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OPTIMIZING A PORTFOLIO OF AGRI-ENVIRONMENTAL INVESTMENTS

Purpose. *The purpose of the article is to substantiate theoretical-and-methodological provisions for building investment portfolios in agribusiness by the criterion of minimizing environmental risk of selected investment-financing strategies.*

Methodology / approach. *In the article, on the basis of the dialectical method of cognition, the following methods were used: abstract-logical – in the systematization of scientific papers on the problem of diversification and optimization of the agricultural investment portfolio; system analysis and comparison – in the study of portfolio theories and concepts; computational and constructive – in the analysis of environmental-and-economic factors of the profitability of agricultural land use; economic-and-mathematical modeling – in the process of modeling the optimal portfolio of agri-environmental investments by the criterion of minimizing the risk of a particular investor, caused by the action of soil degradation factor in Sumy region. The materials of the Main Department of Statistics in Sumy region and the Sumy regional branch of the Institute of Soil Protection of Ukraine have formed the informational basis of the research.*

Results. *The optimization of the agri-environmental investment portfolio is due to the modification of the approach by the American Economist H. Markowitz "risk-return analysis" and its adaptation to the conditions of real investment. The paper uses a conservative approach to investment, which involves the construction of portfolios on the criterion of minimizing investment risk due to the influence of soil degradation for a particular investor. This factor requires the determination of the investor's environmentally related risk, which manifests itself in the following directions: a) a decrease in crop yield due to the action of the factor of high soil pH; b) a decrease in the sales price for crop products because of contamination with heavy metals; c) an increase in the cost of agricultural production in deteriorated ecological conditions. Evaluation of agribusiness investment attractiveness on environmental-and-economic grounds provides for the consideration of the above areas from the standpoint of state, banking, foreign investment and self-investment. Assessment of investment quality identification is performed on the basis of calculation of the investor's income elasticities to environmental risks on the example of Sumy region, which provides investment rationality decisions in the field of agricultural land use, considering environmental factors. It is substantiated that the highest investment quality is characterized by the bank's investment financing strategy.*

Originality / scientific novelty. *The methodological approach to the definition of investor's environmental risk in agricultural land use is improved. It is calculated considering the influence of factors of environmental destruction of land and soil resources (soil pH, pollution with heavy metals, etc.) on sources of profit, as well as with the definition of returns on investment resources (crop yield, ecological sales price, and income). The system of environmental-and-economic indicators in the formation of the investment portfolio is substantiated, including the following: the*

structure of investments, which is developed considering the influence of the environmental factor; portfolio investment risk due to environmental factors; and the investment portfolio yield adjusted for the level of environmental risk which provides an assessment of the investment attractiveness of agricultural land use on an environmental-economic basis. A methodical approach to substantiate investment decisions in the agriculture of the Sumy region is proposed, which along with considering the environmental factor, is in calculating the elasticities of investor's income to the environmental-and-economic risks, which increase the correctness of financial decision-making.

Practical value / implications. *Theoretical-and-methodological provisions and conclusions obtained in the study can be used to justify the direction of investment capital in the field of agricultural land use, considering the level of environmental-and-economic constraints.*

Key words: *agricultural land use, agri-environmental investments, investment portfolio, return on investments, environmental risk of the investor, payback resource of agro-investments, investment strategies.*

Introduction and review of literature. Environmentally sound agricultural land use requires the attraction of significant investment resources at different levels of management: national, regional and local. Investment activities in the field of agricultural land use should be conducted in accordance with the principles of sustainable development. However, assessments of modern agricultural land use in the context of regions of Ukraine indicate the presence of a high risk of investment in some areas, in particular in the Sumy region [1, p. 53]. The desire of investors to minimize the risks associated with environmental factors (in particular, the non-optimal use of soil, which leads to a shortage of crops, and, consequently, the investor's income) naturally raises the question of the formation of an optimal structure for attracting investments in agricultural land use with ecological-and-economic optimization of their structures. The problem of ecological-and-economic assessment of the quality of investments in agricultural land use has remained on the periphery of scientific research. However, this issue is especially relevant given the fact that according to the consulting companies, under modern conditions of market agro-economic activities, the requirements of individual investors for the quality of investments are significantly increasing. An increase in the investment attractiveness of the agricultural activities should be based on the formation of motivational incentives for raising funds based on determining the environmental-and-economic optimality of investment decisions. The relevance of these issues determines the importance of the topic of scientific research.

