Spectral analysis and mapping of unregulated landfills in Varna, North-East Planning Region of Bulgaria

Temenuzhka Spasova *[a], Daniela Avetisyan[a], Adlin Dancheva[a], Iva Ivanova[a]
[a]Space Research and Technology Institute at the Bulgarian Academy of Science (SRTI-BAS), Bulgaria, Acad. G. Bonchev Str., bl.1, Sofia 1113, Bulgaria, Tel. +35929883503;
Miroslav Y. Tsvetkov[b]
[b]Nikola Vaptsarov Naval Academy

ABSTRACT

The Research, Innovation and Digitalisation Programme for Economic Transformation in Bulgaria is one of the tools to respond to the country's strategic needs and priorities for the implementation of a common research and innovation development policy in favour of the country's accelerated economic development. It also responds to the need to speed up the processes of public sector digitalisation and to build an enabling digital environment that ensures high-quality and secure exchange of information between different spheres of life and enhance the effects of their interaction[1].
Developing a useful hybrid spectral analysis model to track climate change is the aim of this research. The subject of research is the dynamics tracked by the hybrid model for spectral analysis of unregulated landfills. For this purpose, a database of several identical climatic seasons (10 years) was created and processed to verify and validate the research based on satellite and in situ data.
The study covers an example from NUTS2, the North East (BG33) planning region (under the Regional Development and Improvement Act). The generated data is of high value according to the European Commission. They are for a period of at least five years. The study of the unregulated landfills is of national importance and the selected events from the territory of Bulgaria have been studied and monitored through a complex approach based on satellite data and ground-based innovative spectrometric equipment through a mobile spectrometer and a thermal camera. Indices such as Normalized Difference Vegetation Index (NDVI), Normalized Differential Greenness Index (NDGI) and Tasseled cap transformation (TCT) are also applied. Data from Orthophoto, Landsat-9 OLI-2/TIRS-2, Sentinel 2MSI and Sentinel-3 SLTRS satellites were used. Data from Corine Land Cover 2018 Copernicus and Open data were also used in the study.
Through this research, the data being generated for unregulated landfills can be supplemented and will be used to create of register and their use by various stakeholders.

Keywords: LST, NDVI, NDGI, TCT, unregulated landfills, spectrometer

1. INTRODUCTION

Mapping the area around unregulated landfills through remote sensing has multiple benefits, including improving waste management, protecting the environment from pollution, and preventing potential health risks to people. It also helps government and local authorities identify and implement measures to clean up affected areas and prevent future unregulated landfills.
The use of remote methods and in situ monitoring of unregulated landfills provides accurate, subjective factor-independent and up-to-date information on the location and size of landfill. This allows authorities to quickly identify and respond to problem areas, analyze trends in illegal waste disposal and plan effective measures to clean up and prevent future pollution (fig. 1)[2].
Last but not least, the data generated helped create a registry and its use by various stakeholders.
The Research, Innovation and Digitalisation Programme for Economic Transformation in Bulgaria is one of the tools to respond to the country's strategic needs and priorities for the implementation of a common research and innovation development policy in favour of the country's accelerated economic development. It also responds to the need to speed up the processes of public sector digitalisation and to build an enabling digital environment that ensures high-quality and secure exchange of information between different spheres of life and enhance the effects of their interaction[1].
This research is part of a methodology that the authors wish to provide for the benefit of administrations, NGOs and

*tspasova@space.bas.bg; http://www.space.bas.bg/en/structure/department/asi

Tenth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2024), edited by A. Christofe, S. Michaelides, D. Hadjimitsis, C. Danezis, K. Themistocleous, N. Kyriakides, G. Schreier, Proc. of SPIE Vol. 13212, 132121L · © 2024 SPIE · 0277-786X · doi: 10.1117/12.3038624

citizens, with the aim of greater efficiency in decision-making.
The creation of a digital register of illegal landfills by economic regions in Bulgaria will enable much higher control through monitoring and the creation of a statistical database that can be actively used for the various NUTS 2 in Bulgaria. Examining unregulated landfills in the Varna region, compared to other regions, may be important due to the specific urban and ecological context, including the proximity to the Black Sea, which makes it sensitive to environmental problems. Varna is a large city with a significant flow of tourists, which can lead to an increase in waste and challenges for its management. Focusing on this area can help identify and solve specific problems, raise public awareness and protect the area's natural resources.

