GeoTerrace-2021-023

Web mapping of soil pollution in Lviv region

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SUMMARY

In recent years, there has been a growing interest in soil analysis in terms of environmental quality assessment. The purpose of such research is to quantify the harmful (excess) content of harmful elements and the degree of soil contamination, i.e., getting into its various chemicals, toxicants, waste from agricultural and industrial production. The program of agrochemical certification of agricultural lands provides for the study of soils for the content of salts of heavy metals, residual amounts of pesticides (RAP). Soil is the main source of their entry into food, and through them into the human body. In many cases, heavy metals are present in soils in small quantities and are not harmful. However, their concentration in the soil may increase due to exhaust emissions from vehicles, application of phosphorus and organic fertilizers, use of pesticides and other agrochemicals. The resistance of soils to heavy metal pollution is different and depends on their buffering. Soils with high adsorption capacity and, accordingly, high content of clay and organic matter can contain these elements, especially in the upper horizons. Assessment of the ecological condition of soils by the content of heavy metals is carried out by comparing their actual content in the soil with such indicators as the maximum allowable concentration (MPC) and geochemical background for a particular type of soil in a particular area. As a result of the analytical control of soils within the sanitary protection zones and in the places of accumulation of waste of the enterprises of Lviv region it should be noted that pollutants of land resources are mainly industrial waste and accumulators of household waste (landfills, sludge sites). The main purpose of this work is to create a web map of environmental soil pollution in the Lviv region. To achieve this goal, we collected and systematized geospatial statistics related to the ecological condition of the soils of Lviv region. The choice of software for the development of a web map of soil pollution has been made. A template of applications for the development of a web map based on the indicators of 428 soil sampling in places of their contamination by industrial enterprises and landfills has been selected. Thus, a web map of soil pollution in Lviv region was developed in the software environment "ArcGIS Online".

Keywords: web mapping, geospatial data, maximum permissible concentration (MPC), ecological mapping, soil pollution, interactive map, ArcGIS Online

Introduction

Disturbance (destruction) of soils is a complex set of anthropogenic and natural processes of change of physicochemical and mechanical characteristics of soil. As a rule, the first cause of soil disturbance is human-initiated processes (for example, mechanical tillage, transformation of soil layers in construction, soil compaction due to transport, livestock grazing, irrigation or other changes in groundwater and surface water, soil pollution and etc.). The results of these primary changes can be amplified many times under the influence of natural factors, such as wind, rain flows, and so on. That is, the soil is a very complex and vulnerable system that has been formed over the centuries, but can be destroyed by improper human actions in a matter of years, months and even days (Department of ENR, 2019).

Erosion has the greatest destructive effect on soils. Soil erosion is the process of capturing soil particles and carrying them by water or wind, as well as the process of destroying the upper, most fertile layers of soil. Under the influence of human activity there is an accelerated (excessive) erosion, which often leads to complete destruction of soils. At the same time, the losses of soil components are not compensated and there is a sharp decrease in its fertility. Soil destruction is hundreds and even thousands of times faster than during natural erosion processes. Under natural conditions, soil fertility is constantly maintained by the fact that nutrients taken by plants fall back into the soil with precipitation, mineralize and re-enrich it. In agriculture, only a small part of the biomass is returned to the soil, the other is collected during the harvest. The soil of monoculture is especially depleted. Erosion is also facilitated by deforestation, which deprives the soil of a protective layer (Department of ENR, 2019). In addition to erosion, the most significant reasons for the deterioration of the quality of land resources in Ukraine are: 1) secondary salinization of soils; 2) flooding and drying of lands; 3) anthropogenic and man-made soil pollution.

Methods of investigation

The main purpose of this work is to create a web map of environmental soil pollution in the Lviv region.

To achieve this goal, the following tasks are set and solved in the work:
- Collection of geospatial statistics related to the ecological condition of soils of Lviv region.
- Selection of software for the development of a soil pollution web map.
- Selection of application template in the ArcGIS Online platform.
- Creation of a web map of soil pollution in Lviv region.

