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INDEX INSURANCE AS AN INNOVATIVE TOOL FOR MANAGING WEATHER RISKS IN THE AGRARIAN ECONOMIC SECTOR

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Abstract

This article justifies the use of a new methodical approach to index insurance of agricultural producers against weather risks, in particular, the use of the thermal-hydraulic combined index (Ith) as the weather index of the effect of several triggers (temperature and precipitation) on yields, taking into account the uniformity of weather and climatic conditions over time. General scientific methods of scientific knowledge and research of economic phenomena are used for the scientific solution. The theoretical and methodological bases of the research are the works of scientists and practitioners involved in researching the market of agricultural insurance services in general and the issues of developing an effective system of agrarian insurance, in particular. The main method of research is the method of mathematical statistics, namely, a multivariate analysis of variance. This article presents research on the application of index insurance schemes while using weather index products. The advantages and disadvantages of these products are considered and the mechanism of the index insurance is described in general. The article considers the possibility of applying a rainfall index with a temperature threshold, and the thermal-hydraulic index (Ith) that takes into account and simultaneously combines several parameters is calculated. Considering the research findings, the authors suggest the adoption of the compound thermal-hydraulic index (Ith) and present a detailed description of the functioning of this mechanism. Approbation of the methodological tools was carried out on the example of the Uman District of the Cherkasy Region of central Ukraine.

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1. INTRODUCTION

The strategic task of the agrarian policy of the state lies in the formation of efficient competitive agricultural production that is able to provide food security for a country as well as increase the export of some types of agricultural products and foodstuffs. One of factors of the stability of the economic development of agricultural production and an effective tool for ensuring the financial and economic stability of agricultural enterprises is agricultural insurance. At present, Ukraine has a significant potential for the development of agriculture and increased influence on the European markets. At the same time, one of the elements of the market model of the agricultural sector is the creation of a new insurance system in order to reduce the risk level of production activities. However, despite the essential need for such protection, only the first steps in this complex market segment are made in Ukraine.

The study of the process of the formation and sale of insurance products in the agricultural sector is directly related to the specifics of agricultural production. A high level of sensitivity primarily to natural and climatic, technogenic, anthropogenic, socio-economic and other risks, requires the professional selection of necessary and often innovative insurance products that can meet the demands of farmers regarding insurance protection.

2. THEORETICAL BACKGROUND

The study of insurance features in the agricultural economic sector is given considerable attention by economists.

In recent years, there has been much discussion about index insurance as a modern and perfect type of agricultural insurance allowing the solving of problems of the traditional type of insurance. A number of Ukrainian scientists have been studying the process of the formation and sale of insurance products (in the context of classical (traditional) and index (innovative) products) in the agricultural sector of the economy, including Botvinovskaya (2011), Gudz (2016), Malik & Gudz (2015), Onisko & Tomashevsky (2013), Sadura & Tomashevsky (2012), Sinitsyna (2011) and Sholoyko (2009).

Current trends in the foreign experience of index insurance of agrarian risks have been extensively studied. Botvinovskaya (2011) studies and summarizes the international use of index schemes for the insurance of agrarian risks. Onisko & Tomashevsky (2013) stop studying one of the index insurance types, which is the insurance of crop yields based on weather indices. Researchers have concluded that crop yields are significantly affected by weather conditions. Traditional insurance products, which are widely offered in the Ukrainian insurance market, have a number of shortcomings and do not always fully meet the needs of agricultural enterprises in an adequate insurance protection. Therefore, they propose the implementation of index weather insurance, which has advantages over other insurance products, such as simpler and clearer information requirements, suitability for different farms, a low level of abuse and a quicker insurance indemnity. Sholoyko (2009) considers classical and index insurance products for the crop production branch, not giving advantage to any of them. Sinitsyna (2011) carries out a comparative analysis of insurance products for agricultural crop insurance nd argues in favor of indexed insurance products. Gudz (2016) considers information systems and technologies in the insurance protection of agrarian businesses, concluding that insurance is one of the most information-intensive and information-dependent types of business. The introduction of information technologies in the process of planning and managing activities of insurance companies involves not only the processing of large and interconnected data sets but can also be used to analyze them and justify options for management decisions.

