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## MODELS OF INSURANCE OPTIMIZATION IN AGRIBUSINESS

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### МОДЕЛІ ОПТИМІЗАЦІЇ СТРАХУВАННЯ В АГРОБІЗНЕСІ

The article examines agricultural insurance as a vital tool for the sustainable development of the agricultural sector. Agricultural insurance allows farmers to minimize operational risks and supports the financial stability of agribusiness. Agricultural insurance is not widespread in Ukraine because available insurance products do not meet current challenges and their terms lack flexibility. Besides, insurance payments are not transparent so that farmers do not trust insurance companies. But during the war, it is extremely important to promote agricultural insurance which can protect Ukrainian agriculture in difficult times. All of the above justifies the topic of the conducted research based on the methodical foundations of mathematical modelling, comparison, deduction, and generalization. The purpose of the article was to identify the features of insurance in agribusiness, and also to develop economic and mathematical models to optimize some parameters of insurance including risks and utility. The first result of the study made it possible to recommend implementing comprehensive insurance products related to agribusiness, such as insurance for crops, livestock, agricultural machinery, property, and liability, not to mention insurance against financial risk of non-payment by buyers and price fluctuations in agricultural markets. The second research outcome identified the top insurance companies. They have introduced innovative insurance products adjusted to the war risks, offered advanced index insurance and combined insurance with lending from reliable partner banks. The third study result contained two mathematical models meant to empower farmers in the field of agri-insurance. The model calculations enable farmers to balance the cost of insurance and potential agribusiness losses depending on their probabilities. At the same time, decision-making based on utility function complies with risk acceptance and opts for the optimal insurance parameters to provide the maximum benefit for agribusinesses regarding their specific characteristics. The practical value of the research recommendations lies in increasing the efficiency and attractiveness of agricultural insurance, which is a key factor in post-war recovery and enhancing the economic security of agribusiness.

У статті розглядається агрострахування як життєво важливий інструмент сталого розвитку аграрного сектору. Агрострахування дозволяє фермерам мінімізувати операційні ризики та підтримує фінансову стабільність агробізнесу. Агрострахування в Україні не занадто поширене, оскільки наявні страхові продукти часто не відповідають сучасним викликам, а їхні умови не відзначаються гнучкістю. Крім того, страхові виплати є непрозорими, через що фермери не довіряють страховим компаніям. Але під час війни надзвичайно важливо сприяти розвитку агрострахування, яке здатне захистити сільське господарство України у складні часи. Все вищезазначене чималою мірою обґрунтовує тему проведеного дослідження, виконаного за допомогою математичного моделювання і методів порівняння, дедукції та узагальнення. Метою статті було визначити особливості страхування в агробізнесі, а також розробити економіко-математичні моделі для оптимізації деяких параметрів страхування з урахуванням ризиків та корисності. За підсумками дослідження ідентифіковано комплексні страхові продукти, рекомендовані до впровадження в агробізнесі. До цього переліку віднесено страхування сільськогосподарських культур, худоби, аграрної техніки, майна та відпові-

дальності, не кажучи вже про страхування від фінансових ризиків через неплатежі з боку покупців і коливання цін на аграрних ринках. В роботі виявлено провідні страхові компанії, які запровадили інноваційні страхові продукти, адаптовані до воєнних ризиків, засновані на вдосконаленому індексному страхуванні та поєднані з кредитуванням від надійних банків-партнерів. У статті запропоновано дві економіко-математичні моделі оптимізації. Розрахунки за першою моделлю дозволяють збалансувати вартість страхування та потенційні збитки в агробізнесі, охарактеризовані їхніми ймовірностями. Прийняття рішень із застосуванням функції корисності в другій моделі узгоджується з толерантністю до ризиків та дозволяє обирати оптимальні параметри страхування з максимальною вигодою згідно зі специфікою агробізнесу. Результати дослідження є практично цінними як такі, що сприяють підвищенню ефективності та привабливості агрострахування, адже воно є ключовим фактором післявоєнного відновлення і посилення економічної безпеки агробізнесу.