Agricultural production is one of the riskiest types of business [2–6] and, therefore, subject to estimation of probable bankruptcy due to specific risks [7]. In work [8], a systematic detailing of agro-economic risks was made and it was indicated that, in general, in the industry there are five types of specific risks that should be subject to economic assessment and minimization, namely, the production [9; 4], market [10], institutional [11], demographic [11; 12], and financial risks [13; 14]. As the comprehensive statistical analysis in work [8] shows, only 2 % of scientific works from the aggregate sample are devoted to the study of financial agro-economic risks. As a rule, the analysis of financial risks is reduced to the study of

problems associated with the search for optimal financing instruments.

However, financing of the agricultural sector should be based primarily on attracting investments and increasing the interest of individual investors in the results of their activities. For this, it is necessary to create attractive, fast-payback and environmentally effective investment projects at the national [15; 6] and international levels [16], including by attracting funds from stock markets [17]. At the same time, agricultural sector generates a rental income, which makes this business attractive for the investors [21; 22].

Increasing the investment attractiveness of the agricultural sector seems possible primarily due to the optimization of the "risk-return" ratio. For the first time such an assessment was conducted by American economist H. Markowitz in relation to securities [18], and then these assessments evolved in the works of W. Sharp et al. [19] and J. Tobin et al. [20].

A number of foreign studies are devoted to the formation of optimal investment portfolios in the agricultural sphere [23–26]. An attempt to optimize the investment portfolio in relation to organic agricultural land use was performed in the work [27]. Based on the use of statistical indicators for assessing the risk of investments (standard deviation), scientists have carried out the optimal distribution of investment resources in the formation of a portfolio of agricultural land use crops. The work [28] is devoted to the consideration of environmental characteristics in the conducting and optimization of operational agricultural activities.

In the domestic scientific literature, the task of optimizing an investment portfolio is reduced primarily to determine its objective criteria. Among the one-criterion methods for optimizing the quality of investments, the most widespread are the approaches of the neoclassical financial school, which operate on the criteria for maximizing income or minimizing risk [29]. Risk management tools are also intensively used for specific markets [30] and rental economies [31].

Thus, the analysis of scientific papers on the indicated topic proved the need to further solve the problem of considering environmental factors and corresponding risks when forming a portfolio of agricultural investments.

The purpose of the article. This article substantiates the theoretical-and-methodological provisions for constructing investment portfolios in agribusiness by the criterion of minimizing environmental risk of selected investment-financing strategies. Achieving this goal involves the analysis of foreign approaches and determining the algorithm for estimating the optimal portfolio of agri-environmental investments for the regional economy.

Results and discussions. First, it should be emphasized that the exceptional importance of agriculture in the national system of food and environmental security requires a balanced investment support for its development on a sustainable competitive basis. Foreign practice shows that in the global ecospace of agricultural development, certain institutional systems of investment support for agricultural entities have been formed (Table 1).

Table 1

Global systems of state investment support for agriculture: the experience of the most successful countries

Country	Type of investment support	Characteristics of investment support
USA	Direct subsidies that are replaced by yield or profit insurance options	Generally, American farmers can choose a marketing support scheme from two main programs: the first one, price loss coverage (PLC), which provides compensation if crop prices fall below predetermined levels; and the second one is agriculture risk coverage (ARC), which provides payments to farmers when incomes fall below the national average. In addition, there are several more options for crop or income insurance. Thus, the federal government can subsidize insurance premiums at rates ranging from 38 % to 80 %, depending on the level of coverage and options chosen by manufacturers. Such a high level of subsidies is necessary in order to make agricultural products affordable
Netherland	Direct subsidies provided to young farmers or for environmental purposes	Having achieved significant positions in the global market, the main priorities in agriculture are now not so much productivity growth but sustainable development, innovation, improved animal welfare, or the use of renewable energy sources. For example, among the subsidies that farmers can receive, there is a program to secure a part of the loan, which the state is ready to undertake. Small or medium-sized entrepreneurs or, for example, young farmers under the age of 39 can apply for this program. The goal of this program is to attract more young entrepreneurs to the agricultural sector. These funds can be invested in construction, land, machinery, or mobile equipment. In addition, the state supports farms where the use of chemicals and pesticides has been abandoned. To ensure the competitiveness of these eco-products, the government, for example, has signed agreements with supermarkets and the Federation of Agricultural and Greenhouse Production to expand the distribution of these products. Another goal in agriculture is to expand the use of biomass as a fuel on farms. Thus, it is planned to replace 30 % of oil products with “green energy” by 2030. Therefore, research in this area is supported
France	Concessional lending and direct subsidies	A developed network of trade unions has a significant impact on the state's agricultural policy, taking care of the working and living conditions of farmers, as well as maintaining the “minimum level of income” even in the event of crop failures or natural disasters. The taxation system is also special: the calculation of the amount of income subject to taxation is based on land cadaster data, average cost of production, production costs, as well as crop yields and livestock productivity. An average of up to 40 billion euros a year is spent on supporting farmers. The mechanism of concessional loans for agriculture is based on the principle of state repayment by the bank of the difference between the contractual interest rate and the rate of the concessional loan granted to the farmer. They can raise funds for the purchase of new agricultural machinery at 3–4 % per annum and for the purchase of land – at about 7 % per annum. In addition to the government, French farmers are also supported by the European Union through the common agricultural policy (CAP): France receives about 17 % of the total budget. On average, one farm receives about 12 thousand euros in subsidies per year
Australia	Compensation for economic losses caused by natural and man-made factors through grants and preferential lending; there is a system of preferential taxation	Government financial support is provided to farmers to compensate for losses caused by natural or human-made factors. Such support can take various forms: grants, short-term loans at low interest rates, and so on. The state also provides tax benefits to farmers to compensate for depreciating agricultural equipment. Finally, to protect the national agricultural sector, the government applies a system of special payments and import duties. Concerning taxation, producers of different types of agricultural products pay taxes at different rates

