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Formation of a Sustainable Model of Agro-Industrial Production as a Factor of Environmental Protection

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ABSTRACT

Modern environmental protection challenges require rethinking the role of the agro-industrial complex (AIC) in ensuring sustainable development. In the Republic of Kazakhstan, as in other countries, the environmental burden from agriculture is increasing, manifested in soil degradation, pollution of water resources, and a decrease in biodiversity. The agricultural sector can become an important tool for economic growth and environmental stabilization. The study is based on the analysis of official documents, statistical data, international scientific publications, Food and Agriculture Organization (FAO) reports, and media materials. Comparative analysis methods and strengths, weaknesses, opportunities, and threats assessments are used to identify Kazakhstan's agricultural sector's strengths and weaknesses. Factors that negatively affect the preservation of an environment favorable for life and health are identified, and the main methods to develop agro-industrial production as a factor contributing to environmental protection were determined. There are many opportunities for conserving natural resources using traditional and innovative agricultural methods. The authors identify methods of agro-industrial production (precision farming, smart farms, vertical farming) and potential agricultural sectors (sturgeon farming, saiga breeding, Artemia salina breeding, maral breeding, organic production) that will contribute to protecting Kazakhstan's natural environment.

1. INTRODUCTION

Modern agriculture worldwide faces a challenge: ensuring food production growth without harming the environment [1, 2]. Increased agricultural land, the intensive use of chemical fertilizers [3], soil degradation [4], and greenhouse gas emissions are becoming key global environmental problems [5-7]. According to estimates by international organizations, including the Food and Agriculture Organization (FAO), agri-food systems contribute significantly to climate change, air and water pollution, and biodiversity loss [8-10] (Figure 1).

Against this background, it is imperative to search for sustainable solutions to transform the agro-industrial complex (AIC) from a source of environmental threats into an environmental protection tool [11].

In the Republic of Kazakhstan, the issue of interaction between agriculture and nature is extremely important. Despite vast natural resources and a traditionally high proportion of the rural population, the agricultural sector exerts significant pressure on the country's ecological systems [12, 13]. Erosion and salinization of soils, depletion of water resources, and air pollution undermine the region's natural potential (Figure 2).

Thus, considering the existing problems, agriculture, as an integral part of the economy, should develop to minimize environmental risks [14]. Researchers point out that creating a high-quality environment at a certain level to improve humanity's well-being is one of the main tasks of the economy [15, 16].

Many researchers consider this problem and look for ways to solve it (economically, legally, and technologically) [17-22]. However, each country has regional features related to its geographical location, nature [23], climate, state agrarian and environmental policy, and legislation based on this [24, 25]. The mentality of the population, its traditions, and national and cultural characteristics are also important.

Comprehensive research is lacking in the scientific and practical literature on the potential of agro-industrial production for environmental protection. In Kazakhstan, little attention has been paid to this issue in the scientific and specialized literature [26]. For a long time, the idea prevailed that economic interests are much more important than environmental ones. Hardly any works assess the potential of Kazakhstan's agro-industrial production and the possibilities of using it for environmental purposes.

The importance of preserving the quality of the natural environment [27] and the lack of fundamental analysis of the issues of minimizing environmental risks in agriculture in Kazakhstan's economic science determined the choice of the research topic.

Based on this, this study aims to identify promising areas of agro-industrial production that can contribute to environmental sustainability in Kazakhstan and develop recommendations to reduce agriculture's negative environmental impact.

