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To cite this article: E S Malysheva *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **937** 032070

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IOP Conf. Series: Earth and Environmental Science **937** (2021) 032070 doi:10.1088/1755-1315/937/3/032070

Complex Analysis of Data from Agrochemical and Soil-Erosion Monitoring Using Geoinformation Systems

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Abstract. The article describes a comprehensive analysis of agrochemical and soil erosion monitoring data, using the example of the Alekseevsky district of the Belgorod region with the use of a geoinformation system. The GIS automatically generates tables with data grouped by various characteristics: soil type, degree of erosion, slope steepness and exposure. The content of mobile forms of phosphorus and potassium, organic matter, and the level of soil acidity in the context of the district in areas with different exposures, the degree of erosion and the steepness of the slope was analyzed. The most productive soils are located on the plain, followed by the slopes of the northern exposure, neutral, then southern. Erosion processes occur more strongly mainly on the slopes of the southern exposure, and the northern slopes are characterized by humidity. Down the slope, the nutrient content decreases, the level of soil acidity increases.

1. Introduction

The experience of scientific research in the field of agriculture shows that the most important production resource of the country is the soil. Its agricultural ecological state affects not only the productivity of specific crops, but also the overall productivity of the agro-industrial complex. State land monitoring is one of the key mechanisms to ensure highly effective nature management, allowing to ensure the rational exploitation of soil resources. Such monitoring is a system of measures for observation, assessment and forecasting of the state and exploitation of lands based on various quantitative and qualitative characteristics, the most important of which are soil acidity, the content of organic matter, toxic elements, mobile forms of micro- and macro-elements (in particular phosphorus and potassium) [1-5].

The literature has accumulated a sufficient number of facts proving the inseparable connection between agrochemical indicators of soil and its soil-erosion characteristics [6-11]. However, the use of geographic information systems (GIS) to combine them into a common data stream is not widely considered, despite the fact that the advantages of applying the elements of digital agriculture, namely precision agriculture, in a comprehensive data analysis are obvious. The introduction of GIS tools in the monitoring system can rationally carry out agrochemical survey taking into account soil differences and develop a system of applying mineral and organic fertilizers, increasing soil fertility indicators, which entails a steady increase in economic and export opportunities for agriculture. A set of methods and tools used for soil cover observations includes making statistical observations of qualitative soil deformations and overlaying them on a cartographic base. The functionality of the geographic

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information system will make it possible to optimize all these operations and contribute to a significant reduction in the labor intensity of this process and the financial costs of their implementation [12].

2. Research Objective

To conduct a comprehensive analysis of agrochemical and soil-erosion monitoring data of Alexeevsky district in the Belgorod region using a geographic information system.

3. Materials and Methods

The objects of the study are elementary plots of arable land of Alekseevsky district with a total area of 48465.62 ha. These plots were uploaded to the "GIS Agroecologist Online" for the 11th cycle of agrochemical survey of the Belgorod region.

Soil cover of the surveyed arable land of the region is represented by typical (12420.49 ha), leached (8617.01 ha), common (7739.12 ha), typical carbonate (6812.02 ha), podzolic (4984.4 ha), typical residual carbonate (3259.38 ha), common carbonate (1711.53) chernozems. Small areas are occupied by automorphic salts (1334.09 ha), dark grey forest soils (1026.74 ha), floodplain alluvial-sodic soils (302.65 ha), meadow chernozems (126.14 ha), gully complexes (96.55 ha), grey forest soils (25.26 ha), meadow gleyed soils (10.24 ha) (Fig.1).

Alekseevsky district is one of the leaders in the region by the area of eroded arable land, ranking 3rd after Valuisky and Krasnogvardeisky districts. At the same time, the share of eroded arable soils of the district is 64.2 % [13].