Among foreign researchers, the works of Barnett & Mahul (2007), Clarke et al. (2010), Chantarat et al. (2007), Hellmuth et al. (2009), Meza et al. (2008), Miranda & Gonzalez-Vega (2010), Skees (2006, 2008), and Woodard & Garcia (2008) should be mentioned. In foreign references, the use of index schemes of insurance, including weather-based insurance for agriculture and rural areas in low-income countries, is considered (Barnett & Mahul, 2007). Advantages of index schemes of insurance are largely described in foreign scientific works (Chantarat et al., 2007; Hellmuth et al., 2009; Miranda & Gonzalez-Vega, 2010; Mentel, 2017). Moreover, the authors emphasize the benefits of insurance related to the weather index, as a factor in famine prevention. At the same time, at this stage, the issue of using the latest practices and techniques in agricultural insurance requires increasing attention. In particular, such a practice is the use of index insurance products for agricultural producers.

The purpose of this study is to justify the use of a new methodical approach to the index insurance of agricultural producers against weather risks, in particular, the use of the thermal-hydraulic combined index (Ith) as the weather index of the effect of several triggers (temperature and precipitation) on yields, taking into account the uniformity of weather and climatic conditions over time.

3. RESEARCH OBJECTIVE AND METHODOLOGY

Features of weather index insurance products

General scientific methods of scientific knowledge and the research of economic phenomena are used for the scientific solution. The theoretical and methodological bases of the research are the works of scientists and practitioners involved in researching the market of agricultural insurance services in general and the issues of developing an effective system of agrarian insurance, in particular. The following research methods are used as an economic-statistical method: an abstract-logical method, a graphic method and a scientific generalization method.

In practice, the economic-statistical method is used in the study of mass phenomena, processes, facts and the identification of trends and patterns of their development. It also makes it possible to determine the quantitative effect of individual factors on the result of the study and identify the main factors that led to changes in the course of economic processes. In this study, this method is one of the main methods. After all, using the method of mathematical statistics, namely, multivariate analysis of variance, the justification of the influence of individual parameters (the average monthly air temperature and precipitation amount) on the yield of the agricultural crop is carried out (winter wheat in Uman district of the Cherkasy region). The main features of the application of this method in this study are described below.

Insurance products are divided into classical, based on the assessment of losses, and index products which are determined by means of certain indices. Carrying out a choice of those or other insurance products, agrarians are interested in obtaining an effective insurance protection in terms of coverage of risks by insurance, its cost and the amount of insurance compensation in case of an insured event.

Index insurance has appeared on the domestic market of agricultural insurance relatively recently but in practice, it is regarded as a worthy alternative to traditional insurance products due to simplicity and cheapness. The calculation of indices correlating with risks of agricultural crop production is based on information on weather parameters and crop yields (Sinitsyna, 2011).

In this article, we will focus on weather index products in more detail.

Weather index products are in the stage of introduction in Ukraine. It is a new type of insurance products. These products enable to easily determine losses caused by the impact of adverse weather conditions in the cultivation of various crops. The insurance on the weather index, which is calculated by hydro meteorological services, is based on the deviation of temperature or weather data of the current year from the average multi-year values. In this case, payments are established using an objective parameter - a certain combination of a number of weather-related metric data, for example, the amount of precipitation, soil moisture and their regularity (Baimisheva, 2017). Insurance based on weather indices is most suitable for agricultural production in the regions of Ukraine where crop losses are widespread due to drought, excessive moisture and frost. Thus, weather index-based insurance can be a better alternative to classic crop insurance because it helps to avoid problems associated with the risk of moral harm. Also, it has simple and understandable information requirements, suitability for various farms, a low level of abuse and quick insurance reimbursements. Although the agrarian insurance is promising in Ukraine, this product does not enjoy wide popularity, primarily due to inadequate information support and logistics of domestic hydro meteorological services.

