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WASTE ACCUMULATION AND GEOECOLOGICAL ASSESSMENT OF THE TERRITORIES AROUND THE LANDFILLS IN KOKSHETAU

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ABSTRACT: Every year, the amount of household and industrial waste, which is stored in landfills, occupies vast areas, and hurts the environment increases. This work's goals are to analyze the accumulation of waste in Kokshetau using retrospective statistical data and assess the level of technogenic influence on the vegetation cover and soils of the territories near the Kokshetau landfills by interpreting satellite images of territories. In this research, the authors used retrospective analysis and remote sensing based on the normalized relative vegetation index (NDVI). Satellite images of vegetation from 2017 to 2021 were processed for the territories under consideration. A retrospective analysis of the waste accumulation showed that households accounted for the bulk of waste (80%). The dynamics of waste generation were inversely related to the number of waste processing enterprises. The interpretation of the images showed that the NDVI in the territory around landfill №1 varied in the range of 0.23 - 0.36 from 2017 to 2021, and this result indicated highly sparse vegetation and a high anthropogenic impact. In the territory around test site №2, the normalized relative vegetation index varied in the range from 0.44 - 0.30, the nitrogen index varied from 0.44 to 0.41, and the chlorophyll index ranged from 1.68 to 1.46 from 2017 to 2021. A decrease in the vegetation indicators and an increase in the area of problem zones indicate an annual increase in negative anthropogenic impacts.

Keywords: Waste, Landfill, Vegetation Indicators, Environmental assessment

1. INTRODUCTION

The environmental pollution associated with household and industrial waste is becoming an increasingly urgent problem every year. Waste occupies large areas and is a source of increased environmental risk [1-3]. In Kazakhstan, the bulk of waste is stored in municipal solid waste (MSW) landfills. Landfills pollute the atmosphere, soil, groundwater, and water bodies, exerting chemical, thermal, sanitary-epidemic, zoogenic- and phytogenic effects. Inside landfills, various chemical and biochemical processes take place, and as a result, substances that are hazardous to the surrounding biota are formed, in concentrations tens and hundreds of times exceeding the permissible standards. Pollutant fluxes are transferred to soil, water, and plants [4-7].

The ecological state of the natural environment near MSW landfills remains stressed, and the level of pollution control is insufficient. Environmental monitoring of the areas affected by landfills is carried out, as a rule, by the landfill enterprises. There are doubts about the objectivity of the results obtained and the lack of influence on these enterprises by interested parties. From our point of view, an independent assessment of the impact of the activities of these enterprises on surrounding territories is needed. On the other hand, monitoring involves indicators only of the content of toxicants in the soil and the total biomass of plants. The influence of pollutants on the state of phytocenosesas a whole is not within the sphere of interest of regulatory organizations. Notably, the common- assessment procedure includes outdated methods that do not provide complete information about changes in natural systems and the degree of their degradation.

Geographic information systems (hereafter GIS) are increasingly being used for quality control of the state of the environment. More than a quarter of all publications in international journals involve the application of GIS in environmental monitoring and natural resource management because modern GIS can successfully solve almost any spatial problem. GIS is used to collect, store, organize, search, transfer, and display data. At the same time, a GIS system can be controlled, detect pollution halos, determine emission sources, optimally form transport networks, etc. [9]. Human economic activity reduces the stability of ecosystems in almost all countries, which necessitates the identification of effective methods for monitoring their condition. The goals of this work are the following:

1 analyze the accumulation of waste in Kokshetau using retrospective statistical data.

2 assess the level of technogenic influence on the vegetation cover and soils of the territories near the Kokshetau landfills by interpreting satellite images of the territories.

2. METHODOLOGY

Studying the ecological states of the territories regarding the disposal of solid household waste was carried out at the landfills in Kokshetau, Kazakhstan. The first landfill is locatekilometerstres from the Kokshetau-Omsk highway; it ceased its activity in 2017. The second landfill is locatekilometerstres from the village of Krasny - Yar is currently operating, and covers an area of 10,38 hectares. To identify the dynamics of waste accumulation in the Akmola region, official statistical yearbooks prepared by the Statistics Department of the Akmola region for 2010 to 2020 were used.

An assessment of the degree of technogenic impact of landfills on phytocenoses and soil was conducted by remote sensing using the normalized relative vegetation index (NDVI), chlorophyll content, soil surface moisture index, and nitrogen content in plant leaves.

