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ADAPTIVE AGRICULTURAL MANAGEMENT: RESPONDING TO CLIMATE CHANGE

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Abstract
In the article, main theoretical and methodological aspects of implementing adaptive management in functioning of agricultural enterprises in conditions of natural and climatic changes are considered. Theoretical approaches to determining the essence of adaptive management have been generalized, with identification of priority characteristics that have developed in modern economic conditions. Directions of comprehensive activity for implementation of adaptive management measures in strategic aspect have been determined. It has been considered the main directions of adaptive management of agricultural production and implementation of adaptive systems in conditions of climatic changes and specifics of technogenic direction of adaptation of agricultural production. Organizational aspects of agricultural production in the context of climate change have been substantiated, relating to both territorial location of individual enterprises and farms and technological innovations. It has been identified state management supporting adaptation of agricultural production in the context of climate change based on the systemic approach, including main components of the state management system. Functional purpose of the state management policy supporting adaptation of agricultural production is to ensure effective adaptive management, which is determined by the degree of organizational support of the state management system. Functional areas cover diverse activities of agricultural enterprises from optimizing the use of water resources and chemical fertilizers, adjusting timing of sowing and harvesting crops to implementing risk management measures in the context of climate change. The emphasis is on importance of taking into account aspects of risk and uncertainty of environmental conditions, and development of the appropriate risk management mechanism have been proposed.

Keywords*: Agricultural Sector, Adaptive Management, State Policy, Innovative Development, Natural and Climatic Factors, Agriculture, Change Management, Risk Management.*

JEL Codes: *Q12, Q14.*

Introduction

Adaptive development of the agricultural sector is a new trend that combines measures aimed at implementing functions of planning, organization, regulation and control by both state authorities in the interests of supporting the leading sector of the national economy and at the micro level in the context of ensuring strategic changes in activities of the enterprise. As the experience of foreign countries shows, the key aspect of effective organization of the agricultural sector of the economy in the context of climate change is the level of state support for

entrepreneurial activity both in current aspect and in strategic perspective. The areas of state support relate to both effective agricultural management and management of land and water resources, solving issues of optimizing the use of fertilizers, countering climate challenges for agriculture, and modernizing technological processes in agricultural production. Under various socio-economic and political conditions of the external environment, as well as in conditions of increased natural and climatic threats, adaptive management contributes to transformation of the nature and structure of agricultural production, regulates the influence of climatic factors based on necessary operational and strategic changes, which actualizes the issue of using modern technologies and tools of managerial influence.

Literature review

Modern scientific community pays sufficient attention to the issue of adaptive management of agricultural production, which is caused primarily by natural and climatic changes, implementation of principles of the "green economy" and proclamation of the Global Development Goals as priority strategic directions for functioning of national economies of countries.

Ahn Sora et al. (2018), Ashofteh Parisa-Sada et al. (2017) investigate hydrological impact of drought-adaptive agricultural water management and analyze the role of adaptive water management policies and strategies. Babaeian Fariba et al. (2023), Deineha O. et al. (2022) developed dynamic the adaptive policy pathways to climate change for water management in agriculture using socio-hydrological modeling, and also investigated capabilities of adaptive management of transport logistics in agricultural enterprises. Haileslassie A. et al. (2020), Han Y. et al. (2024) analyzed changing agricultural landscapes in Ethiopia and the impact of climate on wheat production to develop spatially coordinated climate-adaptive agricultural management.

Hossain Md Lokman et al. (2024), Klius Y. et al. (2023), Grigoraș-Ichim et al. (2018) investigated adaptive strategies and implications for sustainable agricultural development and water resources management, and carried out adaptive modeling of the size of the resource base as the measure of efficient agricultural enterprise management.

Li Peng et al. (2024), Lyra Aikaterini et al. (2023), Norton Jeanette et al. (2019), Grosu et al. (2021) performed the adaptive assessment of agricultural sustainability of different fertilizer management options for the green manure and the corn crop rotation system, simulated water resources management scenarios under climate change for adaptive management of coastal agricultural watersheds, and considered features of adaptive management of nitrification in agricultural soils.

