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Study of the Possibility of Using the Bottom Organomineral Accumulations of the Lakes of the North Kazakhstan Region to Obtain Innovative Fertilizers for the Development of Organic Farming and Agrotourism

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Abstract: This publication presents the results of studies of the bottom sediments (sapropels) of lakes in the North Kazakhstan region. The purpose of this study is to identify the possibility of using sapropels from the lakes of the region in obtaining innovative fertilizers for organic farming. For this purpose, geoinformation technologies, field research, statistics, and chemical and chemical-analytical methods were used (automated spectrometric methods of segmented flow analysis, photocolorimetry, flame photometry, and inductively coupled plasma atomic emission spectrometry). During the first stage of this study, the bottom sediments of three lakes in the region, which were at different stages of eutrophication, were selected to study the chemical composition of the raw materials. The sapropel of Lake Penkovskoye had optimal indicators. Further, an analysis of the territory of the region for the development of agrotourism was carried out. The aim of this study is to substantiate the prospects for the use of sapropel in the production of innovative fertilizers. The natural origin of sapropels allows them to be used in the production of environmentally friendly and safe products. Reducing the use of artificially synthesized mineral fertilizers will make agriculture and the environment safe and sustainable. This will further contribute to the development of agrotourism in the region.

Keywords: bottom sediments; sapropel; lakes; organic farming; innovative fertilizer; agrotourism; environmental safety

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1. Introduction

Humanity, at the present stage of development, is facing a large number of global challenges. Two main issues are environmental and food security. To solve these problems, development concepts aimed at sustainability, environmental friendliness, safety for health, and the environment are being developed in the United States. A promising direction of sustainable development, which helps to implement these principles, is the move towards organic farming [1–3]. It is based on the use of natural resources. The technology of the resource consumption and production of the final product is aimed at reducing the impact of anthropogenic factors on the environment. This minimizes human impact and eventually harmonizes the relationship between society and nature [4].

Currently, obtaining a good crop yield is due to a number of features. On the one hand, it is influenced by the intensification of agricultural production and the use of chemical technologies, and on the other hand, environmental friendliness and organic farming are key. Chemical elements and their compounds are the basis of plant development; therefore, harvesting nitrogen, phosphorus, potassium, carbon, and oxygen among them is of great importance [5].

The complex use of the listed elements and compounds in plants ensures their growth and development, forms a green mass, and determines the qualitative and quantitative indicators of agricultural products. The complexity of the transformation and nutrition of plants is due to the physic-chemical processes that occur in the atmosphere and in the soil [6,7].

The lack of nutrients and substances in the soil is replenishment by applying fertilizers. First of all, these are synthesized mineral fertilizers, which are widely used in agriculture in all countries. Annual losses of natural nitrogen, macro, and microelements are compensated by an increase in the volume of fertilizers [8–10].

The loss of nutrients from the soil occurs as a result of the absorption abilities of plants, as well as their removal as a result of water and wind erosion [11]. The production of mineral fertilizers is a fairly cheap and well-established technological process; However, their unlimited use is unsafe for humans, living organisms, and the environment as a whole. This leads to a loss of the sustainability of development and to the destruction of agroecosystems. The unbalanced use of mineral fertilizers leads to environmental problems, such as soil degradation and the pollution of surface and groundwater [12–14].

The absorption of nitrogenous fertilizers by plants leads to an increase in their concentrations in the final product. The use of crop products with an excessive content of nitrogen-containing compounds (nitrates, nitrites) leads to numerous diseases and poisoning. There is a need to regulate the use of mineral fertilizers, partially doing so or later completing the replacement with organic fertilizers. These prospects are aimed at creating organic products that are safe for humans and the environment [15,16].

Kazakhstan, and in particular the North Kazakhstan region, has high natural resource potential for the development of organic farming. The developed agricultural sector of the economy and the availability of natural resources make the republic attractive for the implementation of the principles of a "green economy" and "green technologies". A unique resource is the bottom sediments (sapropels) of lakes in the North Kazakhstan region [17]. The features of sapropels found in natural lakes are their organic origin, their environmental friendliness, the presence of nutrients, micro- and macro-elements in the composition, and the convenience of extraction, as well as the variability of application [18,19].

The use of bottom silts or sapropels has become widespread across the territories of many states. They are used as feed additives in poultry and animal husbandry as well as being used as additives in soil substrates [20–26]. Sapropel can also be part of the manufactured vermicompost, which is used as an additional food to increase the yield of agricultural plants by farmers [27,28].

Bottom sediments are used as a balneo-resource. Therapeutic mud is used to restore the musculoskeletal system for the treatment of skin and neurological diseases, and for others. Moreover, they can be used directly for the conditions of recreation in the reservoir, as well as being transported for use in healthcare institutions [29,30]. This feature of bottom sediments contributes to the development of balneological tourism, which is widely developed in many countries [31,32].

Bottom sediments are one of the several factors of organic farming which will accompany the development of agrotourism in Kazakhstan. To date, this industry is at the initial stage of development, which is confirmed by a small number of publications focused on this topic. According to Western scientists, agrotourism can be a form of recreation in rural areas; it can also exist in the form of the active participation of tourists in the socio-cultural life of rural settlements. This is understood as the participation of tourists during the technological process of growing environmentally friendly crops, including participation in gastronomic tours. In this, the role of organic farming is great, which contributes to the production of environmentally friendly products that are necessary for human health. This aspect will contribute to the development of green technologies, as well as the production of green safe products for humans, which is one of the prerequisites for the development of agrotourism. Organic farming, the production of environmentally friendly products, will, in turn, arouse interest from investors in expanding the possibility of the production and application of organic fertilizers, as well as forming a tourist cluster [33–35].

Sapropels are formed as a result of natural processes in the form of colloidal sedimentary matter in freshwater lakes, consisting of benthic and planktonic residues [36,37]. The composition includes soil humus, which falls from the watershed area during snowmelt and erosion processes. Silts fill the bottom of lakes and the thickness of the layer of their occurrence can reach up to 10 m [38]. As a result of genesis, reservoirs may dry out; in these cases, sapropel may be under a layer of peat [39,40].

The features of sapropels depend on the physical and geographical characteristics of the territory where the reservoir is located. These are climate, geological structure, relief features, soil, and vegetation cover [41]. The selected factors determine the qualitative and quantitative characteristics of sapropels. Sapropels may contain various substances in large quantities; among them are mineral macro–components (HCO_3^-, CO_3^{2-}, SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, Na^+, and K^+ ions) that determine the salt composition of lake water. Additionally, trace elements are present in small amounts in the water of lakes. The gases H_2S, CH_4, H_2, NH_3, O_2, and CO_2 dissolved in water are represented by a separate group [42]. Notably, O_2 dissolved in water is of particular importance. It is a part of the physiological processes of living organisms and determines the oxidative and reducing environment in chemical processes [43]. Organic substances in water are in the form of true and colloidal solutions and suspensions. They are represented by amino acids, carbohydrates, proteins, and fatty acids; they also include the remains of dead plant and animal organisms [44–47].