Features of weather index insurance products are grouped in Fig. 1.

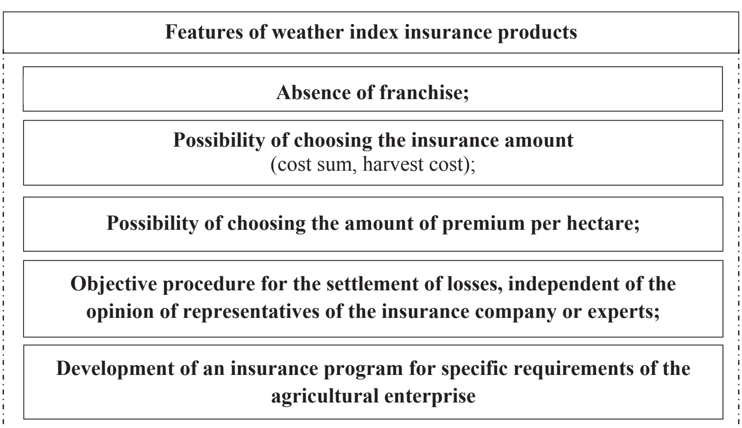


Fig. 1 – Distinctive features of weather index insurance products. Source: own processing

It should be noted that insurance companies have begun to work with index agro-insurance products since 2003. However, index insurance in Ukraine has not become popular among agricultural producers so far. At present, two types of index products are offered – the yield index and the weather index.

Mechanism of functioning of index insurance

The key features of the mechanism of functioning of index insurance are shown in Fig.2. Index insurance has a clear algorithm for determining damage which is based on certain indicators only, for example, weather data and mathematical models. As a rule, the development of index programs is rather a complicated and time-consuming process but in the future, such programs work quickly, simply, and, as a result, are cheaper. It should be noted that in the center of the mechanism of the program is an index that is a special indicator characterizing the effect of the intensity of a certain risk on the crop yield. The limiting value of this indicator characterizes the beginning of the insured event and corresponds to a critical loss of yield for a farmer. Of course, the index should show very precisely how the specific risk affects crop yields (this is due to the quality of the product development – reliability and accuracy of data, a mathematical model, etc.).

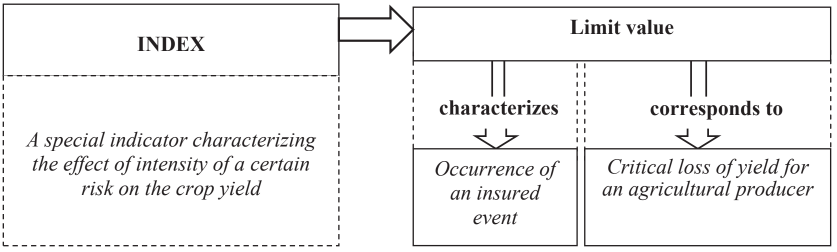


Fig. 2 – Mechanism of functioning of index insurance. Source: compiled by the authors

Despite the fact that Ukraine is in a zone of relatively calm climatic conditions, the influence of global climate change has been manifested recently: extreme droughts, severe frosts without snow, excessive rainfall - all these phenomena not only occur periodically in a once-temperate climate, but, according to experts, will increase in the future.

As a consequence, both producers and experts of the agrosphere see the need for adequate tools for managing risks associated with the weather. One of the opportunities that could partly solve this problem is the insurance development. However, it should be noted that effective insurance products are needed with a balanced cost and level of payments, reliable insurance partners, etc.

The weather indices include the established level of temperature, precipitation, wind force and other meteorological parameters affecting yields. In this article, we will consider the possibility of applying a precipitation index with a temperature threshold and calculate the thermal-hydraulic combined index (Ith). After all, due to the joint action of high temperature and precipitation absence, the yield losses will be more significant than in case of precipitation absence and normal air temperature.

