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# Agroecological Assessment of Suitability of the Steppe Soils of Ukraine for Ecological Farming

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**ABSTRACT**

The intensive development of industry generates a number of negative consequences, which leads to an ecological crisis. As a result, the soil on which plant products are grown is polluted by radionuclides, heavy metals, pesticides, and chemicals. That is why in the early 1960s, the alternative farming, which is also called biological, biodynamic or organic, began to develop in Europe. The movement for alternative farming is widely developing in industrialized countries with a high level of chemization of agriculture. Therefore, the proposed topic is extremely relevant in terms of rational nature use, ensuring the sustainable development of territories, as well as food security in Ukraine. The article deals with agroecological assessment of suitability of agricultural land of the Steppe Zone of Ukraine for ecological farming and bases on the modern data from the Kherson branch of the state institution "Institute of Soil Protection of Ukraine". Spatial modeling of the presence of nutrients in the steppe soil of Ukraine was made by the means of ArcGIS 10.1 product. Taking into account the obtained data and spatial modeling, the territories with soils of limited suitability for ecological farming occupy 67.2% (1194.5 thousand hectares) of the Kherson region, unsuitable soils are located on 16.7% (297.4 thousand hectares) of agricultural land of the Steppe Zone of Ukraine and suitable lands were detected on 16.1% (286.2 thousand hectares) of the territory of the studied lands. The conclusion was made that with the actual availability of lands occupied under ecological farming (4.3% or 75.9 thousand hectares), the territory of the Steppe Zone of Ukraine has a prime potential to increase the area under ecological farming by 4.2 times. Therefore, the article paid attention to ecological farming, taking into account the specifics of the content of trace elements in the steppe soils and their compliance with the methodology for determining whether soils belong to the categories of suitable, limited-suitability and unsuitable for ecological farming.

**Keywords:** agricultural land, spatial modeling, GIS-technologies, agroecology, agrochemical indicators, nutrients.

## INTRODUCTION

According to the modern scientific literature, there are two meanings which describe organic agriculture and often used interchangeably, but apparently, ecological and organic farming are not the same. While ecological farming views the soil, it works on as a part of a larger ecosystem, organic farming focuses on the final product (Nobari et al., 2021). Theoretically, organic products could be produced keeping agroecology in mind. In practice, it means if the products that want to claim an "organic" label in the EU must keep ecological farming in mind. In the past, any products grown without pesticides, herbicides, the use of GE or man-made fertilizers, or livestock feed additives could claim to be organic. Today, the word starts to have a more holistic meaning. According to the EU, for a farm to be considered organic, it should also limit the impact it has on the environment and encourages: responsible use of energy and natural resources, biodiversity, preservation of regional ecological balances, improvement of soil fertility, and maintenance of water quality (Dudiak et al., 2021).

Some Ukrainian scientists consider ecological farming to be defined as such an attitude to agriculture, the goal of which is to create a sustainable, from the point of view of humanity, quality of the environment and an economically justified production system (Pichura et al., 2021a). Their main idea is to use self-regulatory mechanisms of agroecosystems, local and resources obtained on the territory of the farm, and management of ecological and biological processes and reactions. The use of external energy sources, both chemical and organic, is limited as much as possible. In European countries, ecological farming is based on ecosystem management, rather than attracting resources from outside (Pichura et al., 2021b).

Today, in scientific articles there is a conclusion that ecological farming system is not considered an intensive technology of agricultural production. Ecological farming is a system of reducing the input of energy resources from the outside to obtain the products that do not use synthetic chemical compounds. The main goal is the production of food products without the use of potentially dangerous substances, which means that they are relatively safe for consumption. The use of commercial fertilizers and pesticides is prohibited (Pichura et al., 2020).

Some European scientists stress that synthetic fertilizers are replaced by manure and composts, and the preservation of organic matter and nitrogen reserves is ensured by expanding the cultivation of legumes to green fertilizers. Specially bred varieties, crop rotations and buffer plants are used to protect agricultural plants from pests and diseases (Podawca et al., 2020). According to the data of domestic and foreign scientists, the productivity of ecological farming in relation to conventional farming ranges from 56% to 107%. A conventional farming system is considered to be a farming system where all agricultural activities are carried out on the basis of general scientifically based recommendations without taking into account the specific conditions of the farm (Shennan et al., 2017).

