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Vasyl PETRYCHENKO[1], Volodymyr LYKHOCHVOR[2], Ihor DIDUR[3]
and Hanna PANTSYREVA[3*]

SCIENTIFIC ASPECTS OF ORGANIC SOY PRODUCTION IN UKRAINE

Abstract: Taking into account European experience, theoretical and methodological foundations of scientific aspects of organic soybean production in Ukraine have been implemented, aimed at the greening of agriculture, through the preservation of natural soil fertility and the rational use of bioecosystems. It has been established that soybean production, through the introduction of bioorganic technologies, contributes to the improvement of agricultural culture, the restoration of soil fertility, and an increase in the amount of protein products and nutritious feeds. Experimental studies have proven that soil organic matter is a key indicator of its fertility, since it actively affects plant nutrition and improves the physicochemical properties of the soil, as well as the migration of chemical elements. The most important soil processes are closely related to the greening of the agricultural sector. It has been proven that the main source of organic matter for increasing soil fertility is the development of organic models of soybean growing technologies. It is substantiated that the agrobiological potential of these technologies in sustainable production zones of non-irrigated lands will contribute to the creation of a “Soybean belt”. A new stage in soybean production is proposed, which will allow rational use of the region’s hydrothermal resources, increase the gross yield of soybean seeds, promote the biologisation of agriculture and the production of high-quality and environmentally friendly products.

Keywords: soybean, organic farming, soil fertility, soybean belt, gross production

Introduction

Awareness by the world scientific community of the growing ecological threat due to intensive farming stimulated the development of alternative models of management that better corresponded to the vital interests of society [1]. This is the model of organic soybean production, which provides the growing global market with certified, high-quality, environmentally safe products [2].

“Organic production” is a science-based agricultural practice without the use of synthetic plant protection products and fertilisers, which is based as much as possible on crop rotation, the use of plant residues, organic fertilisers, legumes, organic production waste, mechanical soil cultivation and contributes to increasing fertility and improving the structure soil and ensuring full nutrition of plants [3, 4]. Thus, organic soybean production is a comprehensive system of management and production of food and nutritious feed, which combines scientifically based aspects of technological cultivation models in order to

[1] Institute of Feed Research and Agriculture of Podillya of NAAS, Av. Yunosti 16, 21021 Vinnytsia, Ukraine
[2] Lviv National Environmental University, Vladimir the Great, 1 m. Dubliany Lviv region, Lviv, 80381 Ukraine
[3] Vinnytsia National Agrarian University, Vinnytsia, Sonyachna 3, 21002, Ukraine, ORCID: HP 0000-0002-0539-5211
[*] Corresponding author: apantsyreva@gmail.com

preserve natural resources and apply high standards in ensuring the country's food security through improving the livestock industry [5]. The study of European experience in adapting to climate change and the possibility of its application in Ukraine under martial law, along with ensuring environmental and social effects, is aimed at implementing a system for modernising the organic soybean production model, which will help reduce the impact of degradation processes on the soil cover of Ukraine.

Material and methods

The implementation of the sustainable development strategy in Ukraine is based on ensuring national interests and fulfilling international obligations, focusing on long-term environmental and social stability. It includes overcoming existing imbalances, in particular in the environmental sphere, and harmonising global climate change trends with international standards. The key tool for this harmonisation is the introduction of scientifically based methods of organic soybean production, which should become the basis for sustainable development of the agricultural sector.

One of the priorities is to study the world soybean market, determine its share in the structure of global oilseed production, as well as analyse the most promising areas for sustainable soybean production on non-irrigated lands. An important aspect is the creation of guaranteed production zones, which will ensure stable supply of this crop to the domestic market and for export.

