APPLICATION OF REMOTE SENSING DATA TO MONITOR THE THERMAL POLLUTION FROM WASTE DISPOSAL SITES

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Abstract: *The problem of waste management has existed since ancient times. In the modern world, waste generation is directly related to human activity. A large percentage is related to the production of household waste caused by the consumerism of each household. Toxins, leachate and greenhouse gases are one of the main causes of environmental pollution as a result of landfills. Over time, these toxins seep into the soil and groundwater, affecting the quality of the soil itself and drinking water in the area. Leachate, on the other hand, is a highly toxic liquid that forms when waste breaks down in a landfill and water filters through the waste. It is of great importance to take strict measures and monitor the landfills. Thanks to GIS and Remote sensing, efficient and complex monitoring of regulated and unregulated waste landfills can be done. The aim of the present work is to explore the possibilities of aerospace data analysis and to show different methods of processing, interpretation and visualization. Optical images from the Multispectral Instrument (MSI) on the Sentinel 2 platform of the European Space Agency's Copernicus program were used. Thermal bands from the Landsat 5 – 7 (ETM) and Landsat 8/9 (OLI / TIRS) sensors of the Landsat program were used to calculate land surface temperature. For the purpose of primary recognition of the studied objects, the satellite images are orthogonalized.*

ПРИЛОЖЕНИЕ НА ДИСТАНЦИОННИТЕ ИЗСЛЕДВАНИЯ ЗА МОНИТОРИНГ НА ТОПЛИННОТО ЗАМЪРСЯВАНЕ ОТ ДЕПА ЗА ОТПАДЪЦИ

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Ключови думи: *Управление на отпадъците, замърсяване на околната среда, ГИС, топлинен канал*

Резюме: *Проблемът с отпадъците съществува още от дълбока древност. В съвременния свят, генерирането на отпадъци е пряко свързано с човешката дейност. Един голям процент е свързан с производството на битовите отпадъци, причинени от консуматорството на всяко едно домакинство. Токсините, инфилтрата и парниковите газове са едни от основните причинители на замърсяване на околната среда, в следствие на депата за отпадъци. С течение на времето тези токсини проникват в почвата и подпочвените води, като оказват влияни*

е върху качеството на самата почва и питейната вода в района. От друга страна инфилтрата е силно токсична течност, която се образува, когато отпадъците се разграждат в депото и водата се филтрира през отпадъците. От голямо значение е взимането на строги мерки и наблюдение на депата за отпадъци. Благодарение на Дистанционните изследвания може да се направи ефикасен и комплексен мониторинг на регламентирани и нерегламентирани депа за отпадъци. Целта на настоящата разработка е да се разкрият възможностите на аерокосмическите данни и да се покажат различни методи за обработка, интерпретация и визуализация. Използвани са оптични изображения от мултиспектралния инструмент (MSI) на платформата Sentinel 2 на програмата Copernicus на Европейската космическа агенция. Топлинните канали от сензорите Landsat 5 – 7 (ETM) и Landsat 8/9 (OLI / TIRS) от програмата Landsat са използвани за изчисляване на температурата на земната повърхност. С цел първично разпознаване на изследваните обекти, сателитните изображения са ортогоназирани

Introduction

On a global level, unregulated landfills are a growing problem. Illegal dumping is the improper disposal of waste at any location other than a regulated landfill or facility. It is known as “open dumping” or “midnight dumping”. The most common sight is in open areas, in ditches, on the outskirts of settlements, in wooded areas, streams and rivers. The risks to human health associated with illegal dumping are significant. Unregulated landfills may be accessible to people who could come into contact with chemicals (liquids or dust) or be injured by metal waste materials and sharp edges of glass or metal objects.

The present work examines the case of the unregulated landfill, which is located on the territory of the city of Sofia, in close proximity to the residential districts of Mladost 4 and Gorublyane. The area on which an unregulated landfill is located is on groundwater, which can cause various environmental problems. Dumping of earth masses, construction and household waste has been observed for several months. According to the project, the surveyed territory was intended for a park. Inspections were carried out by the metropolitan municipality, but to date no measures have been taken.

