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USE OF OPEN, SPATIAL AND SATELLITE DATA FOR THE PURPOSE OF RESEARCHING LANDFILLS FOR MUNICIPAL

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Abstract

The present work traces the development of an illegal landfill near the town of Svoge in Bulgaria. After 2016, a waste management plan is prepared on the territory of the municipality and a decision is made to dispose of it by depositing it in a regional landfill for municipal waste in the town of Kostinbrod. The aim of the study is to trace the development of biochemical processes that took place on the territory of the former landfill and whether their impact continues to this day. Data from the Open Data Portal (https://data.egov.bg/), the National Spatial Data Portal INSPIRE (https://inspire.egov.bg/bg), satellite data and GIS, several spectral profiles and indices such as Normalized difference vegetation index (NDVI), Tasseled Cap Transformation (TCT) were used.

Composite images from the multispectral instrument (MSI) of the Sentinel 2 platform and radar (SAR) from the Sentinel 1 platform of the Copernicus program of the European Space Agency were used. The surface temperature of the landfill was calculated using the heat channels from the Landsat 5–7 (ETM) and Landsat 8 and Landsat 9 (OLI / TIRS) sensors. A combination of radar and optical data was made. Data from different seasons and years were used to monitor the dynamics of thermal pollution in the study area. Quantitative and qualitative assessment of the territory on which the landfill is located has been made. Last but not least, the role of high-value open data in environmental monitoring has been demonstrated, which will reduce the administrative burden of making responsible decisions for each smaller municipality and will be successfully implemented in future methodologies for improving Digital twins through technical work in Destination Earth (DestinE) and information about any point, area or globally significant territories.

Introduction

More and more open and spatial data have been used in making adequate and fast decisions not only in business and decentralized administrations, but also in large numbers in municipalities and settlements, as there is a huge shortage of highly qualified experts, especially in the Northwest region of Bulgaria.

Low budgets in small settlements and capacity shortages are the reason for the introduction of this type of research, which can be carried out by much less but qualified staff.

When there is such an abundance of high-value data in the administration, Open and Spatial data, the Copernicus and Landsat program, data from daily and year-round measurements of the Ministry of Environment and Water, it must be used and achieve great economic benefits and added value.

Many administrations, NGOs, citizens, and business organizations in Bulgaria are involved in environmental monitoring and climate change, but they often miss the opportunity to minimize the administrative burden and the re-use of data and the use of data from research projects.

There are many unregulated landfills in the country, but control measures and sanctions are often neglected. Many of these landfills are visible to citizens on a daily basis. The situation is similar at this landfill, which is near the Iskar River. There are many settlements along the river and unfortunately in most of them the biological and physico-chemical indicators are not good, moderate or are unknown, the presence of Cu, Mn, Al, Fe is observed.

Nowadays, with the ability to generate as much information as possible from a point, profile or area, a different method or approach makes it possible to successfully generate Digital Twins on Earth and obtain information not only about landfills or pollution, but about all spheres of life in real or near real time.

In times of economic crisis, war, shortage of drinking water in many parts of the world cannot be allowed to pollute such a strategic river that flows into the Danube and not to use the great amount of different types of Open Data.

Study area

The researched site is located in close proximity to one of the natural landmarks of the Republic of Bulgaria – the Iskar Gorge. From there passes the longest river, which flows entirely within the state – the Iskar River, which is a right tributary of the Danube. The landfill is located on the western slope, which has a steep slope between the town of Svoge and the village of Tserovo. The site has existed for at least 20 years and can be on the list of illegal dumps to this day. In January 2021, the landfill posed a great danger of environmental catastrophe, as much of the garbage fell into the Iskar River, leading to congestion and difficult cleaning of the riverbed.