The reaction of the soil solution is an important indicator of soil fertility, which significantly affects the growth and development of plants and the activity of microbiological chemical and biochemical processes. The assimilation of soil nutrients and fertilizers by plants, mineralization of organic matter, efficiency of applied fertilizers, crop yield and its quality largely depend on the reaction of the soil. There are actual (active) and potential acidity. Potential acidity is divided into metabolic and hydrolytic. Hydrolytic acidity characterizes the total acidity of the soil, as it includes all potential and actual acidity. Metabolic acidity is expressed by the pH value of the salt extract.

The pH of the salt extract determines the degree of acidity of the soil. According to the degree of acidity, soils are divided into groups: very strongly acidic (pH <4.0), strongly acidic (pH 4.1-4.5), moderately acidic (pH 4.6-5.0), weakly acidic (pH 5.1-5.5), close to neutral (pH 5.6-6.0), neutral (pH 6.1-7.0), slightly alkaline (pH 7.1-7.5) (Department of ENR, 2019; Department of ENR, 2020).

The soil is most often contaminated with metal compounds and organic matter, oils, tar, pesticides, explosives and toxic substances, radioactive, biologically active combustible materials, asbestos and other harmful products. The source of these compounds is most often industrial or domestic waste, buried in certain places, or unauthorized landfills. Contamination of soil with heavy metals such as mercury, cadmium, lead, chromium, copper, and zinc is quite dangerous.

Heavy metals are present in the soil as natural impurities, but the reasons for the increase in their concentrations are related to:

- industry (non-ferrous and ferrous metallurgy, energy, chemical industry);
- agriculture (irrigation with contaminated water, use of herbicides);
- incineration of fossil fuels and waste;
- by motor transport.

Heavy metals are toxic and interfere with the activity of soil microflora. Their concentration in the soil can persist for decades and even centuries. The content of heavy metals, radionuclides, nitrates and pesticides in soils is shown in Table 1 (Department of ENR, 2019).

Table 1– *The content of heavy metals, radionuclides, nitrates and pesticides in soils in 2020*

Type contaminant	Number of samples	MPC mg/kg of soil	Min concentration mg/kg of soil	Max concentration mg/kg of soil
Cd	1831	0,7	0,1	0,35
Pb	1831	6,0	0,8	2,24
Cu	1479	3,0	0,8	2,20
Zn	1479	23	0,42	1,83
Co	1479	5,0	0,8	2,24
Mn	1479	---	7,0	33,8

The Lviv branch of the State Institution "State Soil Protection" monitors the quality of agricultural soils in the Lviv region. In 2020, the Lviv branch of the State Soil Protection Department carried out agrochemical certification of agricultural lands on farms in nine administrative districts. The area of surveyed lands is 36,589 hectares. The degree of acidity is dominated by soils with a neutral reaction of the soil solution (pH 6.1-7.0), the area of which is 17909 ha or 48.9% of the surveyed lands. The area of acid soils (pH <5.5) is 10,400 ha, which is 28.4% of the surveyed lands. The weighted average soil acidity is 6.3 units. The content of humus (organic matter) varies from very low (<1.1%) to very high (> 5.0%). Dominated by soils with an average (2.1-3.0%) content, the area of which is 11950 ha or 32.7%. In terms of the content of easily hydrolyzed nitrogen compounds, the largest area (23956 ha or 65.5%) is occupied by soils with a low degree of supply. The content of mobile phosphorus compounds is dominated by soils with high (10407 ha or 28.4%) and high (9722 ha or 26.6%) degree of supply, mobile potassium compounds - medium (10373 ha or 28.4%) and high (9114 ha or 24.9%) (Department of ENR, 2020).

The agrochemical characteristics of the surveyed lands by humus content are given in Table 2 (Department of ENR, 2019).