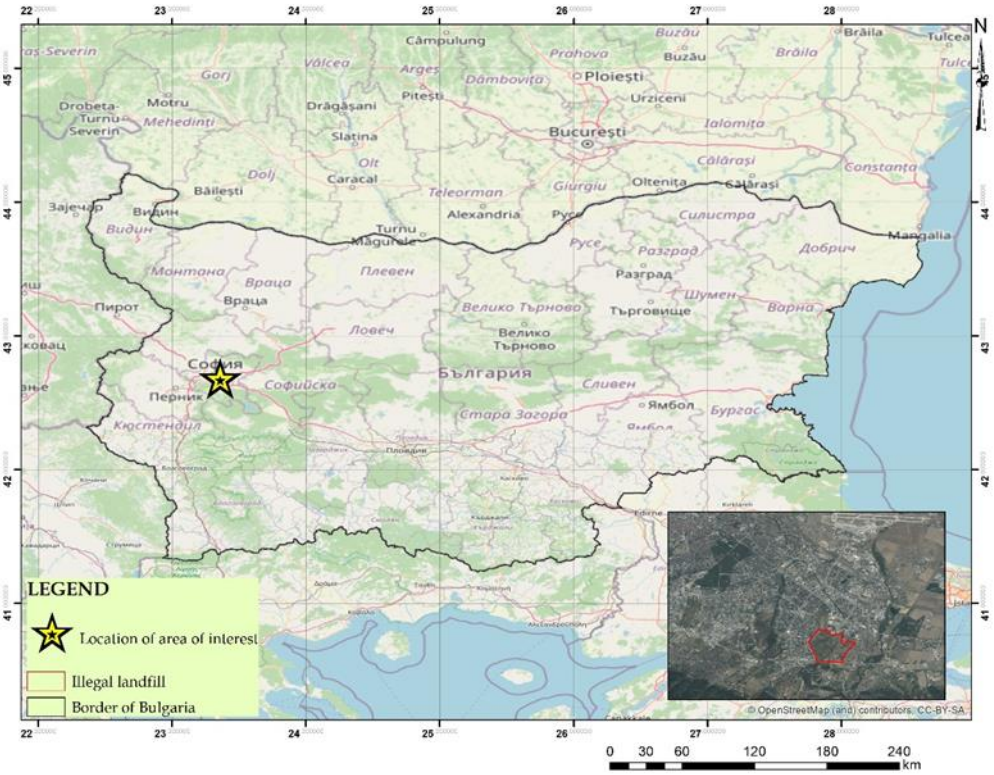


Fig. 1. Location of area of interest

Materials and methods

This survey methodology is based on the use of satellite data that examines bands on the thematic infrared sensors (TIRS). From this data, information is extracted about the actual heat emission of waste disposal sites, which is related to the land surface temperature of the surveyed sites. The landfill temperature is calculated using the Digital Number (DN) contained in the TIRS. The multispectral instrument (MSI) Sentinel-2 sensor data is used for the spectral characteristics. The same data was also used for Tasseled Cap Transformation (TCT) and this is the most commonly used landfills recognition method. [1].

A general formula for Landsat 4–9 can be written:

(1) $$T_{[K]} = a * ln^{-1}\left(\frac{b}{c*Q+d} + 1\right)$$

Where *a, b, c*, and *d* are the constants for the different types of Landsat images, T is the pixel temperature (K), Q is the spectral brightness coefficient of the surface in the thermal band. Landsat (4–9) satellite images are downloaded from web page https://earthexplorer.usgs.gov/ [2].