It should be noted that the insurance application by the index of weather conditions leads to the fact that agricultural producers no longer need to state and justify crop losses to obtain insurance compensation.

4. RESULTS AND DISCUSSION

Calculation and justification of the use of the thermal-hydraulic combined index (Ith) in the regional context

The index insurance was applied, namely the thermal-hydraulic combined index on the example of Uman district of the Cherkasy region. The source of the initial information characterizing the agro meteorological conditions of vegetation of agricultural crops (in this case it is winter wheat) is the result of observations of weather conditions carried out at the meteorological station "Uman" located in Uman district of the Cherkasy region (from 2000 to 2015).

In this case, the weather index is used. In particular, limit values of temperature and precipitation are determined during flowering and grain filling (April-June) which reduces the yield of winter wheat. Using the method of mathematical statistics, namely the multivariate analysis of variance, we will justify the influence of the average monthly air temperature and the amount of precipitation in April-June on the yield of winter wheat in Uman district of the Cherkasy region (Fig. 3 shows the initial data). The yield data of winter wheat were taken on the basis of a long-term stationary field experiment (conducted from 1964) of the Department of Agrochemistry and Soil Science of Uman National University of Horticulture. In work, in calculations, the average yield data were used for four fields in 2000-2015. In all fields of the experiment, one variety of winter wheat was sown. The cultivation technique was recommended for this zone and equally used in all variants of the experiment. TheWeather data are taken (temperature and precipitation amount) according to Uman Meteorological Station.

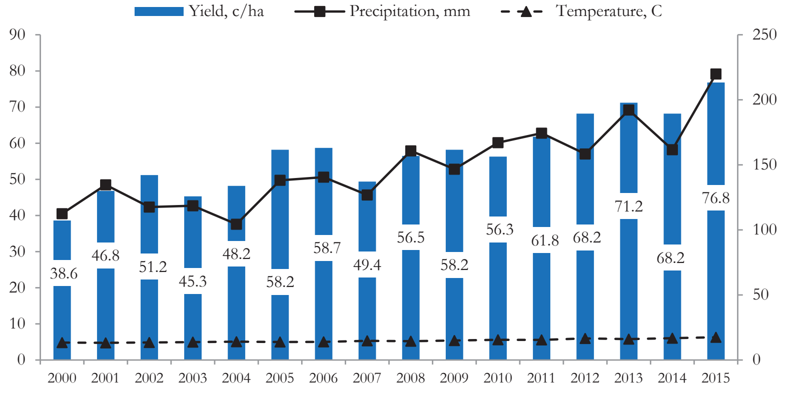


Fig. 3 – Yield of winter wheat and values of weather factors: air temperature (average for April-June) and precipitation (April-June) in Uman district of the Cherkasy region in 2000-2015. Source: authors' processing

The data obtained (Fig.3, initial data) were checked for normal distribution. The type of data distribution was determined by Kolmogorov-Smirnov and Shapiro-Wilk methods (Vukolov, 2015). In addition, normality is visible from the constructed histograms (Fig. 4).

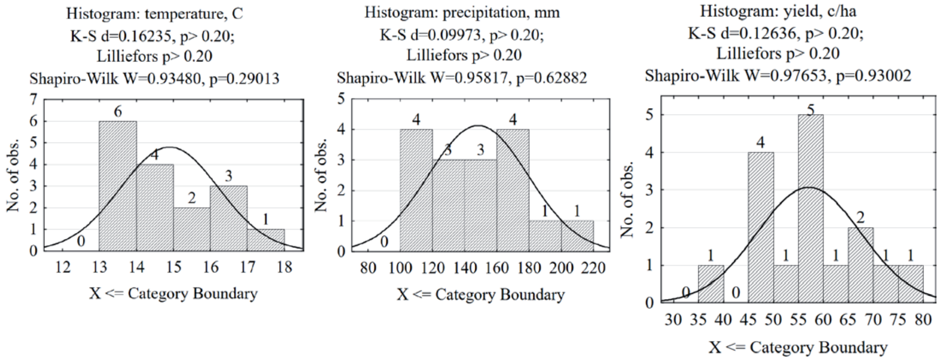
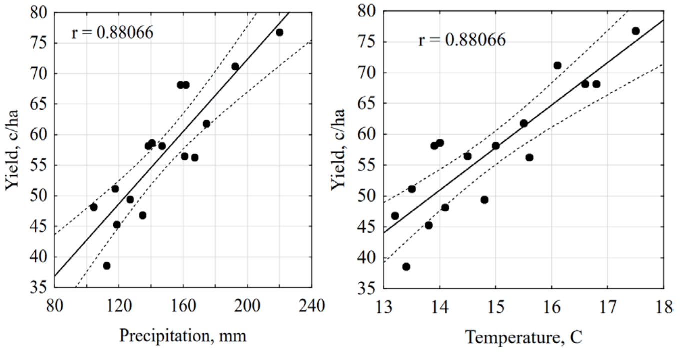


