \\ 0.9w_{i0} \le w_i \le 1.1w_{i0}; i = 1..k; \\ \sum_{i=1}^{k} w_i = 1; \quad w_i \ge 0; i = 1..k. \end{cases} \quad (8)$$

The first ratio of system (8) describes the condition that the risk of crop production during re-planning of the area should be minimal. The second ratio provides the lowest acceptable margin of the portfolio profitability, established expert way. The third, fourth and fifth ratios establish boundaries for permissible changes in area under crops.

Tasks (6) and (8) are mutually dual, so it enough to restrict solving the problem (6). Let’s solve problems (6) and (8) with nonlinear programming methods. To solve the problem of optimizing the areas under crops structure, we used the statistical data of the four main crops in Ukraine profitability for the period 2008 - 2016 (Table 1).

The calculations performed on the relations (5) - (6) showed that under the existing distribution of sown areas between crops in Ukraine, the overall level of crop

production risk is $V_0 = 5{,}48\%$, and the overall level of profitability of crop production is $r_0 = 20{,}19\%$ (Table 2). The solution of the problem (6) - (7) for the maximum profitability at the existing level of risk allowed to get the maximum value of the total profitability level $r_0 = 20{,}2\%$, as well as the recommended (optimal) values of the area under the crops (4th and 5th columns of Table 2). In order to increase the crop production profitability in Ukraine on $\Delta r = 0{,}01\%$, it is necessary to reduce the sown area for cereals and potatoes and increase it for the rest of the crops.

Table 1 Profitability of crops and vegetables production in Ukraine in 2000-2016 (%)

Year	Cereals	Sugar beets	Potatoes	Vegetables in the open
2000	64,8	6,1	14	-1,7
2001	43,3	1,5	11,4	-0,8
2002	19,3	-8,6	24,2	8,9
2003	45,8	6,2	33,5	30,9
2004	20,1	-0,8	-0,7	-5
2005	3,1	4,8	17,8	16,1
2006	7,4	11,1	56,2	14,8
2007	28,7	-11,1	24,7	14,1
2008	16,4	7,1	7,9	11,1
2009	7,3	37	12,9	19,1
2010	13,9	16,7	62,1	23,5
2011	26,1	36,5	17,7	9,9
2012	15,2	15,7	-21,5	-6,8
2013	1,5	2,7	23	7
2014	25,8	17,9	9,2	16,7
2015	43,1	28,2	24,2	47,5
2016	37,8	24,3	-3,2	19,7
Average profitability for 2008-2016 (r_i)	20,8	20,7	14,7	16,4
Risk (σ_i)	6,24	10,68	13,63	8,68

Source: by data [19]

Another approach (dual problem (8)) is to minimize the risk of crop production when the previously achieved level of profitability is maintained. Results of solving the problem (8) are given in the last two columns of Table 2.

Table 2 Optimization of agricultural crops areas portfolio for Ukraine

Crop	Real structure of areas under crops		Maximum profitability with preserving risk level		Minimum risk with preserving profitability level	
	Share	Area under crops, thousands of ha	Share	Area under crops, thousands of ha	Share	Area under crops, thousands of ha
Cereals	0,876	15014,2	0,873	14969,91	0,875	15008,46
Sugar beets	0,019	319,8	0,021	351,78	0,021	351,78
Potatoes	0,079	1351,86	0,077	1318,27	0,075	1279,72
Vegetables in the open	0,027	459	0,029	504,90	0,029	504,90
Total area	1	17144,86	1	17144,86	1	17144,86
Profitability, %	20,19		20,20		20,19	
Risk, %	5,48		5,48		5,47	

Source: calculated by authors by data [19]

Calculations show that it is possible to reduce the level of risk $V_0 = 5{,}47\%$ with maintaining the level of profitability $r_0 = 20{,}19\%$. To do this, it is necessary to reduce the area under grain crops and potatoes, while increasing it under other crops. Two approaches considered by us to optimization are illustrated in Fig. 1 (dash lines).

Other options for setting the task of optimizing the portfolio of areas under crops are also possible. For example, it is possible to solve the problem (8) without imposing restrictions on the level of profitability. As a result of solving this problem, we will receive a portfolio with a minimum risk level and a minimum overall profitability (Table 3, Column 2-3). Another approach is the structure of the areas under crops portfolio, which is characterized by maximum profitability without limits of risk (this means that we agree on the maximum level of risk). The vital structure of areas under crops is given in columns 4-5 of Table 3.