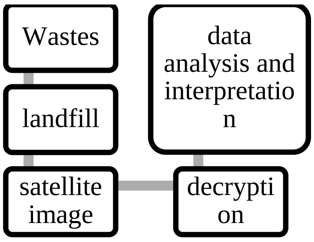


Fig. 1 Overall schematic of the research methodology.

The principle of the method was to obtain satellite images of growing seasons from 1.05. to 29.10, from 2017 to 2021 for the territory under consideration for remote monitoring. When processing the images, decoding, and monitoring of the vegetation cover were carried out using NDVI and other vegetation was calculated in the ArcGIS environment by using channels in the red and infrared spectra. Recent experience with vegetation indices allowed us to determine trends in the changes in vegetation cover (decrease in vegetation density, the appearance of open soil areas, etc.). This method made it possible to assess the degradation of the soil surface, especially in areas with intense erosion activity.

3. RETROSPECTIVE ANALYSIS OF WASTE ACCUMULATION IN KOKSHETAU

The city of Kokshetau is the administrative center of the Akmola region, the Republic of Kazakhstan. Currently, 147327 people live in the city, over the past ten years the population in Kokshetau has increased by 10631 people, which is an approximately 7% increase. From 2010 to 2018, in the city of Kokshetau, there was an increasing trend in the number of organizations involved in sorting and disposing of waste (Figure 2), on average over these years, the number of such enterprises has tripled.

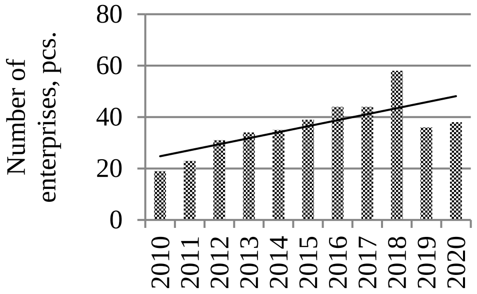


Fig. 2 Changes in the number of enterprises engaged in sorting and disposing of waste in Kokshetau.

In 2019, due to the economic crisis and changes in legal requirements, the number of waste recycling organizations fell sharply by almost 35%. Currently, this indicator is slightly increasing. However, at the same time, the level of waste recycling is quite low, and currently, in Kokshetau, is approximately 7%. As seen in Figure 3, volumes correlate with the number of enterprises engaged in waste processing, and the correlation coefficient is 0.83.

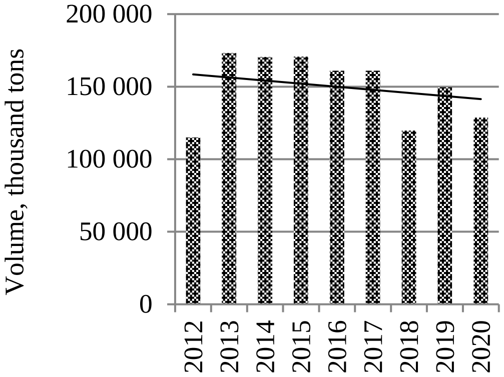


Fig.3 Dynamics of solid waste generation in Kokshetau.

With an increase in solid waste-related enterprises, the amount of waste decreased from 2013 to 2017, and in 2018, with a decrease in the number of enterprises, the volume of waste increased. An analysis of waste by the source of generation showed that in the city of Kokshetau, the main share of waste is household waste, at approximately 80%. In that of household waste, the amount of industrial waste increased from 2012 to 2014, and then there was a sharp decline, probably due to the introduction of waste-free technologies and n enterprises.

Street waste, including waste from unauthorized landfills, gardening and park waste, as well as waste from markets makes up no significant amount of the total waste. In 2019, the amount of park waste increased sharply almost 12 fold, and in 2020 it decreased slightly. Figure 4 shows that the amount of waste generated by households in 2013 increased sharply, more than 2-fold, which was probably due to the introduction of stricter types of accounting and control. From 2013 to 2018, this indicator varied slightly. In 2018, there was a sharp decrease in waste generation by households, at almost a third, but in recent years 2019-20to 20, this indicator has been increasing.