According to modern concepts, the term "agroecological condition of the soils" is defined as an integral indicator of its ecological stability, level of fertility and sanitary-hygienic condition. The information about soil contamination with heavy metals, pesticides, and radionuclides is a mandatory component for determining and justifying the suitability of soils for ecological agriculture in order to keep soils in appropriate condition for their further effective use. Land suitability assessment is based on the principles of systematic methods of research and analysis (Pichura et al., 2023).

Thus, the main goal of the article is to evaluate the agroecological properties of the steppe soils and, with the help of modern software, to build spatial models which reflect their suitability for ecological farming.

## MATERIAL AND METHODS

For the research and spatial modeling, the data of the 11th round of whole agrochemical surveys of

**Table 1.** Methodology for determining suitability of agricultural land for ecological farming according to its agrichemical indicators

| Indicators of the sanitary and hygienic condition of the soil | Standards by the level of suitability | | |
|---|---|---|---|
| | Suitable | Limited suitability | Unsuitable |
| Density of contamination by radionuclides, $K_i/km^2$: | | | |
| Cs-137 | <1 | 1–5 | >5 |
| Sr-90 | <0.05 – 0.05-0.02 | | >0.05 |
| Content of moving forms of heavy metals, relative to the MPC | <1.0 | | ≥1.0 |
| Content of residues of pesticides, relative to the MPC | <1.0 | | ≥1.0 |
| Indicators of ecological sustainability of the soil: | | | |
| Content of humus in the arable layer, %: | >4.0 | 4.0–2.0 | <2.0 |
| Reaction of soil solution, units ($pH_{salt}$) | >5.5 | 5.5–4.6 | <4.6 |
| Agrochemical indicators of soil fertility, mg/kg | | | |
| Content of nitrogen (N) | >40 | 40–30 | <30 |
| Content of phosphorus (P) | >30 | 30–15 | <15 |
| Content of potassium (K) | >300 | 300–200 | <200 |
| Movable forms of trace elements, mg/kg | | | |
| Zinc (Zn) | >5.0 – 1-23 | 5.0-2.0 – <1 | <2.0 – > 23 |
| Manganese (Mn) | >20 – 10-100 | 20-10 – <10 | <10 – >100 |
| Copper (Cu) | >0.5 – 0.5-3 | 0.5-0.2 – <0.5 | <0.2 – >3 |
| Cobalt (Co) | >0.3 – 0.15-5 | 0.3-0.15 – <0.15 | <0.15 – >5 |

the agricultural land of the Steppe Zone of Ukraine (2016–2021) was used; these were conducted by the Kherson branch of the state institution "Institute of Soil Protection of Ukraine" (Boiko et al, 2018).

The article is based on the method of classifying the suitability of agricultural land for ecological farming according to their agrochemical indicators (Breus et al, 2018). This method was determined by the scientists of the Institute of Agroecology and Nature Use of the National Academy of Sciences of Ukraine (Table 1).

As a result of research, cartograms of the heterogeneity of soil distribution according to agrochemical and ecological-toxicological indicators were created, which became the basis for zoning and determining the areas of agricultural land in the Steppe Zone of Ukraine according to their suitability for ecological farming.

## RESULTS AND DISCUSSION

Study of soil ecological sustainability indicators. It was determined that according to the humus content (Fig. 1a) in the soil layer of 0–20 cm, only 0.1% of agricultural lands are suitable, 80.5% have limited suitability, and 19.4% are unsuitable for ecological farming.