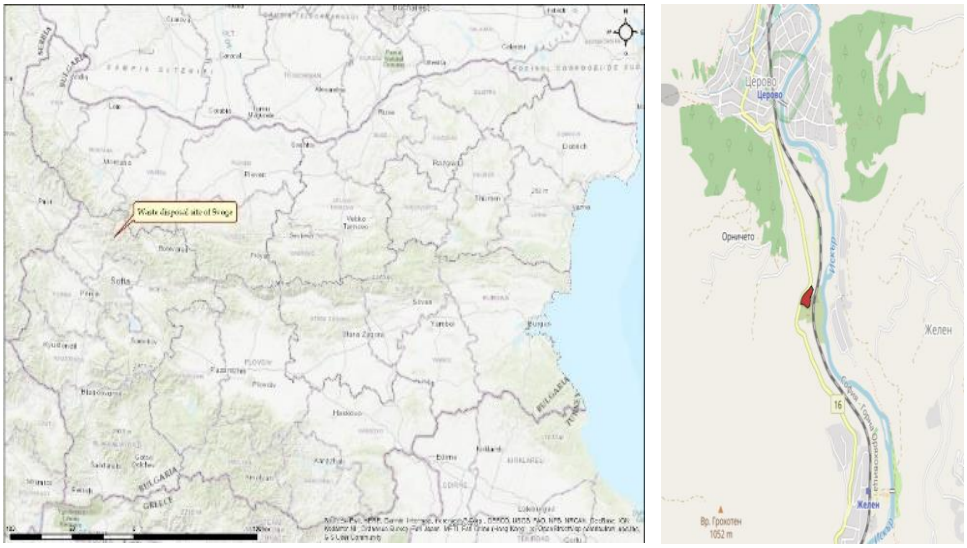


Fig. 1. Map of areas of interest

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. In this case, data from the Landsat 5 TM sensors is most appropriate, using a band 6 with a wavelength of 10.40–12.50 μm for Landsat 8 OLI / TIR band 10 wavelength 10.6–11.19 μm [1, 2] for calculation of the endemic heat radiation from the landfill. The selected images are from different years and different seasons. 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 used landfills recognition method. This approach was chosen because it is possible to interpret, classify and analyze phenomena and processes related to the dynamics and change of the basic components of the earth's surface – moisture, soil, and vegetation [3, 4]. For better visualization of the landfills, a combination of radar and optical images from Sentinel 1 SAR and Sentinel 2 MSI were used (Table 1) [5].

Data from the Open Data Portal, Copernicus and Landsat data and test spatial and spectral profiles were used [6, 7].

Table 1. Satellite data

DATE	SATELLITE
18.07.2010	**Landsat 5 ETM**
08.05.2022	**Landsat 9 OLI**
28.08.2015	**Sentinel 2 MSI**
13.04.2022	**Sentinel 2 MSI**
15.08.2015	**Sentinel 1 SAR**

We can write a general formula for Landsat 4–8: [3, 5–8]

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

Where a, b, c, 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 channel Landsat (4–8) satellite images are downloaded from web page https://earthexplorer.usgs.gov/. 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) $$T_{[C^0]} = a * Ln\left(\frac{b}{c * Q + d} + 1\right) - 273.15\,,$$

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

The time series for WDS are formed together with the mask for clouds and "blankness" and are entered into the database. The time series of images for temperature for each landfill or WDS is systematized [9].

Results and Discussions

This article traces the development of the illegal landfill over a period of 12 years. Different methods were used for identification and visualization of the studied object. An established methodology for recognizing and calculating the temperature of the earth's surface was used to study the development and what happens after most of the waste has been moved to a recultivated landfill in the town of Kostinbrod.

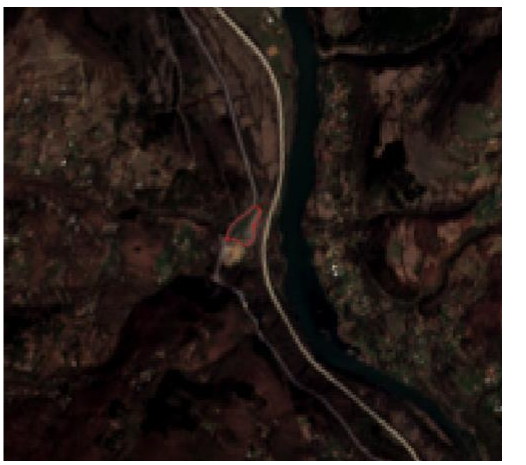
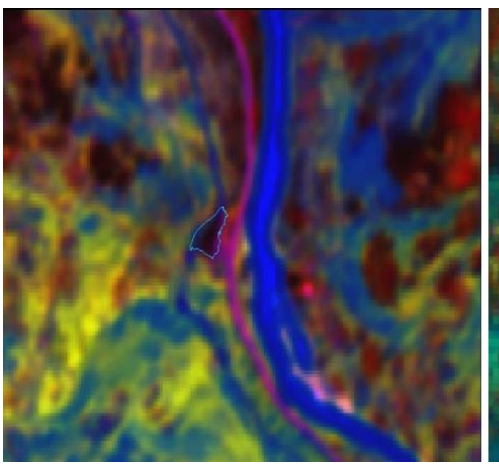


