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Olena Shubravska

Innovations in ensuring the climate resilient agriculture

Institute for economics and forecasting NAS of Ukraine

Abstract: *The definition of climate resistant agriculture is given. Key global trends in innovative provision of climate resilience of agriculture are outlined. The process of innovative technologies introduction in Ukraine, aimed at strengthening the climatic resilience of agriculture, is characterized.*

Key words: climate resilience; agrarian innovative technologies; global trends; drought resistance.

Agricultural resilience, like the resilience of any system, is defined as a measure of how many disturbances such a system can withstand before the "critical threshold" is crossed, and it undergoes drastic changes and imbalances (that is, it loses the ability to cope with the set tasks before her). Therefore, the resilience of the agricultural system, as the main producer of food, becomes a key factor in ensuring national food security.

The natural and climatic conditions, and especially their sharp changes observed in recent years, have a huge impact on agriculture resilience. Agriculture, as is known, depends much greater than other sectors of the economy on climatic transformations (in particular, on rising global temperatures, changes in the level and structure of precipitation). The fluctuations in agricultural production indicators caused by such changes are a significant reason for the instability of farmers' incomes and, in general, a violation of the economic stability of the agricultural sector. The consequences of climate change pose a significant threat to the food security of the population, as they lead not only to an increase in the volatility of agricultural crop yields and animal productivity, but also to an increase in the scarcity of natural resources for agricultural production (primarily, water) due to their faster depletion compared to the regenerative capabilities of the natural environment.

In its turn, agrarian business directly provokes the degradation of natural resources and the increase of the mentioned climate changes, mainly due to the growth in greenhouse gas emissions, more than 20% of which, according to estimates [1], is accounted for by global animal husbandry [2]. Therefore, ensuring the climate resilient agriculture is inextricably linked with ensuring its climate neutrality.

In a general sense, resilience to climate change is defined as the ability to anticipate, prepare for, and respond to hazardous climate events [3]. Thus, climate sustainability of agriculture is its ability to develop, resisting and overcoming the negative impact of natural shocks and simultaneously reducing the carbon footprint by using appropriate adaptation mechanisms.

Innovation plays a key role in the process of adapting agricultural production to increasing climate change. Only with their help is it possible to ensure the food needs of the growing population without cutting down forests and expanding agricultural land, while maintaining the quality indicators of soil and water resources at the appropriate level. The fight against the climate crisis requires innovations in the methods of tilling the soil and caring for farm animals, seed production, and the production of material and technical means. The goal is the wide implementation of climate-adapted technologies that allow to lower water consumption, reduce plowing of land, ensure waste-free production and, accordingly, minimize costs.

It is obvious that the introduction of innovative technologies requires systematicity. In this context, the automation of all production processes is important. Farm automation involves combining agricultural machinery, computer systems, electronics, chemical sensors, and data management into a single system to improve equipment efficiency and raise decision-making. The use by farmers of automated combines, drones, autonomous tractors, as well as sowing and weeding with the help of autonomous mechanisms makes it possible to use available resources more effectively, to increase the yield of plants and the productivity of animals.

In Ukraine, before the full-scale war, a significant increase in spraying drones was observed in the market of services in the agricultural sector. Domestic farmers recognized their main advantage as clear work in certain areas of the field without damage to vegetation and soil compaction. However, with the beginning of a full-scale invasion, work

with agricultural drones became more difficult, primarily due to the difficulty of reserving airspace. According to the results of 2021-2023, the total area of crops treated by agricultural drones in Ukraine was 3.1 million hectares (1 million, 1.2 million and 0.9 million hectares, respectively). This made it possible to reduce fuel consumption by 17.1 million tons, reduce carbon emissions by 43.4 thousand tons, harvest an additional 486.7 thousand tons. In the post-war period, a fivefold increase in growth of the agricultural robotics market is projected.

Weather disasters, primarily droughts, increase the requirements for drought resistance of agricultural crops, which is the key to food security for the growing global population. In this connection, geneticists can apply minichromosome technology, which involves improving plant traits, in particular, increasing their drought resistance, but without changing genes. This technology makes it possible to grow crops that require less chemical protection and fertilizers, achieve bio-enrichment and increase the content of nutrients in plants.