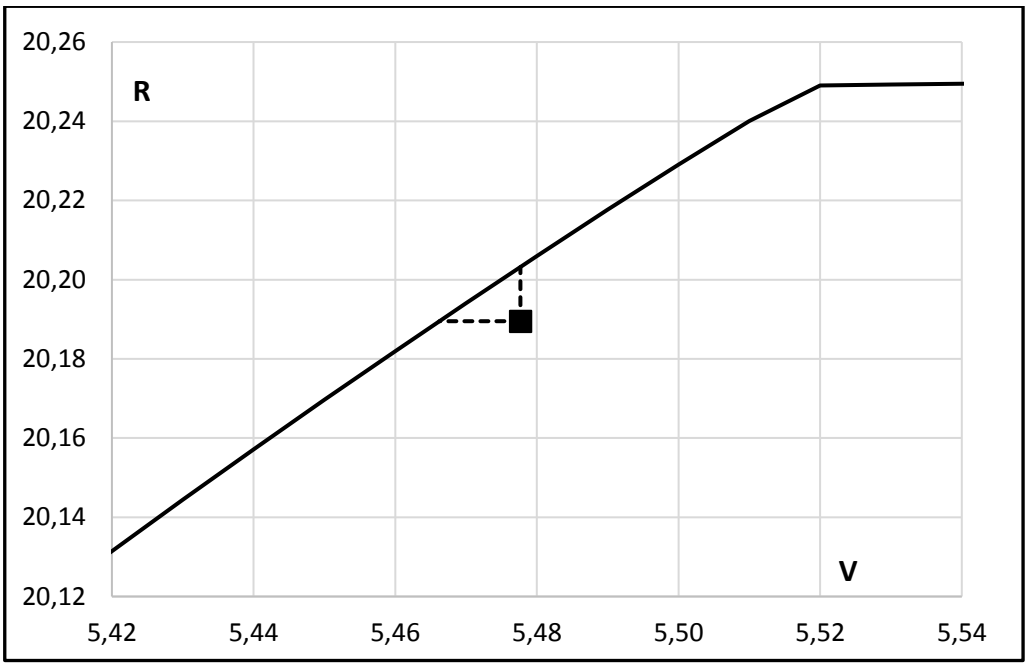

Figure 1 - Efficient set of areas under crops portfolio

Source: calculated by authors by data [19]

By changing the risk value V_0 in task (6) - (7) from the minimum to the maximum value with a certain discrete step and solving the problem at maximum profitability, we obtain a set of portfolios known as an effective set [21]. The image of the areas under crops of Ukraine effective portfolio is shown in Fig. 1. The graphic form confirms the existence of a non-linear direct relationship between the level of sown crop risk and its profitability. The square tag in Fig. 1 corresponds to the current state of crop sector. Dash lines drawn from the point of existence state indicate that the actual level of risk is slightly higher than the optimal one, and the overall profitability can be increased without risk changes.

4. Risks of agrarian production. Crop production is a high-risk branch of economics, since the result of production here is heavily dependent on a complex of constantly changing conditions. The functioning of crop branch is tied to the uncertainty of the external environment state which causes the emergence of various production risks.

First of all, the efficiency of the crop industry depends to a large extent on climatic factors that are not subject to management. Weather-climatic risks are associated with the onset of adverse natural phenomena and weather processes.

Therefore, the correct strategy of agrarian production is to adapt to changing weather conditions in order to maximize economic benefits.

Table 3 Optimization of agricultural crops areas portfolio for Ukraine without restrictions on the level of profitability and risk

Crop	Minimum risk portfolio		Maximum profitability portfolio	
	Share	Area under crops, thousands of ha	Share	Area under crops, thousands of ha
Cereals	0,863	14801,13	0,888	15227,27
Sugar beets	0,021	351,78	0,017	287,82
Potatoes	0,087	1487,05	0,071	1216,67
Vegetables in the open	0,029	504,9	0,024	413,1
Total area	1	17144,86	1	17144,86
Profitability, %	20,13		20,25	
Risk, %	5,42		5,54	

Source: calculated by authors by data [19]

Significant fluctuations in annual volumes of production lead to corresponding price fluctuations, and as a consequence, to the economic instability of the industry. A high harvest in accordance with the price dependence law of the offer causes a reduction in the price of grown produce and profitability of production and vice versa. Fluctuations in the price of produce (profitability) are a source of economic risk in agrarian production.

