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VEGETATION ASSESSMENT NEAR LANDFILLS IN TWO CITIES IN KAZAKHSTAN USING NDVI AND SAVI

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Abstract
This research aims to assess the environmental impact of municipal solid waste landfills on vegetation in the vicinity of landfill sites, focusing on two cities in Kazakhstan, Stepnogorsk and Kokshetau. The study utilized vegetation indices, specifically the Normalized Difference Vegetation Index (NDVI) and the Soil-Adjusted Vegetation Index (SAVI), to assess the health and density of vegetation. Landsat 8 OLIC2L2 satellite imagery spanning from July to August in the years 2017–2022 was processed in the ArcGIS program. The SAVI was employed to adjust for soil type and vegetation density. In the Stepnogorsk and Kokshetau sanitary zones, NDVI values during summer (2017–2022) ranged from 0.12 to 0.21, with SAVI values for Kokshetau between 0.15 and 0.25. ArcGIS analysis shows increased degradation and desertification, influenced by wind direction. NDVI and SAVI remote sensing effectively assessed vegetation in the sanitary zones of both landfills. The research underscores the significant environmental impact of municipal solid waste landfills on the surrounding vegetation.

Keywords: ArcGIS, chlorophyll content, environment, landfills, solid waste, soil pollution

Introduction

The issues of waste disposal are currently among the most pressing environmental problems (Ydyrys *et al*. 2023). The growth and development of cities has led to the formation of large areas occupied by municipal solid waste (MSW) landfills, which are technogenic objects that harm the environment (Bekezhanov *et al*. 2023). The natural environment surrounding MSW landfills is subjected to a significant anthropogenic load, which quite often exceeds nature's self-purification capacities many times over (Ashikhmina 2008, Kurmanbayeva *et al*. 2022, Rodrigo-Ilarri *et al*. 2022). In the Republic of Kazakhstan, MSW is disposed of at landfills. This process results in not only disturbance to the landscape but also extensive pollution of soil, water bodies, and air (Popov *et al*. 2017). Within the landfill, chemical and biochemical processes occur, and the substances generated are hazardous and exceed permissible limits of pollutants (Poputnikova 2010, Zavizion 2019).

At present, the environmental conditions in MSW landfills are stretched to their limit, and comprehensive monitoring is needed to control the pollution of these areas (Kakabayev *et al*. 2020, Bayazitova *et al*. 2022, Dayanthi *et al*. 2023). Comprehensive research on the physical, chemical, and biological aspects of soils, their hydrological properties, and their radius of influence is needed to select suitable areas for identifying MSW landfill sites (Mukhambetov *et al*. 2023). However, due to the high cost of research, in most cases, very few MSW landfill siting decisions are made with such information.

Many scientists have used geographic information systems (GIS) to study lands in the vicinity of MSW landfills. These technologies are used for qualitative environmental control, management, identification of pollution halos, and determination of emission sources (Ansabayeva 2023).

Researchers at the Research Institute of Water and Environmental Engineering of the Valencia Polytechnic University in Camí de Vera (Spain) developed the Weighted Environmental Index (WEI) based on object-oriented models and GIS data. The index was developed to integrate all available information from large and detailed GIS databases. WEI has been used to analyse the changes in environmental values due to changes in land use over time at two application sites (Meera Gandhi *et al*. 2015, Rodrigo-Ilarri *et al*. 2020a,b).

Countries across the world are successfully utilizing GIS, remote sensing, and spectral bands for urban waste planning and management. The advantage of a sustainable choice for the disposal of solid waste based on GIS lies in saving time and costs (Solano Meza *et al*. 2020). The use of remote sensing has become a feasible and economically effective solution for monitoring, detecting, and analysing the spatial and temporal characteristics of MSW landfill sites (Yu *et al*. 2020, Aslam *et al*. 2022, Révolo-Acevedo *et al*. 2023).

Thus, the utilization of remote sensing has become a feasible and economically efficient solution for monitoring, identifying, and analysing the spatial and temporal dimensions and changes in landfills. The application of Landsat satellite imagery and the types of soils and environments that can be used is a cost-effective method for studying the geolocation of MSW landfill sites (Singgalen 2022, Bayazitova *et al*. 2023). Assessing the degraded area of the landfill site, the impact and condition of the soil, and plant health is vital to monitoring the natural environment (Iankovich 2017, Neinavaza *et al*. 2020).

The primary purpose of this research is to assess and evaluate the state of vegetation in the vicinity of MSW landfills, with a specific focus on landfill sites located in the cities of Stepnogorsk and Kokshetau in Kazakhstan.

Material and Methods

The objects of the study are selected MSW landfills in the Akmola region of Kazakhstan: an MSW landfill of the city of Kokshetau and an MSW landfill of the city of Stepnogorsk.

The Kokshetau MSW landfill site is located 3 km northwest of Krasny Yar village and 600 m northwest of Elita village in the Akmola region (Fig. 1). The primary purpose of the Kokshetau MSW landfill is the receipt and burial of waste. The landfill has been in operation since 2014. Its area spans 8.33 ha. As per regulatory requirements, the sanitary protection zone of the facility is 500 m radius (Ministry of Health of the Republic of Kazakhstan, 2022). The MSW landfill of Kokshetau accepts municipal waste from Kokshetau and Krasny Yar. The population of Kokshetau city is 141,396 people, and Krasny Yar has 9,940 residents.

Figure 1. Map Akmola region of Kazakhstan showing the landfill locations in Kokshetau and Stepnogorsk

The Stepnogorsk MSW landfill has operated since 2017. The area of the MSW landfill plot spans 20.3356 ha. The main type of activity is the collection, transportation, and storage of MSW at the landfill. The nearest settlement is the city of Stepnogorsk, located 1.0 km to the west of the landfill. The population of Stepnogorsk is

66,468 people. The sanitary protection zone of the MSW landfill is 1,000 m radius.