Ruiu Maria laura et al. (2017), Takeda M. (2021) developed adaptive actions to contextual changes for sustainable agricultural management, and investigated trends in agricultural water resources management. Tian Y. (2024), Yusheng C. et al (2024) analyzed adaptive control and supply chain management of intelligent agricultural greenhouse using the intelligent fuzzy auxiliary cognitive system, and also investigated adaptive management of agricultural heritage systems.

Thus, generalization of theoretical approaches allows us to conclude that adaptation contributes to achieving economic security of organization and improving management processes. agricultural enterprises, which requires further scientific research in this area, taking into account importance of state influence and development of the appropriate state support policy.

The purpose of the work is to improve existing theoretical and methodological provisions for implementation of adaptive management in activities of agricultural enterprises in the context of natural and climatic changes and in the context of updating state policy in this direction.

Results

Agricultural enterprises are characterized by certain industry features that determine the priority and feasibility of adaptive management, among which the priority condition is dependence of the agricultural production on natural and climatic conditions and natural and biological cycle of growing plants and animals. Under the influence of existing climatic challenges, such as increasing temperatures, uneven precipitation and

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decrease in their amount, frequent droughts and floods, it is appropriate to characterize adaptive agricultural management by the following trends that have developed in modern economic conditions:

- seasonal cyclicality of production;
- sectoral structural proportions (disproportions) of crop production and livestock production;
- horizontal integration and deepening of production links in the chain "raw materials - processed products - finished products";
- updating state support and developing strategic state policy measures, especially in relation to innovative enterprises in development of innovative adaptive technologies.

Therefore, comprehensive activities to implement adaptive management measures in strategic aspect are aimed at:

- effective management of risks associated with changes in natural and climatic conditions and man-made activities;
- use of modern approaches, methods and technologies in planning and managing economic activities based on optimizing the use of water and land resources, improving technological processes, switching to growing other types of crops etc.

Active development of scientific research, especially in the natural sciences, has formed theoretical and applied basis for implementation of technogenic technologies for agricultural management under the influence of challenges of natural and climatic changes (Maksymova et al., 2024), primarily in the direction of the crop sector. The main directions of adaptive management of agricultural production and implementation of adaptive systems are active use of resource-saving and highly adaptive technologies, which are based on automation and computerization, which generally contributes to the growth of innovative technological and production potential of enterprises (Hutorov et al., 2021; Shelenko et al., 2023) and risk tolerance in conditions of natural and climatic changes. Technogenic direction of adaptation of agricultural production is considered a priority, since most scientists consider it as an operational challenge to investors in the form of possible obtaining of positive financial results using highly productive technical means, new types of fertilizers of chemical origin, technologies for growing plants and fattening animals, bioenergy resources, etc. (Barlett, Peggy F., 1980; Mary Abdul Majid et al., 2024; Zakharchuk et al., 2022). Focusing on technological development at the micro level further contributes to solving tasks of national importance, namely development of the agricultural market, meeting demand for agricultural products, ensuring competitiveness of agricultural producers. Widespread use of man-made systems currently prevails in most countries, however, in the context of emergence of the digital economy, technological processes of agricultural production are increasingly oriented towards the use of artificial intelligence technologies, drones, sensor tools for tracking climate change, automation of animal husbandry and crop production processes. Similar trend is also explained by inexpediency of exponential growth of costs for non-renewable resources, increasing damage to the environment, and deterioration of food quality due to high man-made impact.

The focus on achieving sustainable development goals has formed new alternative approaches to land use and ensuring effective functioning of the crop production sector. Thus, adaptive technologies are focused on the maximum biologization of agricultural processes, as they contribute to formation of specific species and varietal structure of crops, improvement of crop rotation, widespread use of biological methods and plant protection products, and spread of rational agricultural techniques, which together, unlike traditional technologies, prevents disruption of the ecological balance.

Analysis of leading world experience in the field of adaptive management allows us to identify the following priority areas for organizing agricultural production in the context of climate change, which relate to both territorial location of individual enterprises and farms and technological innovations:

- specialization of crop production according to agroecological soil types and adaptive potential of individual crop crops;
- adaptation of cultivation technologies to agroecological soil types, existing level of

production intensification and economic structure;
- territorial placement of agricultural producers based on considering specifics of landscape connections;
- ensuring sustainable reclaimed agricultural landscapes through the ecologization of technological processes based on the rational use of new types of biologically active fertilizers;
- carrying out land reclamation and agrotechnical measures on drained lands in accordance with environmental requirements (Mary Abdul Majid et al., 2024; Linmei Shang et al., 2021).