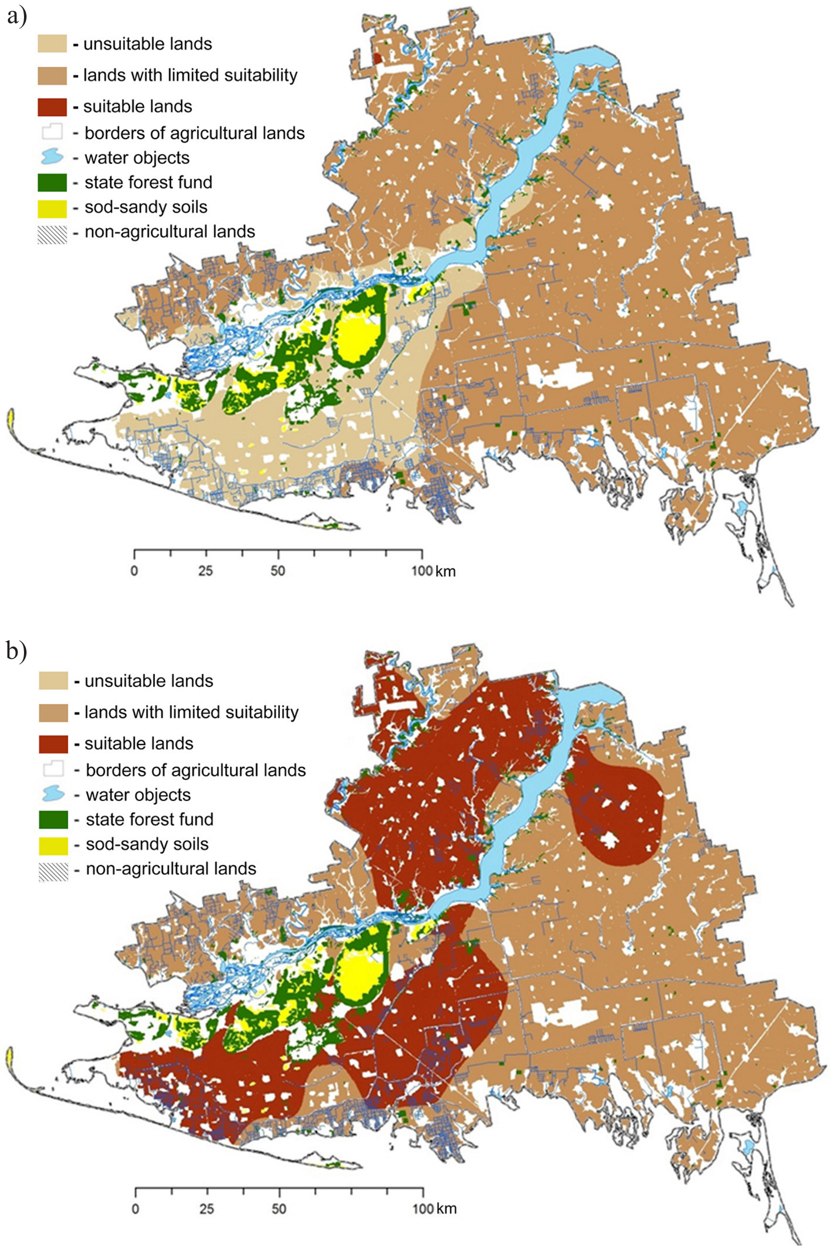


**Figure 1.** Spatial models of land suitability for ecological farming by the indicators of ecological sustainability of the soil: a – humus; b – pH