Production-technological risks may include: lack of seed material; insufficient fertilizers; lack of fuels and lubricants; insufficient number of agricultural machines and devices; non-compliance with agronomic terms. Possible financial and commercial risks include: insolvency of the agricultural commodity producer; credit risk; inflationary risk; currency risk (if the farm exports produce or buys imported materials); competitive risk; risk of underperforming profits; price risk; investment risk; marketing risk, etc. Political and legal risks include: change of legislative norms; changing conditions of support (subsidies, grants, exemptions); restriction of the monopoly price level; limitation of exports, etc.

The classic approach used by Markowitz to measure the risks of financial portfolios is to calculate the variance. However, such an approach involves the normal distribution of financial assets. In addition, the variance describes a two-way risk, that is, the increase in the likelihood of large profits leads to an increase in variance that does not respond to the definition of risk as the expectation of a negative event [11]. The income statistics of financial assets study showed that it has a property of "heavy tails" [20] - [21], [18]. This means that the law of distribution of return differs from normal.

Recently, other measures that are applicable to different laws of distribution and are calculated on the basis of the loss function corresponding quantiles, the so-called quantitative measures of risk. The most common ones are Value-at-Risk (VaR) [22] and conditional VaR (CVaR), which is a generalization of VaR [23], [24].

Our research is based on a traditional approach to assessing the economic risk of agrarian production, which is to calculate the variance of profitability [25]. However, taking into account the above critical remarks on such an approach, it is more appropriate to assess the risk as a semivariation of profitability, that is, taking into account only the negative deviations in profitability from the average. Then, to get an estimate of the annual value of economic risk, we get the expression

$$V_{eij} = \begin{cases} \overline{r_j} - r_{ij}, if\ \overline{r_j} > r_{ij}; \\ 0, \quad if\ \ \overline{r_j} \le r_{ij}. \end{cases} . \tag{9}$$

Here r_{ij} - the meaning of profitability j-th crop in the *i*-th year expressed in percents $\overline{r}_j$ - the average value of profitability j-th crop for a certain time period. The overall economic risk assessment for a particular crop is determined by the expression

$$V_{ej} = \sqrt{\frac{\sum_{i=1}^{n} V_{eij}^2}{n-1}}, \tag{10}$$

where n - duration of the observation period.

To estimate the weather-climatic risk annual value, one can use the share of area under j-th crop loss due to unfavorable conditions during the *i*-th vegetation period

$$V_{kij} = \frac{S_{0ij} - S_{1ij}}{S_{0ij}} * 100\% . \quad (11)$$

Here S_0 - the area under crops, S_1 - the area harvested, i - the year number.

For estimating the total risk, which takes into account both weather-climatic and economic components, it is necessary to use a ratio that takes into account the correlation between two types of risks

$$V = \sqrt{V_k^2 + V_e^2 + 2V_k V_e \rho_{ke}} . \quad (12)$$

From expression (12) it follows that different risks can increase the effect of each other in the case of the same direction, or weaken the action of each other in the case of different orientations. There are reasons to believe that weather-climatic and economic risks will be anti-correlated. Indeed, in the case of the crop part loss due to adverse weather and climatic conditions, the price of the corresponding product increases, which leads to an increase in the production profitability. However, for individual crops, the correlation of risks can be either positive or negative, depending on the comparative effect of the part of the harvest loss and the increase in the purchase price. The significance of production risks for different crops, calculated by us using available statistical data [19] based on the expressions (9) - (12) are given in Table 4.

Table 4 Risks of agricultural crop production in Ukraine (%)

Risks	Cereals	Sugar beets	Potatoes	Vegetables in the open
Weather-climatic	4,91	5,33	0,13	1,13
Economic	6,24	10,68	13,63	8,68
Total	7,09	12,60	13,61	9,18
The coefficient of linear correlation between two types of risks	-0,21	0,14	-0,11	0,39

Source: calculated by authors by data [19]

To estimate the annual risk weights for a several crops portfolio, we used the ratio

$$V = \sum_{j=1}^{k} V_j S_{0j} \Big/ \sum_{j=1}^{k} S_{0j} \,. \qquad (13)$$

The annual weather-climatic and economic risk assessments for agricultural industry in Ukraine, executed by us using the expressions (9) - (12) and the statistical data on sown and harvested areas and the corresponding profitability are presented in Fig.2.