Special attention should be paid to the agro-ecological justification of the role of soybean in solving the problem of providing the world and national markets with vegetable protein. Increasing the gross production of soybean seeds is an important step towards the biologisation of agriculture, which will allow obtaining high-quality and environmentally safe products, in accordance with the requirements of the Strategy for Environmental Security and Adaptation to Climate Change for the period up to 2030, as well as other regulatory acts, such as the Law of Ukraine "On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the period up to 2030" and the European Green Deal.

In addition, it is important to take into account in the context of implementing the sustainable development strategy the need to adapt to changes in the agro-industrial sector, in particular through responding to risks arising in the field of agro-industrial production, which is specified in the "Economic Strategy of Ukraine 2030". One of the key areas is also ensuring the country's food security, which is especially relevant in conditions of martial law, as provided for by changes in the legislation of Ukraine on creating conditions for ensuring food security.

Thus, the introduction of organic soybean production within the framework of strategic national and international programs is an important step towards achieving sustainable development, contributing to the environmental, economic and social stability of Ukraine [6].

Results and discussion

According to its biochemical composition, soybean is a unique, leading protein-oil crop in world agriculture. The specific weight of soybeans in the structure of world production of oil crops is 58 % [7]. In terms of growth rates and production volumes, soybean has no equal in European countries (Fig. 1). Soy is capable of rapidly increasing agricultural culture, reviving and improving soil fertility, increasing the amount of available products and fodder, it occupies a central place in the solution of protein [8].

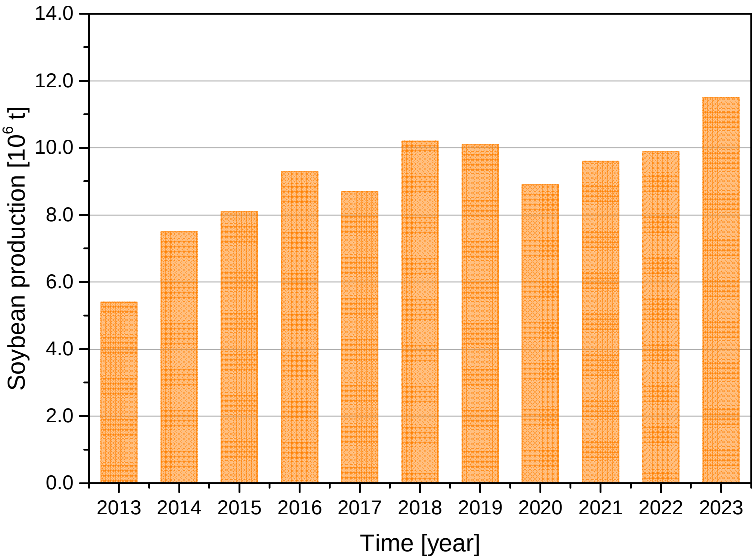

Fig. 1. Dynamics of soybean production in European countries (2013-2023). *Source: authors' research according to the data of the Austrian Development Agency, State Service of Statistics and the Ministry of Agrarian Policy of Ukraine*

Soybean production in European countries has a clear upward trend starting from 2020 [9]. Analysing the production volume data, it was established that in 2023 the growth rate reached 11.5 million tonnes (tonne = t = 10^6 g = Mg) which is 16.2 % more than in 2022. Over the last decade, the least amount of soybeans was harvested in 2013, compared to 2023, the dynamics of soybean production in European countries increased by more than 113.0 % (Table 1).

Table 1

Volumes of soybean production in Ukraine and Europe

European country	**Years**		**Change**	
	2022	**2023**	**[10^6 t]**	**[%]**
Ukraine	3732	4410	+678	+18.2
Italy	610	1040	+430	+70.5
Serbia	440	404	-36	-8.3
France	380	420	+40	+10.5
Austria	244	275	+31	+12.7
Croatia	200	253	+53	+26.5
Hungary	127	165	+38	+29.9
Slovakia	130	165	+34	+26.5
Total	5863	7132	+1269	+17.8

Source: authors' research according to the data of the Austrian Development Agency