Fig. 4 – Data distribution histograms. Source: authors' processing

Crop yield, precipitation and temperature indicators were well distributed, since the Kolmogorov-Smirnov test indicators were more than 20, while the Shapiro-Wilk test indicators were more than 0.05.

According to the Chaddock scale, there was a direct high connection between precipitation, temperature and yield, since the Pearson correlation coefficients were 0.888133 and 0.88066, respectively (Fig. 5).



• Elasticity of winter wheat yield by the amount of precipitation and temperature (in terms of each indicator)
–Linear (elasticity of winter wheat yield by the amount of precipitation and temperature).

Fig. 5 – Elasticity of winter wheat yield by precipitation and temperature. Source: authors' processing

The equation of the regression model with respect to the influence of the average monthly air temperature and the amount of precipitation (April-June) on the winter wheat yield in Uman district of the Cherkasy region is:

$$y = - 22.8979 + 0.1625\,x_1 + 3.7523\,x_2\,, \qquad (1)$$

y – Winter wheat productivity, c/ha;

x_1 – precipitation, mm;

x_2 – temperature, °C.

The function was examined for the autocorrelation of residues by determining the calculated Durbin-Watson coefficient (1.581298) and its comparison with the data tabulated. For the total number of observations of 16 and two variables, DW_L and DW_U functions were 0.98204 and 1.5386, respectively. In subsequent calculations, it was found that the statements 0 < DW < DW_L, DW_L < DW < DW_U, 4-DW_U < DW < 4-DW_L и 4-DW_L < DW < 4 were false and DW_U < DW < 4-DW_U corresponded to reality. This indicates that there is no autocorrelation of residues in the studied function. Thus, the set of observations was chosen correctly.

The model describes the dependence at 92.1% and also is adequate to (F = 36.36 at F_{cr} = 9.01). The coefficient value is 0.92. Student's t-criterion was used to estimate the coefficient of pair correlation. The regression coefficients are statistically significant (tx_1 = 2.497867, tx_2 = 2.477299, at t_{cr} = 2.35, test. > t_{cr}) (Fig. 6).

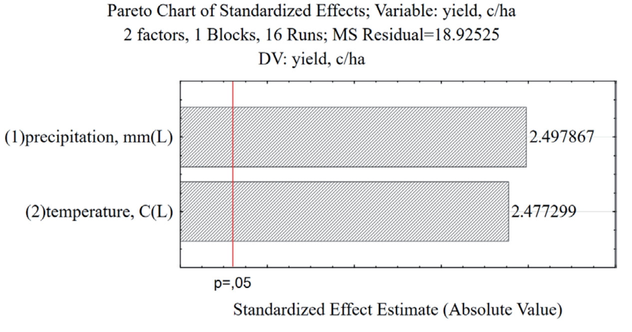


Fig. 6 – Standardized effect estimate (Pareto chart of Standardized Effect). Source: authors' processing

Thus, a close correlation was found between the yield of winter wheat and values of the average daily temperature in April-June (average for three months) and the precipitation amount (for three months).