The condition of vegetation near the MSW landfills was studied using vegetation indices – the Normalized Difference Vegetation Index (NDVI) and the Soil-Adjusted Vegetation Index (SAVI) (Mallick 2021, Eka Rahma Wati *et al*. 2023). To derive the NDVI value, we used a series of Landsat 8 OLIC2L2 images of the territory of the Akmola region (Kokshetau and Stepnogorsk) for the period from July to August 2017–2022 from the USA Geological Survey website. These indices were calculated at points along direction lines and the points of assessment were located along the following directions of the wind rose: north, south, east, west, and southwest. The NDVI was calculated using channels 8 (near-infrared, NIR) and 4 (red, RED). Space images were processed in ArcGIS software using the Image Calculator function to calculate the NDVI.

To determine the density of vegetation (NDVI) at a certain point on the image, we used formula (1), according to which the NDVI index is equal to the difference in the intensities of reflected light in the red and infrared ranges, divided by the sum of their intensities. The values of the NDVI range within [-1.0 to +1.0].

The NDVI is calculated using formula (1):

NDVI = (NIR-RED) / (NIR+RED) (1)

Where, NIR = near-infrared reflectance; RED = red reflectance

The calculation of the NDVI relies on the two most stable (independent of other factors) sections of the spectral reflectance curve of vascular plants. In the red region of the spectrum (0.6–0.7 μm) lies the maximum absorption of solar radiation by the chlorophyll of higher vascular plants, and in the infrared region (0.7–1.0 μm) is the area of maximum reflection of leaf cellular structures. That is, high photosynthetic activity (associated, as a rule, with dense vegetation) leads to less reflectance in the red part of the spectrum and more in the infrared.

The SAVI was calculated using formula (2):

SAVI = [(NIR-Red) / (NIR+Red+L)] × (1+L) (2)

where L = [0;1], L=0 for the highest foliage index, L=1 for the lowest, the optimal value L=0.5.

This index is used to adjust vegetation index values based on soil type and vegetation density. SAVI values range from -1 to 1, with higher values indicating greater vegetation cover and soil fertility. A value of zero indicates no vegetation cover, and negative values indicate areas with high soil reflectance and low vegetation cover.

Results and Discussion

The study examines retrospective images of sanitary protection zones of the Kokshetau and Stepnogorsk MSW landfills in the years from 2017 to 2022 in the summer periods from June to August. The control point is located 1,000 m to the south of Kokshetau and 1,500 m to the south of Stepnogorsk. Figure 2 presents a diagram of the values of the NDVI in the summer periods of 2017-2022. The Kokshetau MSW landfill has been operating since 2014, which has produced a negative impact on the state of vegetation in later years. In 2017, the NDVI ranged from 0.13 to 0.16, which corresponds to a low level and indicates the thinning of vegetation. In 2018, the NDVI rose to 0.17-0.21, which is the best reading throughout observation. This increase in the index in 2018 is probably because the landfill was not yet in operation in 2017. In 2019, the index was between 0.18 and 0.20, which is evidence of the technogenic impact of the MSW landfill. In subsequent years, the NDVI has decreased to between 0.13 to 0.18. The NDVI at the reference site is 0.31, which indicates vegetation is in a better condition than that at the landfill site.

The best vegetation conditions according to the NDVI were found in the northern direction, where the values ranged from 0.15–0.2. In 2019–2022, a decrease of the NDVI to 0.13-0.16 was observed in the southern, western, and southwestern directions. The predominant wind direction is southwesterly. The lowest values of the index, 0.13 to 0.17, were found in the southern direction, and the southwestern direction, where they were 0.13 to 0.18.

A reduction in the NDVI was observed throughout the operation of the MSW landfill and the dispersion of harmful pollutants in the dominant direction of the wind.

The values of the NDVI along the directions of the wind rose are provided in (Sup. Table 1). The Kokshetau MSW landfill satellite images are shown in Figure 3. Examination of the image's points to the zones with the highest NDVI values (0.19), which are highlighted in green. Areas with the lowest values of the index (0.13) and the greatest number of plots with degrading vegetation are also identified and highlighted in red. The territory within the MSW landfill is found to be disturbed, which is also indicated in the image in red.

As indicated by Fig. 3, degradation of vegetation cover is found in the southern and southwestern directions, as highlighted in red. In the western and eastern directions, there is vegetation represented by shrubs, yet their condition also worsens with time. The MSW landfill has been in operation since 2014, which has resulted in the deterioration of vegetation. The study of the state of vegetation in 2017–2018 based on satellite images indicates red spots. This is evidence of the emergence and expansion of desertification zones. Since 2020, there has been an increasing trend of deterioration of vegetation in the southern direction, which is indicated by the presence and expansion of red areas in the images.

The values of NDVI for the period from 2017 to 2022 in the vicinity of the sanitary protection zone of the Stepnogorsk MSW landfill are shown in Fig. 4. The highest NDVI values were observed in 2017 in all directions of the wind rose, ranging from 0.16 to 0.2, which should probably be attributed to the start of landfill operation. In 2018, the NDVI values ranged from 0.14 to 0.18, showing a negative impact on vegetation. In later years, the index drops to between 0.14-0.16, which means a deterioration in the condition of vegetation. At the control point, the NDVI value was 0.28, which points to a better condition of vegetation compared to the area near the sanitary protection zone.

The values of NDVI in the vicinity of the sanitary protection zone of Stepnogorsk are given in (Sup. Table 2). The values of NDVI decrease the most in the west, south, and southwest directions of wind movement, which is caused by the prevailing southwest wind direction. The index decreases to the lowest values of 0.14 in the south and west wind directions and 0.13 in the southwest, south, and west wind directions.

The satellite images of the sanitary protection zone of the Stepnogorsk MSW landfill for 2017–2022 are shown in Fig. 5. As can be seen from the images, the area filled with municipal waste increases during the operation of the MSW landfill. In addition, in the southern direction, the land is experiencing desertification and vegetation is deteriorating over time compared to that in the northern direction. This fact is explained by the movement of the wind in the southwest direction.