After the georeferencing procedure of the thermal images the cutting out of the rectangular sections in each image covering the vicinity of the geographic coordinates is carried out. The time series {Q1, Q2, . . . , Qn} of the images in the thermal channel of each WDS are extracted. The data from the image is converted into the surface temperature {T1, T2, . . . , Tn} using transformation:

(2) $$T_{[°C]} = a * ln^{-1}\left(\frac{b}{c*Q+d} + 1\right) - 273.15$$

Where:

a is the K_2 = Thermal conversion constant for the band (K2_CONSTANT_BAND_n from the metadata);

b is K_1 = Thermal conversion constant for the band (K1_CONSTANT_BAND_n from the metadata);

c is M_l = Radiance multiplicative scaling factor for the band (RADIANCE_MULT_BAND_n from the metadata);

d is L_λ = Spectral radiance $(W/(m2 * sr * \mu m))$;

Q = L1 pixel value in DN;

T = TOA (Top of Atmosphere) Brightness Temperature [1]

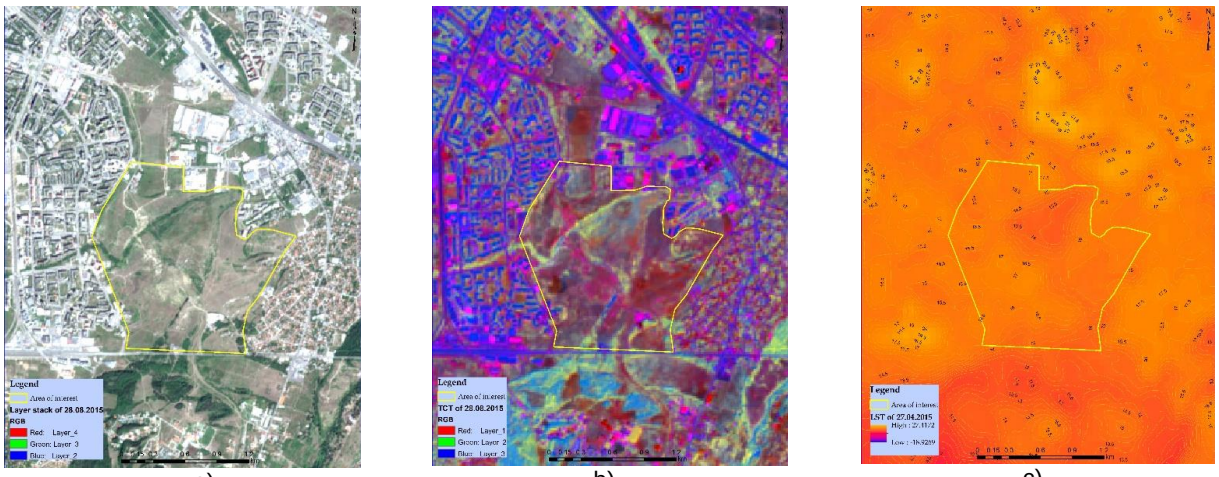
The time series for the illegal dumps are formed together with the mask for clouds and “blankness” and are entered into the database. The time series of images for temperature for the illegal dump of Mladost 4 – Gorublyane area is systematized.

Results

The thermal radiation from an unregulated landfill is monitored. From the research done, it is noticed that the terrain was used for disposal of waste of different composition and origin already in 2012, when the construction of this part of the Mladost 4 district began (Fig. 2). Different satellite data from different years and seasons were used to process the images