Fig. 2. Composite image from Sentinel 2 from 28.08.2015 Bands: 4-3-2;
Fig. 3. Composite image from Sentinel 2 from 13.04.2022 Bands: 4-3-2; Average of all images used in the analysis for Landsat 7 (left) and Landsat 8 (right)



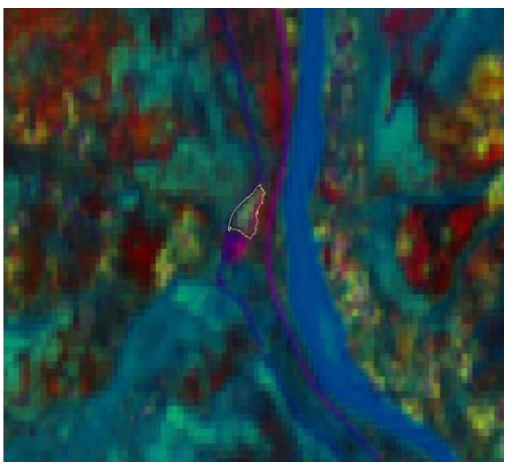


Fig. 4. TCT from 28.08.2015

Fig. 5. TCT from 13.04.2022

The composite optical images (Fig. 2 and Fig. 3) are from the multispectral instrument Sentinel 2 MSI in the visible range and bands 4, 3, 2. The image from 28.08.2015 clearly shows the boundaries of the landfill, as it was made on a clear day and without atmospheric disturbances. TCT transformation (Fig. 4 and Fig. 5) remains the safest way to identify landfills. The outlines are clearly visible, but in 2022 (Fig. 3 and Fig. 5) there is a relocation of the landfill south of the borders and its volume is significantly reduced, but it is still there and obviously not everything is transported to Kostinbrod, as is mentioned in a 2017 report of the municipality of Svoge and again remains a serious problem.

The second-class road II-16 passes through it, and just below it is an important railway artery that connects Northern and Southern Bulgaria.

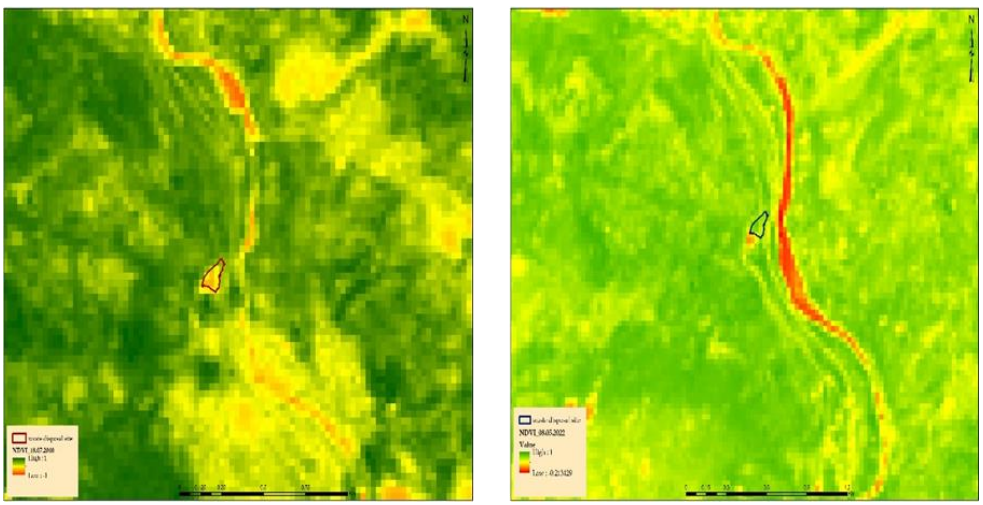


Fig. 6. NDVI from 18.07.2010; Fig. 7 NDVI from 08.05.2022
LST averaged over threetime intervals: 2000–2005, 2006–2010, and 2011–2015 (left to right)

The NDVI (Fig. 6 and Fig. 7) again showed the same trend as in the figures above. In the image from 18.07.2010 (Fig. 6) the landfill is completely within its boundaries, but in Fig. 7 from 08.05.2022 it has been slightly shifted to the south, and a new landfill has been formed. No change and damage to the vegetation is observed, except in the places where the landfill is.