Many chemical components and compounds affect the composition of bottom sediments; these are biogenic elements—compounds of nitrogen, phosphorus, silicon, and iron. Thus, the chemical composition of sapropels is represented by a finely dispersed organic, biogenic inorganic substance with mineral impurities [48–54].

The physical and geographical location of the territory of the North Kazakhstan region within the South of Western Siberia determines the features of the formation of sapropels. This is influenced by climate, relief, aquatic vegetation, surface runoff within the catchment area, etc. [55]. The process of eutrophication in lakes is the basis for the formation of a large amount of sediment deposition (sapropels) and a high content of organic matter in them [56–58]. It is caused by the visually pronounced overgrowth of the water mirror [59].

Lakes with an overgrowth area of 50% or more were selected for this study. Of the 2.328 lakes in the region with an area of more than 10 hectares, 32% of the lakes are eutrophic (Figure 1). Despite the insignificant thickness of sapropels in lakes, the number of such natural reservoirs is significant [55]. The availability of mining and the convenience of transport logistics are additional positive factors. This proves the potential of sapropel resources in the natural reservoirs of the studied region, as well as the possibility of their use.

The object of our research is the sapropel of lakes Gusinoe (Maloe), Golozubka, and Penkovskoye. These lakes are located within the boundaries of the Kyzylzhar district in the North Kazakhstan region. The sapropels of the listed lakes are bottom sediments formed from the remains of higher plants, animals, pollen, spores of coastal vegetation, and phytoplankton.

The purpose of this work was to study the possibilities of processing and using the sapropels of the lakes in the North Kazakhstan region for organic farming and the development of agricultural tourism. Potential lakes have been identified for this purpose. The chemical composition of the sapropels in these lakes has been studied. As a result of the analysis of the chemical composition, the sapropel of Lake Penkovskoye has been selected as the most promising for the production of innovative fertilizers. The technological feature of the production lies in the creation of a liquid fraction of an environmentally friendly fertilizer. The peculiarity of the resulting fertilizer is the possibility of using it in different concentrations in the pre-sowing treatment of seeds for various crops. The environmental friendliness of the fertilizer makes its use safe for humans and the environment. This is especially true when considering modern volumes of the use of mineral fertilizers and the areas of use in which they are steadily growing. The agrarian direction of the region's economy, the large amount of cultivated land, and the natural resource potential determine the creation and use of fertilizers based on natural resources for the development of organic farming, as well as agrotourism [60–62].

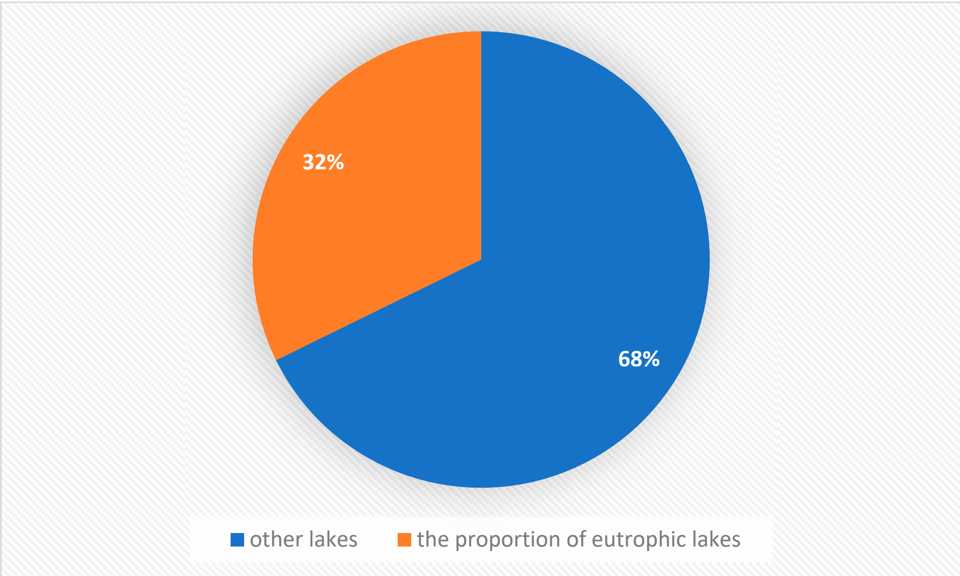


Figure 1. The proportion of eutrophic lakes of the North Kazakhstan region. Source: Own elaboration.

In combination with the natural, cultural, and historical features of the territory, it can become the basis for the formation of agricultural tourism in the prevailing agricultural sector of the regional economy [63–68].

The studied works on the use of bottom sediments as fertilizer revealed their widespread use in Africa and Eurasia [21,26]. In Europe, research is also underway regarding the use of lake bottom sediments in agriculture. Sapropels of the lakes in Lithuania and Latvia are used as activators in the growth of vegetable and grain crops. In addition, when sapropel is introduced into the soil, the qualitative composition of the soil is changed [20,25]. The use of sapropels as fertilizers for the soil in the form of substrates has been applied to the crop rotation of agricultural crops in Lithuania. Their subsequent long-term influence on the physico-chemical properties of the soil and yield was subsequently determined [36].

The studies we have reviewed on the use of sapropels from lakes allow us to draw conclusions about the effectiveness and prospects of using bottom sediments as organomineral fertilizers via application to the soil. The innovative technology proposed by us differs from the ones studied since it is based on the production of a liquid fertilizer. In addition, the resulting fertilizer is proposed to be used for the pre-sowing treatment of the seeds of agricultural crops. This will reduce the use of xenobiotics and make agriculture and the environment safe and sustainable. At the same time, the idea of using bottom sediments directly from local lakes has been confirmed. Organic farming, the production of organic and safe products, will, in turn, arouse interest from investors regarding plans to expand the possibility of producing and exporting fertilizers in the form of a concentrate.

Thus, a number of aspects can be distinguished. Firstly, scientific research on this topic is relevant but has not been properly developed in Kazakhstan. Secondly, organic farming is aimed at the development of green technologies in agriculture and can contribute to the development of agrotourism. This may help to avoid the risks associated with the excessive, irregular use of mineral fertilizers in agriculture. Thirdly, this study is aimed at the rational use of natural resources in the North Kazakhstan region. This will contribute to the sustainable development of the studied region and Kazakhstan as a whole.

2. Materials and Methods

To study the features of the geographical positions of the lakes during their selection, geoinformation technologies were used and satellite images were analyzed. This made it possible to determine the availability of the lakes and their logistics. The observations and descriptions of the lakes revealed the hydrological, hydrobiological, and morphological features of the lakes [69]. Sampling and analyses of the raw materials were carried out according to the generally accepted methodology of using a bottom sampler. Samples of each lake under investigation were taken from three points (near the shore, in the open part, and in the middle). Chemical and analytical studies of the selected material were carried out on the basis of the certified laboratory of «EcoLux-As» Stepnogorsk in Kazakhstan.