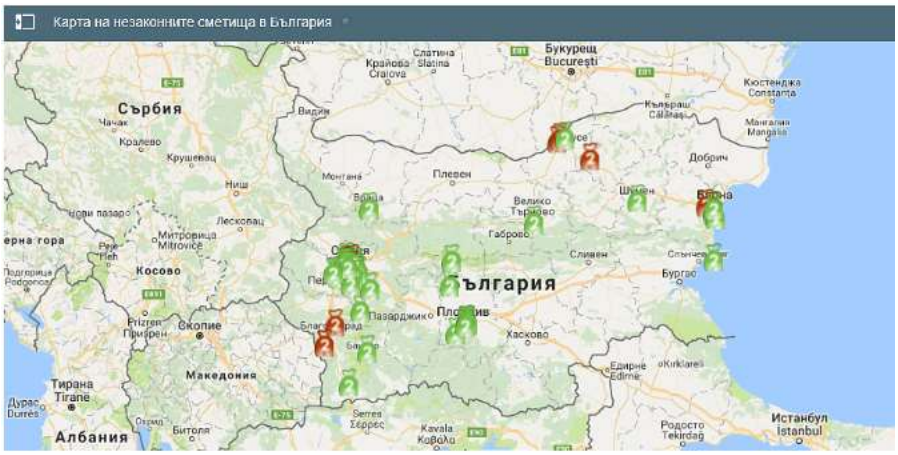


Figure 1 Unregulated Landfill Mapping Initiative[2]

According to the environmental legislation on waste management in Bulgaria, the duties of mayors of municipalities include identifying pollution, preventive actions to prevent unregulated waste pollution, as well as taking immediate measures to clean up already polluted areas outside the designated places for dumping waste[3].
One of the most problematic areas with pollution through unregulated landfills is that of the city of Varna, around the Asparuhovo bridge, Asparuhovo district, where video surveillance has already been implemented around garbage containers and places that have already been cleared of landfills.
On the website of the Municipality of Varna[4], information is published on Measures to prevent the generation of waste and the prevention of unregulated waste disposal.
Measures and actions in the medium term are:
Provision of video surveillance of the cleared terrains, which are municipal property, through mobile devices with real-time data transfer.
Optimizing the organized system for collection, utilization and disposal of construction waste from repair work, generated by households on the territory of the municipality.
Optimizing the organized system for separate collection and recycling of packaging waste generated by households on the territory of the municipality.
Introduction of home composting in the municipality, through the use of composters. The measure will be implemented in single-family houses located on the territory of the city of Varna, including settlements and in the villages of Varna Municipality.
Reducing the use of single-use products and encouraging the population to use reusable shopping bags. Running a campaign and providing reusable shopping bags[4].
Measures and actions in the long term are:
Construction of a municipal system for separate collection and recycling of biodegradable waste to support the transition to a circular economy.
Construction of an integrated system for the management of end-of-life car tires generated on the territory of the municipality of Varna, including providing an installation for their utilization.
Five unregulated landfills were found only in 2021 in the area around the Varna district "Asparuhovo"[5].
Highly versatile, light and affordable, plastic materials are employed in countless industrial applications and have become extremely useful for modern society. As a result, since 2000 the annual production of plastics has doubled, soaring from 234 million tonnes (Mt) to 460 Mt in 2019. The used volumes of these synthetic polymers have been increasing constantly

and increased more rapidly than any other commodity, including steel, aluminium and cement. The majority of plastics in use today are virgin plastics, made from crude oil or gas, while plastics made from recycled material only accounted for 6% of global plastics use in 2019[6].