Thus, the adaptive management policy is focused on biologization and ecologization of agricultural production, the purpose of which is to ensure performance of the photosynthetic function of crop production. In turn, the use of the agroecological microzonation priciple of agricultural lands, the adaptive approach to selection of new plant varieties and animal breeds, the formation of environmentally sustainable agroecosystems will contribute to effective use of cultivated crops. Taking into account these natural and climatic factors as changes in average annual temperatures, uneven precipitation, extreme weather events, makes it possible to ensure that characteristics of the soil and climate correspond to characteristics of the cultivated crops, which affects the choice of crop rotation, adaptation of the structure of land to climatic conditions of the particular area. Thus, based on the use of adaptive technologies of agricultural production, agroclimatic zoning and zonal specialization are ensured by focusing on local bioclimatic resources. Adaptive systems, in comparison with technogenic ones, have higher parameters of stability, are characterized by effective use of natural resources and energy efficiency.

World experience and the work of experts in the field of agricultural development indicate the use of adaptive technologies as imperative for effective agricultural management in the context of meeting growing demands of the population for food. However, counteraction to climate challenges is not always regulated properly, which makes it urgent to involve public administration tools. This is of particular importance in the absence of the proper approach to implementation of adaptive management principles, paying significant attention to intensification of production processes, and lacking the balance between benefit and rational use of natural resources. Thus, according to experts, the risk of degradation of natural resources is currently increasing, which poses the threat to the environmental safety of agricultural products: both agricultural raw materials and processed products (Food and Agricultural Organization of the Poor Nations, 2024). In the future, this will have negative socio-economic consequences for development of rural areas.

State management of supporting adaptation of agricultural production in the face of climate change is proposed to be considered as the system as a set of interconnected objects and subjects that interact on the scientific basis, and using sectoral and territorial approach in management. The input of the public administration system refers to the resource potential of agricultural production, which will contribute to effective adaptation of the producer to changing environmental conditions, in particular climate change, as well as managerial potential of management of agricultural enterprises.

Characteristics of the output include specific directions of the state policy and decisions of authorized authorities aimed at achieving the goals and objectives of adaptive management in the context of climate change based on innovative technologies and organizational and managerial changes.

The functional purpose of the state administration policy to support adaptation of agricultural production is to ensure effective adaptive management, which is determined by the degree of organizational support of the state administration system. Functional areas cover the diverse activities of agricultural enterprises from optimizing the use of water resources and chemical fertilizers, adjusting the timing of sowing and harvesting crops to implementing risk management measures in the context of climate change (Fig. 1).