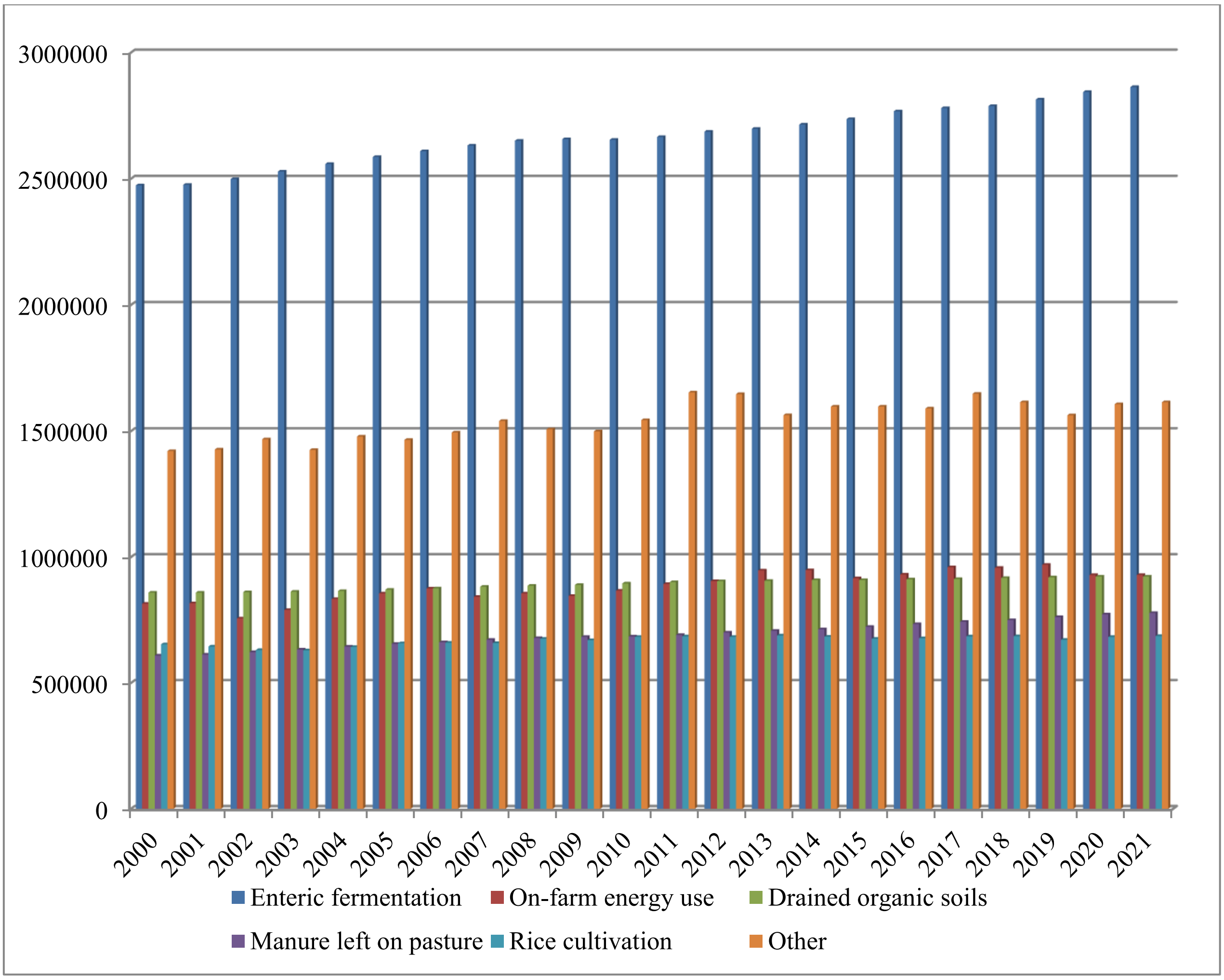

Figure 1. Emissions affecting biodiversity as a result of agro-industrial processes in 2000-2021 [10]

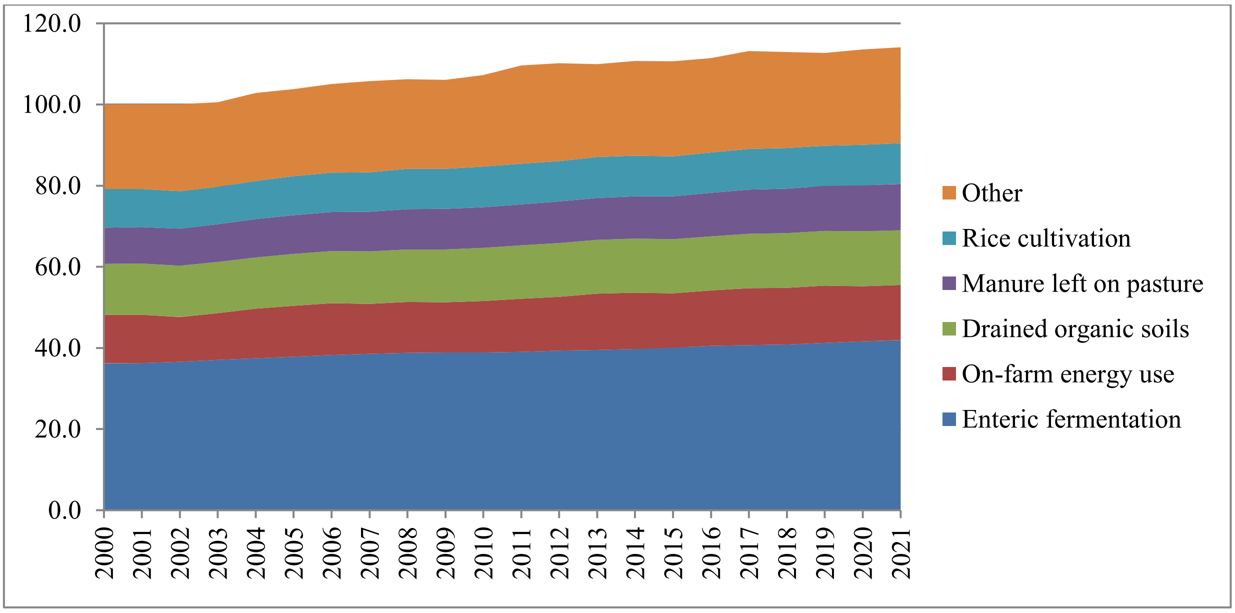

Figure 2. Global emissions coming from agriculture for 2000-2021 by type of activity [10]

2. MATERIALS AND METHODS

2.1 Research design

The study employed theoretical, analytical, and prognostic methods of research. Its main task was to identify the possibilities of transforming agro-industrial production into an instrument of environmental protection in Kazakhstan. The prognostic component was implemented through scenario analysis combined with expert evaluation. The theoretical framework was constructed on the basis of sustainable development theory, ecological modernization theory, and institutional economics.