Continuation of Table 1

Country	Type of investment support	Characteristics of investment support
Canada	State monopoly in the market and the system of provincial and federal programs for investment support of agricultural producers	Specially created state-owned companies regulate the supply of these goods to the market by controlling domestic production and restricting imports through high duties, which can be as high as 200 %. Such a system, on the one hand, allows Canada to avoid direct subsidies to the sector, and on the other hand, it harms consumers, because due to government regulation, prices for the final product in Canada are 30 to 300 % higher than in other countries. Other Canadian agricultural products (grain, pork, veal, etc.) are sold on nearly market terms, although a special credit organization, Farm Credit Canada, was created for farmers. In addition, the country has provincial and federal programs to support agricultural producers including: short-term loans up to 400,000 USD at low interest rates with partial interest coverage; state credit guarantees for the purchase of agricultural land; voluntary mechanism of guaranteed purchase prices; preferential crop insurance against natural disasters and weather conditions; financial support for the promotion of products abroad; emergency financial support during emergencies; subsidizing the transportation of grain through a port in the north of the country
Germany	Indirect ways of financing the industry	State aid is prohibited in the EU under the Treaty on the Functioning of the European Union, as it hinders the free competition in the internal market. But there are some exceptions to this principled prohibition. In particular, possible social assistance to individual consumers, humanitarian aid and grants to farms that have suffered losses since the restoration of Germany
Poland	Concessional lending to farmers	The state tries to support small agricultural enterprises, which demonstrate the gradual dynamics of production growth, especially in light of European surcharges for arable land or certain products. In Poland, several banks specialize in agricultural lending, including BGZ. On long-term loans (up to 10 years) the state can compensate half the interest rate. In Poland, preferential lending to the agricultural sector is also popular, when an entrepreneur can pay only 3 %, and the state returns the rest of the amount at the bank's interest rate

Source: generated by the authors based on [32].

The presented systems of state investment support for agriculture also indicate the impossibility for farmers to rely solely on budget financing, which pushes them to seek financial resources from other sources. Therefore, the question naturally arises about the need to increase the investment attractiveness of the industry. A potential investor will first be guided by such investment characteristics as profitability and risk, and will optimize this, based on certain own motivation. Foreign and domestic agro-industrial experience testifies to such approaches to optimizing the investment portfolio (Table 2).

It should be noted that the low investment attractiveness of agriculture is determined by the natural resource characteristics of the industry and the associated environmental risks. In the conditions of irrational agricultural management, there is a limitation of the presence of investment capital due to the natural resource dependence of the industry and the associated environmental risks.

From the perspective of our study, the most acceptable criterion for optimizing the portfolio of investments in agriculture under the influence of environmental factors is one that guarantees a certain income at a minimum level of risk to the investor, because:

1. In the context of human-intensive nature management, the quantification of investment risk is closely related to the economic loss from nature components destruction in agribusiness production, so the criterion for minimizing investment risk meets the general criterion for minimizing environmental losses of the expected investor's income.