Estimating the reliability of parameters of the regression equation, it is understandable that the chosen parameters are significant. Further, it is necessary to assess the materiality of the connection. For this we calculate the partial coefficient of determination (d_x) which shows how much the variation of the effective feature (in our case this is the productivity of winter wheat) is due to the variation in characteristics (average monthly temperature and precipitation) that are included in the regression equation:

$$d_x = r_{yx} * \beta_x, \tag{2}$$

r_{yx} – paired coefficient of the correlation between the productive and factor characteristics;

β_x – corresponding coefficient of the multiple regression equation in a standardized scale.

When summarizing, such a moment as the value of the determination coefficient (approximation reliability) R^2, which shows the degree of correspondence of the model to the initial data, was also taken into account. Its value can be in the range from 0 to 1. The closer R^2 to 1, the more accurately the model describes the data available (Table 1).

As a result of calculations, the value of the determination coefficient was 0.8483. This indicates that the variation in the yield of winter wheat in the Uman District of the Cherkasy Region is explained by 84.83 %, by the change in the average monthly temperature in April-June (by an average of three months) by 1°C and precipitation (for three months) by 1 mm; the remaining 15.17 % are due to other factors. Moreover, the influence force of each of the factor characteristics on the resultant one is almost equivalent, with an insignificant predominance of x_1 (precipitation) – 56.9% over x_2 (temperature) – 56.6 % (temperature).

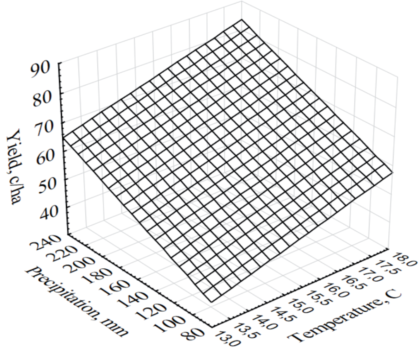


Fig. 7 shows that the highest yield was at 200-240 mm of precipitation and a temperature above 16°C.

The dependence and degree of influence of temperature and precipitation on the yield were similar, as evidenced by partial and beta correlation coefficients (Fig. 8).

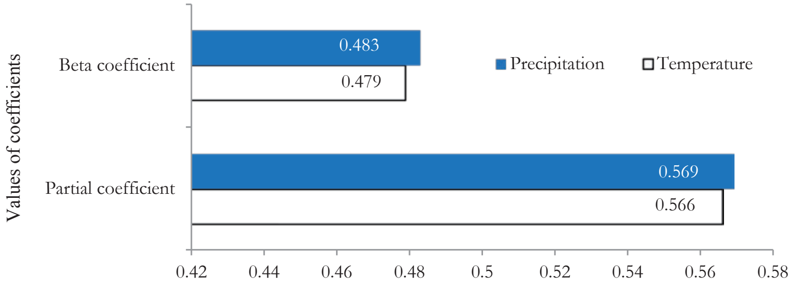


Fig. 8 – The dependence and degree of influence of temperature and precipitation on the yield of winter wheat. Source: authors' processing

Thus, in the Cherkasy Region, namely the Uman District, it is possible to use the rainfall index with a temperature threshold for winter wheat in April-June. As for the index value, we can take the average value of temperature in April-June for the studied period, which is 15.9°C, and the average value of precipitation in April-June, which is 151.6 mm.

The interval determining the occurrence of an insured event, from the authors' point of view, can be taken as:

- Relatively to the temperature parameter: 14.9°C <15.9°C <16.9°C;
- Relatively to the precipitation parameter: 141.6 mm <151.6 mm <161.6 mm.

Thus, using the regression equation, it is possible to calculate the limit value of the index of the occurrence of the insured event. In our case, the value of the yield of winter wheat equal to 61.4 c/ ha was calculated.

Features of the mechanism of functioning thermal-hydraulic index (Ith) are shown in Fig. 9.