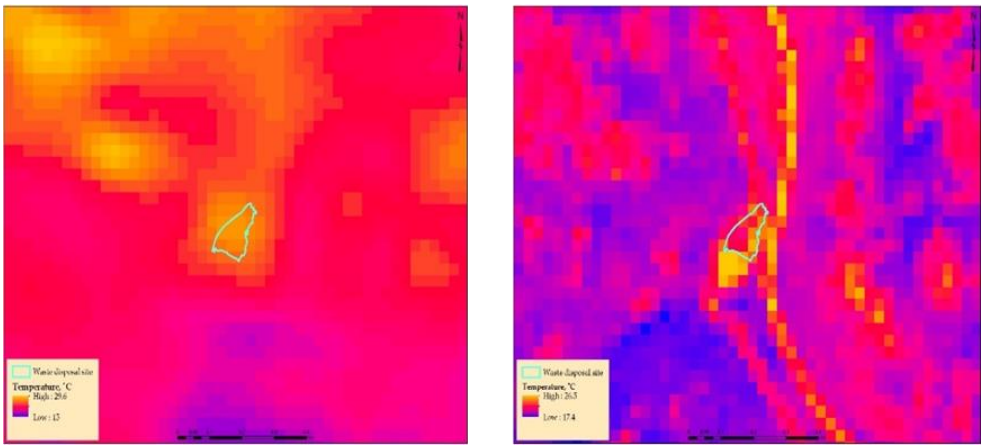


Fig. 8. Land Surface Temperature (LST) from 08.07.2010; Fig.9 Land Surface Temperature (LST) from 13.04.2022

Landsat 5 ETM was used to represent the surface temperature from 08.07.2010 (Fig. 8). There is a clear increase in temperature at the landfill, reaching +29.6 ℃ in the center of the site, which is typical for all studied landfills. The trend continues with the next image (Fig. 9) from 13.04.2022. Here the trend is similar to that of the TCT, NDVI of 2022 based on data from Copernicus. The landfill has been moved directly to the south of its borders, with the highest temperature in the newly formed landfill +26.5 ℃ and continues to radiate heat in its old border.

Fig. 10 and Fig. 11. Field images, author: Adlin Dancheva, Temenuzhka Spasova

The images from the field research (Figures 10 and 11) were taken in May 2022. The rubbish and part of the rock structures and vegetation on which spectral profiles are made are clearly visible (Fig. 12). From the spectral profiles one can clearly see the spectral curve at five different points and the fifth point is from the waters of the Iskar River. The high values of reflectance are noticed, which is also observed from the SAR image from 15.08.2015. Spectral reflectance levels are high in the area of the landfill, which contrasts sharply with data from the vegetation in the area. Both types of polarization vv vertical and vh vertical-horizontal were used for verification, as there is a strongly truncated relief.