*Key words: agribusiness insurance, insurance companies, optimization models, risks, utility function.*

*Ключові слова: страхування агробізнесу, страхові компанії, моделі оптимізації, ризику, функція корисності.*

### STATEMENT OF THE PROBLEM IN GENERAL TERMS AND ITS CONNECTION WITH IMPORTANT SCIENTIFIC OR PRACTICAL TASKS

Insurance is a powerful mechanism for transferring the financial burden of potential losses from an individual or entity to an insurer. Insurance is a central component of a broader risk management strategy meant to transform unpredictable, large-scale potential losses into predictable, bearable costs. Consequently, instead of dealing with the possibility of a catastrophic financial setback, individuals and businesses can stabilize their finances and ensure continuity by converting risk into a defined, budgeted expense. What is more, insurance encourages proactive risk mitigation and financial protection, as insurers often offer lower premiums to loyal clients who demonstrate a commitment to safety measures and preventative actions. In essence, insurance is a key financial tool that fosters security and stability by pooling risk among many, thereby protecting the few that experience a loss.

Agricultural insurance is critically important in Ukrainian agribusiness because the national economy heavily depends on its agriculture. However, in spite of the above benefits, the implementation of agri-insurance in Ukraine is not widespread as it should be. There are several reasons for this. Firstly, the main barrier is the high cost of insurance services, which is often unaffordable for small and medium-sized farms. Secondly, there is a low level of trust in insurance companies among farmers, which is due to past negative experiences, comprehensive procedures, and a lack of transparency in policy terms and claim payouts. Thirdly, a shortage of high-quality and flexible insurance products adjusted to the

peculiarities of Ukrainian agriculture is another factor that contributes to the inhibition of insurance progress. It is worth mentioning that to some extent, recent state insurance programs have made a difference. But the legislative framework is not properly regulated yet. Finally, the uncertainty and specific risks associated with the ongoing Russian-Ukrainian war are typically beyond the standard insurance policies so that they present a significant hindrance that limits the development of the agri-insurance market in Ukraine.

All of the above implies that it is expedient and timely to employ mathematical modeling to explore optimal insurance in agribusiness taking into account risks and utility inherent in Ukrainian farming.

### ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Literature on agri-insurance is vast. Relevant recent studies are as follows. The research [1] has examined what influences farmers' decisions about insurance and suggested ways to improve agricultural insurance to address the challenges arising from climate change. The scholars aimed to show that there is a balance between insurance payouts and subsidies, which make up a farmer's total income, and the premiums they pay, which are part of their expenses. The study concluded that once this balance is achieved, multi-peril agricultural insurance can help reduce the negative impacts of climate change.

M. Rajeev and P. Nagendran highlighted that insurance is especially important for protecting small-scale crop growers in developing nations. The study findings clarified a connection between the interest rate of informal lending and whether farmers adopt crop insurance as they often want

to avoid losses but cannot afford insurance. The research suggests logical ways to set crop insurance premiums that can overcome the challenges of informal lending. The research inferred that by improving farmers' financial literacy and ensuring a reliable loss assessment mechanism, agri-insurance can earn farmers' trust and increase their participation [2].

According to [3], livestock insurance requires its reshaping to cope with unreliable data and fraudulent claims. These issues can be addressed by using technologies such as blockchain and the Internet of Things. Their implementation will contribute to livestock insurance transparency and real-time monitoring. Ultimately, these digital solutions will speed up the supply chain, eliminate intermediaries, secure transaction records, and make them tamper-proof.

A. Puska et al. [4] argued that agri-insurance is a key factor in improving farm productivity by protecting farmers from various risks if insurance products are appropriate and provided by a reliable company. Therefore, the authors offered a decision-making procedure employing fuzzy methods and sensitivity analysis to evaluate insurance companies. It incorporated several criteria, such as the subject of insurance, basic and supplementary risks covered, the insurance premium, payment method (for example, immediately, after the harvest, or in installments), the subsidization and possible delays of payments, limitations and additional services, and the insurance premium.

Agricultural insurance in Ukraine has been studied in many recent publications by Ukrainian scientists. S. A. Vlasiuk et al. carried out a comprehensive study of the agricultural insurance services market in Ukraine based on the rating of insurance companies under the current conditions of a full-scale Russian invasion of Ukraine. The researches noted that the improvement of agricultural insurance in Ukraine can be associated with the measures provided by the Law of Ukraine "On the Features of Insurance of Agricultural Products with State Support" (issued in 2024 with amendments and clarifications), and the active implementation of efficient international practices in the field of agri-insurance [5].