Instrumental research methods were used to analyze quantitative and qualitative indicators of sapropels. The quantitative content of trace elements in the extracts, discovered after the acid decomposition of the soil solution, was determined using the method of inductively coupled plasma atomic emission spectrometry GOST ISO 22036-2014. According to the method of atomic emission spectrometry of inductively coupled plasma, the solution was dispersed using a spray gun and the resulting aerosol entered the plasma torch. In a radiofrequency inductively coupled plasma, the solvent first evaporated; then, dry salts also evaporated, dissociated, atomized, and underwent ionization. Atoms or ions were thermally excited and the number of photons emitted during the transition to a lower energy level was measured using optical emission spectrometry. The spectra were separated by a diffraction spectrometer and the intensities of the emission lines were recorded by photosensitive devices. The element was determined by the wavelength of radiation (photon energy), while the concentration of the element was proportional to the intensity of the radiation (the number of photons). The content of the inorganic nitrogen compounds in bottom sediments was determined by the automated spectrometric method of the segmented flow analysis of soil extracts according to ISO 14255:1998. The exchange of potassium was established by using a flame photometer GOST 26210-91. The method is based on the extraction of potassium from the soil with a solution of ammonium acetic acid concentration c (CH_3COONH_4) = 1 mol/dm^3 with a soil-to-solution ratio of 1:10 and the subsequent determination of potassium in the extract on a flame photometer. Additionally, the electrical conductivity and pH of the aqueous extract medium were determined. Based on the results of the analysis of the qualitative and quantitative compositions of bottom sediments, the optimal composition of raw materials was determined for further research [70]. Chemical and technological methods would then be used to produce a liquid fraction of an innovative fertilizer from selected sapropel. The resulting liquid concentrate allows for its future use in a diluted form and in different proportions during pre-sowing seed treatment [71].

To analyze the possibility of agrotourism development in the territory of the North Kazakhstan region, statistical data of sown areas detailing the areas of grain and vegetable crops for the 2017–2021 period were studied [72]. To identify the use of mineral and organic fertilizers, the areas of their application over a five-year period were studied. This would reveal the dynamics of both acreage and fertilization areas within the boundaries of the administrative districts of the territory of the studied region. These aspects, combined with the natural resource potential and the presence of recreational, cultural, ethnic, and historical sites, in our opinion, contribute to the development of ecological and agricultural tourism [73–75].

The use of natural resources from the lakes of the region for the production of innovative fertilizers will contribute to the development of organic farming.

3. Study Area

Based on the peculiarities of the physical and geographical conditions and factors, the research area was located in the southwestern part of the West Siberian Plain, which is part of the Ishim Plain; this area is characterized by a flat, sometimes maned, relief. There were no geological faults. Geomorphologically, the region is a flat lake-alluvial plain [76]. The climate is sharply continental, characterized by frosty winters and short moderately hot summers. The average monthly temperatures in January range from −18.50 °C to −19.50 °C and the average monthly temperatures in July range from +18.80 °C to +19.50 °C. The average duration of sunshine in the studied area is 2.200 h per year, with the maximum being in July. The average annual precipitation is about 314 mm. The average annual absolute humidity is 4.8 mb and the average annual relative humidity in the study area is 69% [77–79]. These natural factors and conditions led to the formation of the agricultural sector of the economy, resulting in a well-developed agriculture system. They also have an impact on the studied aspects, including the hydrological and geomorphological features of lakes. The lakes are fed by the Spring melting of snow and by precipitation [80].

The presence of a large number of lakes made it possible to choose optimally suitable reservoirs for this study. The criteria for selecting the lakes were environmental friendliness, the presence of bottom sediments, the convenience of transport logistics, and accessibility. Based on this list, three lakes were selected (Figure 2).

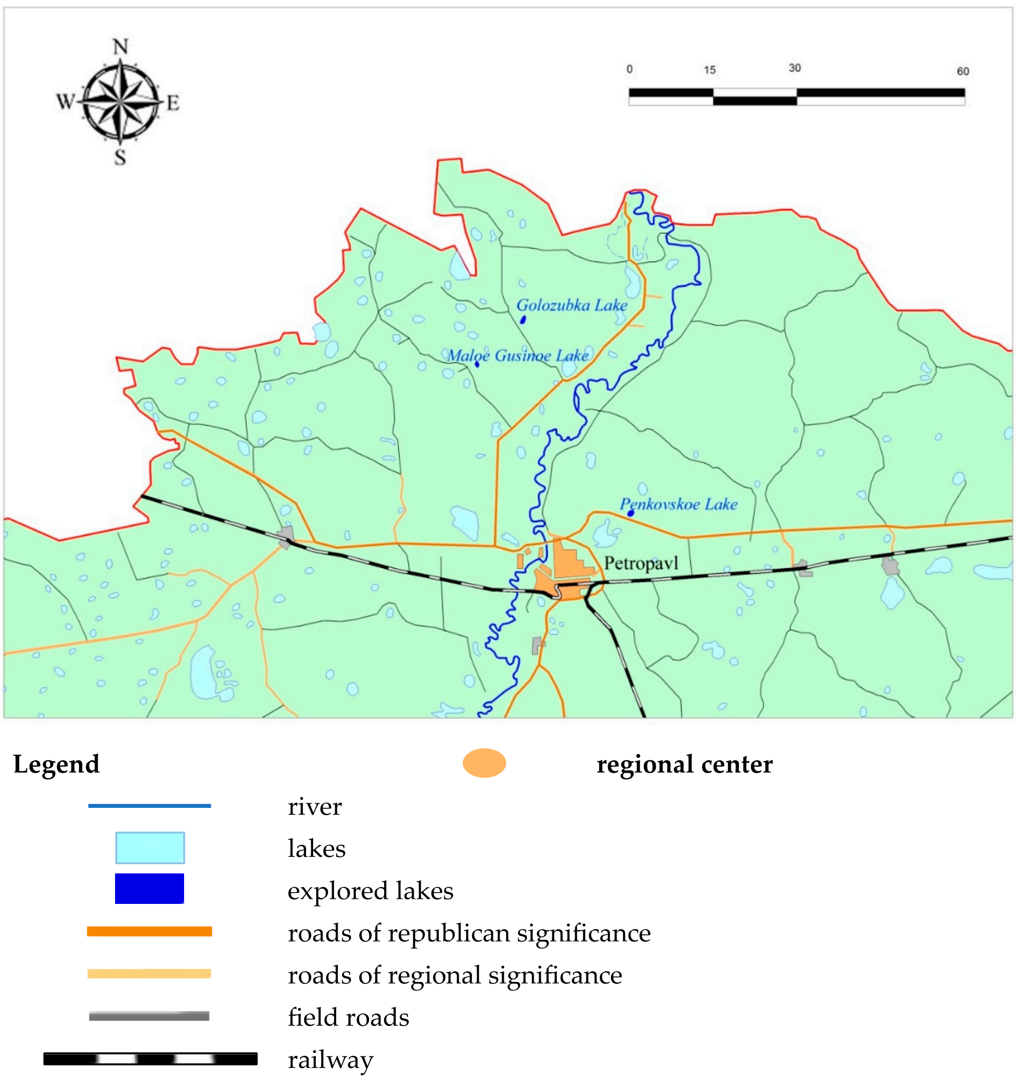


Figure 2. Cartographic layout of the studied lakes. Source: Own elaboration.