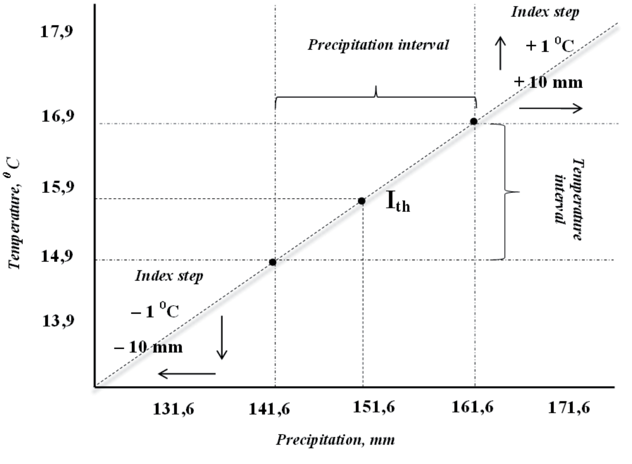


Fig. 9 – Peculiarities of the mechanism of thermal-hydraulic index functioning (Ith). Source: own processing. Source: authors' processin

Based on the data obtained, we can say that, in the analyzed period (2000-2015), for seven years (2000-2005 and 2007), an insured event occurred, which was due to a change in temperature and precipitation in the most important period of vegetation.

When insuring weather indices, the amount of compensation depends on the degree of change (step size) of the insured index. When developing an insurance product, insurers specify the cost of changing each step of the index, for example, in our case, each temperature degree and every 10 mm of precipitation (except for threshold values). Further, when there is the insured event (the fall/ increase in the weather index), the compensation is calculated by the formula: the unit value of the index x the degree of the index change x the number of hectares of the insured crop. Weather indices can be calculated for different crops and different periods of vegetation.

5. CONCLUSIONS

Insurance coverage in the agrarian sector of the Ukrainian economy is essential because, as a result of unfavorable weather conditions, agricultural producers have significant losses. Ukraine belongs to a risky agricultural area, largely due to the dependence of the agricultural producers' performance on the influence of weather factors. Due to climate change, the weather conditions in this region are becoming worse. In many Ukrainian regions, rising temperatures and droughts may become factors that ultimately limit the productivity of agriculture. It is one of the most important sectors of the Ukrainian economy.

This is why such an important tool as agricultural insurance can help agricultural producers minimize losses caused by adverse weather conditions and enable them to pay off their debt obligations, loans in particular. This time is characterized by the emergence of an agricultural insurance market in Ukraine, and there is great potential for its development. In the Ukrainian agricultural insurance market, classical insurance products are presented in the context of mono- and multi-risk insurance with their multi-branch product range. Index insurance products are innovative insurance products in the domestic agricultural insurance market on the basis of yield, profitability, weather and vegetation indicators. So, in particular, weather index products in Ukraine are in the stage of development and implementation, and they are rather new regarding the range of insurance products. They allow us to determine the damage from the effects of adverse weather events in the cultivation of various crops relatively simply. In practice, insurance index schemes have become widespread and have long been operating on the agricultural insurance market of different countries with the multi-branch product range of indexed insurance products.

To sum up, we can conclude that indexed insurance schemes using weather index products can be of use in the Cherkasy Region. This is associated with several reasons: Low cost of administrative costs; possibility of insurance of system agricultural risks caused by natural conditions; possibility of solving problems of moral hazard and asymmetric information (the conclusion of an insurance contract does not affect the occurrence of an insured event); reducing the load on the state budget in cases of unfavorable weather conditions that cause significant losses to agricultural enterprises.

This article considers the possibility of applying a rainfall index with a temperature threshold, and the thermal-hydraulic index (Ith) is calculated (using the method of mathematical statistics, namely, multivariate analysis of variance), which can take into account and simultaneously combine several parameters. Taking into account the performed calculations, the authors came to the conclusion that it is positive about to use this innovative insurance product (Ith) as a weather index of the influence of several triggers, which takes into account those phenomena that really affect the yield reduction and at the same time compensates the real damage to a farmer.

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