Fig. 2. Illegal dump of Mladost 4, Source: Google earth, orthophoto from 2012

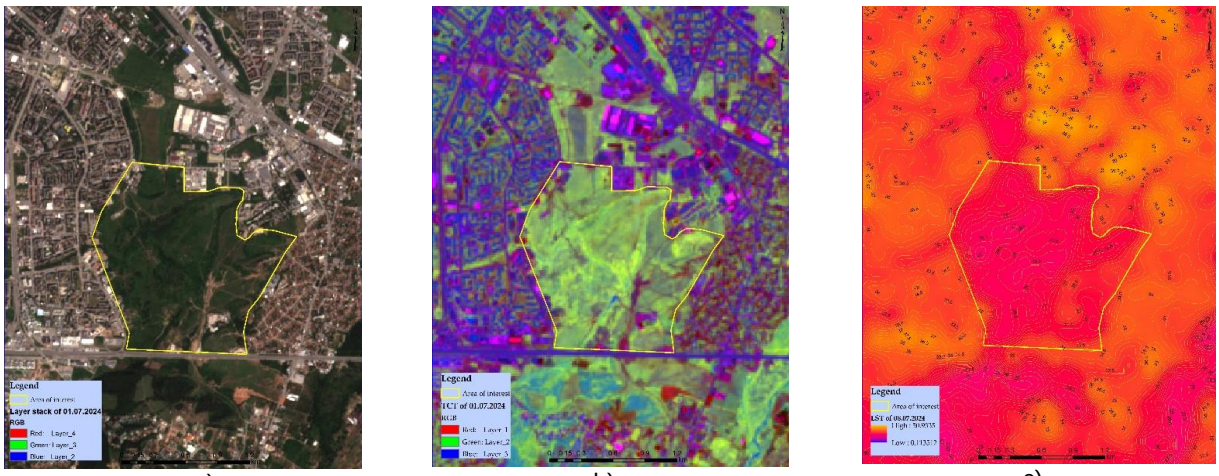
Sentinel 2 images used were transformed by tasseled cap. This model proves to be very effective in recognizing specific types of vegetation and their change over time. The unitary matrix of the Tasseled Cap transformation is fixed for each sensor. The use of TCT for satellite images results in a pure rotation and translation, thus the results obtained have a changed structure compared to the primary data, which allows for a clearer and more precise recognition and classification of the different components (soils, vegetation, water) from the land cover. After the segmentation of the satellite images, homogeneous clusters are obtained, which are clearly defined - brightness, greenness and wetness [3].



a) b) c)

Fig. 3. Different interpretation of illegal dump of 28.08.2015

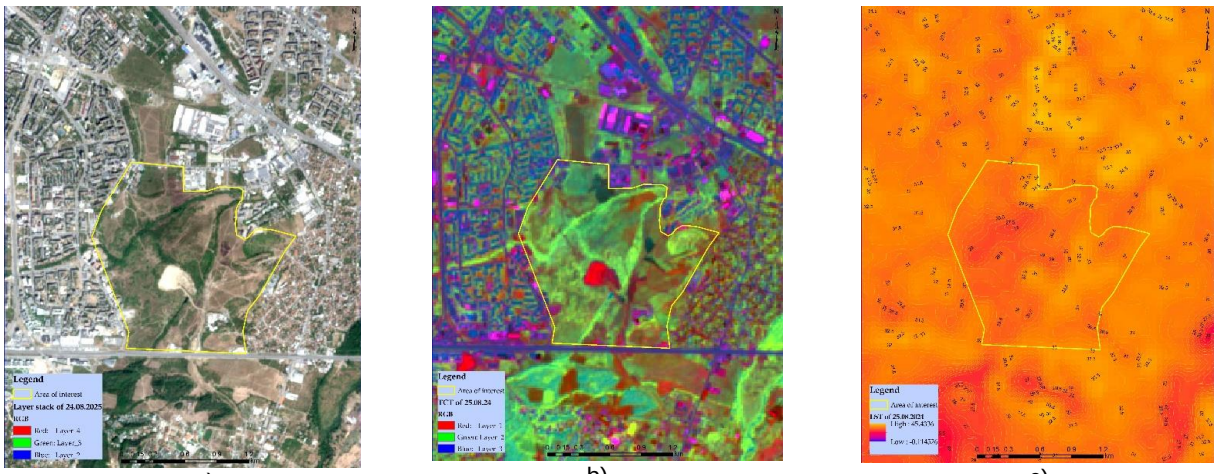
Figure 3 a) shows a composite image from Sentinel 2 in the visible range, where the distribution of waste in the affected part of the territory can be visually seen. Figure 3 b) shows the TCT for the same date, observing the distribution of litter along a north-south direction. To prove the thermal pollution theory, the thermal band from Landsat 8 was used (Fig. 3 c). A higher temperature is observed on the north-eastern side of the studied site, as there are industrial buildings with sheet metal roofs, which have heated up and in this case emit a greater amount of heat than the surrounding environment. Inside, within the boundaries of the object, it can be seen that the places where the waste is located have a higher temperature than the rest of the surface, and it varies + 15 °C and reaches + 17 °C, where the accumulation of waste is more – large (Fig. 3 c).