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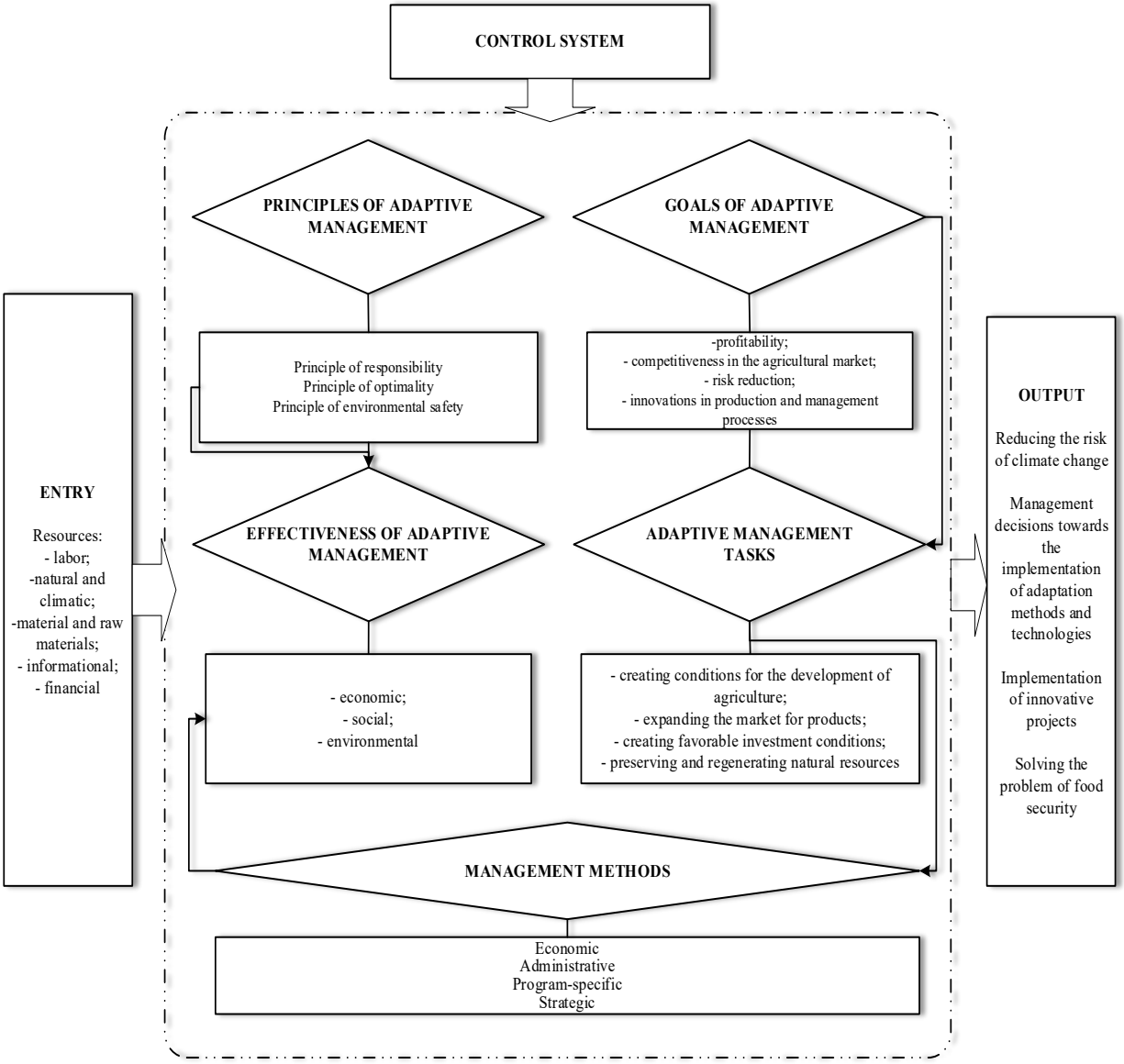

Figure 1. State management of support for adaptation of agricultural production to climate change

**Source: author's development.*

Therefore, adaptive management of agricultural production is effective if certain principles are followed. In our opinion, it is advisable to highlight the following:

- principle of responsibility. It involves compliance with conditions of the technological process, established deadlines and standards.
- principle of optimality. Introduction of adaptive technologies, especially digital ones, involves rational management of costs and their optimization, as well as mobilization of internal reserves of the agricultural enterprise, which will positively affect forming the cost of production, provided that the integrated approach is taken.
- principle of the environmental safety is to promote the production greening based on the rational use of natural resource potential based on low-waste and waste-free technologies, and to reduce the level of environmental pollution.

Development of measures for implementation of adaptive management begins with integration into the new management system of the potential of agricultural production, taking into account agricultural specialization and established production relations with partners. Effective management of the potential will ensure

maximum adaptation while reducing financial costs. This will ensure transition to adaptive technologies at minimal cost and in a short time. Available unique natural resource potential characterizes domestic agricultural production as one of the leading subjects of the world agricultural market. However, the analysis of the state of development of agricultural production in Ukraine allows us to conclude that production volumes of both crop and livestock products are decreasing.

The analysis of the dynamics of agricultural production volumes in Ukraine for 2021 (pre-war year), 2022-2024 allows us to identify key trends in changes in the agricultural sector under the influence of the full-scale war, as well as to assess their impact on economic development of the state (Figure 2).