2.2 Data sources and collection

The materials were official data published in the open press on the official websites of government agencies of Kazakhstan. The main sources included the Ministry of Agriculture of the Republic of Kazakhstan, the Bureau of National Statistics of the Agency for Strategic Planning and Reforms, and the Committee on Ecology, Geology and Natural Resources. Using document analysis, we studied laws, concepts for developing agriculture in Kazakhstan, environmental protection, programs for digitalizing economic processes, and reports from government agencies on implementing agricultural and environmental policies.

The FAO's reports were documented to illustrate the conflict of interests between the development of global agriculture and the protection of the natural environment.

An analysis of scientific literature and media materials was also carried out using general scientific methods of comparison, systematization, and generalization of information. It was conducted using Scopus and Web of Science databases with keywords such as "sustainable agriculture Kazakhstan," "agro-industrial complex environmental protection," "green economy transition," "agro-industrial modernization," and "climate-resilient agriculture." A review of academic literature in international journals allowed us to identify the most effective methods of farming with a sparing effect on the environment (precision farming, smart farms, vertical farming, organic production), which are innovative or little used in Kazakhstan.

Also, the Kingdom of Belgium and the People's Republic of China's experience developing promising new industries for Kazakhstan (producing *Artemia salina* and sturgeon farming) was summarized.

To ensure validity and reliability, only officially recognized or peer-reviewed sources were used. Cross-checking between national and FAO datasets was performed to avoid inconsistencies.

In addition to studying the data presented in scientific papers, we studied statistical data from the FAO reports, which include more up-to-date information and confirm the permanent process of environmental degradation.

2.3 Statistical and historical analysis

The study used statistical analysis (we considered the statistics on the share of the rural population of the total population, environmental pollution, and the number and dynamics of individual animal species) and the historical method [28] (in the study of the stages of involvement in agricultural turnover of objects of the animal and plant world, the development of the legal framework, and the process of introducing innovative technologies into agro-industrial production).

To collect the data obtained, we used special methods for assessing and forecasting the development of agricultural sectors-SWOT analysis. The SWOT matrix was constructed through utilization of multiple methods together. A systematic literature review of scientific articles, in addition to national policy documents coupled with FAO statistical reports identified initial factors. After refinement and validation, specialists were interviewed regarding these preliminary factors. Experts assessed each factor's importance regarding Kazakhstan's agro-industrial development. Each factor's importance concerning environmental protection was also assessed by experts.

To strengthen analytical rigor, application of a prioritization system occurred. Each expert scored individual SWOT factors according to their importance using a 5-point Likert scale (1=very low importance, 5=very high importance). Each factor was assigned a relative weight since the scores were then averaged.

2.4 Expert interviews

The primary sources of information were interviews with experts to corroborate the documentary and statistical data. Twelve experts in agriculture, environment, and policy development were selected using three criteria including work experience. They also needed affiliation with relevant institutions as well as direct involvement within projects located in Kazakhstan.

Official letters along with online forms were then sent to relevant organizations that included government agencies, research institutes and universities so that experts could then be recruited via an open call. Representatives were invited to nominate specialists when they met the predefined criteria. Participation was entirely voluntary, and all respondents were informed that their contributions would remain anonymous.

3. RESULTS AND DISCUSSION

3.1 Government policy and regulatory framework analysis

In light of familiarization with global values, Kazakhstan is pursuing an active policy on the conservation and rational use of natural resources [29], reflected in the norms of new legislative acts and strategic documents.

In particular, in 2013, the Concept for the Transition of the Republic of Kazakhstan to a green economy (Decree No. 577 of the President of the Republic of Kazakhstan dated May 30, 2013) was adopted, where the interests of nature and the economy were interconnected. It established target indicators for the sustainable use of water resources, the development of high-performance agriculture, and waste management, which have now been partially achieved.

The negative impact of agro-industrial production continues to be realized. Agriculture accounted for approximately 9.3% of total greenhouse gas (GHG) emissions in 2022, while the processing industry contributed 7.6%, and mining and quarrying about 78.1% of the sectoral total (Figure 3). The electric power supply sector added only 1.4%. It clearly illustrates that, although agriculture is not the largest single polluter compared to the dominant energy sector, its environmental footprint is higher than that of several industrial branches, particularly in terms of methane and nitrous oxide emissions linked to livestock and fertilizer use.

Thus, agricultural lands are susceptible to agrogenic soil pollution. Irrational farming methods reduce soil organic matter reserves and can contribute to transferring pollutants into the food chain (soil-groundwater-plants-pasture animals, birds-humans) [30, 31]. Pollutants in soil, groundwater, and the food chain lead to an increase in human diseases and mortality (various types of intoxication, diarrhea, cancer, etc.) [32, 33].