Table 2– *Characteristics of soils by humus content*

Soil area, %						Weighted average, %
very low < 1,1	low 1,1-2,0	average 2,1-3,0	increased 3,1-4,0	high 4,1-5,0	very high > 5,0	
1,7	25,5	32,7	27,7	7,7	4,8	2,8

The agrochemical characteristics of the surveyed lands on the content of easily hydrolyzed nitrogen are given in Table 3 (Department of ENR, 2019).

Table 3– *Characteristics of soils by nitrogen content, which is easily hydrolyzed*

Soil area, %				Weighted average, mg/kg of soil
very low < 100	low 101,0-150,0	average 151,0-200,0	increased > 200	
16,5	65,5	13,5	4,5	121,9

Agrochemical characteristics of the surveyed lands on the content of mobile phosphorus compounds are given in Table 4 (Department of ENR, 2019).

Table 4– *Characteristics of soils by the content of mobile phosphorus compounds*

Soil area, %						Weighted average, mg/kg of soil
very low < 20	low 21-50	average 51-100	increased 101-150	high 151-200	very high > 200	
0,7	3,7	26,3	28,4	26,6	14,3	136,9

The agrochemical characteristics of the surveyed lands in terms of the content of mobile potassium compounds are given in Table 5 (Department of ENR, 2019).

Table 5– *Characteristics of soils by the content of mobile potassium compounds*

Soil area, %						Weighted average, mg/kg of soil
very low ≤ 20	low 21-40	average 41-80	increased 81-120	high 121-180	very high > 180	
3,1	19,4	28,4	24,9	16,9	7,3	79,07

During 2020 the Department of Instrumental and laboratory control of the State Environmental Inspection in Lviv region made 428 soil sampling in areas of pollution (industry, landfills, etc.). As a result of the analytical control of soils in the places of accumulation of waste, it can be concluded that the pollutants of land resources are mainly accumulators of household waste (landfills) and industrial waste (Department of ENR, 2019; Department of ENR, 2020).

Results of investigations

Given the above, to create a web map of environmental soil pollution in the Lviv region, we used a very convenient and popular platform "ArcGIS Online". In order to start working in the selected platform, it is necessary to collect and structure data in the environment "Microsoft Office Excel" (Sohor et al., 2018; Sohor et al., 2020).

Excel spreadsheets were developed for our case:
• sampling of soils in places of their pollution by industrial enterprises and landfills, provided by the department of instrumental and laboratory control of the State Ecological Inspectorate in Lviv region;
• analyzes on the content of mobile forms of heavy metal salts in soil samples conducted by the Lviv branch of the State Soil Protection Service;
• observations on the quality of agricultural soils in the Lviv region, carried out by the Lviv branch of the State Institution "State Soil Protection".

To visualize the map of Lviv region, the "OpenStreetMap" was used in the platform "ArcGIS Online" with the borders of Lviv region and the districts of the region (Yarema et al., 2016; Yarema et al., 2017).

In order to plot our data on a map, a map with the defined coordinates of each soil contaminant and soil quality values was first created using the ArcGIS Online environment. To do this, we exported the spreadsheet we created "Microsoft Office Excel" to the environment "ArcGIS Online" (Yarema et al., 2019).

After the actions performed above, we combine the map with the borders of Lviv region and the soil quality map and get our web map (Fig. 1).

You can view the created web map at the following link:
• https://arcg.is/1WLuue

Recommendations and conclusions

Thus, examining the problem of soil quality in the Lviv region in terms of environmental pollution, we can summarize the following:

- We have collected and systematized geospatial statistics relating to the ecological condition of the soils of Lviv region.
- The choice of software for the development of a web map of soil pollution has been made.
- We have selected a template for applications for the development of a web map on the indicators of 428 soil sampling in places of contamination by industrial enterprises and landfills.
- A web map of soil pollution in Lviv region has been developed in the ArcGIS Online environment.

Figure 1 *Map of soil contamination of Lviv region in the environment "ArcGIS Online"*

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