Assessment of the NDVI of vegetation cover in the sanitary protection zones of MSW landfills in the Akmola region (Stepnogorsk and Kokshetau) reveals that in the summer periods (July–August) of 2017–2022 the index varies from a minimum value of 0.12 to a maximum value of 0.21.

SAVI Results. In 2017, the values of SAVI ranged from 0.2 to 0.24, which is low compared to other years (Fig. 6). This result can be attributed to the disposal of waste at the MSW landfill site in previous years. The highest SAVI values were observed in 2018, ranging from 0.26 to 0.3, as the MSW landfill site did not accept waste in 2017. In 2018, the index dropped to its minimal value of 0.22. In 2020–2022, the SAVI values in the vicinity of the sanitary zone of the MSW landfill declined. The lowest index values were observed starting in 2020 in the southwest and south directions – from 0.15 to 0.27. This decrease is due to the direction of the southwest wind. The highest values were detected in the north, ranging from 0.2 to 0.3. The control value is 0.4, meaning an average density of vegetation. The respective values of the SAVI are provided in Sup. Table 3.

The SAVI values in the period from 2017 to 2022 in the vicinity of the Kokshetau MSW landfill ranged on average between 0.15 and 0.3. This level indicates a low density of vegetation and the presence of areas with degraded vegetation cover.

The images of the sanitary protection zone around the Kokshetau landfill calculated using SAVI are shown in Fig. 7. The figure shows increased degradation of vegetation in the south and southwest directions. The values of SAVI fall between 0.15 and 0.3, indicating a weakened condition of vegetation. The land areas covered by vegetation have a green color (0.28), while areas with low values of the vegetation index are indicated with lilac and are characterized by a low density of vegetation cover (0.15). As indicated in the figure, zones with disturbed vegetation cover are found in the south and southwest direction.

The highest SAVI values, from 0.2 to 0.25, were recorded in 2017, which is when the MSW landfill began its operation. In 2018, the values decreased to 0.19–0.21. In 2019–2022, the SAVI values in the area affected by the MSW landfill

Plate 20

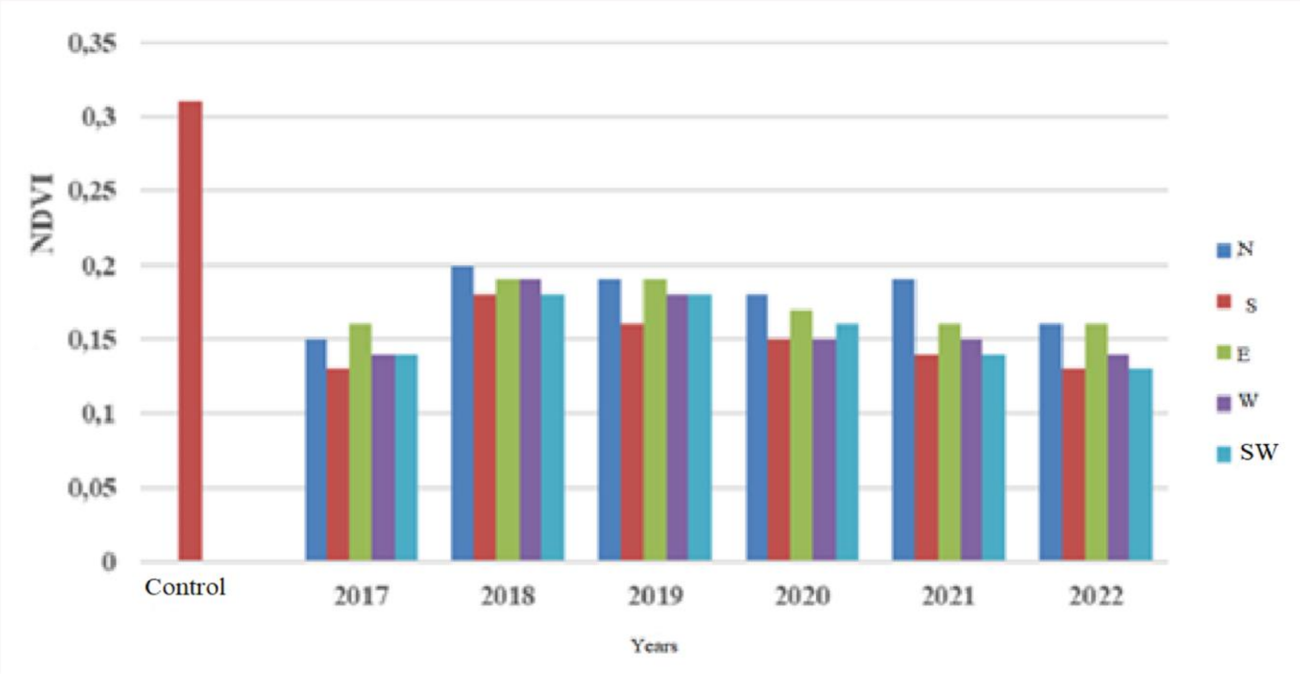

Figure 2. NDVI values for the period from 2017 to 2022 in the vicinity of the Kokshetau MSW landfill

