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ADAPTIVE MANAGEMENT OF CLIMATE RISK IN AGRICUTUAL ENTERPRISES

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Abstract

Global climate change, the high degree of uncertainty and the risks of natural disasters require the construction of modern mechanisms for adapting agriculture to changing climatic conditions. The distributional effects of environmental policies can contribute to improving the sustainability of agroecological systems. In accordance with this, the purpose of this study was to substantiate possible directions for improving the system of adaptation of agriculture to climatic risks. The study used the methods of logical and comparative analysis with the use of information review, as well as the analysis of profitability to justify the strategy of adaptation of agricultural enterprises to climate risks. The constructed model of formation of agribusiness profitability with the account of climate risks, allowed us to conclude that it is necessary to maintain the stability of the functioning of agroecological systems on the basis of ensuring subsidiary responsibility in terms of compensation for potential damage to economic entities affected by risk factors. The creation of regional environmental funds is considered a key tool for mitigating the consequences of climate risks. This element of the risk management strategy can contribute to the realization of the potential production opportunities of the economic system, adaptation to climate change and mitigation of the negative consequences of climate change.

Keywords: Climate risks, disaster mitigation, global warming, land-use policy, sustainable land-use system

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1. Introduction

The increasing frequency of adverse climate events such as droughts, floods, tornadoes, and snowfalls in various regions of the world at the end of the XX – beginning of the XXI century, which occurred and caused great socio-economic consequences promoted interest in the problems of climate change. The global average annual temperature increased by more than 0.7° C over the period of 1986-2016 compared to 1901-19601. The greatest degree of warming is manifested over arid areas in the Northern Hemisphere. Most researchers concluded that the anthropogenic nature of warming is associated with an increase in the con-centration of CO2, CH4 (Lacis et al., 2010), water vapor and a number of other greenhouse gases in the atmosphere of our planet. As noted, anthropogenic deforestation and agriculture have a major impact on the rate of warming.

Warming leads to shifts in climate zones, primarily in the form of an increase in the dry climate and the extent of arid lands. Increase in climate variability has a strong negative impact on terrestrial ecosystems, including a decrease in crop yields. About 18-43% of the fluctuation in the yield of major crops is due to extreme temperatures and precipitation.

Climate change factors, including temperature, precipitation and the frequency of extreme events, affect the parameters and rates of soil degradation (Challinor et al., 2014) and agricultural well-being. At the same time, climate shocks have a particularly strong impact on small producers (Vermeulen et al., 2012).

Global warming will have an increasing impact on the increasing frequency and intensity of extreme weather and climate phenomena. According to estimates, 50-80% of the land will experience extreme temperatures which will increase in the XXI century. Increased heat stress is expected to increase soil moisture and runoff deficits.

Many studies suggest that the factors and impacts of climate change are highly uncertain (Nordhaus, 2011). Extreme phenomena limit the ability to effectively adapt to climate change and mitigate its effects, which determines the high risks of agriculture (Kunreuther et al., 2012).

Risk reduction directly depends on the analysis of the risk assessment and the quality of the measures applied. Therefore, the more accurate the conclusions of the risk assessment are, the more effective the risk mitigation measures will be. Land-use planning (Saunders & Kilvington, 2016), increased risk awareness, climate change adaptation strategies (Ojo & Baiyegunhi, 2020) and government support (Unay-Gailhard & Bojnec, 2020) are considered key tools for disaster risk reduction. Global climate change, the high degree of uncertainty and the risks of natural disasters require the construction of modern mechanisms for adapting agriculture to changing climatic conditions in the context of spatial, temporal, economic and environmental aspects that have a significant impact on the development of regional systems.

2. Problem Statement

The complexity of risk management in implementing the principles of sustainable development in agriculture indicates the need to optimize efforts to adapt and mitigate the effects of climate change through risk sharing among the involved participants. The theoretical justification of problem solutions to

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global climate change risks is of great scientific and practical interest and this work is aimed at solving them.

3. Research Questions

The issues tackled in this paper are directly based on the hypothesis of the study, which implies that the system of distribution of risks of climate change has a significant impact on the sustainability of agricultural enterprises. In accordance with this, in our opinion, it is advisable to consider the following issues:

- to conduct a theoretical substantiation of the system of climate risk distribution among the involved participants;
- to assess the possible consequences of risk allocation on the economic results of agricultural production;
- to present an argument for possible directions to improve the mechanism for managing climate risks in regional agriculture.

4. Purpose of the Study

The purpose of this study was to present an argument for possible ways to improve the system of adaptation of agriculture to climatic risks.

5. Research Methods

The methods of logical and comparative analysis with the use of information review and statistical data were used as general scientific research methods. When deciding on the economic assessment of the risks of the impact of climate change on agriculture, we proceeded from the principles of utility assessment based on a comparison of the expected benefits and costs of land use. Climate factors are seen as additional external effects of the shift with the account of the risk assessment. Agricultural production is considered by us as a system with many factors of production and many products, the relationship between which is described by the neoclassical production function in the format:

$$y = f(x_1, x_2, \ldots, x_n), \quad (1)$$

where $x_1, x_2, \ldots, x_n$- factors of production with positive and decreasing marginal productivity and constant returns to scale. The potential or actual damage to land use can be determined using the methodology of environmental impact assessment based on balance-sheet constructions (Dubovitski et al., 2020).

6. Findings

Considering the model of the agricultural economy of the region, we proceed from the condition of the functioning of the firms in it in the number of n-units whose activities are related to climatic risks. The target function of the company is aimed at making a profit:

$$f_i = v_i\, p_i - c_i(v_i) - e_i(v_i), \quad (2)$$

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where: v_i is the volume of the produce of the *i-firm*;

p_i - price of the produce of the *i-firm*;

c_i - expenses of the firm on the produce in the volume v_i;

e_i - ecological component per produce unit in the volume v_i.