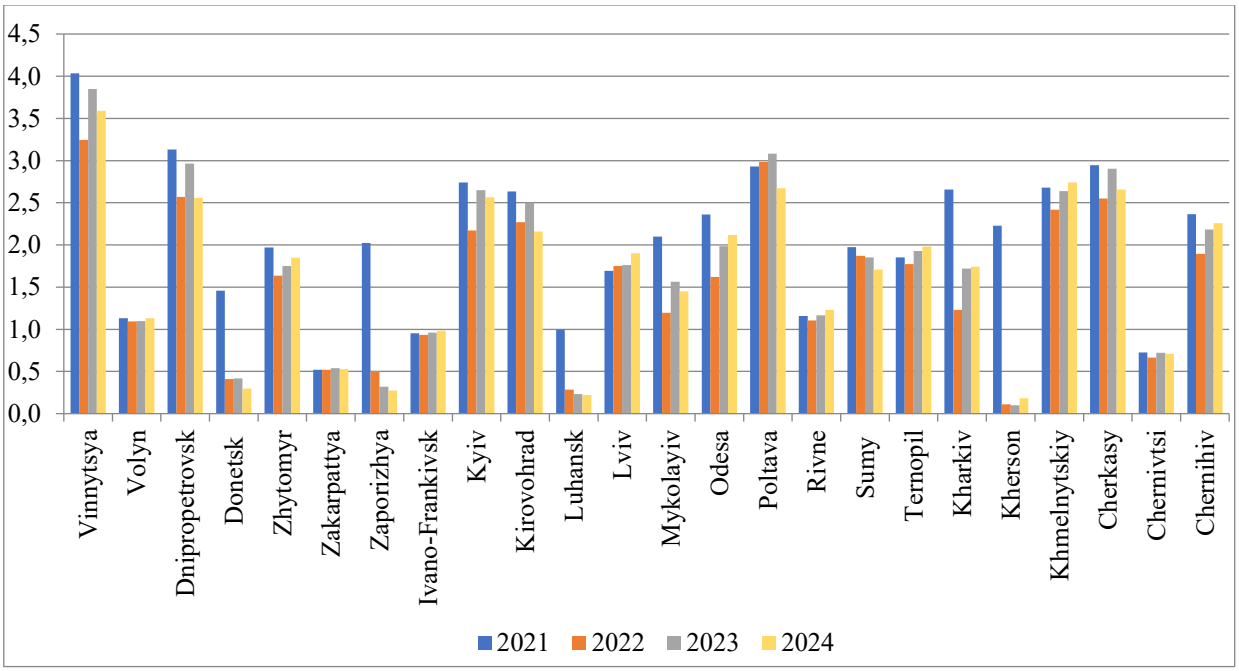

Figure 2. Volumes of agricultural production in Ukraine for 2021 – 2024, in 2021 constant prices, billion USD

**Source: based on State Statistics Service of Ukraine (2024).*

In 2022, most regions experienced significant reduction in production volumes. This is explained by temporary occupation of territories; active hostilities; destruction of logistics and infrastructure; risks for agricultural producers; and shortage of resources (fuel, fertilizers, equipment).

The largest drops in 2022 were recorded in Kherson region: - 2.12 billion USD (95% drop); Zaporizhya region: - 1.52 billion USD (-75%); Donetsk region: - 1.05 billion USD (-72%); Luhansk region: - 0.71 billion USD (-72%); Kharkiv region: - 1.43 billion USD (-54%); Mykolayiv region: - 0.90 billion USD (-43%).

In 2023, there is stabilization and restoration of production volumes in some regions. This is due to the deoccupation of some territories; adaptation of agricultural producers to wartime conditions; restoration of export logistics (via the Danube, road, railway); state support (grants, loans, insurance); activity in relatively safe regions.

In 2023, gradual recovery of the agricultural activity was observed in the number of Ukrainian regions that had previously experienced significant reduction in production due to military operations. In particular, Kharkiv region demonstrated the most noticeable growth: the volume of agricultural production increased from 1.23 billion USD in 2022 to 1.72 billion USD in 2023. Significant improvement in indicators also occurred in Mykolayiv region, where production increased from 1.20 to 1.56 billion USD, as well as in Odesa region - from 1.62 to 1.99 billion USD, which indicates partial stabilization of the situation and restoration of

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agricultural infrastructure. Similar positive dynamics were observed in Kyiv region (from 2.17 to 2.65 billion USD), Vinnytsya region (from 3.24 to 3.85 billion USD), and Dnipropetrovsk region (from 2.57 to 2.97 billion USD).