a) b) c)

Fig. 4. Different interpretation of illegal dump for July, 2024

From 2015 to July 2024, this practice of illegal dumping of waste is gradually ending and is taking shape as a period of "lull". A return of the vegetation cover was observed in the studied territory. This is also clearly visible from the presented 3 images from figure 4. In figure 4 a) a composite is made in the visible range of the electromagnetic spectrum. In figure 4 b) TCT is made. In this case, the vegetation can stand out most clearly from the rest of the surface. The remaining anthropogenic objects such as buildings, roads, etc. are clearly visible. From the calculated surface temperature, the usual heat islands that are characteristic of landfills are not observed, excluding the others that are heat islands from the urban environment (Fig. 4 c).



a) b) c)

Fig. 5. Different interpretation of illegal dump of 25.08.2024

A month later, the terrain is again used for disposal of waste of different composition and nature. From the presented composite image with 4-3-2 optical channels, a huge spot appears, which was not there until this stage (4 a). The TCT of the image clearly shows that it is something that is not characteristic of the study area. From the land surface temperature (4 c), a rise in temperature is observed precisely in the part where this spot is observed. It is also possible to notice a spread of this temperature in separate parts of the area of interest. The temperature in the center of the affected area varies from + 31 °C and reaches + 33.5 °C. A drone shot of the affected area was taken. From the obtained results, uncontrolled disposal of waste is clearly visible in the entire territory of the studied area.

Fig. 6. Drone images

Conclusions

Urbanization has a negative impact on the environment mainly by generating pollution, changing the physical and chemical properties of the atmosphere, and covering the soil surface [4]. Thermal energy is another side effect that results from the decomposition of solid household waste. The generation of heat from municipal waste landfills is also responsible for the formation of a microclimatic zone around the landfill, which has consequences for the environment near the landfill. This generated heat is somewhat similar to urban heat islands (Urban Heat Island - UHI) [5].

References:

1. Dancheva, A, Methods for identification and visualization of municipal waste disposal sites using aerospace data, Ecological Engineering and Environment Protection, No 2, 2021, p. 56–60
2. https://earthexplorer.usgs.gov/
3. Spasova, T, Differentiated approach to flooded areas, surface water monitoring sites and wet snow cover based on remote sensing methods and GIS", p. 18–20
4. https://www.urbanheatislands.com/home
5. Mahmood, Khalid & Batool, Syeda & Faizi, Fiza & Nawaz Chaudhry, Muhammad & ul haq, Zia & Rana, Asim & Tariq, Salman. (2017). Bio-thermal effects of open dumps on surroundings detected by remote sensing—Influence of geographical conditions. Ecological Indicators. 82. 10.1016/j.ecolind.2017.06.042
6. Hu, X.; Xu, H. A new remote sensing index for assessing the spatial heterogeneity in urban ecological quality: A case from Fuzhou City, China. Ecol. Indic. 2018, 89, 11–21.
7. Nedkov, R.,Orthogonal transformation of segmented images from the satellite Sentinel - 2,"Comptes rendus de l'Académie bulgare des sciences,70(5), 687–692 (2017)
8. Richter, A., M. Kazaryan, M. Shakhramanyan, R. Nedkov, D. Borisova, N. Stankova, I. Ivanova, and M. Zaharinova. "Quality enhancement of satellite images and its application for identification of surroundings of waste disposal sites," Proc. SPIE 10444, 104441N-1-7 (2017).
9. USGS, Landsat 8 Data Users Handbook, 2016, vol.2 URL: https://landsat.usgs.gov/sites/default/files/documents/Landsat8DataUsersHandbook.pdf
10. Tucker, C.J., "Red and Photographic Infrared Linear Combinations for Monitoring Vegetation," Remote Sensing of Environment, 8, 127–150 (1979).