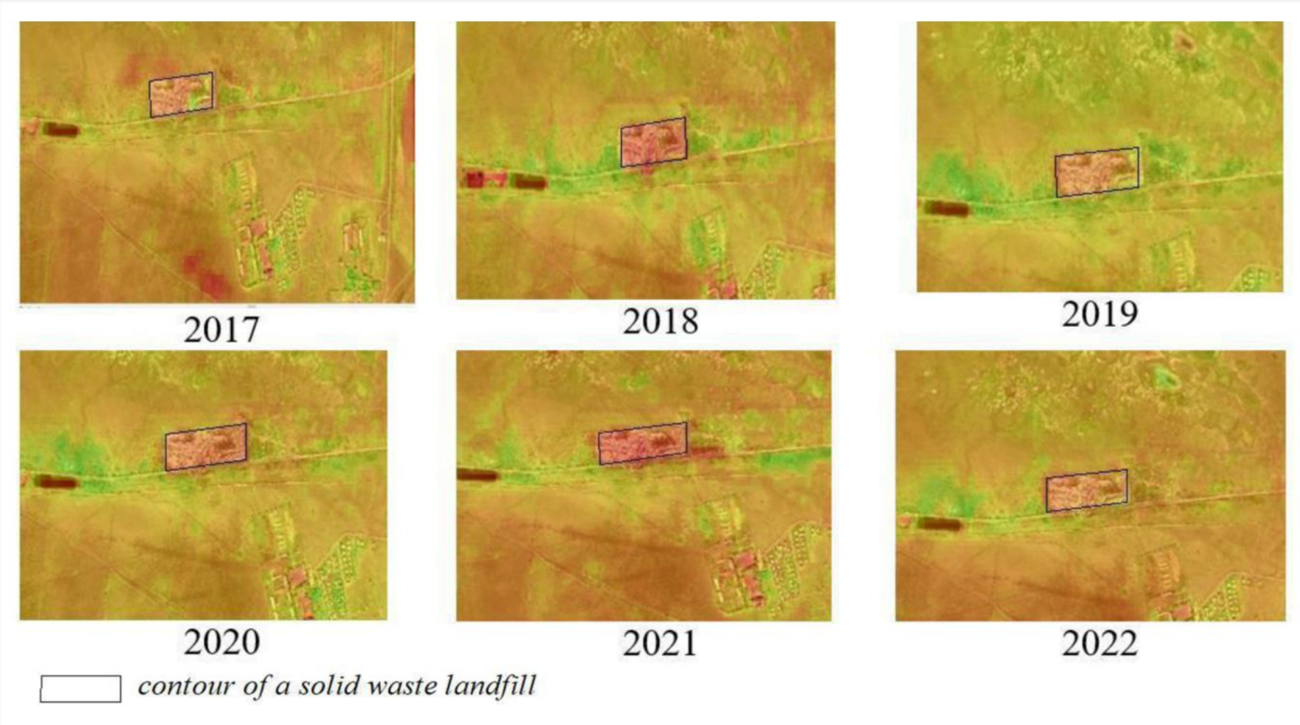

Figure 3. Satellite images of the sanitary protection zone of the Kokshetau MSW landfill processed in Arc GIS

Plate 21

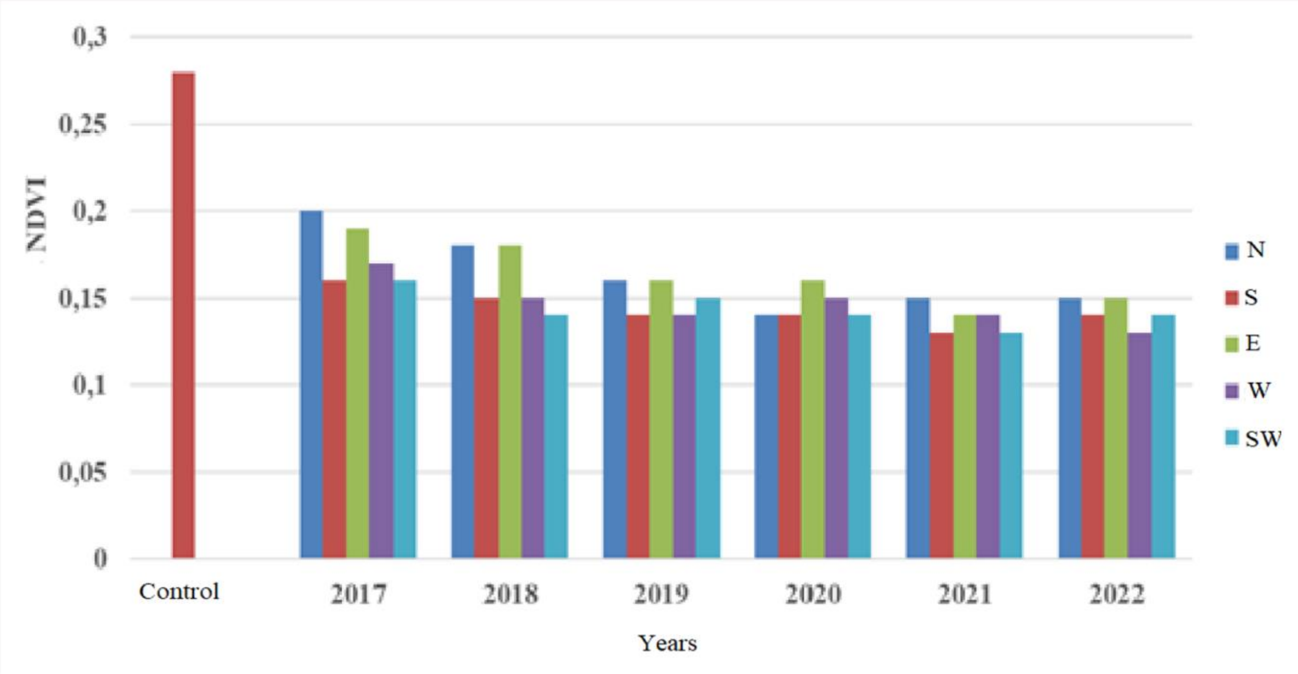

Figure 4. NDVI values for the period from 2017 to 2022 in the sanitary protection zone of the Stepnogorsk MSW landfill