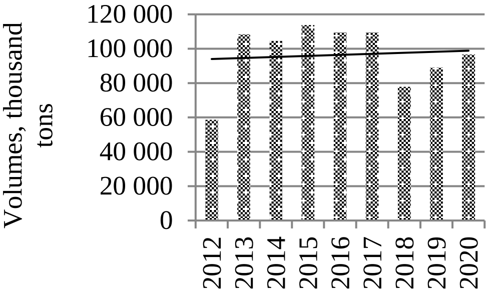


Fig.4 Dynamics of waste generation for households in Kokshetau.

During the years of this research, there was a sharp fluctuation in the amount of waste from construction sites (Figure 5). Compared to 2013, in 2014, this amount was almost half; in subsequent years, this figure increased significantly. In 2020, 2,500 thousand tons of waste were waswerenerated at the construction sites of Kokshetau. This scenario was probably due to the implementation of large-scale construction projects and the increase in the number of construction companies. Thus, the study of the dynamics of waste generation from 2010 to 2020 showed that the indicator thof e number of enterprises engaged in sorting and disposing of waste correlates withindicatorcatof of the volume of waste.

With more enterprises involved in sorting and processing waste, the amount of waste taken to landfills and stored decreased. The bulk of the waste was from household waste, which includes organic residues. Notably, the volume of waste and its structure depends on the level of economic growth; for example, the implementation of large construction projects increased the amount of construction waste.

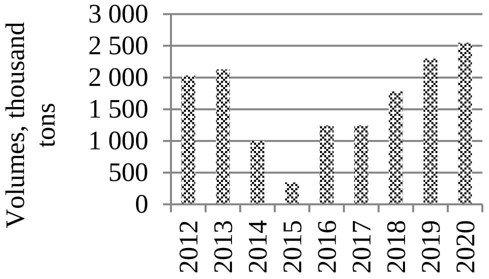


Fig. 5 Dynamics of waste generation at construction sites in Kokshetau.

Until 2017, all solid waste in Kokshetau was transported to landfill №1, located 8 kilometers from the Kokshetau - Omsk highway. Currently, landfill №1 is full and subject to reclamation. In 2017, the new landfill №2 was constructed 2 km from the village of Krasny - Yar, and it is currently operational. In recent years, the volume of waste stored at landfills has fluctuated slightly, on average, by 149 to 932 thousand tons per year. To determine the effect of landfill waste on plants and soils, they were studied using satellite images.

4. ENVIRONMENTAL ASSESSMENT OF THE TERRITORIES AROUND THE KOKSHETAU LANDFILLS USING THE REMOTE SENSING TECHNIQUE.

Spatial images of landfill №1 over five growing seasons from 2017 to 2020 were studied. Interpreting the images showed that the territory of the landfill varied in the range of 0.23–0.36; in some areas, the normalized relative index of vegetation approached zero, which indicated a strong sparseness of vegetation and a high anthropogenic impact (Figure 6). Even though the landfill has not operated since 2017, the negative impact of waste on the vegetation was high until 2020, probably due to biochemical processes in the garbage, the release of toxicants, and high temperatures (landfill smoke was repeatedly observed). In 2021, there was an increase in the NDVI. Similar results were observed when studying the contents of chlorophyll and nitrogen. It should be noted that without reclamation work, the landfill would have a negative technogenic effect on the vegetation and inhibit the restoration processes of the ecosystem over the long term.

To study the impact of the landfill on the nearby territories, spatial images of the site located in the sanitary protection zone of the landfill were studied, taking into account the wind speed and direction (Table 1).

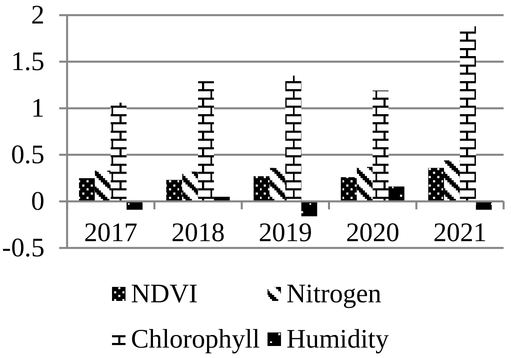


Fig. 6 Dynamics of the indicators of the state of vegetation in the territory of landfill No. 1 in Kokshetau.

After the landfill closure, the vegetation indicators in the territory of the sanitary protection zone recovered faster than those at the landfill. In 2017, the NDVI was 0.27; then, the next year it was 0.34, which was 26% higher; and by 2021, it was 0.53, indicating it had doubled. This result is evidence of the negative impact of the existing landfill and the possibility of self-restoration of the phytocenoses after its closure.