Since 2000, plastic waste has more than doubled, from 156 Mt to 353 Mt in 2019. After taking into account losses during recycling, only 9% of plastic waste was ultimately recycled, while 22% was mismanaged, namely disposed of in uncontrolled dumpsites, burned in open pits or leaked into the environment, making the current plastics lifecycle far from circular (figure 2). Year after year, significant stocks of plastics have also accumulated in aquatic environments, with 109 Mt of plastics already accumulated in rivers, and 30 Mt in the ocean. The vast majority of plastic leakage to the environment takes place in non-OECD countries (86%), driven by soaring amounts of mismanaged waste[6].

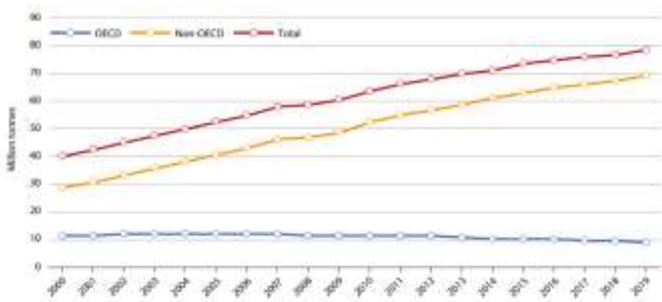


Figure 2. The amount of mismanaged plastic waste has been soaring particularly in non-OECD countries Plastic pollution is becoming increasingly unsustainable[6]

1.1. Region of interest

The North-East planning region includes the districts of Varna, Dobrich, Targovishte and Shumen[7]. This region is characterized by a developed agriculture, thanks to its fertile lands, and a developing tourism sector, especially in the coastal areas. The industrial sector is diverse, with an emphasis on food, textile and chemical industries. The region faces challenges such as low incomes, high unemployment and demographic problems that affect its economic development.

The object of interest is in the city of Varna, district Asparuhovo, Southern Industrial Zone and is close to the "Natura 2000" network - protected area BG0000191 "Varna-Beloslav Lake", announced by Order No. RD-128/10.02.2012 of the Minister of Environment and Water.

Figure 3 Varna city, Asparuhovo district, Southern industrial zone[8] and Area of interest (AOI)

2. DATA AND METHODS

Methods

The methodology for Hybrid spectral analysis model for unregulated landfills in Varna involves analysis of satellite imagery to identify potential dumps and subsequent ground inspections to confirm and assess in detail the sites discovered. GIS technologies were used for data analysis and visualization. This approach allows rapid and comprehensive mapping of the dynamics of the territories occupied by unregulated landfills, supporting management and regulatory decision-making. The description of the Hybrid spectral analysis model for unregulated landfills includes the elements of the complex approach, which are detailed in figure 4.