Sapropel samples were collected at three points in each lake. The data of the sampling coordinates are shown in Table 1.

Table 1. Coordinates of sapropel sampling on the studied lakes.

Sampling Location	Sample Number, Location	Coordinates of Samples
Lake Gusinoe (Maloe)	1 point, coastal zone	55°10′41.86″ N 68°59′14.89″ E
	2 point, open zone	55°10′36.64″ N 68°59′17.53″ E
	3 point, middle zone	55°10′31.43″ N 68°59′14.89″ E
Lake Golozubka	1 point, coastal zone	55°15′35.83″ N 69°4′32.23″ E
	2 point, open zone	55°15′34.22″ N 69°4′35.58″ E
	3 point, middle zone	55°15′32.23″ N 69°4′39.53″ E
Lake Penkovskoe	1 point, coastal zone	54°58′0.39″ N 69°15′56.02″ E
	2 point, open zone	54°58′0.87″ N 69°15′46.88″ E
	3 point, middle zone	54°58′2.26″ N 69°15′35.20″ E

Source: Own elaboration.

The listed lakes were located in one administrative district, in close proximity to the regional center. They were characterized by accessibility and good logistics, which were provided by paved roads.

4. Results

4.1. Characteristics of Research Objects

The analysis of the selected reservoirs allowed them to be classified according to the phenomenological attributes of saprobity zones. According to the classification proposed by R. Kolkvitz and M. Marsson [81] (p. 33), there are four classical zones of saprobity: oligosaprobic, b -meso-saprobic, a -meso-saprobic, and polysaprobic [82].

The classification was based on the analysis of the balance of oxygen and organic matter, as well as the predominance of hydrobionts. According to the description, by the nature of saprobity, Lake Gusinoe (Maloe) belonged to the b–meso-saprobic group. Lake Golozubka had features that allowed it to be attributed to a transitional form, changing from a -mesosaprobic to polysaprobic. Lake Penkovskoye had obvious signs of polysaprobic. This, in turn, was confirmed by external visual and morphological signs. Among them were the degree of overgrowth of hard surface vegetation, depth, the color of bottom sediments, and more. Thus, we can talk about the processes of the eutrophication of reservoirs, which showed the qualitative and quantitative composition of the sapropels of these lakes.

1. Lake Gusinoe (Maloe) was located in the Kyzylzhar district of the North Kazakhstan region, north of the village of Glubokoe (Figure 2). The distance from the regional center of Petropavlovsk was 43 km. The reservoir had an area of 50 hectares. Depth indicators: the maximum was 2.5 m and the average depth was 2 m. The slopes of the basin and the banks were low. The hydrological regime of the lake was caused by the influx of thawed spring waters and precipitation from the catchment area. Groundwater had an impact. There was a drop in the water level by season, from Spring to Autumn.

The formation of hard-surface vegetation was mainly due to common reed (*Phragmites communis*), lakeshore bulrush (*Scirpusla custris*), and narrowleaf cattail (*Typha angustifolia*). Soft surface vegetation was represented by water soldiers (*Stratiotes aloides*), sago pondweed (*Potamogeton pectinatus*), star duckweed (*Lemna trisulca*), and rigid hornwort (*Ceratophyllum *demersum*). The degree of overgrowth in the lake was 20% and the formation of splavins was noted. These facts suggested the waterlogging of the reservoir and the formation of bottom sediments (Figure 3). Lake Gusinoe (Maloe) was leased on the basis of Decree No. 102, dated 16 April 2018, from the public association of "Ecosphera" [83].

Figure 3. Satellite image of the degree of overgrowth of Lake Gusinoe (Maloe).

Sampling was carried out from the northern side of the lake, near the shore, in the open part, and in the middle of the lake (Table 1).

2. Golozubka Lake was located in the North Kazakhstan region in the Kyzylzhar district, north of the village of Sivkovo. The distance from Petropavlovsk was 47 km. The reservoir had an area of 30 hectares and the depth values had an amplitude ranging from 1 to 1.5 m or more. The slopes of the basin were low. There was a drop in the water level in the lake from Spring to Autumn. Food was provided by melting snow and precipitation falling on the catchment area. The influence of groundwater was noted. The total area of overgrowth was 40% and the formation of splavins was noted. (Figure 4). There was a lot of above-water soft vegetation. Hard surface and soft flood vegetation was represented by the typical plants of temperate lakes, including common reed (*Phragmites communis*), lakeshore bulrush (*Scirpusla custris*), narrowleaf cattail (*Typha angustifolia*), water soldiers (*Stratiotes aloides*), stuckenia pectinata (*Potamogeton pectinatus*), and star duckweed (*Lemna trisulca*) rigid. Golozubka Lake was not leased as an object of nature management (Figure 4).

Figure 4. Satellite image of the degree of overgrowth of Lake Golozubka.

Sampling points were located on the western side of the lake, near the shore, in the open part, and in the middle of Lake Golozubka (Table 1).

3. Lake Penkovskoye was located in the Kyzylzhar district of the North Kazakhstan region near the village of Penkovo. The distance from Petropavlovsk was 12 km. The reservoir had an area of 150 hectares and the maximum depth was about 1.0 m; the average depth was 0.5 m. The level regime of the lake was dependent on thawed snow waters, as well as precipitation. There is a continuous drop in the water level from the Spring to the Autumn season. The species composition of vegetation was identical to the lakes described above, with a predominance of water soldiers (*Stratiotes aloides*) and common reed (*Phragmites communis*). The area of overgrowth in Lake Penkovskoye was about 80% and the formation of splavins was noted. Nature management of the lake is not carried out. (Figure 5).

Figure 5. Satellite image of the degree of overgrowth of Lake Penkovskoye.

Sampling points were located on the eastern side of Lake Penkovskoye, near the shore, in the open part, and in the middle of the lake (Table 1).

This study of the reservoirs allowed us to draw conclusions about the genesis of the lakes, through changes in the level values of the depths and the overgrowth area, eventually leading to eutrophication and waterlogging being manifested in the formation of bottom sediments (Figures 3–5). The different stages of the genesis of the eutrophication of the studied reservoirs allowed us to talk about the formation of bottom sediments with different quantitative indicators of chemical elements and substances. This caused qualitative differences in sapropels when using them as an organic fertilizer.