According to the U.U. Uspanov Kazakh Scientific Research Institute of Soil Science and Agrochemistry, the soils of Kazakhstan's central rice-growing regions exceed the maximum permissible concentration (MPC) of lead, nickel, and copper. For example, on the ancient-week-old alluvial plains of the Syrdarya River in the Shieli rice-growing massif, the MPC was two times higher than both mobile and gross forms of lead and 1.5 times higher than mobile forms of nickel [34].

Agricultural lands are also losing quality for other reasons: erosion, desertification, soil salinization due to the mineralization of water sources because of the discharge of a large volume of highly mineralized collector and drainage waters, and the transport of pollutants coming with water from neighboring countries [35].

For example, 24.2 million ha, or 11.3%, of agricultural land in Kazakhstan is subject to wind erosion [14].

The issue of recycling obsolete and unusable pesticides and their containers is urgent. More than 1,500 t of these pesticides and their mixtures are found in Kazakhstan's warehouses and storage facilities, some of which are stored in inappropriate conditions. Approximately 10% of them belong to pesticides with the properties of persistent organic pollutants (POPs). Over 330 thousand pesticide containers have accumulated, which people unknowingly use for domestic purposes [34].

Large livestock complexes and poultry farms are serious sources of pollution for soils, water resources, and the atmosphere [36]. Thus, daily waste averages about 119.1 thousand t in liquid form (urine) and 344.8 thousand t in solid form (manure). Over the past 5 years, waste from cattle has increased by 23.3%, from sheep by 19.2%, goats by 1.2%, horses by 48.1%, camels by 26.9%, and poultry by 3.8% [34].

The environmental damage caused is a consequence of the conflict of interests between agricultural development and environmental protection.