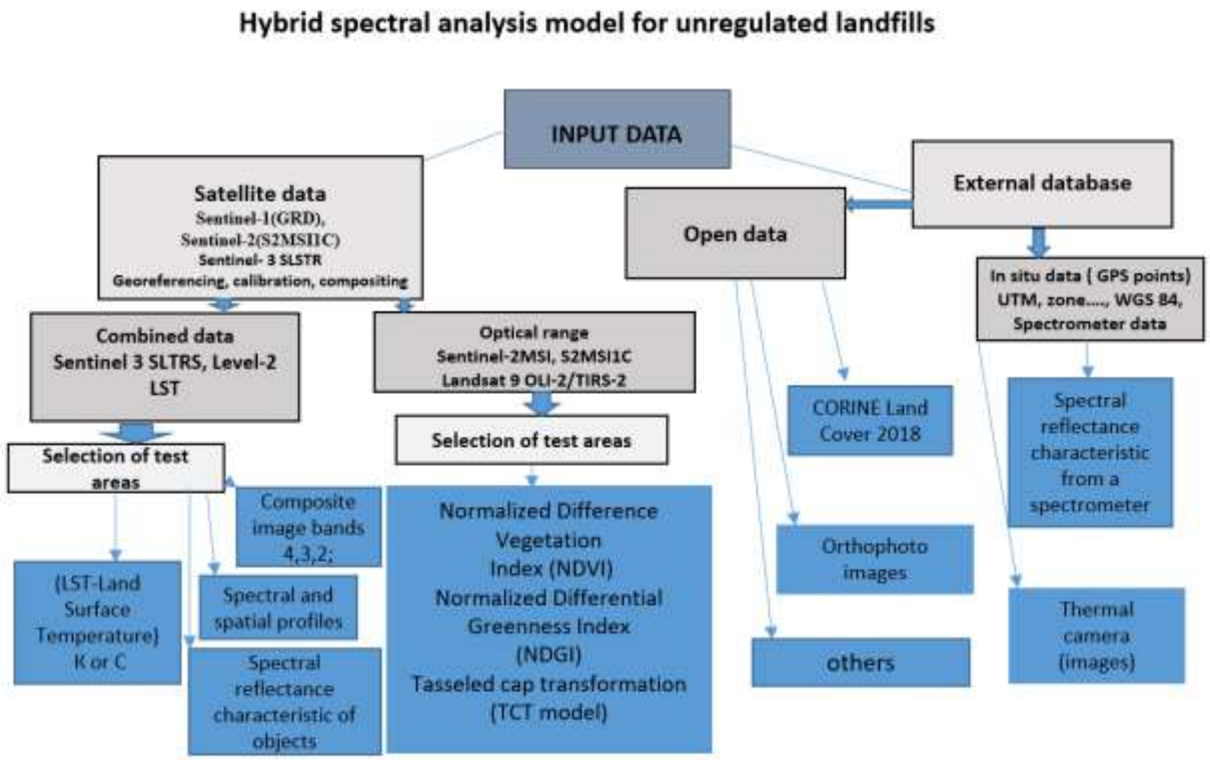


Figure 4 Hybrid spectral analysis model for unregulated landfills

Data

Satellite data

Data from Sentinel-2 by the European Space Agency (ESA) as part of the Copernicus programme were used. Generally, Sentinel-2MSI provides a valuable tool for monitoring and understanding the Earth's surface and can help us take informed decisions about the management and conservation of our planet [9,10,11,12].

The data from Sentinel-3 are from the month of July for the period from 2019 to 2023. The data are from the two satellites Sentinel-3A and Sentinel-3B (table 1, fig. 5).

Sentinel-3 SLSTR Level-2 LST provides land surface parameters at 1 km resolution[13]. In addition, the file is measured with the Land Surface Temperature (LST) value calculated and specified for each pixel.

Landast-8 and Landsat-9 OLI-2/TIRS-2of the NASA with 30-meter resolution about once every two weeks, including multispectral and thermal data (table 1).

Table 1 Satellite images acquisition dates – Copernicus, ESA and Landsat, NASA

Satellite	Date	Satellite	Date
Sentinel-2 MSI	**16/08/2016 10/09/2017 10/09/2018 16/07/2020 19/09/2022**	**Sentinel-3A Sentinel-3B**	**the whole month of July 2019 to 2023 LST Land Surface Temperature**
Landsat-9 OLI-2/TIRS-2	**30/08/2022 07/06/2023**	**Landsat-8 OLI/TIRIS**	**19/06/2013 21/05/2014 26/08/2019**

Satellite data from Sentinel-3 were processed with the SNAP product, which can be freely used and is published on the European Space Agency website[14]. All images were transformed to degrees Celsius for clarity when analyzing the results (fig. 5).
The temperature of the Earth's surface (LST - Land Surface Temperature) is the radiation temperature obtained from infrared radiation.