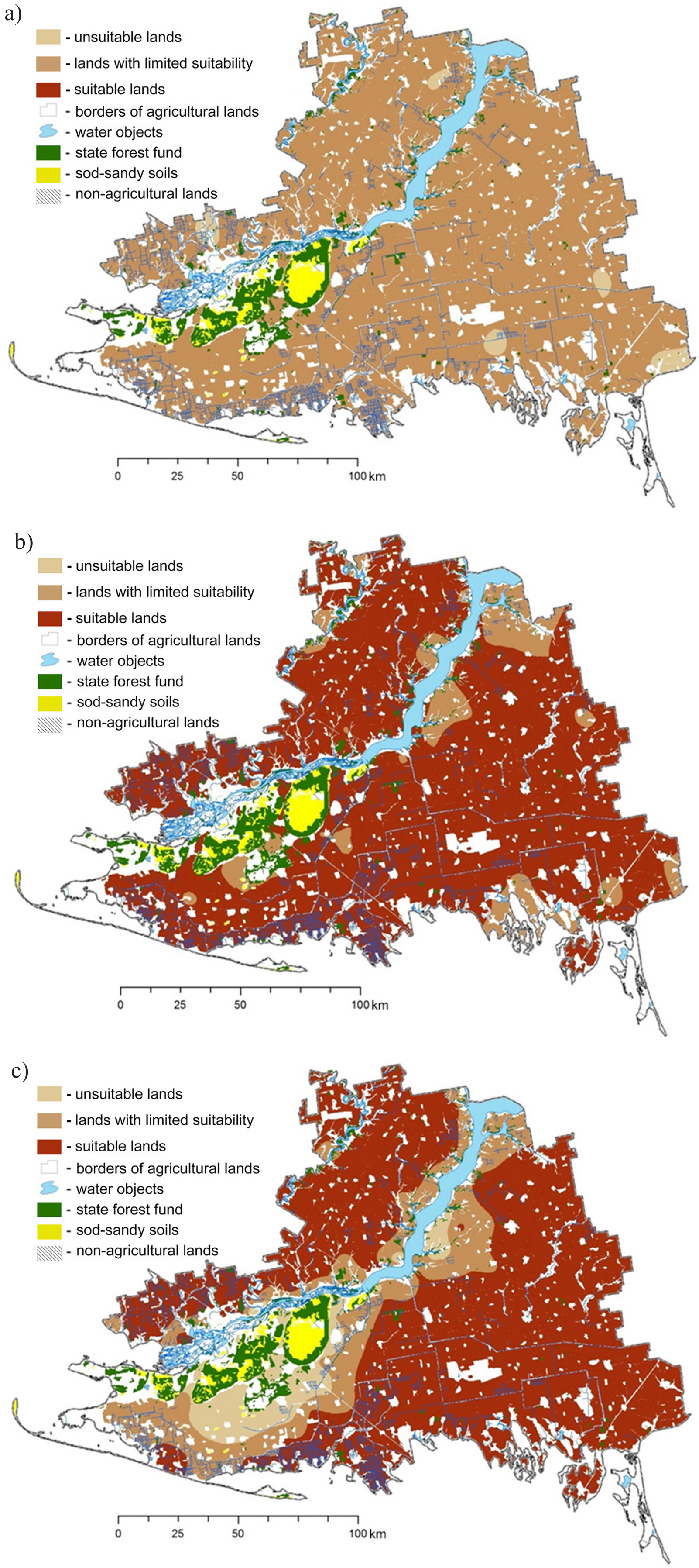


**Figure 2.** Spatial models of land suitability for ecological farming by the agrochemical indicators of soil fertility: a – Nitrogen (N); b – Phosphorus (P); c – Potassium (K)

About 80% of the districts of the studied region have 75% or more of the area of agricultural land suitable and land with limited suitability in terms of humus for ecological farming, 20% of the districts have less than 13% of lands with limited suitability, the majority of their territories are unsuitable for ecological farming. The district with the largest area of land with limited suitability is Novotroitskyi – 151.0 thousand hectares, with unsuitable – Holoprystanskyi (99.2 thousand hectares).

Soil acidity (pH) of soils (Fig. 1b) – 59.4% of agricultural lands are suitable and 40.6% have limited suitability for ecological farming. On the basis of the conducted pH studies, the district with the largest area of land suitable for ecological farming is Velikooleksandrivskyi with an area of 123.7 thousand hectares (98.7% of the entire area of the district), and the district with the largest area of land with limited suitability – Novotroitskyi (151.0 thousand hectares)

Study of the agrochemical indicators of soil fertility. Nitrogen (N) – only 0.1% of agricultural lands are suitable, 97.7% have limited suitability, and 2.2% are unsuitable for ecological farming (Fig. 2a). All regions of the region have 90% or more of the area of agricultural land suitable and with limited suitability for ecological farming.