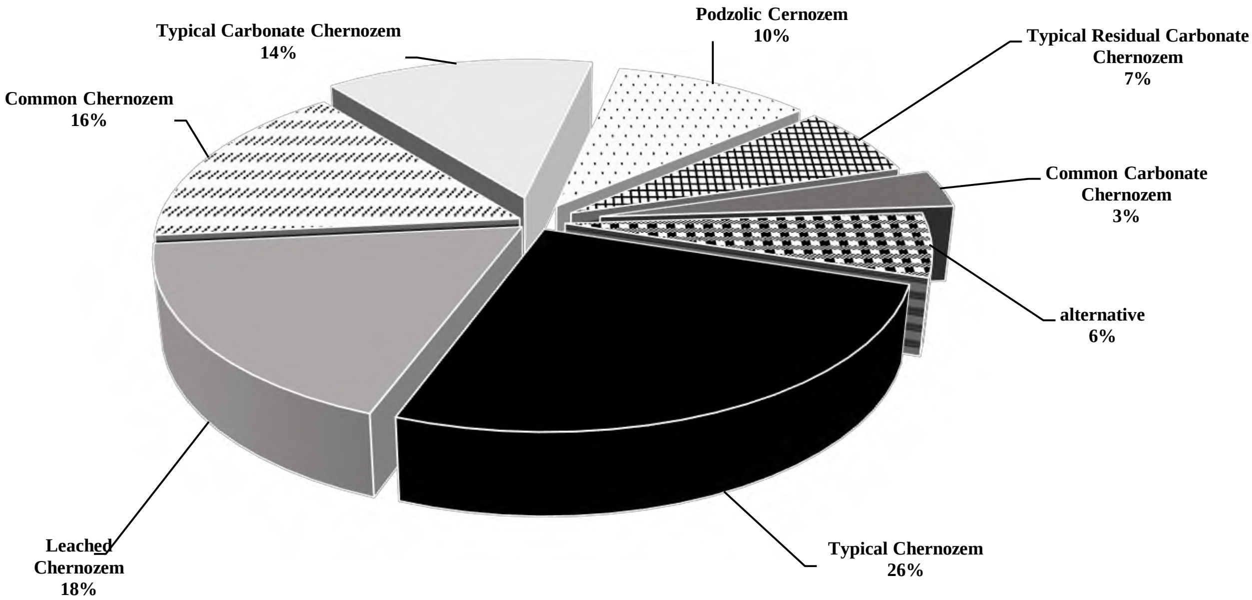

Figure 1. Soil layer of the surveyed arable land of Alexeevsky district in Belgorod region

The article used the materials of agrochemical examination of arable soils conducted by the agrochemical service center "Belgorod" for the 11th cycle. The content of mobile forms of phosphorus and potassium was determined in the soil samples by the Chirikov method; 0.5 M acetic acid solution (GOST 26204-91) served as an extractant. Determination of phosphorus was carried out photometrically, potassium - flame photometrically. The content of organic matter was determined by the method of Tyurin based on the organic matter oxidation by a solution of potassium bromide in sulfuric acid and the subsequent determination of trivalent chromium equivalent to the content of organic matter by photo-colorimeter (GOST 26213-91). Determination of pH of the salt extract (the extractant was 1 M potassium chloride solution) was carried out by potentiometric method in accordance with GOST 26 483-85.

The data of the corrective soil-erosion survey of arable soils, conducted by the Center of Agrochemical Service "Belgorod" in 2014-2017, were also used.

The results of the surveys were entered into the database of the agrochemical service. The database is accessed by means of a special program developed for the needs of the agrochemical service in 2017 on the basis of FSBI «CAS "Belgorodsky". The database together with the software form a software product called "GIS Agroecologist Online". This geoinformation system is protected by patents for the database and software for electronic computers [14-16].

The GIS functionality was used to carry out a comprehensive analysis of the agrochemical and soil-erosion survey data in the context of elementary plots, allowing the least cost to establish the relationship between agrochemical indicators of the soil and its soil-erosion characteristics.

The "Agroecology Online GIS" tools were used to generate reports with the tabular data of different groupings for the arable land of Alekseevskiy district:

- by type (subtype) of soil and erosion degree;
- by type (subtype) of soils, degree of erosion and slope exposure;
- by type (subtype) of soils and slope steepness;
- by type (subtype) of soils, steepness and slope exposure;
- by type (subtype) of soils, steepness and erosion degree;
- by type (subtype) of soils, erosion degree, steepness and exposure of slope.

4. Results and Discussion

As a result of combining the data of agrochemical and soil-erosion monitoring, GIS forms a set of indicators for each working area with a certain type (subtype) of soil, degree of erosion, slope steepness and slope exposure. After processing, the array of obtained data is distributed into different groups according to the specified parameters.

We have formed clustering by soil types, taking into account the degree of erosion, exposure, and slope steepness simultaneously, because the slope steepness is one of the main factors influencing the degree of erosion, while soil washing out depends on both the slope steepness and its exposure [12]. The grouping in such a table first classifies soils by type, then by erosion degree, and then a division is made by steepness and exposure of the slope. The data combined in this way take into account many characteristics simultaneously, on the basis of which a more detailed analysis is possible.

Table 1 shows the groupings by soil type, erosion rate, steepness and slope exposure in the Alekseevsky district of the Belgorod region. All these data are formed into one large table, but in order to make it not too cumbersome, we took its part showing only the most common soil types in the area - typical and leached chernozems. For other soil types the table looks similar.