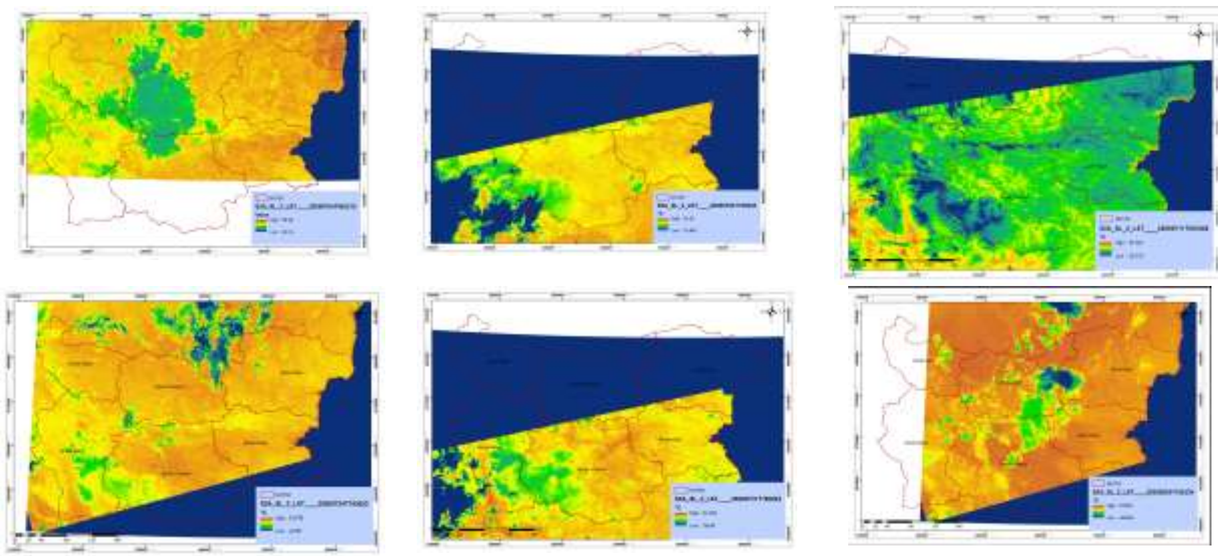


Figure 5 Land Surface Temperature (LST), Sentinel-3, July 2020

Spectrometer data

The field spectral surveys were performed using a spectrometer in the visible range (Sekonic Spectrometer C-800), a full-spectrum color meter that can accurately measure any type of light[15]. The data from the spectrometer is with the following parameters[15]: Color temperature, CCT (Correlated Color Temperature), Δuv (Deviation) between the correlated color temperature and the place of emission of the black body, Hue (in degrees), Sat – Saturation is the index to express the intensity or chroma. Using these data, a study of the color characteristics of the objects was conducted. For each spectral reflectance characteristic (SRC), the color characteristics (color coordinates (x, y) and dominant wavelength) in the spectral range 380-780 nm were calculated relative to CIE 1931 and a standard source of electromagnetic radiation[16].

Thermal camera data

A FLIR thermal camera was used. The thermal sensor has a resolution of 160 × 120 (19,200 points), a temperature measurement range of -20°C to 400°C and accuracy ±3°C or 5% of reading, Thermal sensitivity <0.15 °C, Lens surround angle 55 ° × 43 °, Minimum resolution 0.15 m. On November 11, field research was done and thermal imaging was done.

Open data

Orthophoto images

Orthophotos are digital aerial images that have been adjusted for lens distortion, topographic relief and camera tilt. Due to the specific digital processing they are metrically more accurate than common aerial photographs. Orthophotos are very valuable as reference information and also, for instance, for surveying parcels. They were partially renewed through the years, as the period for renewal of the entire territory of Bulgaria is 3 years. The orthophotos are produced on the basis of digital images processing, which are captured by specific airplane cameras and satellite cameras (2022). Ground Sampling Distance (GSD) is 40 cm[17] (fig.6).

Figure 6 District of Varna, Orthophoto image 2022[17]

CORINE Land Cover 2018

Corine Land Cover 2018 (CLC2018) is one of the Corine Land Cover (CLC) datasets produced within the frame the Copernicus Land Monitoring Service referring to land cover / land use status of year 2018 (fig. 7).
CLC service has a long-time heritage (formerly known as "CORINE Land Cover Programme"), coordinated by the European Environment Agency (EEA). It provides consistent and thematically detailed information on land cover and land cover changes across Europe[18].