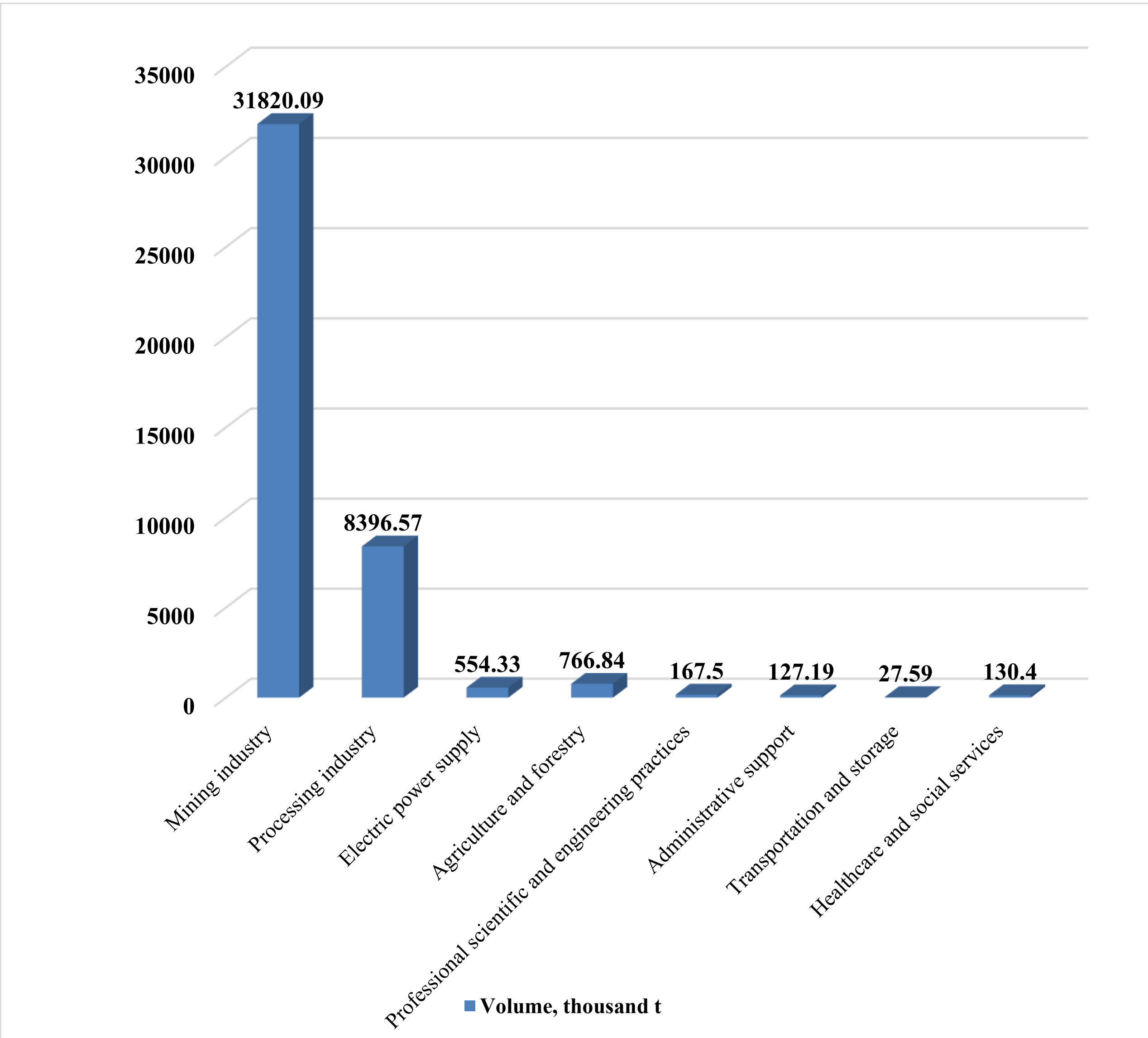

Figure 3. The volume of waste generated in 2022 by source, million t

3.2 Suggested ways to preserve the environment

Preservation of the quality of the natural environment is possible in standard and non-standard ways:

3.2.1 Compliance with environmental requirements

With this method, agricultural enterprises that strictly comply with legislation ensure the preservation of soil fertility and prevent pollution of water and air resources while the natural resources involved in agricultural turnover remain in operation [37]. The low reproducibility of the quality of natural resources can indicate its disadvantage. Still, if necessary, to increase the productivity of the results, the companies attract additional natural resources, e.g., acquire new land plots, lease additional pasture areas, etc.

3.2.2 Environmentally friendly utilization of agricultural resources

These practices help in improving soil fertility, processing agricultural waste, and reducing anthropogenic pressure on soil, water, and atmospheric air.

The rational use of soil resources and the reuse of materials are fundamental aspects of sustainable agriculture. In the context of growing environmental risks, composting is particularly important, as it allows organic matter to be returned to the soil, thereby restoring its structure and improving its fertility and water retention capacity. Such practices form a closed cycle of substances and help reduce dependence on mineral fertilizers. An equally promising area is the conversion of agricultural waste into renewable energy [38]. Technologies for producing biogas, biodiesel fuel, biofuel, and hydrocarbon fuel through hydrothermal carbonization can significantly reduce the burden on natural ecosystems and minimize waste [39-41]. Thus, the integration of composting and energy-efficient innovations ensures the rational use of resources, strengthens food security, and forms the basis for the environmentally balanced development of the agro-industrial complex [42, 43].

3.2.3 Digitalization of the AIC

Digitalization (and innovation in general) and the development of new industries in agriculture can be attributed to non-standard methods. In Kazakhstan, however, the level of implementation of innovative agricultural technologies remains uneven. At present, precision farming tools (e.g., GPS-based field monitoring, automated seeding, and smart irrigation systems) are being piloted in several agroholdings in North and South Kazakhstan regions. For example, innovative technologies include aeroponics, hydroponics, and aquaponics [44]. Thus, AeroFarms has patented the aeroponics technology, which allows year-round cultivation of more than 550 different plant varieties, "ranging from tomatoes, berries, and ending with leafy greens" [45]. According to the company's reports, aeroponics uses a closed-loop misting system as it delivers nutrients directly to plant roots, which results in up to 95% less water consumption compared to conventional farming. Researchers also note that such systems drastically reduce the risks of soil-borne diseases. These systems allow production near urban markets, and this cuts transport-related emissions.

Vertical farming is an innovative technology that effectively cultivates crops in vertically stacked layers [44]. This method enables intensive production in limited urban spaces as well as integrates renewable energy sources for climate control, reduces pesticide use, and has been associated with water savings of 70%, 90%. Singapore and the Netherlands offer case studies about vertical farming. These studies also show its contributions to urban food security, plus its reduction within agriculture's environmental footprint.

The environmental effect of these innovations is that, for example, using aeroponics, hydroponics, aquaponics, and vertical farming minimizes the consumption of soil and water resources [46]. Moreover, the latter technology makes it possible to transfer the processes of growing agricultural products to cities.

Digitalization of agro-industrial production is understood as the use of digital technologies to create and/or change the business model of agro-industrial production [47] to generate new income and opportunities that ensure its competitiveness and comparative advantage in contrast to previous models [48].

The development of new types of agro-industrial production, the large-scale development of which we propose, also ensures environmental safety.

3.2.4 Development of new branches in animal husbandry

Despite the global decline in the consumption of wild animals and plants, poaching persists due to people's lack of awareness and the temptation of large profits from animals and plants that are not involved in agricultural turnover and are found in limited numbers in the wild.

Poaching includes illegal hunting, fishing, logging, and destruction of other vegetation.

Due to poaching, many species of animals and plants from the industrially harvested category have become rare and endangered, or their use has been prohibited. These species include the Caspian seal, sturgeon, saiga, argali, mouflon, etc.

Thus, regarding forest vegetation, saxaul, which is in significant demand for domestic and commercial purposes, is especially popular among poachers. The increased deforestation of saxaul led to a legal ban, Order No. 211 of the Chairman of the Committee of Forestry and Wildlife of the Ministry of Agriculture of the Republic of Kazakhstan dated 13.08.2015, "On the prohibition of lumbering in saxaul plantations on the sites of the state forest fund".