Table 2

Mechanism of portfolio investment in the agricultural sector

Approach	Purpose	Description of the mechanism
Classical theory of portfolio analysis by H. Markowitz	Finding a profitable investment in terms of the optimal combination of return and risk	The universal approach of American economist H. Markowitz is used to determine the optimal proportions of investment portfolios in terms of the structure of investments, profitability and risk. The focus of the approach is the level of correlation of returns on investment assets. It is the consideration of mutual correlations to reduce portfolio risk as much as possible that distinguishes H. Markowitz's approach from the strategy of naive diversification. Risk is viewed as the variance of portfolio assets. Depending on the level of investment risk, portfolios are classified into aggressive (maximizing income), compromise and conservative (minimizing risk)
World Trade Organization (WTO) taxonomy	Promoting fair competition and non-discrimination in international trade	The status of a WTO member imposes obligations to comply with the rules of international fair competition. In accordance with the Agreement on Agriculture, the public investment portfolio can be conditionally divided into green, amber, red and blue box activities. The green box includes measures that are not aimed at supporting production volumes and producer prices, and, therefore, do not violate the principles of fair competition. Only the possibilities of the country's budget (investments in education, science, health care, land reform, environmental protection, restructuring of the industry, the formation of food reserves) limit funding for such events. Amber box measures are considered to be those that produce a discriminatory impact on international trade, and therefore are subject to reduction (subsidies for livestock and crop production, compensation for the difference between the purchase and market prices for agricultural products, provision of goods and services to the manufacturer at prices below market prices, purchase from the manufacturer of goods (services) at prices exceeding market prices, preferential lending to agricultural producers at the expense of the budget). The red box contains prohibited support measures (for example, non-tariff trade regulation, export or import restrictions, etc.). The Blue Box is additional and provides for measures aimed at preventing an overproduction crisis (reduction in livestock and acreage)
Hedge approach	Management of price volatility in agricultural products	The hedge approach provides for the insurance of agricultural producers against high fluctuations in the prices of the required assets. An effective hedging strategy allows reducing the risks of loss of profit, and, consequently, increasing the internal reserves of financing of economic activities that allows us to speak about the investment potential of the hedge approach. The most common types of financial tools (derivatives) in agriculture are futures, swaps and options. The main underlying assets of "agricultural" derivatives in the structure of hedge portfolios are wheat, corn, soybeans, rapeseed, soybean and palm oils, sugar, meat and livestock

Continuation of Table 2

Approach	Purpose	Description of the mechanism
By sources of funding: - international practice	The optimal distribution of investments with obligatory observance of the principle of voluntary choice of the object of investment	In international practice, modern sources of funding for the industry are budget funds, bank loans, own funds of farmers, household savings, stock markets and foreign capital
- national standards		According to the national standards of the State Statistics Service of Ukraine, the sources of financing of the agricultural sector are the funds of the state, banking institutions, Ukrainian farmers and foreign investors. The state strategy is to reorient and transform the mechanisms of budget investment support for agriculture in accordance with WTO requirements. The restrictive nature of the use of banking strategy given the natural and climatic dependence of the industry is a deterrent in the industry. In this context, the combination of banking and government strategies becomes especially relevant. The implementation of the strategy of self-investment can take place on the basis of effective management of financial performance of the enterprise. Intensification of investment relations with foreign counterparties can be carried out through the development of Ukraine's agricultural sector on an integration basis as an associate member of the EU

Source: systematized by the authors.

2. Sustainable agribusiness necessarily presupposes its environmentally balanced development, which requires investment, therefore, the risk as an objectively existing possibility of negative fluctuations in the agricultural management system and the danger of losses for investors is a cardinal limiting factor in the investment attractiveness of agricultural business, the optimization of which is achieved by minimizing deviations in the investor's actual income caused by the deterioration of the system state from its expected value.

3. High economic reproduction dependency on unfavorable climatic conditions, with the susceptibility of commercial agricultural performance to unpredictable price fluctuations, limit the presence of investment capital, considering the associated risks.

Simultaneously, the lack of exposure to the risk of participants in financial relations in the agricultural sector of the economy makes, in our opinion, methodologically justified the use of the criterion for minimizing investment risk when assessing the quality of investments in rural government.

Thus, the desire of investors to minimize the risks associated with environmental factors naturally raises the question of forming the optimal structure of the investment portfolio on the basis of environmental-and-economic modeling.

Based on the global experience of portfolio investment in agriculture, we propose to build our model on the following accepted conceptual and methodological approaches:

1. H. Markowitz's theory of portfolio analysis is based on the provisions that invest a given amount of investment capital in one investment object is riskier than investing the same amount in different objects (diversification principle). Diversification can reduce the overall risk of the investment portfolio. The rule of investment portfolio formation is expressed as the need to optimize the ratio of "risk-return" for a given amount of investment resources [18]. In our study,

H. Markowitz's conclusions on the optimization of the portfolio of securities (financial investments) are used to form a portfolio of real agri-environmental investments at the regional level. The modification of the American economist's approach is, firstly, to understand risk as the probability of environmental-and-economic damage for certain investors, whose motives for presence in the agricultural sector should also be taken into account in our model. The investment portfolios formed in this way can be considered conservative, as the criterion for portfolio optimization in this case is the minimization of investment risk due to environmental factors.