A comparative quantitative analysis of the chemical composition of sapropels in the three lakes revealed their features. The results were also compared with the available data on the maximum permissible concentrations of substances based on accepted state standards.

4.2. Results of the Comparative Analysis

According to the analysis, the pH value of the sapropel water extract of Lake Gusinoe (Maloe) turned out to be 7.62 ± 0.005 (slightly alkaline reaction). The sapropel of Lake Golozubka had a pH = 7.66 ± 0.005 (slightly alkaline reaction). The sapropel of Lake Penkovskoye had a pH = 6.52 ± 0.005 (close to neutral reaction), which allowed it to be attributed to the type of organo-silicate sapropels used as fertilizers.

A significant amount of aquatic and near-aquatic vegetation was a factor of high organic matter content in the Golozubka and Penkovskoye lakes (33–38%) and indicated the duration of the eutrophication process. The relatively low content of organic matter (12.1%) in the sapropel of Lake Gusinoe (Maloe) was obviously associated with the initial stage of eutrophication. The highest indicator of humus content was also observed in the sapropel of Lake Penkovskoye (36.94%). The minimum content was noted in a sample from Lake Gusinoe (Maloe). It was also obvious that the lakes were formed under different conditions of waterlogging in the lake basin, which reflected changes in the climatic indicators of the territory.

According to the results of the analysis of the sapropel of Lake Gusinoe (Maloe), it could be concluded that the content of the organic part in the amount of 12.1% was not enough to achieve good indicators of plant growth and development. The content of the organic component in an amount of less than 15% was not an indicator of sapropel, but of bottom silt, which is much less valuable as a fertilizer. Thus, the best in terms of the amount of organic matter in the composition was the sample of Lake Penkovskoye (38.1%).

Another important indicator of an effective fertilizer was the content of humus. Sapropel humic substances have adhesive properties and bind mineral particles of the soil, which significantly improves the soil structure. These substances have a stimulating effect on plant growth, especially on the assimilation of molecular nitrogen and the development of the root system. Humic acids have an antimicrobial effect, suppress pathogenic microflora in the body, and activate metabolic processes in it. The humus content is due to the content of organic matter, which explained its higher values in the sapropel of Lake Penkovskoye (36.94 mg/kg) and its lowest, respectively, in Lake Gusinoe (Maloe).

The increased phosphorus content (29.32 mg/kg) in Lake Gusinoe (Maloe) indicated the presence of a combination of plant and animal residues and their decomposition products. Phosphorus, along with nitrogen and potassium, is one of the most important macronutrients necessary for the growth and development of plants. It was obvious that sulfur and phosphorus were of autochthonous origin—they were accumulated by sapropel-forming plants in the process of vital activity and were deposited when they died off.

The main part of the macronutrient composition of sapropels is potassium, sodium, aluminum, and calcium, the content of which varies in a wide range.

The high content of exchangeable potassium (532.8 mg/kg), gross potassium (928.34 mg/kg), magnesium (210.4 mg/kg), and sodium (781.5 mg/kg) in Lake Penkovskoye indicated that the studied lake belonged to the eutrophic type. This was also confirmed visually as the coastal strip was very swampy, drifting surface vegetation was widespread, and the formation of wide belts of coastal vegetation indicated so, etc. From this, it could be concluded that the water in Lake Penkovskoye had a low concentration of dissolved oxygen and excess biomass. In a geological sense, such a lake, which is in the final stage of eutrophication, may soon disappear.

The calcium content in Lake Penkovskoye (146.0 mg/kg), revealed as a result of laboratory research, indicated that the main part of it passed into sapropel from the water or was released during the decomposition of calcium-fixing plants involved in the formation of sapropels. Consequently, the main mineral mass of sapropel was represented by biogenic carbonate. Alkaline earth elements, such as calcium, magnesium, manganese, and iron, came not only from terrigenous products but also through assimilation via aquatic plants and the release during their decomposition.

The sapropel of Lake Penkovskoye was rich in trace elements for all necessary elements (except copper and molybdenum). In terms of copper content, sapropel was the leader in Lake Golozubka; in terms of molybdenum content—Lake Gusinoe (Maloe).

In the studied lakes, according to the data on the maximum permissible concentrations of chemicals in the soil, no excess was found regarding all harmful substances, namely, cobalt, chromium, lead, mercury, and arsenic. This was based on national standards of substance content.

Excessive concentrations or the accumulation of a number of substances could affect human health and the quality of the environment. Modern research confirms the relevance of innovative ways of purifying water and soil from heavy metals and other pollutants [84–87]. The use of research methods involving spectrometry allowed us to talk about the wide possibilities of its application [88].

Based on the above-described comparison of samples of three lakes, the sapropel of Lake Penkovskoye had the most optimal composition for the production of innovative organomineral. The sapropel of Lake Golozubka had less valuable properties, but the content of the organic components was also suitable as a fertilizer. The sample of sapropel from Lake Gusinoe (Maloe) showed relatively low values of indicators among the three lakes, which indicated the lack of efficiency of its use for fertilizer production. Taking into account the proximity of the transport communications to Lake Penkovskoye, as well as the increased content of organic matter, humus, potassium, and some trace elements in it, this lake should be considered the main object of our research for the organization of sapropel raw materials extraction. The values of the sapropel samples from Lake Penkovskoye, as well as the convenient transport logistics for its extraction, are factors confirming the possibility of producing environmentally friendly fertilizers. The agrarian direction of the economy will allow the development of promising organic farming and agricultural tourism in the territory of the North Kazakhstan region.

5. Discussion

5.1. Analysis of Acreage and Use of Mineral and Organic Fertilizers of the Studied Region

Official statistical data were used to analyze the acreage of the territory of the studied region [72].

First of all, the share of acreage from the total area of the region was determined. It is about 45%. This confirms the agricultural orientation of the region. The analysis of agricultural land allows us to talk about the predominance of arable land and about its use for the production of food crops.

Upon analyzing the territory of agricultural lands in the North Kazakhstan region, it can be seen thar there are slight changes in the area of crops by the types of crops. During the time period of 2017–2021, there was an increase in the area occupied by crops of grain, oilseeds, and potatoes. This, in turn, allows us to make a possible conclusion about their demand in the market, as well as compliance with the requirements of growing technology in the agro-climatic conditions of the North Kazakhstan region. As of 2021, the main sown area has been occupied by the cultivation of 2440.5 thousand hectares of wheat; the second place is occupied by oilseeds, with 959.9 thousand hectares of this crop. In third place is the area for growing fodder crops, which spans 320.6 thousand hectares. Potatoes and open-ground vegetables account for the growing areas of 31.2 and 5.6 thousand hectares, respectively (Figure 6).