In 2022, 117 cases of animal poaching were identified, 46 of them for saigas. 5,031 horns and 105 saiga carcasses were seized [34].

The ban on saiga antelopes has been lifted due to the increase in their numbers.

In our opinion, the factors that cause poaching should be turned to benefit society and nature: the most sought-after and high-cost natural resources should be produced in an artificial environment.

Kazakhstan has many unique natural resources that most countries do not have. That is why there is such a great demand for some objects of the wildlife of Kazakhstan and their derivatives.

Kazakhstan is home to the largest number of saiga antelopes (about 95% of the world's population). In most countries, they are not found at all. "The habitat of saigas is rare: these unique animals live only in a few regions: the steppes of Kazakhstan, Mongolia, Russia, Uzbekistan, Turkmenistan" [49].

Male saigas become victims of poachers because their antlers are in high demand in traditional Chinese medicine, where their cost reaches 5,000-10,000 USD/kg [49]. Therefore, the number of saigas has been significantly reduced for a long time, and they have moved from being commercial hunting objects to being prohibited animals.

Through their environmental policy, Kazakhstan's government and the public have increased the number of saigas to more than 1.9 million. As a result, the relevant state authorities decided to allow commercial hunting of saigas.

There are risks of reducing the number of saigas due to epizootic diseases [50]. History shows that for this reason, 11 cases of large-scale cattle plague occurred in Kazakhstan, where, an average of 34% of the entire animal population died. Thus, in 1988, according to experts, from 440 to 500 thousand saigas died. The last case occurred in 2015 when over 150,000 saigas died from pasteurellosis [49].

To minimize these risks, it is proposed that a new branch of agriculture, saiga breeding, be created. This will generate a genetic reserve of these unique animals and master the technology of intravital antler cutting.

There is an experience of domestication of wild artiodactyls in Kazakhstan. Maral breeding is a relatively young branch of animal husbandry, having developed in Kazakhstan and Russia for about 200 years [51].

It is also necessary to develop sturgeon farming more actively, as it seems to be the most promising field due to the high cost of its derivative products (black caviar). Besides, fish meat is highly valued in the post-Soviet countries [52].

Commercial sturgeon farming should become a factor in increasing the sustainability of agriculture in Kazakhstan. An example of a breakthrough in this area is the Chinese sturgeon industry, which is leading worldwide. It produces 25-26 thousand t of farmed sturgeon fish per year (as much sturgeon as the USSR produced in its best years), increasing the production of edible sturgeon caviar [53]. Thus, by 2020, China produced up to 84% of the world's sturgeon products.

The idea of producing a very popular aquatic product, *A. salina*, is no less interesting. This crustacean is used in nutrition, medicine, and cosmetology, as well as feed for livestock and fish. This crustacean's chemical composition is characterized by a high content of proteins, fats, vitamins, hormones, and other biologically active compounds. Proteins contain 18 amino acids, eight of which are essential: threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine, and histidine.

China offers a great demand for this crustacean. Based on *A. salina*, Chinese doctors produce unique remedies against erectile dysfunction, and cosmetologists produce skin products.

The crustacean lives only in a few countries, in Kazakhstan, Russia, and the USA, and only in highly saline lakes, so its range on the planet is limited.

Kazakhstan has established its harvesting and primary processing only, not the processing of raw materials for finished products. Individual entrepreneurs rent lakes and supply up to 1.5 thousand t of crustaceans annually.

This sector is mainly developed by representatives of the "gray economy", i.e., poachers. In recent years, the number of crustaceans has decreased by half.

Thus, in 2023, the police of the North Kazakhstan region and the Department of the National Security Committee of the region made the most significant arrests in Kazakhstan, according to them. More than 15 t of illegally harvested *A. salina* were seized from the criminals. However, according to media reports, there have been cases of more illegal harvesting, up to 24 t.

The criminals mastered the development of mass production of *A. salina* earlier than the state agencies. Thus, Chinese citizens detained in Pavlodar had set up a laboratory using special equipment in a rented apartment and started a mini-production facility for this crustacean.

The production of *A. salina* should become an actual production field in Kazakhstan, not just harvesting. Kazakhstan has potential for this, such as a natural habitat and representatives of this aquaculture, and the costs will be minimal compared to other supplier countries that produce this crustacean. For example, Belgium is the world leader in producing and selling *Artemia* cysts. This is a country where there are virtually no Artemias. However, Belgian NV is a leader in the global market. A 500 g jar from this company costs 150 euros [54].

Experts predict that if Kazakhstan organizes the processing of raw materials for finished products and the state creates conditions for export, then for $50/kg, the country will be able to receive $75 million/year rather than $3 million, as it is now [54].

3.3 SWOT analysis of the development of new industries

The SWOT analysis shows the proposed projects' strengths and weaknesses and the associated threats and opportunities (Table 1 and Table 2).

Table 1 can be used to determine the prospects for developing new industries and opportunities to minimize weaknesses and threats.