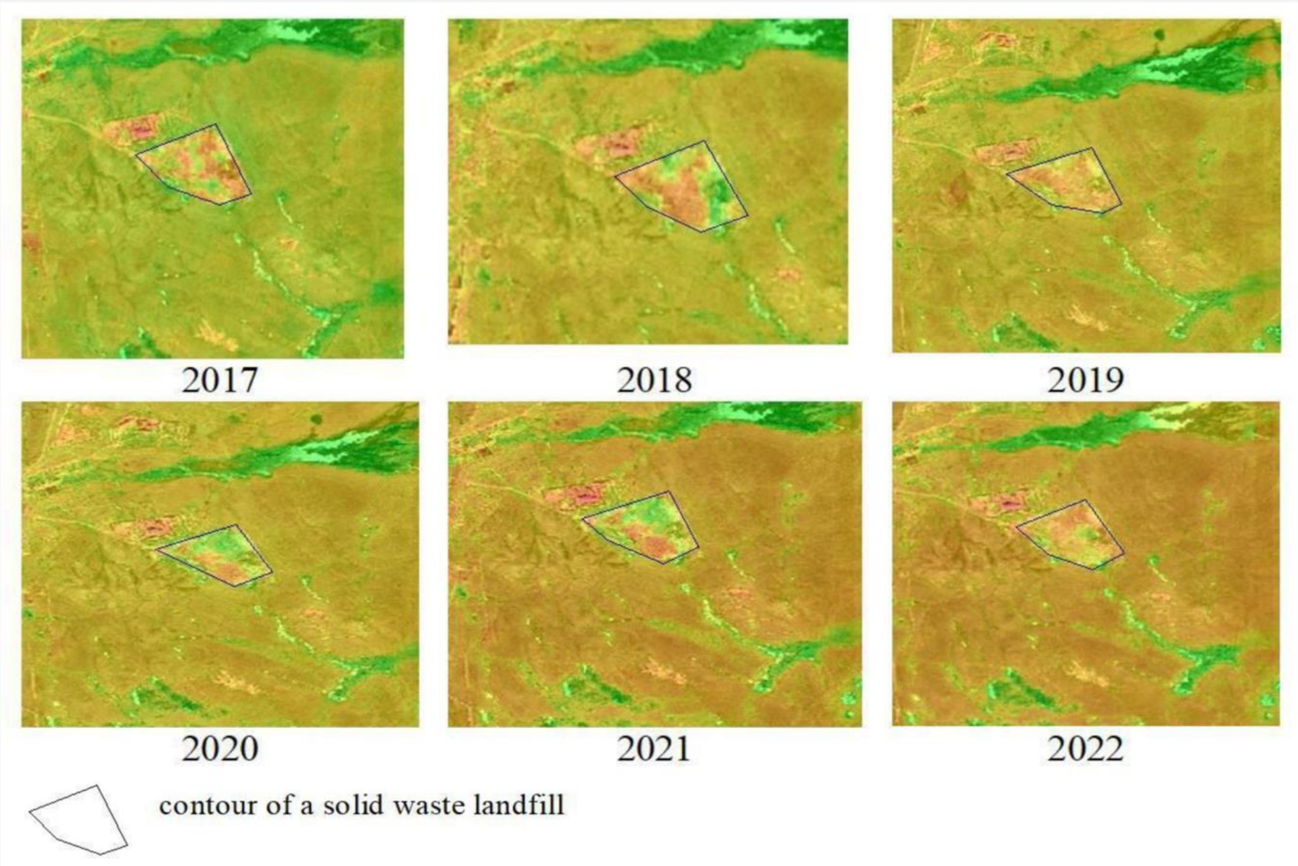

Figure 5. Satellite images of the sanitary protection zone of the Stepnogorsk MSW landfill processed in Arc GIS

Plate 22

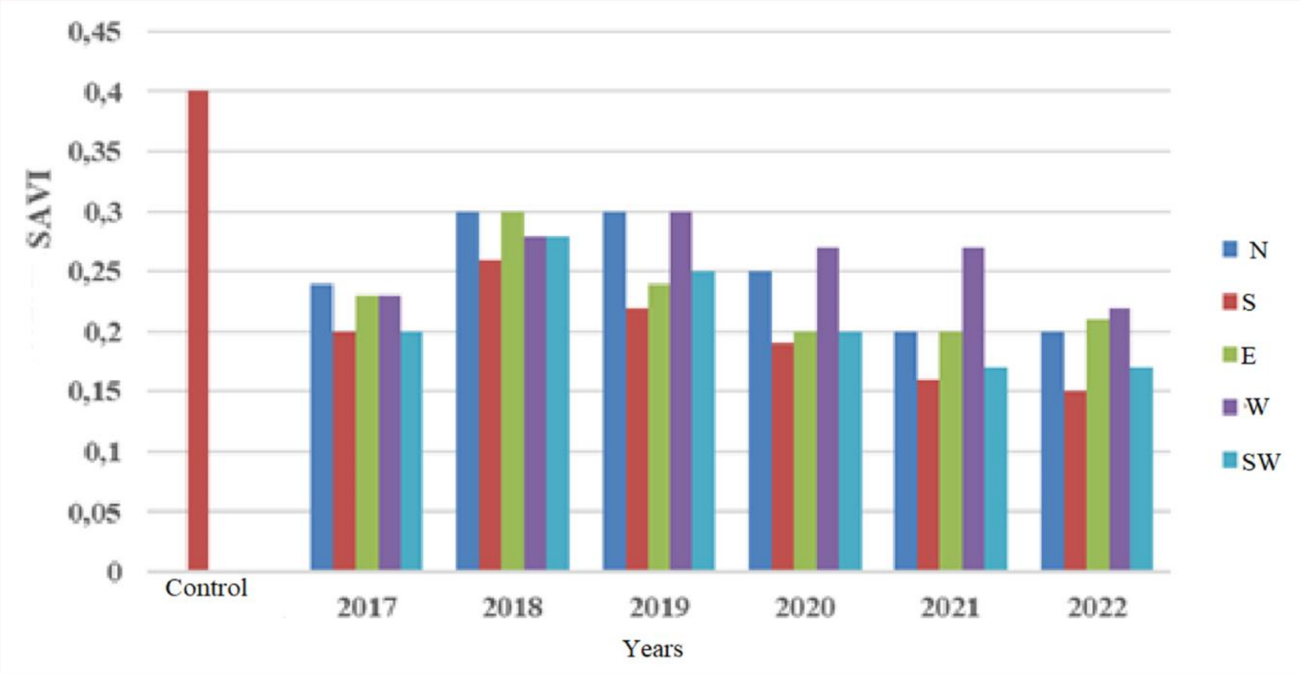

Figure 6. SAVI values for the period from 2017 to 2022 in the vicinity of the Kokshetau MSW landfill site