It should be noted that Ukraine is the leader in the production of soybeans in Europe and is among the ten largest producing countries in the world for 2013-2023 [10, 11]. According to the US Department of Agriculture (USDA), Ukraine rose in the rating by two positions, second only to Brazil - 39 %, the USA - 37 %, India - 27 %, Argentina - 11 %, China - 10 %, Paraguay and Canada [12, 13]. According to a report by the US Department of Agriculture's Foreign Agricultural Service (FAS), soybean production in India will reach 12 million t in 2023, and the crop will be harvested from 12.8 million hectares (hectare = ha = 10^{-2} km^2). Over the past two decades, world production of soybeans has grown to almost 50-55 million t. In addition, trade in soybean processing products is increasing. According to FAO-AMIS research and data analysis, the forecast supply of soybeans for the current marketing season will be 426.4 million t, which is 6.3 % more than the previous period [14, 15].

During the last decade, the sown area of soybeans increased by almost 50 % (Fig. 2). Lower requirements for fertilisers, use of saved seeds, high demand from the EU and demand in the domestic market have made this crop favourable for many farms in Europe [16].

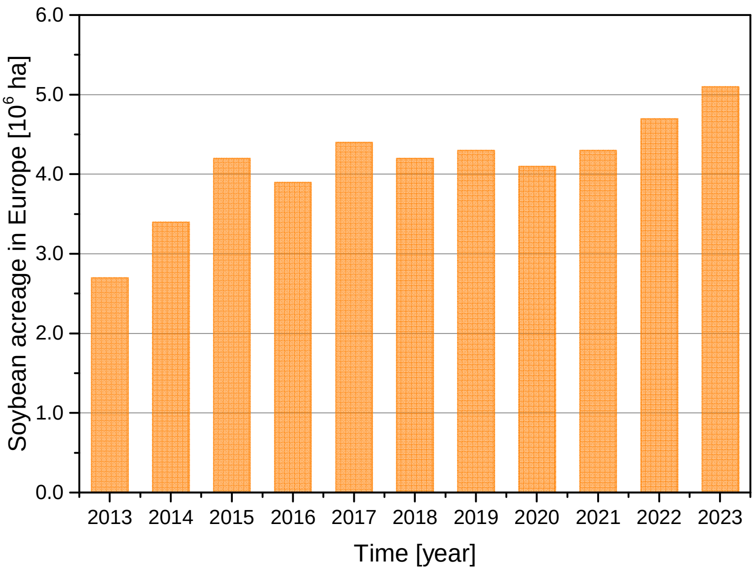

Fig. 2. Dynamics of soybean acreage in European countries (2013-2023). *Source: authors' research according to the data of the Austrian Development Agency*

In the course of the processed statistical data, it was established that in recent years, the sown area under soybeans has been increasing [17, 18]. Therefore, in 2023, the sown areas in Europe by association amounted to 5.1 million hectares, which is 8.5 % more than in 2022. Over the last decade, the smallest sown areas were noted in 2013, compared to 2023. the production level in European countries increased by 88.9 % [19].

Despite the state of war, Ukraine is actively increasing soybean crops (Fig. 3). So, in the current year, soybeans account for 20 % of the area sown under oil crops (19 % in 2022 and 15 % in 2021). This was primarily due to the price situation on the market of oil crops.