There are good prospects for developing sturgeon breeding, saiga breeding, and *A. salina* breeding.

Kazakhstan has unique natural resources (saiga, sturgeon, *A. salina*) that are absent in most countries. Therefore, there is a constant demand for them and a high price. In the Kazakh market, these animals and their products are in high demand.

There are opportunities for breeding these animals, both in their natural habitat and in artificial conditions, with their genetic material that does not need to be transported. The number of listed animal species, except sturgeon, is sufficient for industrial production: the number of the Ural and Betpakdal saiga populations has increased to the previous level, allowing for the lifting of hunting bans, and as for *A. salina*, experts believe that their harvesting on the lakes of only one North Kazakhstan region can bring up to 500 t of cysts in dry form.

The advantages of industrial reproduction of saigas, sturgeons, and *A. salina* are the availability of labor and material resources and the growing digitalization of management processes and economic sectors.

Another critical point is the presence of substantial stakeholders: in recent years, proposals from investors have been repeatedly received. Thus, Chinese companies offered to open a nursery for breeding saigas in the West Kazakhstan region at their own expense, the Chinese Technology Transfer Center of the Shanghai Cooperation Organization (SCO) member states presented a project for growing Artemia in Kazakhstan, the Swiss companies Rey Group, Caviar House & Prunier Group SA and Swiss Choice Holding SA are interested in developing commercial sturgeon breeding and caviar production.

There are also scientific studies and even the practice of keeping saigas, sturgeons, and *A. salina* in an artificial environment.

Table 1. SWOT analysis of new branches of sturgeon breeding, saiga breeding, and production of *A. salina*

S (Strengths)	**Weight**	**W (Weaknesses)**	**Weight**
		lack of export commodity mass;	4.2
		the trend of pollution and depletion of land, water, and other natural resources, high levels of poaching, epidemics;	4.8
		a poor trade and logistics infrastructure;	4.4
		the absence or predominance of small-scale production in the field under consideration;	4.3
the presence of unique natural resources (saiga, sturgeon, *A. salina*), which are absent in most countries;	4.7	lack of staff and qualified specialists;	4.6
preserving the natural habitat of these animals;	4.3	insufficient level of processing of agricultural raw materials;	4.5
a vast and growing demand for products: for black caviar all over the world; for sturgeon in Europe and Asia; for saiga antlers and *A. salina* in the Asian segment (China, Singapore);	4.6	high capital intensity of the industry;	4.7
demand for products in the Kazakh food consumption market;	4.2	low level of digital technologies used;	4.3
significant labor resources: the share of the rural population is 43% of the total population;	4.1	inadequate level of government support;	4.4
a great potential for attracting foreign investments to the AIC; there are already proposals from Chinese investors;	4.4	corruption and administrative barriers;	4.5
the variety of organizational and legal forms of agricultural production;	4.0	limited investments in the development of the proposed industries;	4.6
the growing level of digitalization of Kazakhstan's economy;	4.2	insufficient regulatory, technological, and methodological support;	4.5
scientific research and proven methods exist for sturgeon farming, keeping saigas in an artificial environment, and transporting *A. salina*	4.5	a high proportion of imported production resources	4.2
O (Opportunities)	**Weight**	**T (Threats)**	**Weight**
improving agricultural efficiency based on the development of national competitive advantages;	4.4	increasing competition in international markets;	4.5
		the impact of global climate change;	4.8
the use of an advantageous geographical location for the entry of Kazakh products into foreign markets;	4.3	the risk of ineffective government regulation of the development of new industries;	4.6
high potential for quality, production, and export of products;	4.6	lack of financial and material resources;	4.7
professional development for new industries	4.2	a decrease in the purchasing power of the population due to inflation	4.4

Table 2. SWOT analysis

Aspects	Methods
Strengths (S) and weaknesses (W)	Critical Success Factor (CSF)
Opportunities (O) and external threats (T)	Porter's Five Forces model; analysis of political, economic, social, technological, legal, and environmental factors (PESTLE).