2. The World Trade Organization taxonomy is taken into account when choosing an investment object, namely, environmentally friendly elite seeds of certain crops, which, according to the WTO classification, are measures of the green box and can increase.

3. The national classification of sources of investment financing is taken into account when substantiating strategies for raising funds in the agricultural sector with a distinction between the latter on the basis of investment. Thus, it is proposed to compile investment portfolios for each conservative investor: the state, the bank, agricultural enterprise and foreign agent.

Environmental risks, influencing the investment expectations of investors, are the central element of the model which must be carefully detailed and minimized. This approach can significantly increase the investment attractiveness of agriculture.

The main semantic interpretation of the concept of investment risk of the agricultural system in terms of anthropogenic nature management can be its understanding as environmentally caused losses of expected income of the investor due to reducing, by eco-destructive factors, reproductive effect of the return on investment. Under the resource of return on investment, we propose to understand some source of profit (Fig. 1).

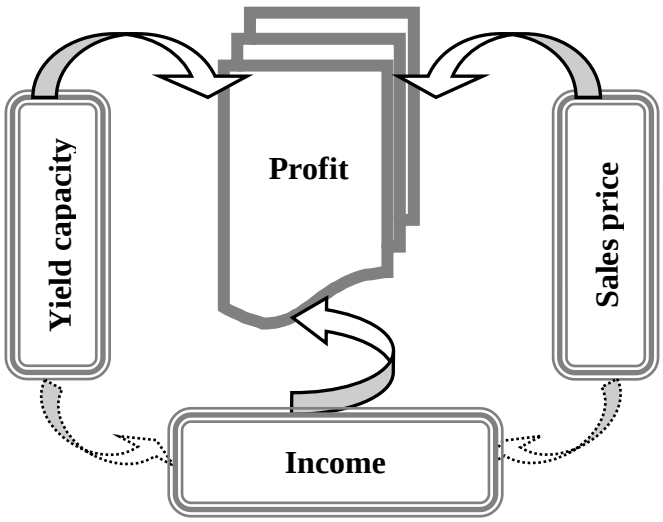

Fig. 1. Profit sources, or return on investment resources, in the agri-management system

Source: generated by the authors.

We propose to study the impact of the environmental factor on the return on investment resources from the standpoint of environmental problems of the use of soil and land resources in agriculture (Fig. 2).

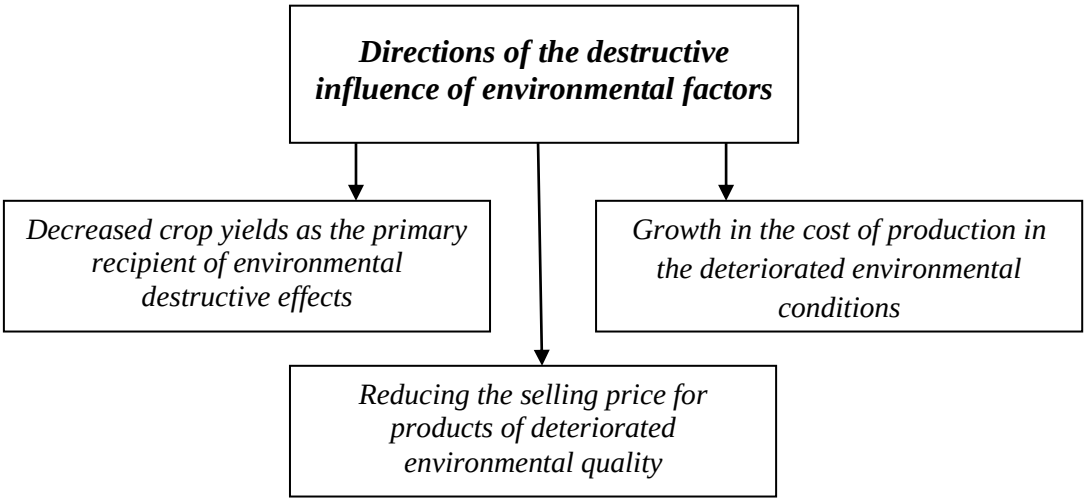

Fig. 2. Directions of the destructive influence of the environmental factors in agricultural production

Source: generated by I. S. Marekha [34, p. 339].