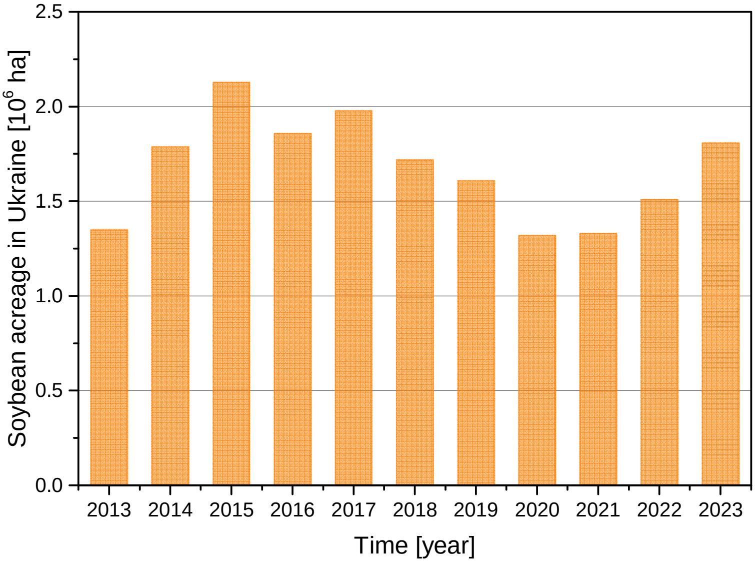

Fig. 3. Dynamics of soybean acreage in Ukraine (2013-2023). *Source: authors' research according to the data of State Service of Statistics and the Ministry of Agrarian Policy of Ukraine*

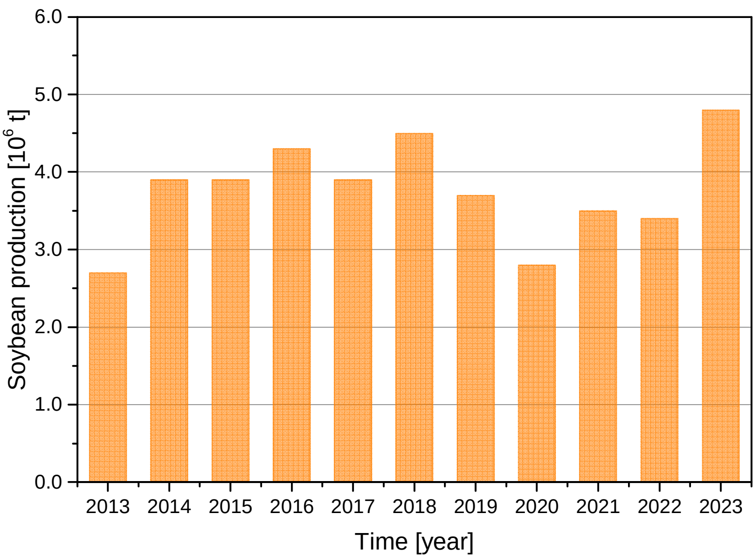

Fig. 4. Gross harvest of soybeans in Ukraine (2013-2023). *Source: authors' research according to the data of State Service of Statistics and the Ministry of Agrarian Policy of Ukraine*

A similar trend in the dynamics of sown areas occupied by soybean cultivation was also recorded in Ukraine [20, 21]. Analysing the statistical data of the State Statistics Service, it was established that in 2023, 1.81 million hectares will be planted with soybeans. of Ukrainian lands, which is 19.9 % more than in 2022. Over the last decade, the smallest cultivated areas were recorded in 2020, compared to 2023, the dynamics increased by more than 37.2 %.

Soy remains in active demand [22]. In 2023, soybean prices increased by 500 hryvnias/t and, accordingly, are $ 460/t - $ 470/t. Therefore, soybean production in Ukraine in 2023 reached 4.78 million t (Fig. 4).

The average yield of soybeans is 2.65 t/ha, although it occupies only 11 % of the total sown areas of grain and oil crops (Fig. 5). Since the area under soybeans in general on the European continent increased by 7 %, the gross harvest of the crop in Europe is forecast to be 16.3 % higher than last year.