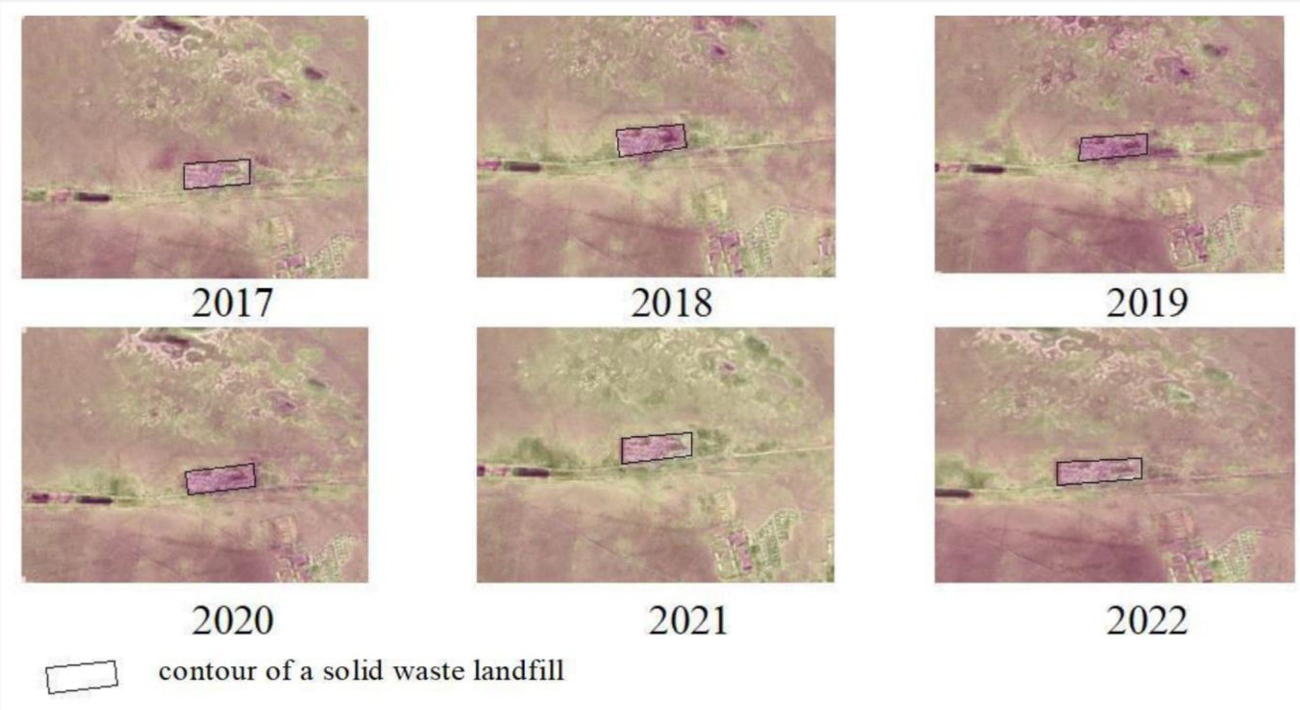

Figure 7. SAVI values for the period from 2017 to 2022 in the vicinity of the Kokshetau MSW landfill site

Plate 23

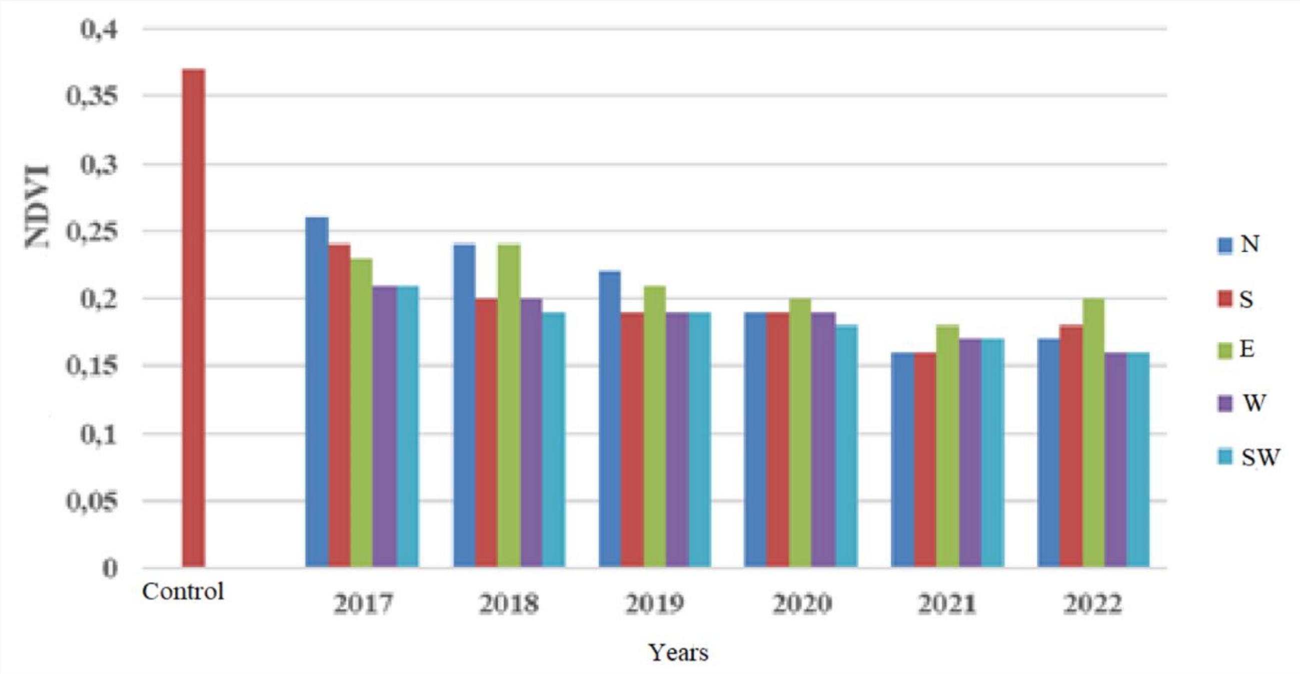

Figure 8. Changes in the SAVI values during the period of 2017-2022 in the vicinity of the Stepnogorsk MSW landfill site