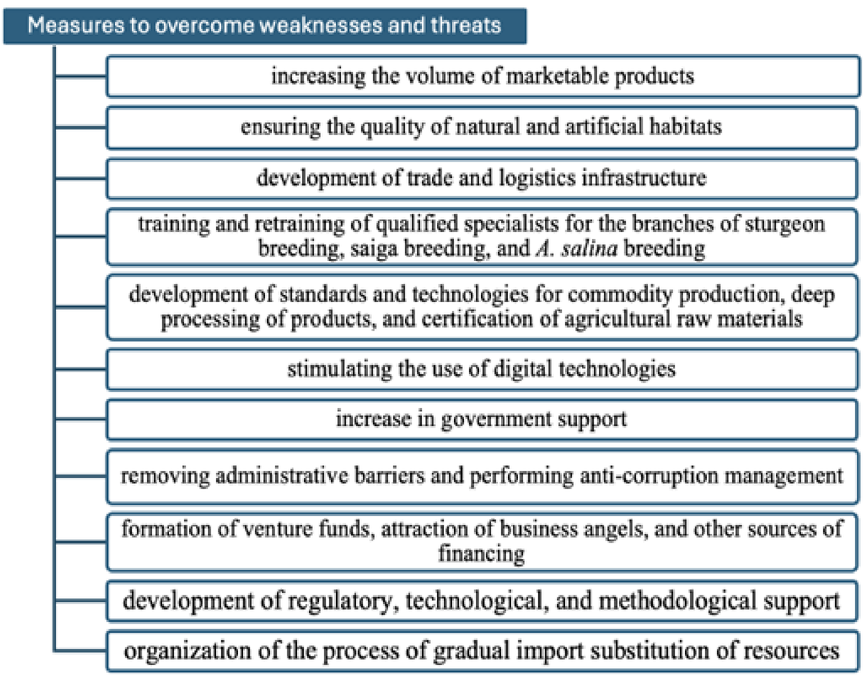

Figure 4. Measures to overcome weaknesses and threats

Artemia Global LLP has begun harvesting *A. salina* (deep processing plant for crustaceans).

As shown in Table 1, the SWOT factors were weighted using expert scoring on a 5-point scale. The highest-ranked weaknesses include ‘pollution and depletion of natural resources’ (4.8) and ‘high capital intensity of the industry’ (4.7), while the most critical threats are ‘climate change’ (4.8) and ‘lack of financial resources’ (4.7). Among strengths, unique natural resources’ (4.7) and ‘global demand for products’ (4.6) were prioritized. This prioritization provides a clearer picture of which factors require urgent policy attention. Thus, scientists from two universities in Kazakhstan (Jangir Khan West Kazakhstan Agrotechnical University and the Institute of Zoology) are dealing with the issues of keeping saigas in enclosures. Nurseries have been established in the West Kazakhstan region, and the ASAR Live nurseries are located in the Nurinsky district of the Karaganda and Ulytau regions.

Commercial sturgeon farming is more widely represented: enterprises in the Pavlodar, Karaganda, Aktobe, East Kazakhstan, Almaty, South Kazakhstan, Mangystau, Atyrau, and West Kazakhstan regions. Among the famous ones are the Uralsky Sturgeon Plant, Caspian Royal Fish LLC, and the Karaganda-Osetr farm.

As a result of our research, we have identified that in order to overcome weaknesses and threats, it is necessary to develop organizational and economic areas (Figure 4).

Thus, our study showed that Kazakhstan has unique opportunities for using agro-industrial production to protect the environment, which requires active development.

First, it is the digitalization of traditional agricultural sectors. Modern technologies enable better management of the natural resources involved in agricultural turnover, like agricultural land, water, and atmospheric air, and obtain more agricultural products (precision and vertical farming technologies, digital land reclamation, smart farms).

Second, the development of new non-traditional branches of agriculture based on the involvement of objects of the animal and plant world [55, 56] in agricultural turnover, which themselves or their derivatives are of high value and in demand on foreign and Kazakh trading platforms [57]. Such industries include sturgeon breeding, saiga breeding, maral breeding, *A. salina* breeding, saxaul cultivation, and the manufacture of organic products.

Considering this, to improve environmental protection and increase the economic efficiency of agriculture, the following solutions are proposed:

1). To conduct fundamental scientific research on developing promising branches of agriculture (saiga, sturgeon, and *A. salina* breeding) at the National Agrarian Scientific and Educational Center, universities, and research institutes specializing in agricultural science.

2). Considering our results, the concept of modernization of agriculture in Kazakhstan, based on the priority development of new industries using elements of the natural environment and the manufacture of organic products, aims to develop a strategic framework to reform agriculture in Kazakhstan. The concept aims to solve two large-scale tasks: environmental protection and food security [58, 59].

3). Additional opportunities should be provided to address the issues of financing new industries, including forming venture funds, attracting business angels, and stable government support [60]. It is necessary to separate startups in these agricultural sectors from startups in other areas and create a more favorable regime, since investors are least supportive of startups in agriculture in Kazakhstan. It is recommended that an annual startup competition in agro-industrial production be held to attract interest in agriculture.

4. CONCLUSIONS

At the current stage of Kazakhstan's development, it is becoming evident that a balance must be found between the agro-industrial sector's economic interests and environmental sustainability priorities.

The analysis shows that Kazakhstan has unique opportunities for transitioning to an agricultural production format that minimizes damage to nature and creates prerequisites for its restoration and reproduction. Due to the use of modern digital technologies, innovative production methods, and the development of innovative agricultural areas, there are opportunities for the region's sustainable development.

The proposed transformation of the AIC requires a systematic approach. Starting with research and pilot projects can transform the agro-industrial complex (AIC). Encouraging policies along with institutional frameworks must then develop plus revolutionary technologies must be implemented at a large scale via active monitoring as well as evaluation. By combining the resources, a new type of agricultural model can be formed: a model focused on long-term sustainability, export efficiency, and environmental safety.

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