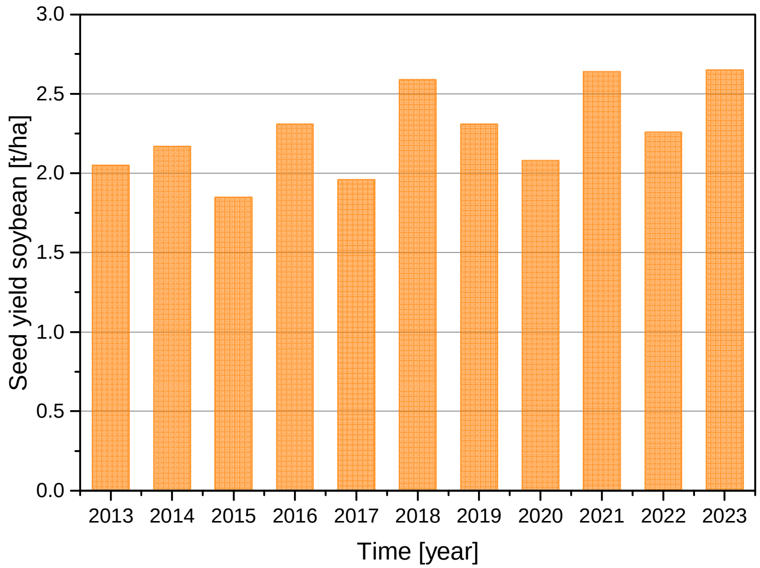

Fig. 5. Average seed yield soybean in Ukraine (2013-2023). *Source: authors' research according to the data of State Service of Statistics and the Ministry of Agrarian Policy of Ukraine*

The maximum yield of soybeans was reached in 2023 (2.73 t/ha) over the past 10 years. The phenomenon of this culture is that during the growing season, two crops are synthesised - protein and fat - and almost all organic substances that are in the plant world [23]. Soybean seeds and products of its processing have long been used in large and developed countries to solve the key problem of protein and renew food resources. Soy provides more than 1.2 t of protein per 1 ha, is well absorbed by the body and dissolves in water [24].

The "Soybean belt" of Ukraine, where zones of sustainable soybean production on non-irrigated lands are identified, is scientifically substantiated at the Podillia Institute of Agricultural Feeds of the National Academy of Sciences [3] (Fig. 6).

Fig. 6. “Soybean belt” (in ha) of Ukraine in 2023. *Source:* developed at the Institute of Agricultural Fodder of the Podillia National Academy of Sciences

Given the development prospects, soybeans can be grown on a fairly large area of the right-bank and left-bank Forest-Steppe of Ukraine, that is, in the “Soybean belt of the country”, which includes 8 regions of the forest-steppe zone and two steppe regions, where 79 % of soybeans are currently grown and about 10 % in southern and central Polissya, as well as the western regions of Ukraine. Thus, in the conditions of climate change [25], the territorial transformation of the “Soybean belt” will contribute to the rational use of the region’s hydrotechnical resources, increase production due to its biologisation of agriculture [3], and obtain high-quality, organic products. Given the development prospects, soybeans can be grown on a fairly large area of the Right-Bank and Left-Bank Forest-Steppe of Ukraine, that is, in the “Soybean belt of the country”, which includes 8 regions of the forest-steppe zone and two steppe, where 79 % of soybeans are currently grown and about 10 % in southern and central Polissya, as well as western regions of Ukraine. Thus, in the conditions of climate change [25], the territorial transformation of the “Soybean belt” will contribute to the rational use of the region’s hydrotechnical resources, increase production due to its biologisation of agriculture [3], obtain high-quality, organic products [26].