In 2024, the trend towards the decrease in agricultural production volumes persisted in some regions of Ukraine, indicating ongoing structural, economic or security difficulties. In particular, in Donetsk region, volumes decreased from 0.42 to 0.30 billion USD, indicating the decrease in production efficiency and limited access to resources. Similar situation was observed in Zaporizhya region, where indicators fell from 0.32 to 0.28 billion USD. In Dnipropetrovsk region, the decrease was recorded from 2.97 to 2.56 billion USD, and in Kirovohrad region - from 2.50 to 2.16 billion USD. This decrease is associated with economic difficulties, insufficient investment support, personnel losses or logistical constraints that could not be overcome even despite more stable conditions compared to regions of active hostilities.

The following trends in agriculture had significant macroeconomic consequences for Ukraine:

1. Decline in agricultural contribution to GDP, as agriculture accounted in 2014-2018 for up to 10–12% of Ukraine's GDP. Decline in 2022 caused an overall reduction in GDP and exacerbated the budget deficit.

2. Decrease in export revenue in 2022–2023, the volume of exports of grain and other agricultural products fell. This affected the foreign trade balance and foreign exchange earnings.

3. Logistics routes have changed, instead of seaports, road and rail corridors to the EU are playing an increasingly important role, which contributes to development of new infrastructure, but increases costs.

Thus, the war dealt serious blow to the agricultural sector, especially in 2022, when production volumes sharply decreased. In 2023-2024, there is the tendency towards gradual recovery, but it is not uniform - some regions have returned to pre-war levels, while others continue to lose volumes. Agriculture remains a critically important sector for the Ukrainian economy, and its restoration is a priority for ensuring the food, economic and social security of the state (Gaidutskyi et al., 2024).

Significant risks to agricultural production have arisen due to the increase in prices and difficulty in the physical availability of seeds, planting material, and mineral fertilizers. This trend is especially pronounced in front-line areas. Logistical risks are also significant. Thus, in 2022, due to problems with transportation of grain crops, production of corn and spring grains was reduced, as most agricultural enterprises sowed the areas intended for these crops with sunflower and soybeans. The lack of mineral fertilizers or their high-cost force them to abandon hybrid varieties of seeds. Losses in agricultural crop production also occur due to negative changes in the environmental sphere. Thus, according to official data, military operations caused damage to the environment of Ukraine in the amount of 890 million USD (Food and Agricultural Organization of the Poor Nations, 2024).

In 2023, about 2 million hectares of agricultural land was unusable due to mining. Significant losses were also caused by destruction of the Kakhovka hydroelectric power station. The most vulnerable to risks remain small businesses, farms and households, which are the main suppliers to the meat and dairy market.

In this context, it is necessary to take into account the aspect of risk and uncertainty of the external environment, which involves development of appropriate risk management mechanism both in the context of state policy to support adaptive management of agricultural production and at the micro level, within the framework of the general strategy development for managing the agricultural enterprise. The concept of forming the mechanism involves the classical functional approach and is based on development of specific areas within the framework of this management functions as analysis and assessment, planning, organization of management process, control and monitoring of the results obtained, as well as with simultaneous implementation of business motivation tools, such as insurance, preferential taxation, access to preferential loans, etc. (Fig. 3).

Adaptive management in conditions of increased risk involves the use, among other things, of effective financial instruments, one of which is agricultural insurance. Its main goal is to

support the economic activity of agricultural enterprises in conditions of uncertainty and protect against adverse events, including natural and climatic ones. In this context, Ukraine needs to pay attention to the experience of the USA and Canada, which actively use the agricultural insurance tool for sown areas (60% of insured sown areas compared to 5% in Ukraine at the end of 2021). In Austria, the coverage level of agricultural products by insurance is 78%, in Cyprus – 100%, in Germany – 43%, in the Czech Republic – 35%, in Spain – 26% etc. (Food and Agricultural Organization of the Poor Nations, 2024).