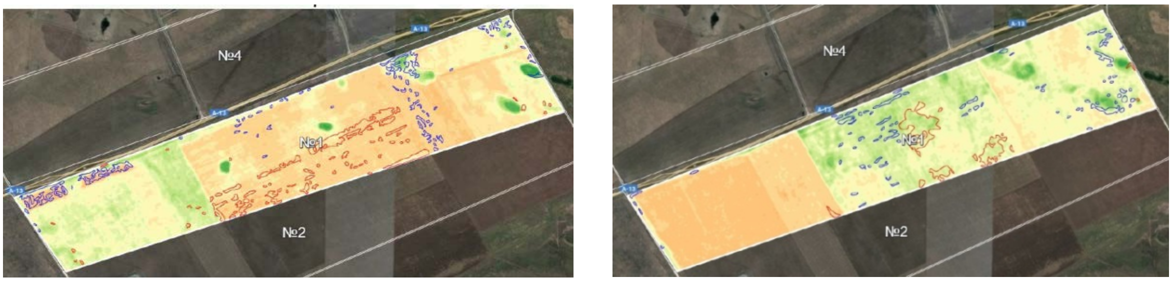
Figure 7 shows spatial images of test site №1 and the sanitary protection zone of test site №1 in Kokshetau for 2017 and 2021. Problem zones of phytocenoses are highlighted in color. A decrease in problem areas by 2021 is visible.

Table1 Dynamics of vegetation indicators in the territory of the sanitary protection zone of the landfill, taking into account the wind speed and direction at №1 in Kokshetau.

Year	Indicators					
	NDVI		Nitrogen		Chlorophyll	
	1	2	1	2	1	2
2017	0.25	0.27	0.33	0.21	1.06	1.28
2018	0.23	0.34	0.32	0.34	1.29	1.41
2019	0.27	0.42	0.36	0.39	1.35	1.32
2020	0.26	0.39	0.37	0.44	1.19	1.71
2021	0.36	0.53	0.44	0.51	1.88	2.13

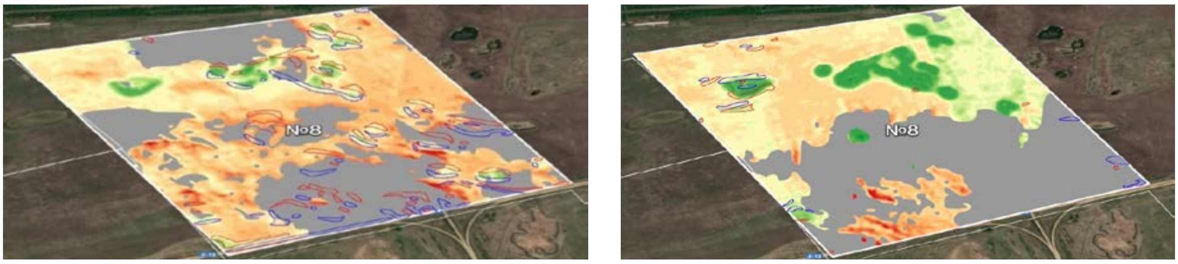
Note: 1 - Landfill №1, 2 - sanitary protection zone of landfill №1.

The results of interpreting the spatial images of landfill №2 and the territory of the sanitary protection zone next to it for five growing seasons from 2017 to 2021 are presented in the table. The normalized relative vegetation index for the territory of the test site varied in the range of 0.44-0.30, which indicates an increase in the negative anthropogenic impact. The nitrogen content indicator also decreased from 2017 to 2021 from 0.44 to 0.41. Similar changes were observed with the chlorophyll index, and its amount was reduced from 1.68 to 1.46.



Sanitary protection zone of landfill №1, 2017

Sanitary protection zone of landfill №1, 2021



Landfill №1, 2017

Landfill №1, 2021

Fig. 7 Spatial images of test site №1 and the sanitary protection zone of test site №1 in Kokshetau, for 2017 and 2021.