In the context of globalization and the rapid development of information technologies, there is a urgent need to improve agricultural insurance mechanisms by implementing digital tools. I. Fedorovych substantiated that this will increase transparency, reduce the rate of fraud, and improve the accessibility of agri-insurance services. In particular, the use of AI will lead to

the formation of a new paradigm of digital agri-insurance which will contribute to a more accurate assessment of insured events and a faster response to changes in farming [6].

D. H. Tsarenko and S. V. Khalin revealed that the effective use of insurance combined with other risk management methods, such as diversification, financial planning, and modern agricultural technologies, boosts the agribusiness sustainability. The main focus of the study was on how to overcome the economic and behavioral factors that, despite the importance of agricultural insurance, lead to the fact that its level of distribution is insufficient [7].

Many scholars analyze agricultural insurance during the period of martial law in Ukraine, which carries previously unseen risks. Despite the war, the insurance market in Ukraine remains viable owing to the fact that the NBU maximally promotes the use of electronic documents and remote settlement of insurance cases [8]. Similarly, O. Bodnar and D. Ivanenko stated that agricultural insurance should maintain financial stabilization, increase investment attractiveness, and ensure food security, which is extremely difficult in the conditions of force majeure during the war in Ukraine. In this regard, the authors proposed promising developments of military-adapted insurance products to enhance the effectiveness of agricultural insurance as a prime factor in post-war recovery and sustainable agricultural development [9].

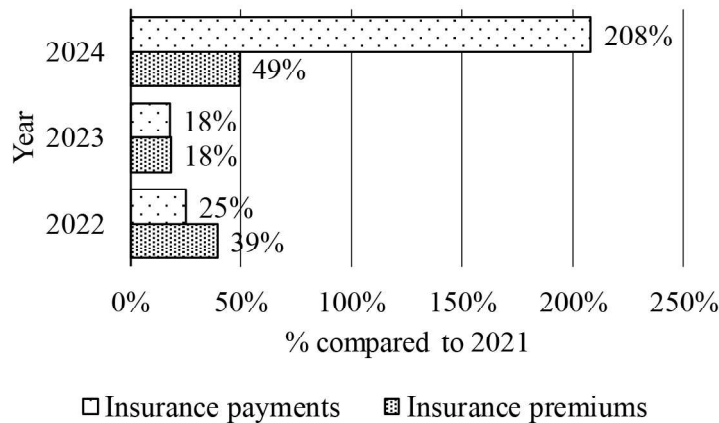
Given all of the above, it makes sense to continue research into developing agri-insurance consistent with the contemporary challenges that Ukrainian agriculture has to address.

#### **FORMULATION OF THE OBJECTIVES OF THE ARTICLE (TASK STATEMENT)**

The purpose of the article was to identify the features of insurance in agribusiness, and also to develop economic and mathematical models to optimize some insurance parameters in terms of risks and utility.

#### **PRESENTATION OF THE MAIN RESEARCH MATERIAL**

According to the study objective, the research aimed at solving three tasks. The first one was to identify the most beneficial insurance products related to agribusiness. The second was to specify the most efficient insurance companies that provide services to Ukrainian farmers. The third task was to develop mathematical models that would help in planning and proving the advantages of insurance at the enterprise level.



**Figure 1. Agri-insurance dynamics in Ukraine**

Source: composed by the author based on data from [14].

Agribusiness meets a large number of risks associated with natural aspects, economic fluctuations and other unforeseen circumstances. Insurance is an important tool for minimizing these risks and maintaining the financial stability of agricultural enterprises. The major types of agri-insurance are as follows [10].

1. Crop insurance in plant production is one of the most common types of agri-insurance, designed to protect from damage of crops and harvest losses. It covers a wide range of risks, including adverse weather conditions, such as freezing and ice crusts in case of winter crops, droughts, hail, floods, hurricanes, lightning strikes, earthquakes, landslides, avalanches and other natural disasters that cause physical destruction. Other optional risks covered include fire and arson, illegal acts of third parties, in particular theft and vandalism, as well as plant diseases and pest infestations. Crop insurance can address the entire production cycle from sowing until harvest or deal with a certain period, for example the spring-summer vegetation. Besides, some crop insurance products compensate only for production costs while the others insure potential yield and revenue based on expected market price.