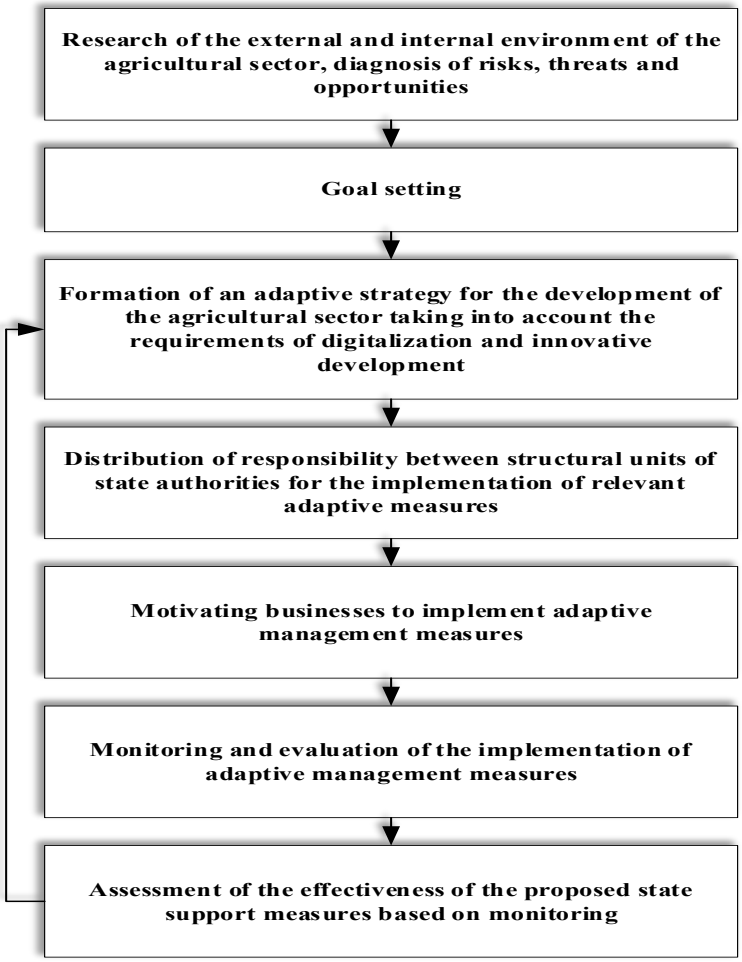

Figure 3. Main stages of risk management in the context of implementing adaptive management of agricultural production

**Source: author's development.*

However, effectiveness and efficiency of agricultural insurance operations depends on program measures of state support, primarily of the long-term nature. As an example, we can offer the experience of the USA, where the Federal Crop Insurance Program has been operating for a long time. The purpose of the program is to insure crops against risks due to climate change and natural disasters, and the program also includes compensation for logistics and field costs. In Canada, there is also the Crop Insurance Program in the event of complete or partial loss (loss) of the crop (CIP), which is combined, that is, it offers the insurance to agricultural producers of the level of yield and losses of the producer's gross income due to changes in market conditions.

The main directions of adaptive management should be correlated with the country's agrarian policy, the purpose of which is sustainable and effective functioning of the agricultural sector to meet the needs of the population and development of rural areas. The leading role in this belongs to the policy of supporting innovations and development of scientific and technical activities related to technologies for countering natural and climatic

challenges. However, the primary condition for targeted adaptive management is investment potential, which development also depends on effective state support. Thus, effectiveness of the implemented adaptive management measures depends on the established contacts with scientific institutions, including higher educational institutions. This will allow the agricultural producer to receive timely and relevant information on modern innovative developments. It is also important to create the specialized information system, the use of which would allow obtaining data on modern technologies and their possible use in innovative projects in the field of technological innovations for adaptation.

Conclusions

The state policy to support adaptation of the agricultural sector to climate change should be based on specific methodological aspects. Thus, when carrying out measures of agro-climatic zoning and placement of agro-industrial production, attention should be paid to the agricultural enterprise as a central system-forming link. That is, specialization of agricultural production should be based on taking into account agro-climatic conditions of each individual enterprise. Since the territory of the country can be located in different agro-climatic zones, and even the territory of one region will not be homogeneous in terms of climatic conditions, soil type, humidity level, etc. the main direction of the state policy should be the micro-level of adaptive management. This methodological approach should become the basis for transition of agricultural enterprises to adaptive management. Adaptive management of the agricultural sector in the context of climate change is characterized by complexity, since it involves consdering all trends in changes in natural and climatic factors of influence with the simultaneous formation of effective models of interaction of the agricultural enterprise with other market entities and state authorities. The analysis and evaluation of existing approaches to implementation of adaptive management measures and development of the effective state support policy prove the high level of applied orientation of the theory of adaptive management in the system of effective functioning of agriculture.

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