As a result of the agroecological substantiation of the role of soybeans in solving the problem of plant protein in Ukraine, the prospects for further research lie in the improvement and development of varietal technologies for growing soybeans [27]. Accumulation of protein and fat in soybean seeds, according to various authors, depends on many agrotechnical techniques [28]. Not the last role among them is occupied by variety, as the biological basis of technology. There are conflicting data on the influence of sowing dates and sowing rates on the protein and fat content of soybean seeds. Some scientists testify that they affect the chemical composition of seeds [29, 30], others believe that the content of protein and fat do not depend on the timing of sowing and sowing rates [31]. Starting from the phase of full flowering (R1-R2), hydrolytic processes intensify in these organs and the outflow of the formed decomposition products into the reproductive organs begins. A significant amount of amino acids and amides enters the ripening seeds from the roots due to the introduction of nutrients, where atmospheric nitrogen is bound by symbiotic fixation and restored to the ammonium form. Therefore, when applying high doses of nitrogen fertilisers, which negatively affect nitrogen metabolism in plants, protein synthesis in soybeans is inhibited [32, 33]. For agroecological substantiation of organic technology of soybean cultivation in Ukraine, it is extremely important to study the effect of fixed nitrogen from atmospheric air, as well as the effectiveness of foliar feeding with complex biofertilisers on the processes of growth, development and seed productivity of soybeans. This will optimise the use of natural resources and reduce dependence on chemical fertilisers, which is an important component of organic farming.

The dominant trends observed in world agriculture in the last decade are the improvement of technologies for growing leguminous crops based on the achievements of biotechnology and organic farming systems. It is characteristic that in the fields of Ukraine, despite the military situation, the use of such technologies is increasing. The pioneers of eco-innovative technologies are, first of all, large agricultural holdings that are financially independent. This enables them not only to obtain high yields, but also to significantly reduce the load on the soil. The expansion of organic farming systems is a positive factor, as it contributes to raising the level of the general culture of agriculture. According to established data [34], about 70 % of soybeans are genetically modified varieties. These products are superior to the development of domestic breeding in terms of yield, and their cultivation technologies, thanks to the use of bacterial preparations and microfertilisers, have a significant advantage in the crop care system. It is thanks to these technologies that there is a significant expansion of the soybean sowing area. At this stage, the association cannot compete with the achievements of foreign research centers, even on their own markets in the field of biotechnology of European countries. Therefore, the main goal of the European Green Course is to transform Europe into a climate-neutral continent [35]. In order not to lose influence on the domestic soybean production market, it is necessary to look for ways to cooperate with leading research centers and agricultural companies. Along with this, considerable attention in the countries of sustainable agriculture, in particular the EU, is paid to greening and reducing the negative impact of intensive crop cultivation technologies on the environment [36]. This is achieved, first of all, by reducing the use of pesticides and mineral fertilisers [17, 37], finding ways to expand biological measures [38], inoculation, reducing the intensity of soil cultivation in accordance with the transition to environmentally friendly technologies No-Till, Strip-Till and Mini-Till. The role of the crop rotation factor and the role of organic fertilisers is increasing [30].

In addition, the revival of animal husbandry can become one of the stabilising factors of the intensification of the production of seeds and protein-oil crops in the post-war reconstruction of the state [2]. Soybeans contain antinutrients, mainly proteinaceous in nature, which can negatively affect the absorption of nutrients by the body. However, these compounds can be neutralised by heat treatment. The main antinutrients in soybeans include protease inhibitors, in particular trypsin and chymotrypsin, which prevent the effective absorption of proteins. Soybeans also contain antivitamins A, D, E, B12, which reduce the availability of the corresponding vitamins to the body. In addition, soybeans contain compounds that reduce the availability of important trace elements, such as zinc, manganese, copper and iron, which can affect the mineral balance in the body. Other antinutrients in soybeans include alkaloids, which can be toxic to humans, as well as phytohemagglutinins, which can cause cell aggregation. An important group of compounds are allergens, which can cause allergic reactions, as well as antihormones, such as those that cause goiter, and estrogenic isoflavones, including genistein and daidzein, which can have hormone-like activity. Oligosaccharides, including stachyose, raffinose, and verbascose, are another group of antinutrients that can cause flatulence, which reduces the comfort of consuming soy. In addition, soybeans contain enzymes, including urease, lipase, and lipoxygenase, which can contribute to the degradation of certain components of the seed and reduce its nutritional value. Heat treatment of soybeans helps to neutralise these antinutrients to a large extent, increasing the bioavailability of nutrients and improving the overall properties of the product [25].