2. Livestock insurance protects against financial losses related to the death, illness, or injury of farm animals such as cattle, sheep, goats, pigs, poultry, and bee colonies. This type of insurance might support Ukrainian animal husbandry that is weaker than crop production [11; 12]. The risks covered by livestock insurance incorporate epidemics of infectious and non-contagious diseases, fire, flood, traffic accidents, natural disasters, theft, or forced slaughter. Some advanced insurance products can compensate even for reduced productivity and potential income loss for the above reasons.

3. Agricultural machinery insurance (like CASCO for farming) protects from breakdown, damage, or theft of machinery that can result in significant financial losses and operational delays. It concerns tractors, combines, seeders, sprayers, and attachments that represent significant assets for any agricultural enterprise. The risks covered include traffic accidents such as collisions, rollovers, hitting an obstacle, fire, explosion, lightning strikes, illegal acts of third parties, for example, hijacking and deliberate damage, natural disasters, mostly flood, hail, storm, hurricane, earthquake, landslide.

4. Additional property insurance is focused on administrative buildings, warehouses, storage facilities, greenhouses, processing equipment, irrigation systems, and other assets used in crop production and animal husbandry. As a rule, the risks covered encompass fire, flooding, theft, natural disasters, and unlawful acts.

5. Liability insurance can be general (regarding the damages caused to third parties while using agricultural machinery) or professional (applicable to agronomists and veterinarians to protect from substantial losses that may arise from their professional errors).

6. Financial risk insurance typically embraces protection against non-payment by buyers and price fluctuations for agricultural products.

The choice of a certain type of insurance depends on the features of the agribusiness, its size, crops grown, animal species, potential threats and regional location [13]. This makes insurance more accessible and appealing to farmers.

With regard to the second task, the study revealed that there are many national companies which provide services in the Ukrainian agri-insurance market. However, over the last few years the volume of insurance payments has dropped on

**Table 1. Model 1 input data**

<b>Amount of loss (Ai), UAH</b>	0	100000	300000	500000	700000	900000
<b>Probability of loss (Pi)</b>	0.4	0.25	0.15	0.1	0.07	0.03

Source: composed by the author.

**Table 2. Model 2 output data**

<b>CI, UAH</b>	25000	25000	75000	75000
<b>Q</b>	0.01	0.05	0.01	0.05
<b>Y, UAH</b>	0	25000	7817.9	75000
<b>G</b>	11.510	11.505	11.499	11.490

Source: composed by the author.

account of the ongoing Russian-Ukrainian war which exacerbates the risks of farming [14]. In particular, Figure 1 illustrates that the worst indicators of agri-insurance were observed in 2023. But the situation has been improving since 2024 owing to new initiatives from insurance leaders such as INGO (<https://ingo.ua/services/agroziziki>), ARX (<https://arx.com.ua/corporate-produkty/agro-multirizikove-strahuvannya> and <https://arx.com.ua/corporate-produkty/strahuvannya-agro-tvarin>), PZU Ukraine (<https://www.pzu.com.ua/corporate/sh.html>) and UNIVERSALNA (<https://universalna.com/agro-insurance/>).

Indeed, INGO together with Syngenta have started a partnership program for index insurance "MeteoZakhist" against three weather risks: drought, heat and rain. The program insures crops of corn, sunflower, rapeseed, wheat and barley. To participate in the program, farmers must use appropriate Syngenta products. The unique efficiency is due to the fact that payments are made automatically based on data received from satellites. During the war, insurance becomes more attractive, as now it protects against military risks. For example, ARX covers losses from hostilities, losses from shelling, mining of territories, damage to equipment and infrastructure (for instance, granaries and warehouses). Such insurance products are intended exclusively for territories controlled by Ukraine, located at a certain distance from the zone of active hostilities and borders with aggressor countries. It is also necessary to pay attention to the state mechanism of compensation of up to 60% of the insurance payment, which makes insurance more accessible to farmers. Finally, financial insurance for farmers from PZU Ukraine and UNIVERSALNA is being expanded, as banks (such as PrivatBank, Ukrgasbank, and others) are launching partnership programs using collateral insurance of assets and future harvests for agricultural crediting.

In compliance with the third task, the formulation and calculation of two mathematical models are proposed to empower Ukrainian farmers in the field of agri-insurance.

