Digital solutions for the ecological aspect of the sustainability of agroecosystems

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Abstract. The article presents the results of the development of a cartographic basis for a specific agricultural landscape used for the production of vegetables and potatoes under irrigation. Studies allow us to say that the landscape features of the territory, namely the exposure of the slope, are clearly correlated with the content of nitrogen, phosphorus and potassium. The slope of the agrolandscape is directed north to the Emurtla River and the values of agrochemical indicators are increased in the same direction. The cartographic basis obtained by us can be used for elements of precision farming, in particular for differentiated fertilization, and for the development of an adaptive-landscape farming system on the farm.

1. Introduction
The application of mineral fertilizers without taking into account the spatial heterogeneity of soil fertility indicators, which can be due to both natural and anthropogenic factors, reduces their effectiveness and even leads to a further increase in fertility diversity. Differences in soil conditions can change the responsiveness of agricultural plants to fertilizers, where there are fewer of them, there is a deficiency of nutrients, and where there is less - an excess, thus reducing the effectiveness of the applied fertilizers. Along with this, the quality of crop production is deteriorating, nitrates, chlorides, sulfates penetrate into ground and surface waters, causing a number of environmental problems.

The introduction of physiologically acidic fertilizers, which include such widespread species as ammonium nitrate and potassium chloride, can acidify the soil solution.

Mineral fertilizers are the main source of soil pollution with heavy metals and toxic elements. This is due to the content of strontium, zinc, lead, etc., in the raw materials used for the production of mineral fertilizers, the complete extraction of which is technologically difficult, and for a number of elements it is not provided at all.

Under the influence of mineral fertilizers, the ratio between humic and fulvic acids changes. The depletion of soils in humus and the transformation of its chemical composition entails a change in the environmental conditions for soil microorganisms [1].

Technogenic impact on the state and development of agroecosystems necessitates the development of methods and techniques for its reduction or prevention. A deep understanding of complex soil processes will help better soil management [2]. Variable fertilization is one of the management methods. Balanced fertilization is an effective way to maintain nutrient availability, as well as to ensure high and stable crop productivity and efficient use of nutrients [3]. Numerous studies show that when using differentiated fertilization, the payback of nitrogen fertilizers is reduced by 1.5 times, direct cost savings range from 20 to 40%, grain yield increases by 10–15%, sunflower by 15–20%,
profitability increases from 0.8 to 2.2% depending on the culture [4-6]. In order to apply differentiated fertilization, first of all, it becomes necessary to create a cartographic basis of various directions (maps of moisture, fertility, phytosanitary state, soil phenotypes [7]). Methods for creating them are different [8,9].

The purpose of the research is to create a cartographic basis based on the results of an agrochemical analysis of the soils of the agrolandscape.

2. Materials and methods
The object of research is the arable land of the Gubinskoye tract (56°08'25.9"N 66°13'43.2"E) LLC "Agrofirma KRIMM" of the Uporovsky district of the Tyumen region. The area of arable land is 128 hectares. The type of soil on this arable land is leached chernozem.

The methodology for creating digital maps using GIS technologies includes the inventory and analytical stage of collecting materials, mapping agricultural landscapes, assessing them for compliance with the criteria of rarity and typicality, and visualizing information in Quantum GIS (QGIS) ver.3.16.3. Geographical, cartographic methods, methods of geoinformation data analysis were used.

When creating a digital map of the field, an image from the Sentinel-2B satellite for January 1, 2021 was used as a substrate. The whole process of developing the cartographic base was carried out in the Quantum GIS (QGIS) ver.3.16.3 program.

3. Results
The inventory and analytical stage of collecting materials showed that the tract of the agrolandscape has a northern exposure of the slope, the slope is directed to the floodplain of the Emurtla River [10], the height above sea level varies from 82 meters to 75, as a result, the facies of the tract are dissected by erosion processes. The proximity of arable land to the swampy floodplain of the river causes the transition of soils from the automorphic series to the alluvial one.

The agricultural use of the landscape has been going on for several years under the conditions of irrigation of vegetable crops and potatoes with circular sprinklers of the brand "Valley", the water source is the river Emurtla. In 2020-21, production potatoes were grown in this field (predecessor - fallow with peat pre-applied due to reduced soil fertility).

The image processing included the merging of spectral channels into a single multi-channel image; for this, a plugin for semi-automatic preprocessing classification (SCP) and a virtual raster creation tool were used.

Further on the image, the vectorization of the boundaries of the study area was carried out; for this, a polygonal layer was created, drawn along the boundaries of the arable land. At the output, a digital map of the field was obtained, with topographic reference and precise boundaries.