Antinutrients in soybeans can cause a number of negative effects in animals, including growth inhibition, reduced feed efficiency, goiter development, hyperfunction and hypertrophy of the pancreas, loss of fertility, allergic reactions, rickets, osteoporosis, anaemia and parakeratosis. Since these compounds can significantly affect the health of animals, it is important to control their levels in the diet. In particular, the maximum permissible concentration of trypsin inhibitors, which does not pose a threat to young animals, should not exceed 3 mg/g, or 1 mg/g for every 10 % of protein in the feed.

One of the indicators that allows you to assess the degree of heat treatment of soybeans is urease activity. For young animals, a safe level of urease in heat-treated grain, meal and other processed soybean products (except soy milk and paste) should not exceed 0.05 pH units. For fattening animals, this indicator can be up to 0.1 pH units, and for cows - 0.2-0.3 pH units. Urease is rapidly destroyed in soy milk and paste, so monitoring the level of trypsin inhibitors is important to determine the safety of these products for animals.

Barothermic processing of soybeans can lead to a loss of 15 % - 20 % of lysine, and when frying its content can be halved. This makes it necessary to add lysine to the diets of monogastric animals if they are fed thermally processed soy feed. This approach helps to compensate for the loss of amino acids, which is important for ensuring normal growth and development of animals [34].

Conclusion

Ukraine is a leader among European countries in soybean production and has consistently been among the top ten largest producers of this crop in the world from 2013 to 2023. This emphasises the country’s important role in the global agricultural market, in particular in the production of oilseeds. In the context of climate change and global environmental challenges, the territorial transformation of the “Soybean belt” in Ukraine is becoming a key factor contributing to the development of new approaches to soybean production. Such a transformation will help to rationally use the region’s hydrothermal resources, increasing the efficiency of agricultural management, and will also significantly increase the production of soybean seeds, which is an important component for both the food industry and feed needs. One of the main tasks facing the agricultural sector of Ukraine is the biologisation of agriculture. It is important to maintain ecological balance, reducing dependence on chemical fertilisers and pesticides, which will contribute to the production of high-quality, organic products. The introduction of organic methods of soybean cultivation will become an important component of the strategy for the sustainable development of the country’s agro-industrial complex. This, in turn, meets the goals of the European Green Deal, which aims to transform Europe into a climate-neutral continent and ensure the sustainable development of agriculture in the face of climate change.

To implement this direction, it is necessary to focus on several key aspects. One of them is the creation of high-yielding soybean varieties that will be adapted to different climatic conditions and different maturity groups. Taking into account sustainable production zones is important for the effective allocation of resources and increasing yields. In addition, it is necessary to optimise the structure of the sown areas of leading agricultural crops, which will allow for more rational use of land and ensure the sustainable development of the agricultural industry. In addition, an important aspect is the introduction of innovative, science-intensive technologies into the process of soybean cultivation, in particular eco-innovative methods that will reduce the negative impact on the environment. This includes the development of new soil cultivation technologies, the use of precision agriculture, the use of biofertilisers and integrated plant protection systems. Of particular importance is the development of regulatory acts regulating the cultivation of genetically modified soybean varieties in Ukraine, which opens up new opportunities for increasing yields and resistance to diseases and pests. It is also worth paying attention to in-depth research into the economic aspects of soybean production, in particular in the context of its use for feed purposes. This will allow for more effective use of soybean products in animal husbandry, which is an important element in ensuring the country’s food security. The integrated development of crop and animal husbandry, in particular organic soybean production, will not only contribute to increasing the overall level of agricultural production, but will also become the basis for sustainable development of rural areas. Increasing the efficiency of the agro-industrial complex and environmental sustainability will contribute to the creation of new jobs, improving the social infrastructure of rural areas, and reducing population migration from villages to cities. This, in turn, will ensure sustainable development and economic stability in agriculture and rural areas as a whole.

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