To solve the problem of increasing the investment attractiveness of agricultural land use by assessing the motivation for making investments, we discovered what criteria for selecting objects for investment the investor considers priority.

We propose to distinguish four types of investors and the corresponding criteria for the selection of investment objects, which we will call the individual preferences of portfolio investors.

Thus, the following motives can act as criteria for selecting crops for agricultural land use for the formation of a portfolio of investments at the regional level: within the framework of the state strategy – the contribution of agricultural crops to ensuring food security in the region; for banking strategy – profitability of agricultural production; from the perspective of a self-investment strategy – the expense intensity of agricultural production; and from the standpoint of foreign investment – the place of agricultural crops in the raw food structure of regional exports [33].

The environmentally determined risk of investing in agricultural land use is found by the formula (1):

$$R(DW_{si}) = DW_{si} * \left(\frac{1}{\left(\frac{EERR_i}{100} + 1 \right)} \right) \left(i = \overline{1,m} \right), \quad (1)$$

where $R(DW_{si})$ – environment-related losses of income, expected by the *s* investor within the *i*-investment alternative in agricultural land use, UAH (USD)/ha;

DW_{si} – expected by the *s*-th investor income from the *i*-investment object in agricultural land use, UAH (USD)/ha;

$EERR_i$ – environmental-and-economic risk of nature reproduction, %;

s – type of investor (investment strategy) (state, bank, equity of enterprises, or foreign investor);

m – the number of cultivated crops in the agricultural ecological-and-economic system vulnerable to the action of environmental factors.

We specify our study in relation to the regional agricultural system on the example of Sumy region, which belongs to the region with an average level of investment attractiveness of agriculture [1, p. 53]. Conducting research at the regional level facilitates the task of localization and identification of agricultural risks. Note that agro-risks are closely related to the concept of environmental-and-economic damage, which is primary.

The following modern works are devoted to the formation of approaches to the assessment of environmental-and-economic losses [35; 36].

Environmental-and-economic risks of nature reproduction are proposed to be determined in terms of separate crops vulnerable to environmental factors, according to the formula (2):

$$EERR_{ij} = \sum_{i=1}^{m} \Delta r_{ij} * |E_i|, \ (j = \overline{1,n}), \quad (2)$$

where $EERR_{ij}$ – environmental-and-economic risk of nature reproduction, calculated for the *i* agricultural crop cultivated in a certain region, %;

Δr_{ij} – the risk component of the model, or ecologically caused loss of yield, a decrease in prices or an increase in production costs for growing the *i* agricultural crop cultivated in the territory of a certain region, %;

E_i – a coefficient of the *i* crop income elasticity regarding crop yield, sales price, or production costs, calculated using methods of correlation and regression analysis;

m – the number of cultivated calciophilic crop species in the agricultural ecological-economic system, which are vulnerable to environmental factors;

n – the number of districts.

The scenarios of environmental-and-economic damage manifestation for the investor can be considered and modeled as follows:

Scenario 1. The environmental-and-economic damage for the investor could be manifested in the form of environmentally caused losses in yield, due to the impact, in particular, the high soil acidification factor.

Scenario 2. The environmental-and-economic damage for the investor could be manifested in the form of an environmentally determined price reduction due to the deterioration of the ecological quality of plants.

Scenario 3. The environmental-and-economic damage for the investor could be manifested in the form of environmental production costs increase to the soil acidity overcome.

The model of finding the optimal structure for attracting green investments in the field of agricultural land use, considering the influence of the factor of ecological instability of soils can be represented as a system of equations (3):

$$\begin{cases} R(DW_s) = \sum_{i=1}^{m}\sum_{j=1}^{n} X_i * v_{ij} * L_s \to \min \\ \sum_{i=1}^{m} X_i = 1; \\ X_i \geq 0 \end{cases}, \quad (3)$$

where $R(DW_s)$ – ecologically determined risk of the *s*-investor's investment in the field of agricultural land use;

X_i – row vector of values of the investment portfolio of the *s* investor of agricultural land use, which determines the optimal investment structure, considering the influence of the environmental factor;

L_s – vector of coefficients of individual preferences of the *s* portfolio investor of agricultural land use;

v_{ij} – elements of the matrix of environmentally conditioned implicit losses of the income expected by the *s*-investor from the investment alternatives being compared:

$$v_{ij} = (R(DW_i) + R(DW_j)) * r_{ij}, \quad (4)$$

where $R(DW_i)$ – environmentally conditioned implicit losses of the income expected by the *s-th* investor from the first investment alternative arising from the influence of the factor of ecological instability of soils;

$R(DW_j)$ – environmentally conditioned implicit losses of the income expected by the *s-th* investor from another investment alternative arising from the influence of the factor of ecological instability of soils;

r_{ij} – correlation coefficient between return on comparable investment alternatives in the field of agricultural land use.