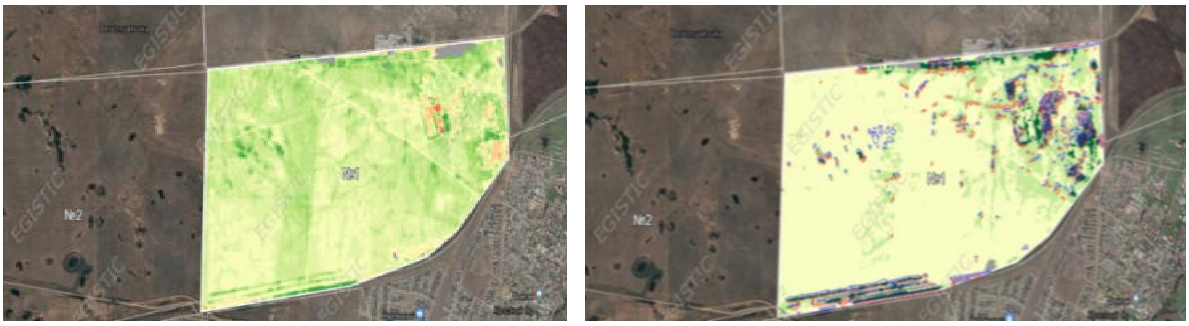
Notably, in 2018, a year after the start of the landfill, the vegetation indicators increased significantly, and the negative impact of the landfill on phytocenoses did not occur, probably due to the aerobic decomposition of organic waste and the ingress of nitrogen, phosphorus, carbon and other elements useful for plants. In subsequent years, the layers thickened, anaerobic processes occurred inside the landfill, and toxic chemicals appeared that negatively affected the vegetation.

Figure 8 shows spatial images and the sanitary protection zone of landfill №2 in Kokshetau for 2017 and 2021. The problem areas are highlighted in color, the areas of which increased by 2021. The pollutants can be seen being transferred to the sanitary protection zone. Accumulating toxic elements increased the degradation of phytocenoses. The level of negative impact from the landfill increased every year.

Table 2 Dynamics of the vegetation indicators for the territory around the operating landfill №2 and the sanitary protection zone, taking into account the wind speed and direction in Kokshetau.

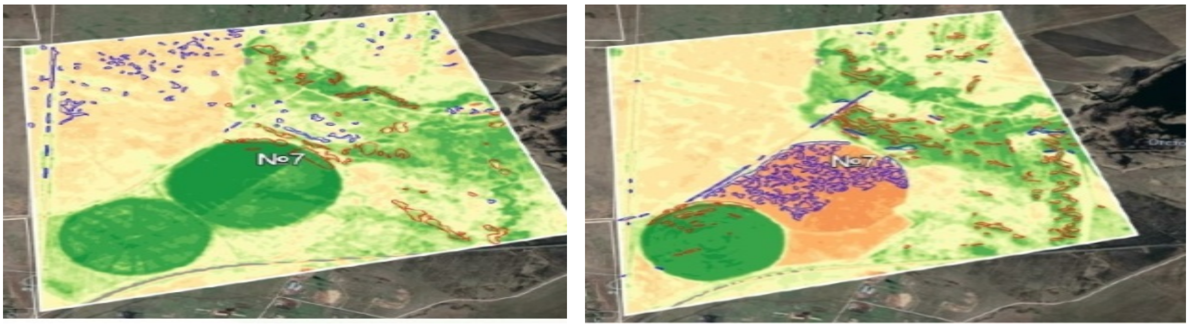
Years	Indicators							
	NDVI		Nitrogen		Chlorophyll		Humidity	
	1	2	1	2	1	2	1	2
2017	0.44	0.43	0.43	0.44	1.68	1.68	- 0.01	-0.09
2018	0.49	0.51	0.52	0.54	2.19	2.49	-0.07	-0.06
2019	0.43	0.37	0.44	0.41	1.72	1.47	-0.10	-0.11
2020	0.32	0.33	0.42	0.43	1.49	1.61	-0.17	-0.12
2021	0.31	0.3	0.41	0.41	1.46	1.46	-0.22	-0.22

Note: 1 - Landfill №2, 2 - sanitary protection zone of landfill №2.



Sanitary protection zone of landfill №2, 2017

Sanitary protection zone of landfill №2, 2021



Landfill №2, 2017

Landfill №2, 2021

Fig. 8 – Spatial images and the sanitary protection zone of test site №2 in Kokshetau for 2017 and 2021.