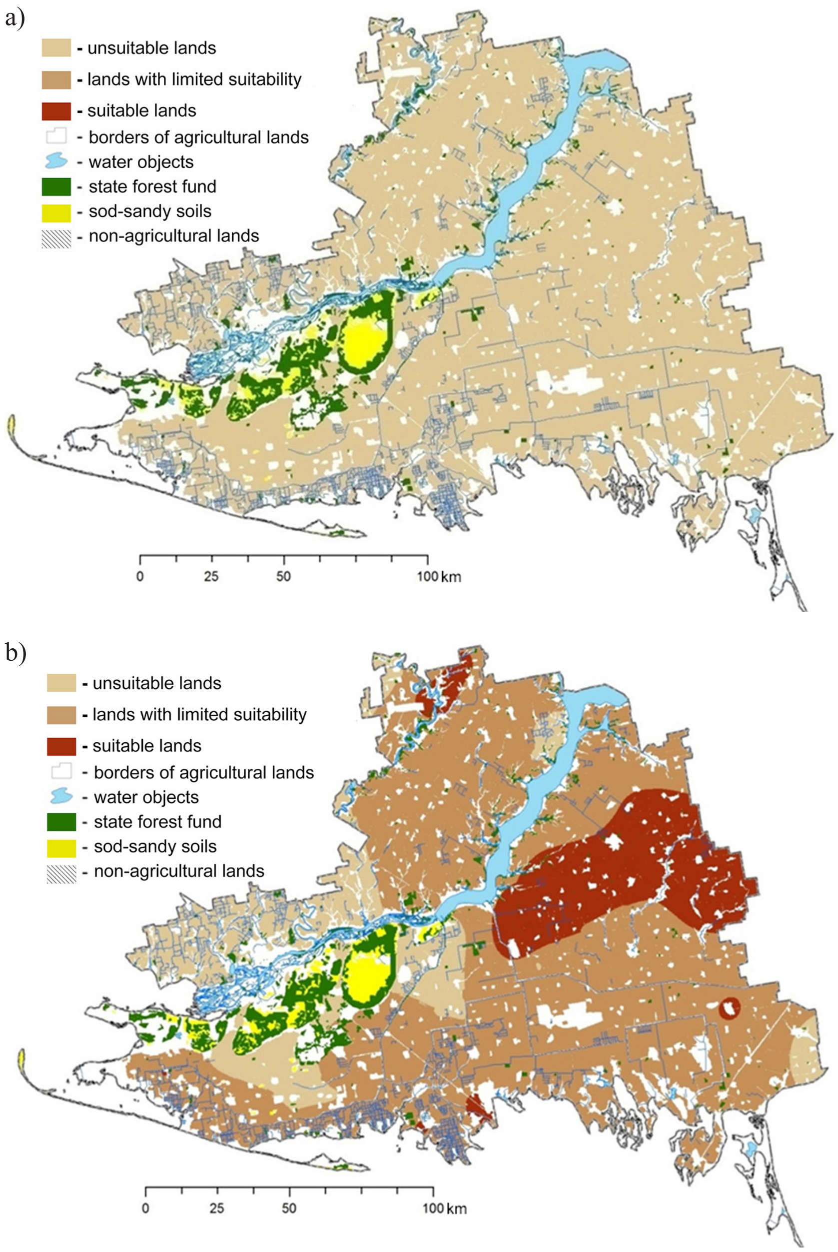


**Figure 3.** Spatial models of land suitability for ecological farming by the movable forms of trace elements: a – Zinc (Zn); b – Manganese (Mn)

The district with the largest area of land from the category unsuitable is Henicheskyi (13.33 thousand hectares or 9.6% of the total area of agricultural land of the district).

The largest area of land suitable for ecological agriculture in the studied territory was identified by the indicators of the content of phosphorus (P) and potassium (K). Phosphorus (Fig. 2b) – 90.2% of the soils of the studied area is suitable, 9.8% has limited suitability. The district with most suitable lands for ecological agriculture in terms of P content – Kalanchatskyi (62.1 thousand hectares).

Potassium (K) – 76.3% of agricultural lands are suitable, 17.6% have limited suitability, and 6.2% are unsuitable for ecological farming (Fig. 2c). The district with the most suitable soils in terms of K content is Novotroitskyi (151 thousand hectares). The largest area of surveyed agricultural land, which belongs to the category of unsuitable, is located in the Oleshky district (43.5 thousand hectares or 64.5% of the total area of agricultural land of the district).

Study of the content of mobile forms of trace elements. The significant heterogeneity of the spatial distribution of the content of mobile forms of trace elements in the steppe soils determines the high variability of land suitability for ecological agriculture (Breus et al., 2020). In particular,