In model 1 we are aware of the potential losses  $A_i$  that can occur with probability  $P_i$ . It is necessary to find the optimal sum insured to minimize the expected cost if the insurance premium rate is  $B$ . To calculate this model, we introduce the unknown sum insured  $X$ , where  $X \geq 0$ . Assuming that the insured sum should not exceed the maximum loss, we obtain the following restriction

$$X \leq \max(A_i).$$

The objective function, which denotes the sum of the insurance premium and the expected uncovered loss, must be minimal

$$F = B \cdot X + \max(0; A_i - X) \cdot P_i \rightarrow \min.$$

The formulated optimization model is non-linear, but spreadsheet tools are powerful enough to calculate it. The model testing was performed for a case of agri-insurance with parameters  $A_i$  and  $P_i$  from Table 1 and  $B=0.03$ .

The found minimal value of the objective function was  $F_{\min} = 27000$  UAH. For calculating the range of the optimal sum insured we included into the model a supplementary restriction  $F=F_{\min}$  and replaced the objective function with  $X \rightarrow \min$  and  $X \rightarrow \max$ . As a result, it was recommended to choose the optimal sum insured between 700000 UAH and 900000 UAH.

Model 2 employed the utility function. This is a fundamental concept in economics and decision theory that allows us to measure the satisfaction got from consuming certain goods or services or possessing a certain level of wealth. In other words, higher numbers imply more desirable outcomes. The utility function explains choice and simulates the risk acceptance such as propensity, neutrality, and aversion. Utility functions are based on the principle of diminishing marginal utility. It argues that as consumption increases, the marginal utility received from each subsequent unit decreases. Hence, the most common type of utility functions is logarithmic.

In the second developed model we are aware of the potential loss  $C_1$  that can occur with probability  $Q$ . It is necessary to find the optimal sum insured in order to maximize the utility function if the insurance premium rate is  $C_2$  and the total value of the object insured is  $C_3$ . To calculate this model, we introduce the unknown sum insured  $Y$ , where  $Y \geq 0$ . Reasoning that the insured sum should not exceed the expected loss, we obtain the following restriction

$$Y \leq C_1.$$

The utility value without insurance amounts to  $(1-Q) \ln(C3)+Q \ln(C3-C1)$ .

The objective function of the model G should maximize the utility value taking into account the insurance premium paid and the uncovered loss, i.e.

$$G=(1-Q)\ln(C3-YC2)+Q\ln(C3-YC2+Y-C1)\rightarrow\max.$$

Like model 1, the formulated optimization model 2 is non-linear, but spreadsheet tools are powerful enough to calculate it. The model testing was carried out for a few cases of agri-insurance with parameters  $C1=25000$  UAH and  $75000$  UAH,  $Q=0.01$  and  $0.05$ ,  $C2=0.03$ , and  $C3=100000$  UAH. The obtained results are displayed in Table 2.

In particular, the recommended strategy for  $Q=0.05$  was to insure against the total potential loss. With a probability of loss  $Q=0.01$ , it was advisable to avoid insurance for a relatively small potential loss of  $C1=25000$  UAH. However, the utility function substantiated that the optimal sum insured should be  $7817.9$  UAH when  $C1=75000$  UAH.

#### CONCLUSIONS AND PROSPECTS FOR FURTHER EXPLORATION IN THIS DIRECTION

Agri-insurance is vital for farmers' financial stability, shielding them from losses associated with unpredictable weather, pests, diseases, and natural disasters. In addition to the named trouble, Ukrainian farmers have to face war risks. To facilitate this burden, firstly, it is recommended to implement comprehensive agri-insurance that covers crop production, animal husbandry, agricultural machinery, property and liability in farming. Secondly, it is advisable to turn to top companies that operate in Ukrainian market, such as INGO, ARX, PZU Ukraine, and UNIVERSALNA whose innovative insurance products are best tailored to the current situation in Ukraine. Finally, it is reasonable for farmers to implement the offered mathematical models while choosing the optimal parameters of agri-insurance to obtain maximum benefits considering their specific features.

Given the dynamic environment and the relevance of the issues raised, it is planned to carry on further research on the application of mathematical modeling to the development of efficient agri-insurance intended to support Ukrainian agribusiness.

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