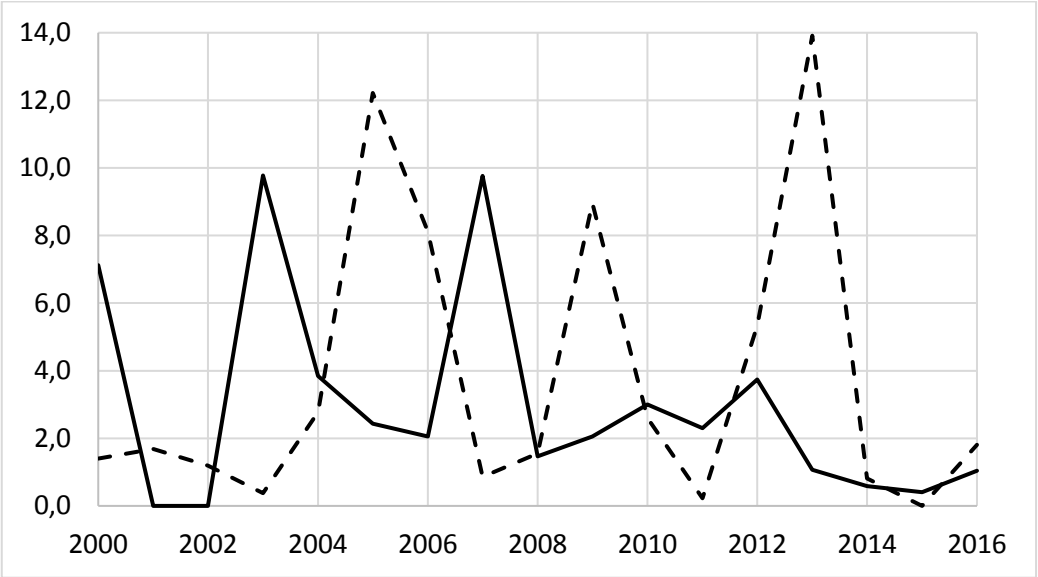

Figure 2 - Assessment (%) of weather-climatic (solid line) and economic risk (dash line) of crops and vegetable branch in Ukraine

Source: created by authors by data [19]

It can be seen from the figure that the main contribution to the overall crop risk is posed by an economic risk. Weather-climatic risk has significantly decreased in recent years, due to the use of new drought-tolerant varieties of seeds and the agrarian production technology improvement. The coefficient of linear correlation between two types of risks of crop growing industry in Ukraine, calculated by us using the expressions (9) - (13) is equal $\rho_{ke} = -0{,}21$.

Similarly, an effective set of portfolios can be built using an assessment of the crops sector overall risk, which includes economic and weather-climatic components. Overall risk assessments were made by us using the expressions (9) - (13). The calculations have shown that the portfolio formula with minimum profitability (minimum risk) and portfolio formula with maximum profitability (maximum risk)

do not differ from those given in Table 3. This can be explained by the fact that the risks of individual crops did not change significantly in the transition from economic risk to general risk (Table 4).

CONCLUSIONS

We propose a methodology for using the optimal portfolio theory to optimize the region's crops branch structure, taking into account the accompanying economic and weather-climatic risk. The levels of the minimum and maximum risks of the crops and vegetables branch of Ukraine are determined. Formed are region's agricultural crops sown area portfolios with the maximum profitability which correspond to different levels of risk (effective portfolios set). Our approaches and the evaluations received can serve as the basis for planning the structure of Ukrainian crops branch, taking into account the accompanying risks. Further research in this direction should take into account possible deviations of the profitability values from the normal distribution law.

BIBLIOGRAFICAL REFERENCES

1. UkrAgroKonsalt. Ukraine. Record grain exports did not bring record currency earnings. [online] http://www.ukragroconsult.com/news/ukraina-rekordnyi-eksport-zerna-ne-prines-rekordnoi-valyutnoi-vyruchki. (access 24 November 2017).

2. Food and Agricultural Organization of the United Nations. [online] http://www.fao.org/publications/save-and-grow/maize-rice-wheat/en/ (access 24 November 2017).

3. AgroPortal. [online] http://agroportal.ua/views/blogs/dobavlennaya-stoimost-v-selskom-khozyaistve-formirovanie-i-raspredelenie/ (access 24 November 2017).