The general costs which an enterprise has for ecological reasons are:

$$e_i = et_i + ef_i, \tag{3}$$

where: et_i is the sum of ecological payment for the use of land resources;

ef_i - costs of environmental protection measures and maintenance of soil fertility.

The parameters of the environmental component are built in accordance with the current legislative structure and are designed to compensate for the damage that the company causes to the environment. The specific nature of the consequences of climate change for agriculture is that extreme weather phenomena determine high risks of farming and negative externalities that do not depend on the activities of the firms themselves. Taking into account the climate risks (y), the environmental component takes the form:

$$e_i = et_i + ef_i - y_i(p_r, d_i), \tag{4}$$

where: p_r is the probability of risk occurrence in a definite period;

d – potential damage to the economical subjects which are influenced by some risk factors (the cost of the short-received produce and the costs to decrease and eliminate the losses).

In this case the level of risk is:

$$y_i(0, d_i) = 0; \frac{\partial y_i(p_r, d_i)}{\partial p_r} \geq 0; \frac{\partial y_i(p_r, d_i)}{\partial d_i} \leq 0; \tag{5}$$

the combination of these conditions (5) implies that if an adverse phenomenon is unlikely to happen the risk is absent as well. With the growth probability at constant estimates of potential damage the level of risk does not decrease. With the growth of the damage estimates at a fixed probability level of risk does not increase. The total damage to the ecological and economic system as a whole by the aggregate of firms reflects the overall negative impact:

$$E = \sum_{i=1}^{n} y_i. \tag{6}$$

Considering the risk probability the profit of the firm can be defined as:

$$f_i = v_i\, p_i - c_i\,(v_i) - e_i\,(v_i) - y_i(p_r, d_i). \tag{7}$$

The amount of the company's profit depends on the volume of production $v \geq 0$ and the amount of funds needed to compensate for the risk $y \geq 0$. In other words, the firm solves the problem:

$$\begin{cases} \frac{\partial f}{\partial v} = \mathrm{p} - \frac{\partial c(v)}{\partial v} - \frac{\partial y(p_r d)}{\partial v} = 0, \\ \frac{\partial f}{\partial v} = -y\frac{\partial y(p_r d)}{\partial v} - 1 = 0. \end{cases} \tag{8}$$

The solution of the system (8) allows you to determine the parameters v' and y' to ensure that the company receives the maximum profit. These logical assumptions are correct if production volumes exceed environmental externalities:

$$v_i\, p_i - c_i\,(v_i) \geq e_i\,(v_i) - y_i(p_r, d_i). \tag{9}$$

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In a situation where a business uses only its own funds to compensate for environmental risks, it is possible that environmental costs, taking into account the risks of product losses, do not provide the company with the opportunity to make a profit:

$$v_i\, p_i - c_i\,(v_i) \le e_i\,(v_i) - y_i(p_r,\, d_i). \tag{10}$$

As a result, there are conditions that lead to loss of income and curtailment of production, especially in small businesses. The regions are interested in maintaining the stability of business functioning and agroecological systems in general, for many objective reasons (Ivanova & Merkulova, 2018, Karpunina et al., 2020a, 2020b), which is a serious reason for the formation of a mechanism for compensating (subsidizing) climate risks on the basis of a regional environmental fund creation. If there is a mechanism to compensate for climate risks in the region, the company's profit, taking into account the possible compensation for the loss, will be determined by the expression:

$$f_i = v_i\, p_i - c_i\,(v_i) - e_i\,(v_i) - y_i(p_r,\, d_i) + b y_i \tag{11}$$

or:

$$f_i = v_i\, p_i - c_i\,(v_i) - e_i\,(v_i) - (1-b) y_i(p_r,\, d_i) \tag{12}$$

If b = 1, the company compensates for all risks on its own. If b = 0, all risks are compensated by the region. In the case of subsidiary liability, the share of compensation is in the range 0 <b< 1.Thus, at any risk level yi> 0, if the mechanism provides for full compensation for all losses of the company, the volume of production will tend to the maximum possible value in these technological conditions. A minimum level of risk can be achieved if the environmental fund has sufficient funds at its disposal. But if we take into account that the funds of the fund may be limited to the amount of L, then the compensation may be part of the damage Li incurred by the firm. In this case, the total amount of regional compensation will be:

$$L = b \sum_{i=1}^{n} y_i, \text{ with } 0 \le L \le E, \tag{13}$$

The strategy of the company's behavior is based on two possible options. Comparing the value $(1-b)y'_b$ with the value Li, the following condition is checked:

$$(1-b) y'_b \le L_i,. \tag{14}$$

This means that the volume of production and the amount of compensation for damage is determined from the decision of the system (8). If the condition (14) is not met, the company compensates for the amount of climate risks based on the condition:

$$y'_b = \frac{Li}{1-b}, \tag{15}$$

and the volume of production in this case is determined by the function:

$$f\,(v_i, y'_b) = v_i\, p_i - c_i\,(v_i) - e_i\,(v_i) - (1-b) y'_b(p_r,\, d_i) \xrightarrow{vi \ge 0} max. \tag{16}$$

7. Conclusion

In the current conditions with a high level of uncertainty and risks of natural disasters, it is obvious that it is necessary to build modern mechanisms for adapting agriculture to changing climate conditions. The creation of centralized environmental funds is considered a key tool for mitigating the consequences of natural disaster risks. In order to maintain the stability of the functioning of agroecological systems, it is advisable to provide subsidiary liability in terms of compensation for potential damage to economic entities affected by risk factors. This element of risk management policy can contribute to the realization of the productive capabilities of the economic system and to adaptation to climate change and mitigation of its consequences.

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