The profitability expected by the investor from agricultural land use of the *i* investment direction is calculated by the formula (5):

$$DW_{si} = \frac{(Inv_i * (1 + K_s)) * Sq_{ij}, \%}{Sq_{ij}, ha}, \quad (5)$$

where DW_{si} – expected by the *s* investor of agricultural land use profitability of the *i* direction of investment, UAH/ha;

Inv_i – the amount of investment required to meet the need for environmentally friendly elite seeds for the *i* – direction of investment (investment alternative), UAH;

K_s – the price of investment capital attracted by the *s-th* investor in the agricultural system, UAH;

Sq_{ij} – the land share involved in the cultivation of the *i* crop of agricultural land use in the *j* district, %;

Sq_{ij} – the area of the land plot involved in the cultivation of the *i* culture of agricultural land use in the *j* district, ha.

Average weighted investment portfolio yield (*D*) is determined by multiplying the specific weight of the *i* investment object (x_i) by the income expected by the *s* investor from *i* object of investment in natural resources:

$$\begin{cases} D = \sum_{i=1}^{m} x_i * DW_{si} \\ \sum_{i=1}^{m} x_i = 1 \\ x_i \geq 0 \end{cases} \quad (6)$$

Investment portfolio profitability, adjusted to the level of environmental risk of the investor, is determined by the following formula (7):

$$D^{ecol} = D - \mathrm{R}(\mathrm{DW_s}) \quad (7)$$

The results of ecological-and-economic modeling of portfolio investments in agriculture on the example of Sumy region for 2019 are presented in Tables 3–5. The research used data from a statistical year-book published by the Main Department of Statistics in Sumy region [37] and materials of the Sumy regional branch of the Institute of Soil Protection of Ukraine.

Table 3

The optimal investment portfolio formed for the Sumy region in 2019, provided that the factor of environmental-and-economic damage is high soil pH

Ecological-and-economic indicators	Investment alternatives: green elite seeds			
	wheat	barley	corn	sunflower
The optimal structure of investment, formed considering the impact of **environmental factors**, %	19[1)] 22[2)] 28[3)] 21[4)]	28[1)] 20[2)] 24[3)] 33[4)]	39[1)] 17[2)] 46[3)] 38[4)]	14[1)] 41[2)] 2[3)] 8[4)]
Investment risk of the portfolio of agricultural crops due to the **environmental factor**, UAH/ha	79.62[1)] 174.10[2)] 9.15[3)] 1.40[4)]			
Return on investment portfolio, adjusted for the level of **environmental risk**, UAH/ha	1019.6[1)] 1409.50[2] 1312.77[3)] 62.04[4)]			

Note. [1)] State investment strategy. [2)] Banking investment strategy. [3)] Self-investment strategy. [4)] Foreign investment strategy (estimates in USD).

Source: calculated by the authors.

Further, it should be emphasized that the achievement of sustainable agricultural land use is possible with the increasing ecological-and-economic feasibility of investment decisions, which provides for establishing functional dependencies between the profitability of environmentally friendly investment capital and the investor's environmental-and-economic risks. The indicator of the greening of the investment portfolio is the investor's income elasticity to the profit changes due to ecological factors. This indicator is calculated according to the classical formula of elasticity [38, p. 202].

Table 4

The optimal investment portfolio formed for the Sumy region in 2019, provided that the factor of environmental damage is understated sales price due to the deterioration of the ecological quality of plants

Ecological-and-economic indicators	Investment alternatives: green elite seeds			
	wheat	barley	corn	sunflower
The optimal structure of investment, formed considering the impact of **environmental factors**, %	18[1)] 23[2)] 25[3)] 15[4)]	24[1)] 22[2)] 16[3)] 23[4)]	45[1)] 18[2)] 56[3)] 43[4)]	13[1)] 37[2)] 3[3)] 19[4)]
Investment risk of the portfolio of agricultural crops due to the **environmental factor**, UAH/ha	85.06[1)] 225.75[2)] 9.38[3)] 50.10[4)]			
Return on investment portfolio, adjusted for the level of **environmental risk**, UAH/ha	976.54[1)] 1341.76[2] 416.52[3)] 1327.06[4)]			

Note. [1)] State investment strategy. [2)] Banking investment strategy. [3)] Self-investment strategy. [4)] Foreign investment strategy (estimates in USD).