Table 1. Results of agrochemical analysis in the Guba field, 2020.

| Sample number | Active acidity, (water) units pH | Exchangeable acidity, (salts) units pH | Hydrolytic acidity, mg.eq/100 g | The amount of absorbed bases, mg.eq/100 g | Organic matter (humus), % | Nitrate nitrogen, mg/kg | Ammonium nitrogen, mg/kg | Mobile phosphorus, mg/kg | Mobile potassium, mg/kg | Mobile sulfur, mg/kg | Exchangeable (Ca) calcium, mg.eq/100 g | Exchangeable (mobile) (Mg) magnesium, mg.eq/100 g |
|---------------|---------------------------------|---------------------------------------|-------------------------------|----------------------------------------------|--------------------------|-----------------------|------------------------|------------------------|------------------------|-------------------------|-------------------------------|-----------------------------------------------|
| 1             | 7.6                             | 7.1                                   | 0.54                          | 47.2                                        | 10.17                    | 29.4                  | 16.0                   | >250                   | 332                    | >24                      | 21.0                           | 3.0                            |
| 2             | 7.9                             | 7.2                                   | 0.56                          | 33.2                                        | 5.84                     | 26.8                  | 9.0                    | 150                    | >500                   | >24                      | 21.0                           | 2.5                            |
| 3             | 6.7                             | 6.2                                   | 2.07                          | 24.6                                        | 11.30                    | 27.0                  | 11.0                   | 212                    | 438                    | >24                      | 24.5                           | 2.5                            |
| 4             | 7.9                             | 7.1                                   | 0.55                          | 46.4                                        | 10.17                    | 29.8                  | 8.0                    | 160                    | 350                    | >24                      | 22.0                           | 3.0                            |
At the object under study, soil samples were taken for agrochemical analysis (table 1). For each sampling point, coordinates were fixed in the same projection as the image (WGS84 EPSG:4326), which can be used to determine their exact location (table 2).

### Table 2. Sampling point locations.

| Sample number | Longitude   | Latitude   |
|---------------|-------------|------------|
| 1             | 66.230657   | 56.143264  |
| 2             | 66.235721   | 56.141447  |
| 3             | 66.241815   | 56.137525  |
| 4             | 66.23615    | 56.138338  |

According to the known coordinates, 4 sampling points were marked inside the arable land vector layer in the created point layer (figure 1). The results of agrochemical analysis from this field were transferred to the layer attribute table.

Further, for some necessary agrochemical indicators, interpolation was carried out using the method of inversely weighted distances (IDW) within the boundaries of the field. Interpolation or interpolation is an approximate or exact finding of a quantity from known individual values of the same quantity, or other quantities associated with it. The IDW method assumes that the influence of the mapped variable decreases with distance from the sample location. As a result of interpolation, we get an approximate picture of the distribution of agrochemical indicators over the area of the entire field (figure 2).
4. Discussion
The resulting map of the distribution of indicators is based solely on the mathematical method, while many features of this field are not taken into account. To obtain more accurate information, it is necessary to compare these maps with maps of vegetation, humidity, relief, and other indicators of a given field. The number of samples taken and the correct distribution of sampling points in the field are also very important.

The presence of digital maps allows you to create detailed instructions on the amount of mineral and organic fertilizers applied to each section of the field. These instructions are loaded into the on-board computer of agricultural machinery going into the field, and through GPS navigation, the technological process is accurately controlled with minimal human participation. Fertilizers are applied using special spreading units, which allow you to vary the application rate depending on the area of the field.

5. Conclusion
Changes in the geochemical migration structure of agricultural landscapes will be reflected in the geochemistry of cultivated crops with a certain lag. The cartographic basis of the Guba tract of the agrolandscape not only clearly shows the distribution of the main agrochemical indicators, but also makes it possible to apply differentiated fertilization to the facies of this tract. Plant nutrients increase their concentrations in the direction of decreasing altitude (13 m difference), the decisive role in the formation of nutrient concentrations belongs here to water migration - surface and underground runoff.

Thus, the facies of the agrolandscape are connected by the migration of chemical elements, which is reflected in the obtained cartographic bases for differentiated fertilization. The slope type of facies is characterized by intensive migration of substances of both natural and anthropogenic nature, as well as the presence of erosional dissection, therefore, the stability of the agrolandscape can be assessed as
relatively stable. The materials presented in the work confirm the general patterns of landscape geochemistry and at the same time reflect the significance of the obtained cartographic material.

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