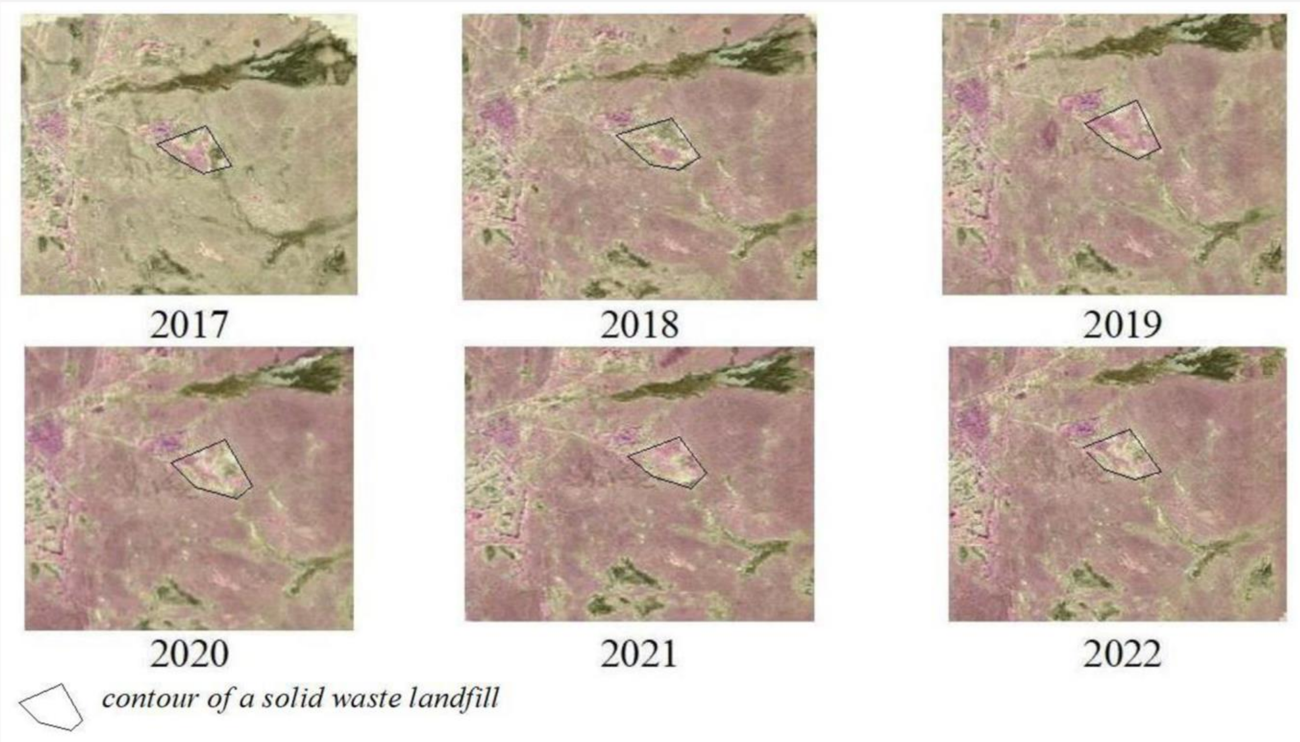

Figure 9. SAVI values for the period from 2017 to 2022 in the vicinity of the Stepnogorsk MSW landfill site

continued to drop. The lowest values, reaching 0.15, were observed in the southwestern, western, and southern directions. This decrease is related to the southwesterly wind direction. The highest values of the index were found in the northern and eastern directions, where the SAVI values range from 0.19 to 0.21. The value of the SAVI in the control is 0.37 (Fig. 8; Sup. Table 4).

As can be seen from Fig. 9, the area of degradation around the Stepnogorsk MSW landfill increases over time. Areas of reduced vegetation density have formed, as highlighted in lilac in the image. Starting in 2019, degradation has been established in the western and southern directions, in alignment with the southwesterly wind direction and pollution of the area during landfill operation.

The values of the SAVI for the period from 2017 to 2022 in the vicinity of the Stepnogorsk MSW landfill within the sanitary protection zone averaged 0.16-0.26. These results indicate a low density of vegetation, and therefore, poor vegetation conditions.

According to satellite images processed in ArcGIS, increased vegetation degradation and desertification were observed under the influence of the prevailing wind direction. Through the use of the NDVI and the SAVI, the state of vegetation in the area of the sanitary protection zones in the Kokshetau and Stepnogorsk landfills was assessed and shown to be deteriorating tending to desertification.

Author contributions

All the authors contributed equally.

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Literature cited

Ashikhmina, T.V. (2008). Influence of municipal and industrial solid waste landfills on the state of the environment. *Vestnik of Vitebsk State Technological University*, 4(6): 14–17.

Aslam, B., A. Maqsoom, M.D. Tahir *et al*. (2022). Identifying and ranking landfill sites for municipal solid waste management: An integrated remote sensing and GIS approach. *Buildings*, 12(5): 605.

Bayazitova, Z.E., A.S. Kurmanbayeva, Zh.O. Tleuova, and N.G. Temirbekova (2023). Application of the thermophilic fermentation method to obtain environmentally friendly organic fertilizer. *Journal of Ecological Engineering*, 24(4): 202–216.

Bayazitova, Z.E., J. Rodrigo-Ilarri, M.-E. Rodrigo-Clavero *et al*. (2022). Relevance of environmental surveys on the design of a new municipal waste management system on the City of Kokshetau (Kazakhstan). *Sustainability*, 14(21): 14368.

Dayanthi, A.K., S.Y.J. Prasetyo & C. Fibriani (2023). Classification of flood disaster risk areas in Semarang City with vegetation index calculation. *Jurnal Tanah & Sumberdaya Lahan*, 10(2): 461–470.