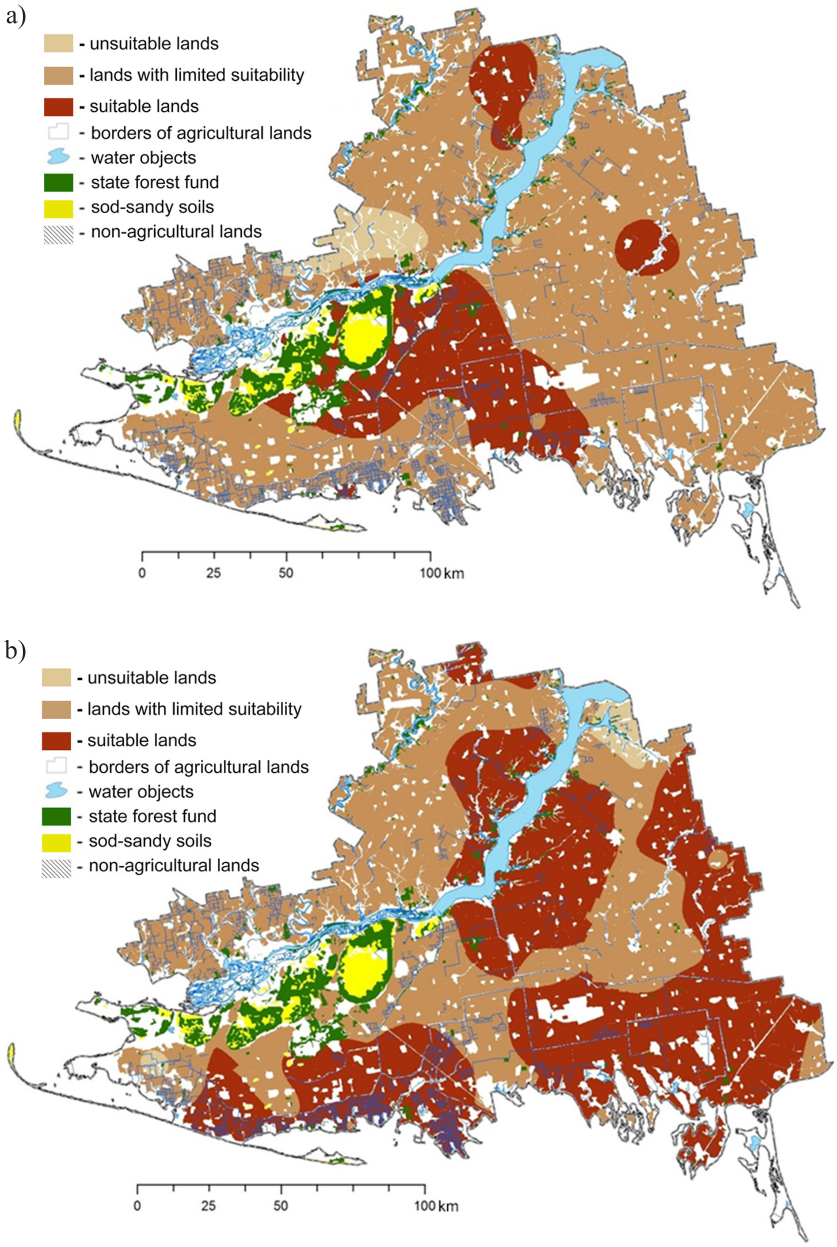


**Figure 4.** Spatial models of land suitability for ecological farming by the movable forms of trace elements: a – copper (Cu); b – cobalt (Co)

all agricultural lands are unsuitable according to the Zinc (Zn) content (Fig. 3a). A small amount of Zn in the soil does not mean that steppe soils are not suitable for ecologic farming, but it must be taken into account during soil cultivation. Accumulation of the required amount of mobile forms of Zn in the soil is hindered by a number of factors, such as soil temperature, high pH level, liming or high carbonate content, compacted soil and low organic matter content that can reduce the mobility and assimilation of Zn by the plant root system (Breus et al., 2022).

Manganese (Mn) – 15.3% of agricultural lands are suitable, 68.3% have limited suitability, and 16.4% are unsuitable for ecological farming (Fig. 3b). The district with the largest area of land from the category suitable is Nizhnyosyrogozhsky (94.5 thousand hectares or 86.9%), the area of unsuitable land is located in Bilozersky District – 99.2 thousand hectares.

According to the content of mobile forms of Copper (Cu) 19.2% of the studied agricultural lands are suitable, 77.8% have limited suitability, and 3.1% are unsuitable for ecological farming (Fig. 4a). The district with the largest area of land suitable for the content of mobile forms of Cu is Chaplinskyi (105.2 thousand hectares or 82.8%), unsuitable – Beryslavskyi district (39.8 thousand hectares or 32.3%).