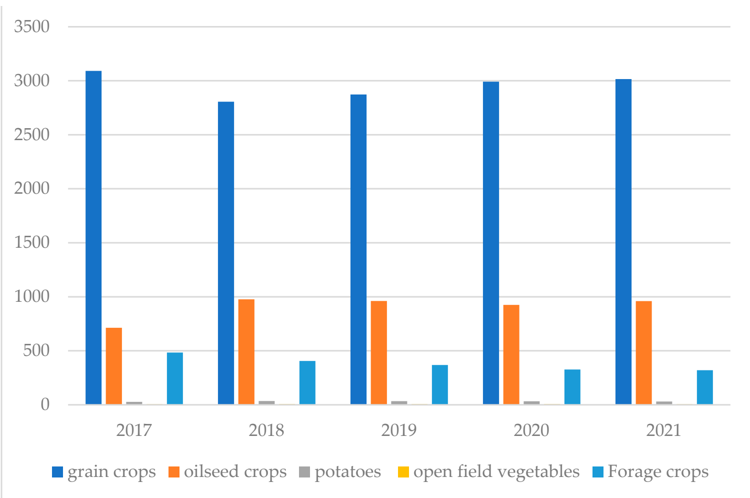


Figure 6. The structure of the areas of the North Kazakhstan region occupied for growing crops in 2017–2021. Source: Own elaboration.

The growth from 2017 to 2020 and the slight decrease in 2021 in the area of land occupied by vegetable crops may be due to the specifics of growing technology and competition from vegetables imported into Kazakhstan. The stable decrease in the area sown with fodder crops, in a five-year dynamic, can apparently be explained by the use of the plant mass of natural meadows for animal feed.

A feature of sowing agriculture in the North Kazakhstan region is the priority for growing grain crops; the occupied area for 2021 amounted to 2878.6 thousand hectares (Table 2).

Table 2. Sown areas of grain crops in the North Kazakhstan region for 2021.

District	Sown Area of Wheat	Barley Sown Area	Sown Area of Rye	Sown Area of Oats	Sown Area of Buckwheat	Millet Sown Area	Total Sown Area of Grain Crops
Aiyrtauskiy	200.5	57.1	-	2.4	0.5	-	260.5
Akzharskiy	165.2	24.1	-	0.6	0.6	-	190.5
M. Zhumabaeva	242.4	34.3	0.5	3.9	0.9	-	282
Esilskiy	158.1	25.9	-	2.4	0.5	-	186.9
Zhambylskiy	167.3	18.4	-	4.6	0.6	-	190.9
Kyzylzharskiy	109.2	17.7	-	2.9	0.5	0.1	130.4
Mamlyutskiy	88.1	17.3	0.1	2.7	0.3	-	108.5
Shal akyn	157.2	28	-	0.6	0.6	-	186.4
Akkayinskiy	119.4	22.3	-	1.6	0.5	-	143.8
Taiynshinskiy	353.5	54.3	-	10.3	1.3	-	419.4
Timiryazevskiy	179.4	17.2	-	2.3	0.2	-	199.1
Ualikhanovskiy	87.9	13.3	-	2.5	0.4	-	104.1
Gabita Musrepova	412.3	57.8	0	4.4	1.6	-	476.1
North-Kazakhstan region	**2440.5**	**387.7**	**0.6**	**41.2**	**8.5**	**0.1**	**2878.6**

Source; developed by the authors using sources [72]. Agency for Strategic Planning and Reforms of the Republic of Kazakhstan Bureau of National Statistics. Available online: https://www.stat.gov.kz/ (accessed on 7 March 2023).

Agro-climatic and soil features, along with the demand on the world market, make Northern Kazakhstan promising in the production of grain crops (wheat and barley).

The largest share occupied by grain crops was noted in the districts of Timiryazevskskiy and Gabita Musrepova. The smallest share was in Kyzylzharskiy and Ualikhanovskiy districts (Table 3).

The increase in sown areas in the North Kazakhstan region, as in many countries of the post-Soviet space, occurred due to the development of virgin and fallow lands in the span of time between the 1950s and 1960s of the last century. During this period, as a result of the constant impact of the anthropogenic factor during cultivation, in combination with soil and climatic features, there was a decrease in the level of humus in the soil. Mineral and organic fertilizers are used to introduce nutrients necessary for growing crops and increase yields (Table 4). The increase in sown areas in the North Kazakhstan region, as in many countries of the post-Soviet space, occurred due to the development of virgin and fallow lands in the span of time between the 1950s and 1960s of the last century. During this period, as a result of the constant impact of the anthropogenic factor during cultivation, in combination with soil and climatic features, there was a decrease in the level of humus in the soil. Mineral and organic fertilizers are used to introduce nutrients necessary for growing crops and increase yields (Table 4).

Table 3. The share of the territory of the districts of the North Kazakhstan region occupied by grain crops in 2021.

District	Total Sown Area of Grain Crops, Thousand Hectares	The Area of the District, Thousand Hectares	Share of Area under Grain Crops, %
Aiyrtauskiy	260.5	962	27.1
Akzharskiy	190.5	804	23.7
M. Zhumabaeva	282	781	36.1
Esilskiy	186.9	514	36.4
Zhambylskiy	190.9	747	25.6
Kyzylzharskiy	130.4	615	21.2
Mamlyutskiy	108.5	410	26.5
Shal akyn	186.4	484	38.5
Akkayinskiy	143.8	450	32.0
Taiynshinskiy	419.4	1143	36.7
Timiryazevskiy	199.1	451	44.1
Ualikhanovskiy	104.1	1287.66	8.1
Gabita Musrepova	476.1	1109	42.9
North-Kazakhstan region	**2878.60**	**9757.66**	

Source; developed by the authors using sources [72]. Agency for Strategic Planning and Reforms of the Republic of Kazakhstan Bureau of National Statistics. Available online: https://www.stat.gov.kz/ (accessed on 7 March 2023).

Table 4. The area of agricultural land in the North Kazakhstan region, on which fertilizers have been applied.