Source: calculated by the authors.

Table 5

The optimal investment portfolio formed for the Sumy region in 2019, provided that the factor of environmental-and-economic loss of the investor is the additional costs of overcoming soil acidity

Ecological-and-economic indicators	Investment alternatives: green elite seeds			
	wheat	barley	corn	sunflower
The optimal structure of investment, formed considering the impact of **environmental factors**, %	22[1)] 21[2)] 42[3)] 36[4)]	31[1)] 18[2)] 28[3)] 40[4)]	32[1)] 16[2)] 30[3)] 24[4)]	15[1)] 45[2)] 0[3)] 0[4)]
Investment risk of the portfolio of agricultural crops due to the **environmental factor**, UAH/ha	54.14[1)] 812.89[2)] 8.88[3)] 1.10[4)]			
Return on investment portfolio, adjusted for the level of **environmental risk**, UAH/ha	1104.04[1)] 1518.44[2] 1525.12[3)] 575.47[4)]			

Note. [1)] State investment strategy. [2)] Banking investment strategy. [3)] Self-investment strategy. [4)] Foreign investment strategy (estimates in USD).

Source: calculated by the authors.

Investor's income elasticity (V) to the profit changes due to ecological factors:

- demonstrates how the income of a conservative investor changes with a decrease in profits in the field of agricultural land use by 1 %;

- determines the desirability of the presence of investment capital in the field of agricultural land use in terms of anthropogenic use of agricultural land resources in

the region.

We propose to assess the choice of the most appropriate investment strategy in the agricultural sector of the economy according to environmental criteria to ensure sustainable socio-economic development of the region.

To implement this task, it is necessary to assess the elasticity of each strategy to the environmental-and-economic risks of reproduction of the agro-economic ecosystem in terms of the elasticity of the investor's income relative to the environmental risks of investing system (V, %) (Table 6).

Table 6

Ecological-and-economic justification of investment decisions in the field of agricultural land use

Investment strategy	The normative value of the elasticity ratio (V, %)	The calculated value of the elasticity ratio	Assessment of the strategy's elasticity to environmental risks	Quality of investments	Investment solution
State investment	$\|V\|<1$	-0.189	Inelastic	High	Profitable
Banking investment	$\|V\|<1$	-0.020	Inelastic	High	Profitable
Self-investment	$\|V\|<1$	-3.836	Elastic	Low	Unprofitable
Foreign investment	$\|V\|<1$	-0.090	Inelastic	High	Profitable

Source: calculated by the authors.

The ecological-and-economic justification of investment strategies in the field of agricultural land use gives grounds to conclude the following economic fact: it is recommended to exclude from the strategic set a self-investment strategy as the most sensitive to the investor's environmental risks, and therefore, due to its low quality, it is not adapted to the adoption of profitable investment solutions and sustainable development of agricultural land use.

Conclusions. Approaches to the formation of optimal investment portfolios in terms of meeting the individual preferences of each of the four investors – the state, the bank, agrarian-self-investor and a foreign agent are proposed. Such approaches imply the improvements in H. Markowitz's method based on considerations of environmental factors and motivation for the investors and adopted to the real investments framework.

For the state strategy of investment support for the agricultural sector, which is a crucial driver for its development, the following results have been obtained according to the third simulation scenario: optimal structure of investments, considering the influence of the environmental factor (wheat – 22 %, barley – 31 %, corn – 32 %, sunflower – 15 %); investment risk due to environmental factors – 54.14 UAH/ha; investment portfolio yield adjusted for the environmental risk level of – 1104.04 UAH/ha.

It was proposed to assess the quality of investment decisions on the basis of calculating the elasticity of the investor's income to environmental risks. Thus, it was

substantiated that a banking investment strategy as such is characterized by high-quality, which responds to a 1 % increase in environmental risks in the ecological-and-economic system of agricultural land use by a 0.02 % decrease in the expected investor income (which is the lowest value among the four strategies under consideration). According to the results of the analysis, it is necessary to exclude from the general strategic set the strategy of self-financing as the one that is most sensitive (elastic) to irrational use of land resources and ensures making unprofitable decisions due to its low quality. The main source of financing for investments in the protection of land resources should be the funds of the state, the bank, and a foreign investor. Prospects for further research should be the step-by-step development of a comprehensive environmental investment strategy for sustainable spatial land use in certain regional conditions in terms of investment ability to ensure reproductive processes in agricultural land use and meet the interests of investors under conditions of environmental constraints.

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