5. CONCLUSIONS

Currently, only 7% of waste is recycled in Kokshetau, and the remaining waste is stored in landfills. A retrospective analysis of waste accumulation showed that the bulk of the waste was generated by households, at 80%. The dynamics of waste generation were inversely related to the number of waste processing enterprises.

The interpretation of the images showed that the normalized relative vegetation index of the territory around landfill №1 varied in the range of 0.23-0.36 from 2017 to 2021, which indicates highly sparse vegetation and a high anthropogenic impact. Landfill №1 has not been operating since 2017, but the negative impact of toxicants on vegetation was high until 2020. Five years later, in 2021, there was an increase in the NDVI. Without reclamation, the landfill would maintain a negative technogenic effect on vegetation and inhibit the restoration processes of the ecosystem for a long time.

In the territory of test site №2, the normalized relative vegetation index varied in the range of 0.44-0.30, nitrogen varied from 0.44 to 0.41, and chlorophyll varied from 1.68 to 1.46 in the period from 2017 to 2021. A decrease in the indicator values indicated an annual increase in the negative anthropogenic impact. The problem areas also increased. Environmental problems related to waste disposal are complex since all the main sources of pollutants are involved in man-made migration flows. Thus, it is extremely important to conduct a comprehensive environmental assessment of territories exposed to man-made impacts using current monitoring technologies, such as remote sensing, where new principles and methods are used and a set of environmental factors can be controlled.

Soils and vegetation play the most important roles in regulating heavy metal fluxes. They can be retained and accumulate in soils, which further affects the state of vegetation and the natural environment overall. Mapping the content of heavy metals in soils using GIS technologies is carried out in many countries, for example, in China, the USA, Ireland, Serbia, and Turkey [9-10], mainly for urban areas, industrial areas, and large cities. In Kazakhstan, in particular, such maps have been created for Aktobe agglomeration [11]. According to researchers, the main advantage of this technology is the ability to use it as an effective tool for organizing, storing, analyzing, displaying, and presenting large arrays of spatial information.

Plants interact directly with contaminated soil and subsurface waters and can be good indicators of ecosystem health. The relationship between the structure and state of vegetation and its spectral reflectivity is expressed by vegetation indices, the most famous of which is NDVI. The indices are calculated based on the results of operations with different spectral ranges of remote sensing data and allow the use of remote sensing images for not only mapping and identifying vegetation types but also assessing the intensity of absorption of PAR (photosynthetically active radiation), the volume and growth of biomass of vegetation, the content of chlorophyll and nitrogen in plant leaves and additional parameters of the structure of the vegetation cover [12-13].

For dominant plants of phytocenoses in areas of ecological risk, it is necessary to identify informative spectral ranges that distinguish the selected species from other vegetation. The spectra of crops are well studied and make it possible to accurately locate them using satellite images. These images are used to assess the state of crops and crop species, both in Kazakhstan and abroad. For example, in the scientific work of Kazakhstani scientists on mapping the range of cannabis seeds, GIS technologies were used [14].

The use of different vegetation indices depends on many factors (type of soil, vegetation, moisture content, etc.). Studies have shown that in drylands, due to the influence of the soil background, the widely used NDVI provides less accurate information than that of other indices, such as the ENVI [15-16]. In Kazakhstan, studies are being carried out on GIS mapping of vegetation in areas of ecological risks, such as the LLP "Center for Remote Sensing and GIS" Terra(Almaty) under the leadership of NP Ogar. However, these areas cover most of the southern and western regions [17].

However, despite the advances in this area, there is a need to develop assessment and accounting methods for specific conditions, depending on the man-made sources and natural components of a particular region. Research related to monitoring areas where landfills are located is not enough to form a scientific basis for the use of GIS technologies. To date, no sound methods have been developed for assessing the content of heavy metals using remote sensing, as GIS maps are static. Tracking pollution processes is limited to the results of ground-based laboratory studies. To study the dynamics of contamination in territories, it is necessary to identify indicators that are correlated with this process and to monitor the changes using satellite imagery. Vegetation indices can serve this purpose. For example, Chinese researchers [18] proposed a new CSVI to characterize the stress caused by excessive copper concentrations in four plant species: wheat, pea, acacia, and ash. Identifying satellite imagery ranges that make it possible to relate soil pollution indicators and the state of vegetation is currently an urgent and feasible task.

6. ACKNOWLEDGEMENTS

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