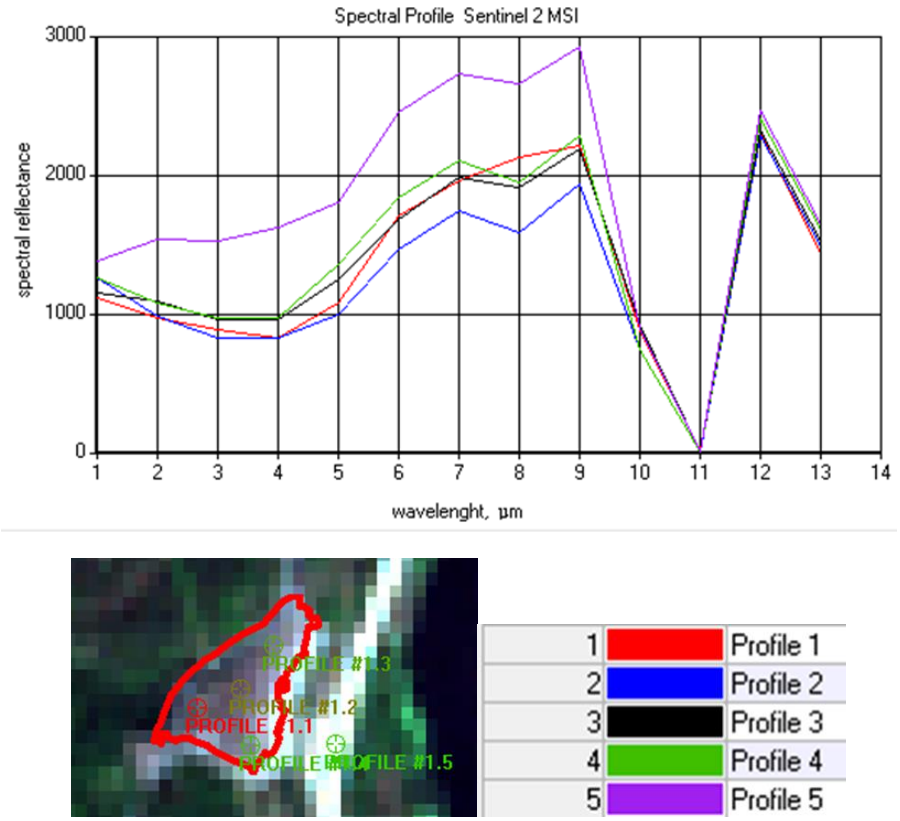


Fig. 12. Spectral profile Sentinel 2 MSI (28.08.2015)

Conclusion

Urgent measures must be taken to remove the waste and clean up the region once the administration has been notified, as this is a precondition for a serious environmental disaster. Climate change signals are not a myth in the area, but a clear

sign that has been proven even by local temperature changes based on Remote sensing.

The data from the Open Data Portal have been used successfully as a source for verification of information and show that the physicochemical parameters are moderate or unknown, the specific pollutants along the Iskar River are copper, manganese, aluminum and iron, biological indicators range from moderate to poor, and unknown data are available for some of the sites.

The analysis of data from Copernicus and Landsat shows an increase in temperature around the landfill, as well as an expansion of its borders to the south.

Of the spectral profiles made, the TCT and NDVI optical indices used, composite optical images in good and clear weather are a reliable source of information, and radar images further verify the information as they are not affected by weather and weather conditions.

From the developed methodology and the use of so many different sources of Open and Spatial Data, correct and informed decisions can be made in environmental monitoring, as well as management decisions at the local or regional level.

Last but not least, this type of information could be used to supplement the information about the specific territory in the construction of the Digital Twins of the Earth, which are in connection with the initiative of The European Commission's Destination Earth1 initiative (DestinE). Information from all sources in a single point or territory that is interoperable will result in high-value environmental data and information and reduce the administrative burden in the country.

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ИЗПОЛЗВАНЕ НА ОТВОРЕНИ ПРОСТРАНСТВЕНИ И САТЕЛИТНИ ДАННИ ЗА ЦЕЛИТЕ НА ПРОУЧВАНЕ НА ДЕПА ЗА БИТОВИ ОТПАДЪЦИ

А. Данчева, Т. Спасова

Резюме

Настоящата работа проследява развитието на незаконно сметище край град Своге в България. След 2016 г. се изготвя План за управление на отпадъците на територията на общината и се взима решение за депониране в Регионално депо за битови отпадъци в гр. Костинброд. Целта на изследването е да се проследи развитието на биохимичните процеси, протекли на територията на сметището и дали тяхното въздействие продължава и до днес. Използвани са данни от Портала за отворени данни (https://data.egov.bg/), Националния портал за пространствени данни INSPIRE (https://inspire.egov.bg/bg), сателитни данни и ГИС, няколко спектрални профила,

вегетационен индекс (NDVI). Направена е ортогонална трансформация на изображенията (TCT).

Използвани са композитни изображения от мултиспектралния инструмент (MSI) на платформата Sentinel 2 и радар (SAR) от платформата Sentinel 1 на програмата Copernicus на Европейската космическа агенция. Повърхностната температура на депото е изчислена с помощта на топлинните канали от сензорите Landsat 5–7 (ETM) и Landsat 8 и Landsat 9 (OLI / TIRS). Направена е комбинация от радарни и оптични данни. Използвани са данни от различни сезони и години, за да се проследи динамиката на топлинното замърсяване в изследваната територия.

Направена е количествена и качествена оценка на територията, на която е разположено депото.

Не на последно място, демонстрирана е ролята на отворените данни с висока стойност в мониторинга на околната среда, което ще намали административната тежест за вземане на отговорни решения за всяка по-малка община и ще бъде успешно внедрено в бъдещи методологии за подобряване на дигитални близнаци (Digital twins) чрез техническа работа в Дестинация Земя (DestinE) и информация за всяка точка, област или глобално значими територии.