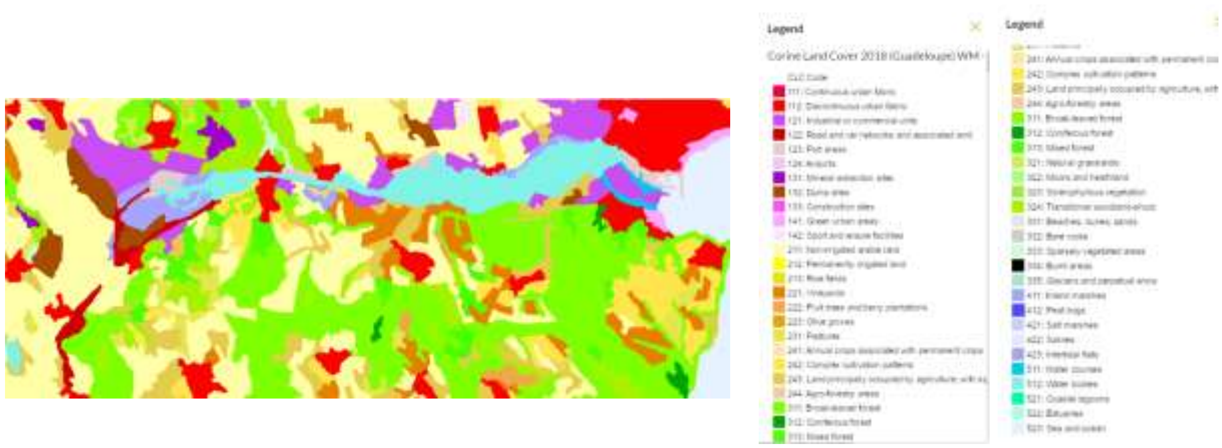


Figure 7 Corine Land Cover 2018 Copernicus[19]

Open data

Open data from the nearest monitoring stations of the Executive Environment Agency in Bulgaria were used. The data are from the System for informing the population about the quality of atmospheric air[20,21] (fig.8) and from the Open Data Portal in Bulgaria[22].

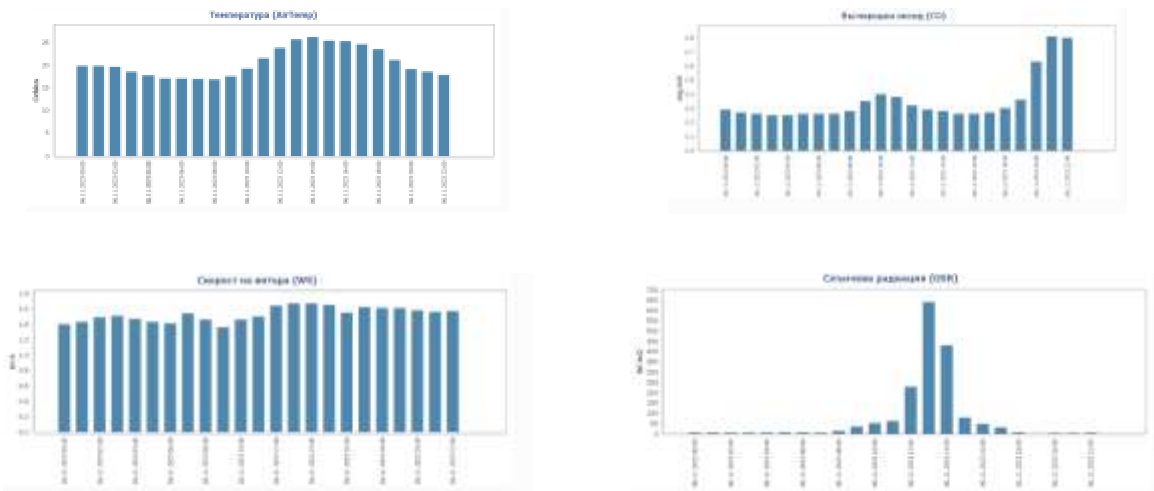


Figure 8 Reference for "Varna - AIS Chaika" station[21]