Eka Rahma Wati, S., A.D. Kusmaningayu, I. Khodijjah *et al*. (2023). Integration of Normalized Difference Vegetation Index (NDVI) and Soil-Adjusted Vegetation Index (SAVI) to identify vegetation covers on an oil-producing landscape in Kedewan, Bojonegoro Regency. *Indonesian Journal of Remote Sensing & Applications*, 1(1): 22–32.

Iankovich, E.P. (2017). Ecological and geochemical assessment of the natural environment of the Tomsky hydrogeoecological polygon using geoinformation technologies. *Candidate dissertation in Geological and Mineralogical Sciences*, *National Research Tomsk Polytechnic University*, *Tomsk*: 136pp.

Kakabayev, A.A., I.B. Fakhrudenova, A.S. Kurmanbayeva *et al*. (2020). Innovative online technologies as a tool of qualified specialists training in the field of waste management. *IOP Conference Series: Materials Science & Engineering*, 826(1): 012026.

Kurmanbayeva, A., Z. Bayazitova, A. Talal *et al*. (2022). Waste accumulation and geoecological assessment of the territories around the landfills in kokshetau. *International Journal of GEOMATE*, 23(96): 179–185.

Mallick, J. (2021). Municipal solid waste landfill site selection based on Fuzzy-AHP and geoinformation techniques in Asir Region Saudi Arabia. *Sustainability*, 13(3): 1538.

Meera Gandhi, G., S. Parthiban, N. Thummalu & A. Christy (2015). Vegetation change detection using remote sensing and gis – A case study of Vellore District. *Procedia Computer Science*, 57: 1199–1210.

Ministry of Health of the Republic of Kazakhstan (2022). Order of the Acting Minister of Health of the Republic of Kazakhstan of January 11, 2022 No. KR DSM-2 “On approval of the Sanitary and epidemiological requirements for sanitary protection zones of objects that are sources of impact on the environment and human health” <https://adilet.zan.kz/rus/docs/V2200026447 > Accessed on 17 April 2023.

Neinavaza, E., A.K. Skidmore & R. Darvishzadeh (2020). Effects of prediction accuracy of the proportion of vegetation cover on land surface emissivity and temperature using the NDVI threshold method. *The International Journal of Applied Earth Observation & Geoinformation*, 85: 101984.

Poputnikova, T. (2010). Ecological assessment of soils and individual components of the environment in the area of municipal solid waste landfill placement. *Candidate dissertation in Biology, Moscow State University, Moscow*: 136pp.

Révolo-Acevedo, R.H., B.J. Quispe-Reymundo, M. Rodríguez-Cerrón *et al*. (2023). Analyzing solid waste landfills using satellite imagery and designing new landfill reception areas. *Journal of Applied & Natural Science*, 15(2): 732–740.

Rodrigo-Ilarri, J., C.P. Romero & M.-E. Rodrigo-Clavero (2020a). Land use/land cover assessment over time using a new Weighted Environmental Index (WEI) based on an object-oriented model and GIS data. S*ustainability*, 12(24): 10234.

Rodrigo-Ilarri, J., M.-E. Rodrigo-Clavero & E. Cassiraga (2020b). BIOLEACH: A new decision support model for the real-time management of municipal solid waste bioreactor landfills. *International Journal of Environmental Research & Public Health*, 17(15): 1675.

Rodrigo-Ilarri, J., M.-E. Rodrigo-Clavero, C.P. Romero & P. Suárez-Romero (2022). Do solid waste landfills really affect land use change? Answers using the Weighted Environmental Index (WEI). *Remote Sensing*, 14(21): 5502.

Singgalen, Y.A. (2022). Tourism infrastructure development and transformation of vegetation index in Dodola Island of Morotai Island Regency. *Journal of Information Systems & Informatics*, 4(1): 131–140.

Solano Meza, J.K., J. Rodrigo-Ilarri, C.P. Romero Hernández & M.-E. Rodrigo-Clavero (2020). Analytical methodology for the identification of critical zones on the generation of solid waste in large urban areas. *International Journal of Environmental Research & Public Health*, 17(4): 1196.

Yu, X., Y. Zhuo, H. Liu *et al*. (2020). Degree of desertification based on normalized landscape index of sandy lands in inner Mongolia, China. *Global Ecology & Conservation*, 23(1): e01132.

Zavizion, Iu.V. (2019). Geo-ecological assessment of municipal solid waste landfill as an element of the natural and technogenic system. *Doctoral dissertation in Technical Sciences, Perm National Research Polytechnic University, Perm*: 193pp.

Ydyrys, S., Ibrayeva, N., Abugaliyeva *et al*. (2023). Regulatory and legal support for the development of digital infrastructure in rural areas as a factor in improving the level of sustainable development and quality of life of the rural population. *Journal of Environmental Management & Tourism*, *14*(5), 69.

Popov, V., Serekpaev, N., Zharlygasov, Z., Stybaev, G., & Ansabaeva, A. (2017). Adaptive technology of environmentally–friendly production of legumes in the dry steppe zones. *Journal of Central European Agriculture*, 18(1), 73–94.

Bekezhanov, D.N., M.V. Demidov, N.V. Semenova *et al*. (2023). Problems of consideration of environmental factors in urban planning as a mechanism for sustainable development. Pp. 49–52. *In*: Buchaev, Y.G. *et al*. (ed). *Advances in Science*, *Technology & Innovation* series (Part F1), Springer.

Ansabayeva, A. (2023). Cultivation of peas, *Pisum sativum* L. in organic farming. *Caspian Journal of Environmental Sciences*, *21*(4), 911–919.

Mukhambetov, B., B. Nasiyev, R. Abdinov *et al*. (2023). Influence of soil and climatic conditions on the chemical composition and nutritional value of *Kochia prostrata* feed in the arid zone of Western Kazakhstan. *Caspian Journal of Environmental Sciences*, 21(4), 853–863.

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