4. Odinczov O. M. Management of Agricultural Production Diversification on the Basis of Economic-Mathematical Modeling / O.M. Odintsov // Scientific

Informational Journal "Business Inform", Kharkiv National Economic University, Ministry of Education and Science of Ukraine. – 2014. – № 7. – P. 113–117.

5. Germanyuk N. V. Theoretical and methodological aspects of diversification in agriculture / N.V. Germanyuk / The Economy of Agro-Industrial Complex. – 2010. – № 8. – P. 25–29.

6. Dankevych V. Ye. Diversification of the activity of high-value agricultural enterprises / V. Ye. Dankevych // Visnyk ZNNU. – 2010. – № 1. – T. 2. Economic sciences. – P.147–155.

7. Tkachuk V. I. Motivational principles of diversification of activities of agrarian enterprises / V.I. Tkachuk // Collection of scientific works of the Taurian state agrotechnological university (economic sciences). – 2013. – № 1 (3). – P. 263-271.

8. Hrytsiuk P.M. Analysis, modeling and forecasting of winter wheat yields dynamics in the regions of Ukraine: monograph. – Rivne : NUWEE, 2010. – 350 p.

9. Hrytsiuk P.M. Optimization of Rivne region crop production structure // The Economy of Agro-Industrial Complex. – 2013, №1 (219). – P. 24-30.

10. Zaburanna L.V. Economic efficiency of grain production and ways of its increase in agricultural enterprises / L. V. Zaburanna // The Economy of Agro-Industrial Complex. – 2014. – № 3. – P. 55-61.

11. Zabolotsky T.M. Modeling of alternative hypotheses in the management of a portfolio of financial assets: dissertation diss. ... Dr. of Econ. Sciences: specialty 00.08.11 / T.M. Zabolotsky – Kyiv : KNEU named after V. Hetman, 2017. – 36 p.

12. Economic encyclopedia / Institute of Economics; Ch. Ed. L. I. Abalkin. – Moscow : Economics, 1999. – 1055 p.

13. Borshhuk I. V. Risk and Return in Portfolio Investments of Commercial Banks / I.V. Borschuk // Finance of Ukraine. – 2002. – № 7. – P. 115–126.

14. Kushh O. O. Methods of management of the bank investment portfolio and their characteristics / O. O. Kushch // Investments: practice and experience.– 2011. – № 10. – P. 12-16.

15. Firsova M. O. Modeling of investment portfolio of Ukrainian companies based on the model of quasi-Sharp / M.O. Firsova // Investments: practice and experience. – 2014. – № 2. – P. 76-78.

16. Zinchuk T. O. Theoretical and methodological principles of diversification of the rural economy in the context of the european experience / T. O. Zinchuk, V. I. Tkachuk // The Economy of Agro-Industrial Complex. – 2011. – № 1. – S. 27–34.

17. Harry Markowitz. Portfolio Selection / The Journal of Finance, Vol. 7, No.1. (Mar., 1952), pp. 77-91.

18. Markowitz H. Foundations of portfolio theory / H. Markowitz // Journal of finance. – 1991. – № 7. – P. 469–477.

19. State Statistics Service of Ukraine [online] http://www.ukrstat.gov.ua/ (access 24 November 2017).

20. Bollerslev T. Modeling the coherence in short-run nominal exchange rates: a multivariate generalized ARCH model / T. Bollerslev // The review of economics and statistics. – 1990. – № 72. – P. 498–505.

21. Fama E. F. Foundations of finance / E. F. Fama. – New York : Basic Books. 1976. – 391 p.

22. Hohlov V. Yu. VaR and the problem of "big tails" in the distribution of profitability / V. Yu. Khokhlov // Risk Management in a Credit Organization. – 2012. – № 2. – P. 35–49.

23. Embrechts P. Modelling extremal events for insurance and finance / P. Embrechts, S. Kluppelberg, T. Mikosch. – Berlin : Springer. 1997. – 655 p.

24. Pflug. G. Ch. Some remarks on the value-at-risk and conditional value-at-risk / G. Ch. Pflug // Probabilistic constrained optimization : methodology and applications / ed. S. Uryasev. – Netherlands : Kluwer. 2000. – P. 272–281.

25. P.M. Hrytsiuk, T.Yu. Babych. Mathematical modelling of grain production profitability in Ukraine taking into account risks. - Int. J. Risk Assessment and Management. – 2017. - Vol. 20, No. 4. – P.307 – 321.