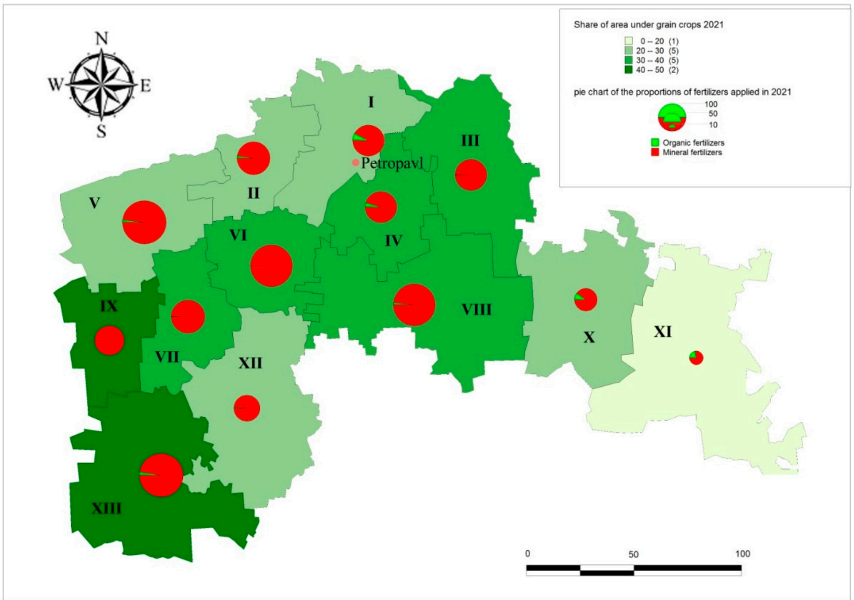
District	Area, Thousand Hectares									
	Mineral Fertilizers					Organic Fertilizers				
	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021
Aiyrtauskiy	32.7	35.8	83.2	33.1	67.5	-	1.6	1.2	0.9	0.8
Akzharskiy	5.8	18	25	45.3	45.1	-	-	-	-	4.8
M. Zhumabaeva	80.5	68.7	59.8	51.6	89.1	0.2	0.1	1.1	0.1	0.1
Esilskiy	85.7	108	110.9	157.4	152.6	1.8	0.7	0.2	0.4	0
Zhambylskiy	82.4	104.6	82.7	146.4	163.5	-	0.5	0.2	0.2	3.1
Kyzylzharskiy	49.1	48.8	53	77.3	80.8	1.8	0.1	3.2	7.8	6.5
Mamlyutskiy	43.8	59.7	68	84.7	97.3	0	3.2	3.7	1.7	2.3
Shal akyn	23.9	27.8	23.5	80.7	104.1	-	3.9	0.4	-	0.1
Akkayinskiy	22.1	36.3	60.7	78.5	88.8	5.3	3.9	7.6	7.8	4.1
Taiynshinskiy	127.4	138.9	140.1	101.6	145.2	0.5	0.3	-	0.7	2.3
Timiryazevskiy	60.2	70.9	52.1	73.8	79.4	-	-	-	-	-
Ualikhanovskiy	37.8	37.6	25.7	13	17.3	4.2	-	-	-	4.9
Gabita Musrepova	64.7	94.1	99.8	141.5	161.7	0.1	2.5	1.1	1.5	3.8
North-Kazakhstan region	**716.1**	**849.2**	**884.5**	**1084.90**	**1292.60**	**13.9**	**16.8**	**17.7**	**21.1**	**32.7**

Source; developed by the authors using sources [72]. Agency for Strategic Planning and Reforms of the Republic of Kazakhstan Bureau of National Statistics. Available online: https://www.stat.gov.kz/ (accessed on 7 March 2023).

Initially, only mineral fertilizers obtained as a result of chemical synthesis were applied. Their constant use has led to the accumulation of nitrates in soils, which has led to the disruption of plant vegetation processes. In recent years, organic fertilizers have been increasingly used; their use is characterized by safety and a complex content of necessary substances. Most often, when applied to the soil, organic fertilizers are used in combination with mineral fertilizers during the period of agro-reclamation measures.

Upon analyzing the quantitative and qualitative composition of the use of fertilizers in the sown areas of the North Kazakhstan region, it can be determined that there is an increase in the use of both mineral and organic fertilizers (Table 4). In the period spanning from 2017 to 2021, there was a steady increase in the application of fertilizers of both types. The use of mineral fertilizers increased in the area from 716.1 to 1292.6 thousand hectares. The use of organic fertilizer increased from 13.9 to 32.7 thousand hectares. It was found that the areas that had experienced the introduction of mineral fertilizers into the soil were predominate. At the same time, there is a steady increase, more than two times, in the areas of organic fertilizer application. This can be explained by the introduction of green technologies and the development of a green economy aimed at the sustainable and safe development of the country. Additionally, it directly depends on the type of crops grown. In addition, the demand for organic farming products is growing in the world market.

This study and analysis of statistical data characterizing the area of sown areas used for growing grain crops and the use of mineral and organic fertilizers in 2021 made it possible to visualize the data on a cartogram (Figure 7). The predominance of territories with the application of mineral fertilizers—1292.40 thousand hectares, over the areas with the use of organic fertilizers—spanning over 32.80 thousand hectares were noted.



Legend ● **regional center**

	District		
I	Kyzylzharskiy	VII	Shal akyna
II	Mamlyutskiy	VIII	Tajynshinskiy
III	M. Zhumabaeva	IX	Timiryazevskiy
IV	Akkayinskiy	X	Akzharskiy
V	Zhambylskiy	XI	Ualihanovskiy
VI	Esilskiy	XII	Ajyrtauskiy
		XIII	Gabita Musrepova

Figure 7. Cartogram of the use of the territory of the administrative districts of the North Kazakhstan region for the cultivation of grain crops and the use of fertilizers. Source: Own elaboration.

The leaders among the administrative districts of the region, in terms of the use of mineral fertilizers on sown areas, are the districts of Zhambylskiy—163.5 thousand hectares, Gabita Musrepova—161.7 thousand hectares, and Esilskiy—152.6 thousand hectares. The lowest values characterizing the use of the fertilizers of the mineral composition were noted in the agricultural lands of the Akzharskiy and Ualikhanovskiy districts—45.1 and 17.3 thousand hectares, respectively. The areas used by organic farming are insignificant. The maximum values are Kyzylzharskiy—6.5 thousand ha, Ualikhanovskiy—4.9 thousand ha, and Akzharskiy—4.8 thousand ha. The minimum values were noted in the areas of Shal akyn and M. Zhumabaeva at 0.1 thousand ha. The Esilskiy and Timiryazevskiy districts do not use organic fertilizers at all. Thus, the share of mineral fertilizers used in a number of districts is 100% (Esilskiy, Timiryazevskiy districts). In all other regions, the share of the use of mineral fertilizers in agricultural areas is more than 90%. The exception is the Ualikhanovskiy district. The sown area of this region accounts for 77.93% of mineral fertilizers and the maximum use of organic fertilizers is 22.7% of the total share of arable land.

A high proportion of the territories of the districts is used for growing grain crops. Areas with a high share of the area under grain crops from 30–40% and 40–50% prevail (Tayynshinskiy and Timiryazevskiy districts). Only one district, Ualikhanovskiy, has values from 0–20%. According to Figure 7, it can clearly be seen that the share of agricultural territories with the application of mineral fertilizers prevails. At the same time, an analysis of the dynamics of statistical indicators of the application of organic fertilizers to the soil for the period of 2017–2021 allows us to conclude that there is an understanding of the need for their use. If in 2017 the application of organic fertilizer in the districts was episodic and was noted only in 7 districts, in 2021 these fertilizers were applied to the sown areas in 11 districts. This can be explained by the introduction of green technologies and the development of a green economy aimed at the sustainable and safe development of the country. In addition, the demand for organic farming products is growing in the world market.