This area of Varna is part of the monitoring network of the EC in connection with the implementation of radiological monitoring of the environment. The data from the performed radiological monitoring are reported annually to the EC and are collected in a pan-European database - REM (Radiological Monitoring of the Environment) [23]. They are published in the Annual Report on the levels of radioactivity in the environment of the countries of the European Community (fig.9a, b).
Station number BG0019 Varna (fig.9b) is located on the area of interest, which is important due to the presence of former uranium mining deposits.

a b

Figure 9 a) Radiological Monitoring of the Environment in Europe[23], b) Station Varna BG0019

Data processing of satellite images

Multiband composite images were created by combining the available 13 bands for Sentinel 2 satellite images and Landsat-8 and Landsat -9. These images were essential for subsequent analysis and processing, as they allowed for the extraction of indices values. Thus, the territory of Varna city, Asparuhovo district, Southern industrial zone is visualized and suitable for further processing.

Index classification

Index classification from satellite images was applied for analyzing the spectral characteristics of satellite imagery, with the aim of identifying and mapping certain features or properties on the Earth's surface. This involves the calculation of various spectral indices, which are derived from the reflectance values of different bands of the satellite imagery. These indices were used to highlight specific features, such as vegetation density, water content, soil moisture, which can be used for various applications, including environmental monitoring. Index classification from satellite images can be performed using various software tools and techniques, including remote sensing software, machine learning algorithms, and image processing techniques. For the purposes of this research, the following indices were used (table 2):

Table 2 Calculation formulas and description of the optical indices used in the study

Index	Formula	References
NDVI Normalized Difference Vegetation Index	$\frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$	Rouse et al. (1973)[24] NDVI is the most widely used spectral index for vegetation monitoring and evaluation of the photosynthetic activity. NDVI is strongly correlated with climate variations and can serve as an effective measure of climate-related vegetation changes
TCT Tasseled cap transformation Kauth-Thomas Transformation	Brightness, Greenness, Wetness	Kauth and Thomas (1976)[25]; Crist and Cicone (1984)[26]
NDGI Normalized Differential Greenness Index	$NDGI = \frac{GR_n(t_2) - GR_n(t_1)}{\lvert GR_n(t_2)\rvert + \lvert GR_n(t_1)\rvert}$	Nedkov (2017)[27]; NDGI estimates slight positive and negative changes in the vegetation green mass for a given period. NDGI ranges from +1 to −1, as NDGI < 0 indicates a negative change, and NDGI > 0 indicates a positive change.

The model for orthogonalization of satellite images proposed by Kauth and Thomas[25] is a very effective method for interpretation, classification and analysis of phenomena and processes related to the dynamics of the main components of the earth's surface – soil, vegetation and water. This type of transformation is called Tasseled Cap Transformation (TCT). The method used for linear spectral transformation in multidimensional space to reduce the correlation between its individual elements using three components – soil, vegetation and humidity – was also used to assess the state of the ecosystem[28] before and after an event. TCT is related to the change of the coordinate axes in the spectral space from the original ones in three uncorrelated directions, preserving their orthogonality – Brightness (TCB), Greenness (TCG) and Wetness (TCW) [28, 29].

Unlike standard indices that use simple arithmetic equations for their calculation, NDGI is based on TCT applied to images containing all 13 bands of Sentinel-2 imagery[30].