4.1. Not washed off soils

Analyzing the table data presented for the not washed off soils of the area, we can note that the maximum content of mobile forms of phosphorus and potassium are characteristic of a plain. It is natural, because nutrients on the flat surface are almost not washed away from the soil. For steepness of slope from 1° to 3° the situation is not very different from plain, but there are differences. Here a slight decrease in the indicators due to the movement of the soil along the slope is noted. The indicators of phosphorus and potassium increase from the warm slope to the cold one, the neutral slope occupies an intermediate value. This is explained by favorable conditions for accumulation of substances on the slopes of northern exposure and more pronounced decomposition and movement of substances on the slopes of southern exposure. Also, the soils on the southern slopes are more carbonate (alkaline) compared to the soils on the northern slopes due to the hydrothermal coefficient effect. Organic matter shows a tendency to grow on cold slopes because the process of humification, which is facilitated by cold humid conditions, is more intensive here.

4.2 Slightly washed off soils

The data on the content of mobile forms of phosphorus and potassium for poorly washed soils show non-linear patterns. Thus, for the slopes with a steepness of 1-3°, the maximum P2O5 values are noted on the slopes of neutral exposition, and the K2O content increases from the northern to the southern slope. For the slopes from 3° to 5°, the situation is somewhat different: the phosphorus content increases from the warm slope to the cold one, but the potassium values increase in the opposite direction. In this case, this can be explained by the small sample area, which does not provide a trace of regularities for these two indicators, as well as the application of different forms of phosphorus and potassium fertilizers to certain areas. As for pH, the tendency of acidity to decrease from northern to southern exposition regardless of slope steepness due to erosion impact is clearly traced on slightly washed off soils. In view of this, the soil profile is washed away more than on the northern slopes, and carbonates are higher. At the same time, on the slopes with steepness of 3-5° the reaction is more alkaline in comparison with 1-3°. The organic matter content indicators for poorly-washed soils decrease from cold to warm slopes, which is explained by favorable conditions for humification on slopes of northern exposure. The organic matter content increases with slope steepness, which is probably associated with the movement of soil fines from 1-3° to 3-5°.

Table 1. Grouping of typical and leached chernozems by erosion degree, steepness and exposure of slopes in Alekseevsky district of Belgorod region

Slope steepness	Area, ha				Mobile forms, mg/kg								pH(HCl)				Organic substance, %			
					P_2O_5				K_2O											
	Cold	Neutral	Warm	Plain	Cold	Neutral	Warm	Plain	Cold	Neutral	Warm	Plain	Cold	Neutral	Warm	Plain	Cold	Neutral	Warm	Plain
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Not washed off																				
0-1°	-	-	-	6360.1	-	-	-	142	-	-	-	176	-	-	-	5.86	-	-	-	5.3
1-3°	5268.06	1255.35	1898.82	-	141	118	115	-	175	172	167	-	5.96	6.06	6.03	-	4.99	4.97	4.93	-
Slightly washed off																				
1-3°	1294.96	416.13	1134.68	-	128	133	131	-	177	178	188	-	5.9	5.92	5.96	-	4.78	4.61	4.4	-
3-5°	1467.8	188.27	533.48	-	122	104	100	-	160	164	166	-	6.02	6.22	6.29	-	4.89	4.88	4.63	-
Mid-washed off																				
3-5°, >5°	747.29	-	499.49	-	102	-	100	-	144	-	153	-	6.17	-	6.3	-	4.85	-	4.31	

4.3 Mid-washed off soils

The indicators of the mobile forms of phosphorus and potassium in the medium-washed soils are also unrepresentative due to the small sample area. For the same reason, it is impossible to speak about the exact trends and patterns for pH and organic matter content. However, it is worth noting that all of the indicators presented in the tables in the medium-washed soils are less than for the non-washed soils, while the pH values are higher and the soil is more carbonate.

5. Conclusions

Application of geoinformation technologies in the complex analysis of agrochemical and soil-erosion monitoring data, enables to obtain data distribution for all possible indicators, grouping them in different variations. This can be used for a more detailed study of differences in the values of soil fertility indicators for different types of soils, different steepness of slopes, exposure and degree of washing away.

As a result of our work, it was established that the highest agrochemical indicators are typical for the soils of plains, followed by the slopes of northern exposure, neutral, and then southern slopes. On the southern slopes, erosion processes are more pronounced. It is explained by intensive warming of top soil layer in spring period, while the bottom one remains frozen. The northern slopes are characterized by better hydrothermal conditions. The general tendency is that down the slope the content of nutrients decreases and soil carbonation increases.

In order to establish clearer regularities, trends and tendencies, it is necessary to increase the area covered, so that the weighted average values of indicators would be more representative and homogeneous.

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