To identify the state and prospects for the development of organic farming in the territory of the North Kazakhstan region, a SWOT analysis ("strengths, weaknesses, opportunities, threats" is a method that allows you to describe the state of any problem) was performed (Table 5).

Table 5. SWOT analysis of the state and prospects for the development of organic farming in the North Kazakhstan region.

Strengths	**Weaknesses**
• Agrarian orientation of the region, favorable agro-climatic resources • Presence of chernozems (more than 80% of arable land) • Flat terrain • The possibility of growing various crops • Production of durum wheat • Demand for products on the world market	• Soil dehumidification • Irregular use of mineral fertilizers • Reduction of indicators of the chemical composition of the soil • Dependence of yield on weather conditions
Opportunities	**Threats**
• Availability of natural resource potential for the production of organomineral fertilizers • Attracting investments from the state and private business • Development of technologies for the production of organic fertilizer based on the bottom sediments of lakes • Introduction of organic farming, production of environmentally friendly products	• Soil depletion • Yield instability • Absence of domestic producers of mineral fertilizers • Chemical pollution of agroecosystems • Weak interest of farmers

Source; developed by the authors.

These conducted studies allow us to conclude that the agricultural sector of the studied region is mainly represented by acreage. Agricultural land is constantly increasing due to the growing demand for food products. Long-term use of land has led to the need to use a large number of fertilizers, among which mineral fertilizers predominate. However, the global strategy aimed at environmental safety and the introduction of green technologies makes it necessary to use organic fertilizers to increase yields. The resource potential of the region makes it possible to produce environmentally friendly fertilizers based on the bottom sediments of local lakes. This, in turn, will allow for the development of organic farming, which will contribute to the development of interest, including from the tourism industry.

5.2. Analysis of the Possibility of Developing Agrotourism in the Territory of the North Kazakhstan Region

An analysis of the natural resource potential, expressed in the predominance of sown areas, allows us to speak about the development of the agricultural sector of the region's economy. Together with agro-climatic features, this makes it possible to produce the necessary food crops in the territory of the region under study. A large number of lakes, and the presence of a raw material base in the form of bottom sediments, provide prospects for the production of an environmentally friendly fertilizer and the development of organic farming in rural areas. The uniqueness of the landscapes and the absence of large industrial polluting enterprises confirm the environmental friendliness of the territory. The presence of an ethno-cultural identity and the possibility of producing organic products make it possible to form agro-settlements. These aspects indicate the possibility of creating a tourist infrastructure in the territories of farms and peasant farms. In Kazakhstan, work is underway to create agro-tourism routes for inclusion in the register of domestic agricultural tourism [89]. One of the brightest examples in the territory of the region is the peasant farm of "Zenchenko & Co" in the village of Novonikolskoye [90]. According to the results of the rating conducted in Kazakhstan, this village was included among the "30 best auls". The farm is a modern agricultural cluster. A feature of the organization of its production is the presence of green technologies for generating electrical energy, environmentally friendly animal husbandry, and organic farming. This economy is not the only one, there is potential for numerous other auls and villages of the North Kazakhstan region and for the development of agro-tourism. This detailed study and promotion of organic farming and agricultural tourism will attract investment from the state and from businesses in the economy of the North Kazakhstan region.

To identify the state and the prospects of agrotourism development in the territory of the North Kazakhstan region, a SWOT analysis was performed (Table 6).

Table 6. SWOT analysis of the state and prospects of agrotourism development in the North Kazakhstan region.

Strengths	Weaknesses
• Agrarian orientation of the region • Favorable agro-climatic resources • The possibility of growing various crops • The presence of a large number of rural settlements • Development of transport infrastructure • State programs aimed at the development of tourism and agriculture • The presence of ethno-cultural diversity and authenticity in rural settlements	• Underdevelopment of the tourist infrastructure, Insufficient coverage in the media and the Internet • Weak interest of farmers • depends on weather conditions

Table 6. *Cont.*

Opportunities	Threats
• Attracting investments from the state and private business • Availability of natural resource potential of the region • Availability of a sufficient number of agricultural formations • Introduction of organic farming based on the use of bottom sediments • Production of environmentally friendly products • Development of tourist infrastructure	• Lack of agrotourism marketing research • Lack of specialists in this industry • Lack of well-formed tourist infrastructure

Source; developed by the authors.

Thus, these conducted studies revealed both positive and negative factors in the development of agrotourism in the territory of the studied region. At the same time, we can talk about the development potential of this area, which needs to be studied and promoted. A detailed study of the popularization of organic farming and agricultural tourism will attract investments from the state and from businesses in the economy of the North Kazakhstan region.

6. Conclusions

The basis of sustainable development is the rational use of natural conditions and resources. In turn, this reduces the risk of a negative impact on the environment and ensures the sustainable development of all sectors of the economy, in particular, agriculture and the tourism industry. These conducted studies have confirmed the presence of the necessary factors in the territory of the studied region that ensure safety and stability.

The North Kazakhstan region has high natural resource potential and favorable agro-climatic conditions for the development of the agricultural sector of the economy. A large number of eutrophic lakes, with high-quality, environmentally friendly bottom sediments that do not require large financial investments to extract, represent one of the foundations for the development of organic farming. The experiences of previous studies have shown the effectiveness of the use of sapropels as organomineral fertilizers.

In these studies, sapropel was used directly as a substrate, which was introduced into the soil during the planting or during the vegetation of plants. The development of new sapropel processing technologies will make it possible to obtain a liquid concentrate that will be used as an innovative fertilizer for pre-sowing seed treatment. The resulting liquid form of this fertilizer will allow, by changing the concentration of the extract, the adaptation of the resulting fertilizer for various crops. Depending on the type and variety of the plant, it will be possible to adjust this concentration for pre-sowing seed treatment. This will affect the germination rate and growth energy of the seeds of agricultural crops, increase productivity, and provide plants with the macro- and micro-elements necessary for humans [91]. The innovative technology of the production and application of liquid fertilizer will contribute to reducing the volume of its use and its transportation. In addition, in this form, the fertilizer is stored for a long time while it occupies a small area of the room. This makes the use of the bottom sediments of lakes in the North Kazakhstan region in this form of fertilizer even more promising.

For further obtaining copyright protection documents and maintaining convenience, this concentrate is called "Saprolin". The natural origin of the innovative fertilizer makes it possible to use it for the production of environmentally friendly organic products. This will reduce the use of xenobiotics and make agriculture and the environment safe and sustainable. The uniqueness of the territory of the region, the agrarian orientation of the economy, and the emerging interest in the development of the tourism industry in this part of the state will become the bases for the development of agricultural tourism. This proves the need for further scientific research, which will eventually make the territory environmentally safe, reduce possible risks, and ensure the sustainable development of organic farming and tourism.

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