As for the content of mobile forms of Cobalt (Co) 51.6% of lands are suitable, 47.0% have limited suitability and 1.4% are unsuitable (Fig. 4b). The largest area, in percentage to the total land area of the district in terms of the content of mobile forms of Co, which is suitable for conducting ecological agriculture, characterizes the Henichesky district (91.9%). The largest area of unusable land is located in the Verkhnyorogachytsky district (19.8 thousand hectares or 30.4%).

Heavy metals (lead, cadmium, mercury), residual amounts of pesticides, presence of Cs-137 and Sr-90 radionuclides are included in the list of toxicants that are determined in the steppe soils. In turn the situation in the region regarding the presence of heavy metals in the soil is quite satisfactory, during the period of research, a slight exceedance of the MPC was periodically detected. Such variations are observed, for the most part, in the soils adjacent to major transport routes. That is, according to the content of mobile forms of heavy metals, residual amounts of pesticides, radionuclides Cs-137 and Sr-90 radionuclides, the steppe soils are suitable for ecological farming (Breus et al, 2022).

Using build-in instruments of ArcGIS 10.1 and based on the results of spatial modeling of the distribution of agrochemical properties, ecological sustainability and trace elements of the steppe soils an integral model of land suitability for ecological farming was built (Fig. 5). It was determined that about 16.7% (297.4 thousand hectares) of researched lands are unsuitable, 67.2% (1194.5 thousand hectares) have limited suitability and 16.1% (286.2 thousand hectares) are suitable.

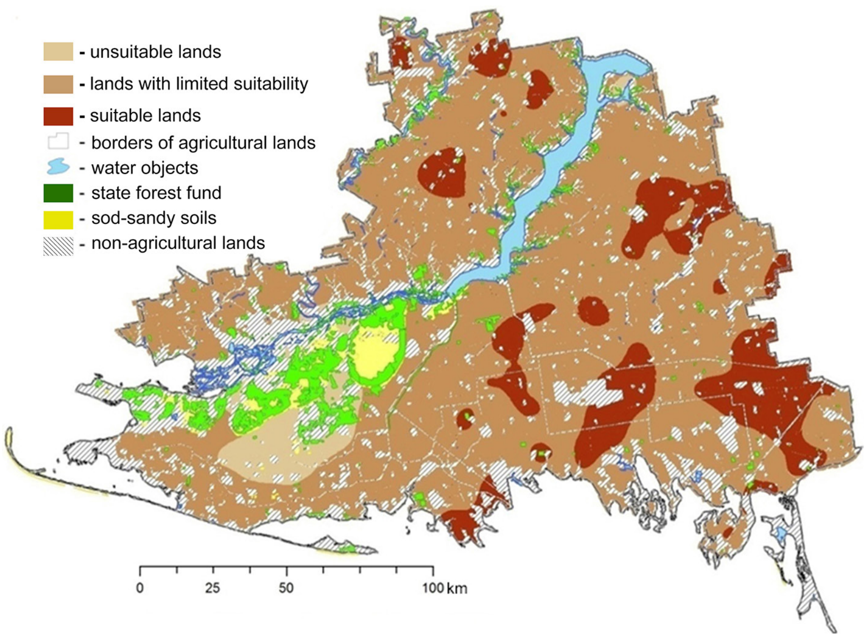


**Figure 5.** Integral map of the spatial distribution of soils according to the suitability for ecologic farming

## CONCLUSIONS

As a result of spatial modeling of the agroecological state of the steppe soils it was determined that 0.1% of agricultural lands are suitable for ecological farming according to the content of humus and N, and 80.5% and 97.7% of lands have limited suitability, respectively. The largest area of suitable land in the studied area was identified by the indicators of the content of P – 86.4% and K – 76.3%. According to the acidity of the soil 59.4% of agricultural lands are suitable for ecological farming. The content of Zn shows that agricultural lands are unsuitable. As for the content of Mn suitable for ecologic farming – 15.3%, Cu – 19.2%, Co – 51.6% of the total area of studied lands of the region. It was determined that about 16.7% of the lands are unusable, 67.2% have limited suitability and 16.1% is suitable. With the actual availability of lands under ecological farming (4.3%), the territory has a primary potential to increase the area by 4.2 times. Under the conditions of the transition period, state and regional support of agricultural producers, these areas can be expanded to 794.0 thousand hectares (44.7% of all agricultural land of studied area).

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