Breeding activities in Ukraine have been significantly intensified in recent years. Even despite the war, foreign companies are investing tens of millions of euros in the field of domestic seed production. For example, the international seed producer Lidea Seeds has a local seed production, a research department and a dairy farm in its structure in Ukraine. This company is focused on the development of the most productive hybrids of corn, sunflower, soybean, sorghum, alfalfa, etc. crops adapted to the soil and climatic conditions of Ukraine. In 2023, the company's investments in local production in Ukraine increased 1.8 times compared to the previous year and reached UAH 1.1 billion.

Among the modern innovative technologies of crop production, precision farming has become the most widespread throughout the world. It is an agricultural resource management strategy that collects, processes and evaluates big data and provides information to farmers based on this. The information obtained allows farmers to optimize production operations, improve soil quality and production productivity. According to forecasts, the global precision agriculture market will reach $16.35 billion by 2028, growing by 13.1% annually.

In Ukraine, the technology of precision agriculture or its individual elements is used by a significant number of primarily large producers. So, according to estimates, among farms with an area of more than 2,000 hectares before the start of a full-scale war, at least half used elements of precision agriculture to some extent or planned to work in this direction. In the EU countries, the share of farmers who work using this technology is almost close to 100%, primarily due to state incentives for the development of such activities. For example, European farmers are deprived of subsidies if they do not carry out professional studies of the condition of their own fields and do not follow the appropriate management technologies. In Ukraine, in peacetime, the implementation of the mentioned practice was limited by its labor-intensiveness, the need for significant initial investments for the purchase of modern machinery and equipment and payment for the services of specialized companies, and the lack of necessary knowledge and skills among domestic farmers. In wartime, the lack of opportunities for the full use of agricultural drones and the sharp aggravation of farmers' financial problems were added to the mentioned obstacles. Therefore, it is obvious that the intensification of the transition to precision agriculture will not take place before the end of the war. At the same time, domestic producers claim that production according to such a system allows them to increase the profitability of their farms by 25-30% compared to traditional technology.

Vertical farming is also considered promising in the world. This is the cultivation of agricultural products in a closed and controlled environment using vertically installed racks (to increase yields in a limited space) and hydroponics or aeroponics. Vertical farms allow growers to control lighting, temperature, water regime and sometimes carbon dioxide levels. This technology provides up to 70% water savings compared to the traditional one.

In Ukraine, such productions are also developing, although they have significant limitations, primarily due to the high cost of electricity. Thus, as the producers note, a third of the costs of vertical farms, which specialize in particular in the cultivation of greens, fall precisely on electricity, as well as on water. At the same time, a closed cultivation system, microclimate management, recirculation and metered water consumption in the production process make it possible to increase productivity (from 30%), reduce water consumption (up to 90%), as well as guarantee the ecological purity of the obtained products.

In crop production, such modern technologies of thrifty farming as No-till, Mini-till, Strip-till, etc. are also actively used. They involve the complete abandonment of traditional plowing or minimal, surface tillage of the soil or its strip loosening, which allows not only to save resources, but also to reduce moisture evaporation, protect the soil from erosion, restore its fertility and biodiversity and, therefore, contribute to decarbonization. In general, 6.8% of arable land in the world is processed using this technology, in particular, up to 3% of arable land in Europe. No-till is most common in the USA, Canada, Brazil, Argentina, and Australia.

In Ukraine, before the war, thrift farming technologies were mainly applied to grain crops. At the same time, areas under No-till accounted for approximately 0.5 million ha, Mini-till – 1.5 million, Strip-till and others – approximately 7 million ha. Arid steppe regions took the lead in implementing such technologies. In 2023, Ukrainian farmers confirmed the trend of changing the method of soil cultivation, namely, the replacement of plowing with minimal soil cultivation and its deep loosening. According to the Ukrainian Club of Agrarian Business, in 2023, the use of plowing decreased by 5%, on the other hand, minimum cultivation increased by 3% and was 8% of cultivated areas.

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Shubravska Olena V. **–** doctor of economics, Professor, Head of the Department of Forms and methods of management in the agri-food complex, Institute for economics and forecasting NAS of Ukraine, Kyiv, e-mail: shubravska@gmail.com