3 RESULTS

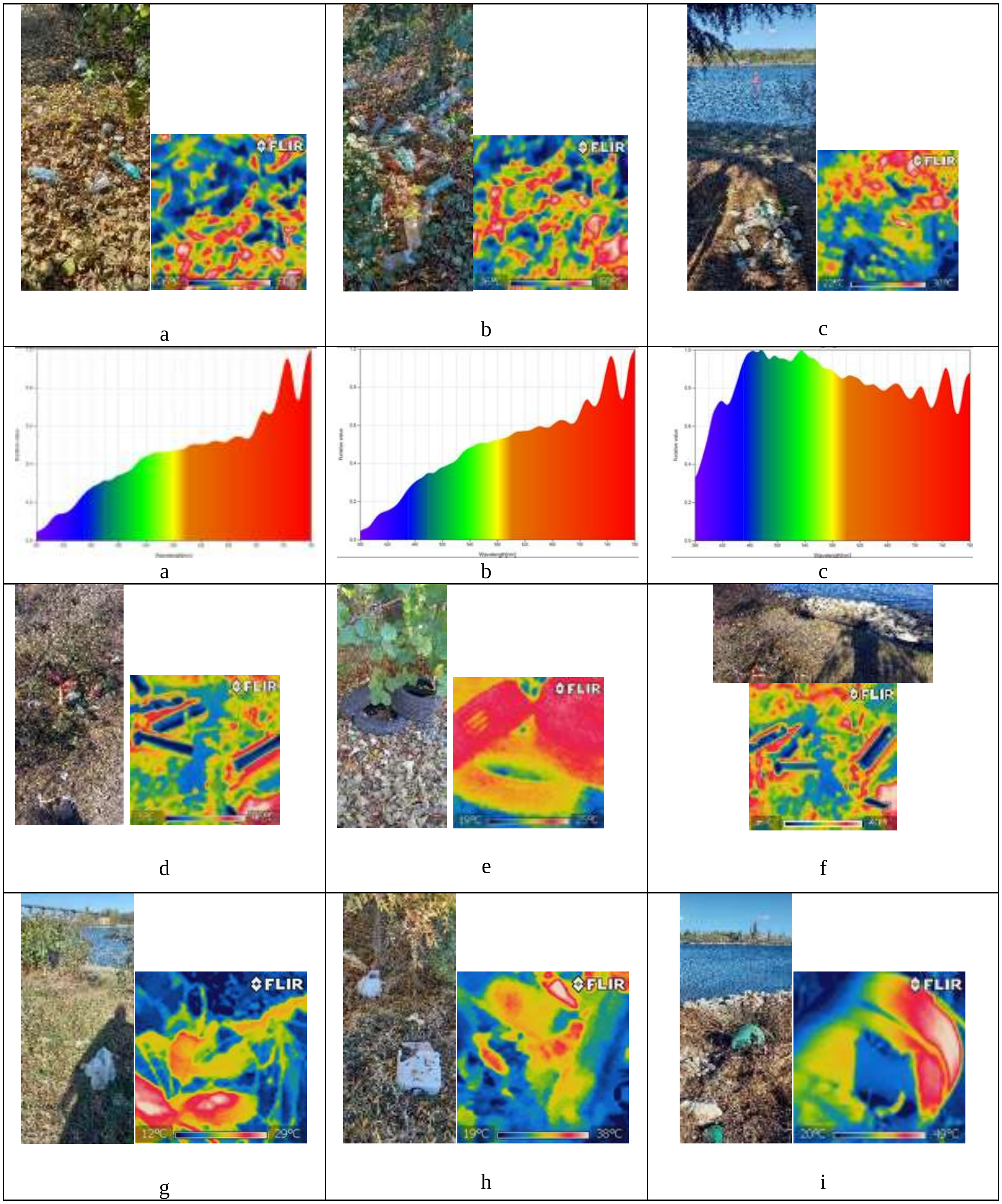
The selected satellite scenes were taken during the summer season, when the vegetation in the area is well represented and there is a presence of high temperatures, as evidenced by the Sentinel -3 SLTRS data (fig. 5).

From the thermal camera images, it is found that even in November, high thermal reflections are recorded, which can be confirmed by the high values of the published open temperature data at the station "Varna - AIS Chaika"

Values from a thermal camera of objects such as plastic and bottles reach up to 50 degrees (fig. 10 a, b), values from a plastic bag and a car tire (fig. 10 g) are about 29 degrees and from plastic containers (fig. 10h, i) from 38 to 49 degrees.

In general, unregulated dumping is scattered all along the coast, showing that even small fractions have high values measured.

Values measured by a mobile spectrometer confirm high values of color temperature. The spectral curves in the visible range from 380 to 780 are fully comparable to data from the Sentinel and Landsat satellites. Last but not least, the spatial resolution is in cm. Given that the objects of interest are scattered and not large in size, it is difficult to recognize the junk. Even if they are visible, they fall within no more than one pixel of the satellite images (fig.11).



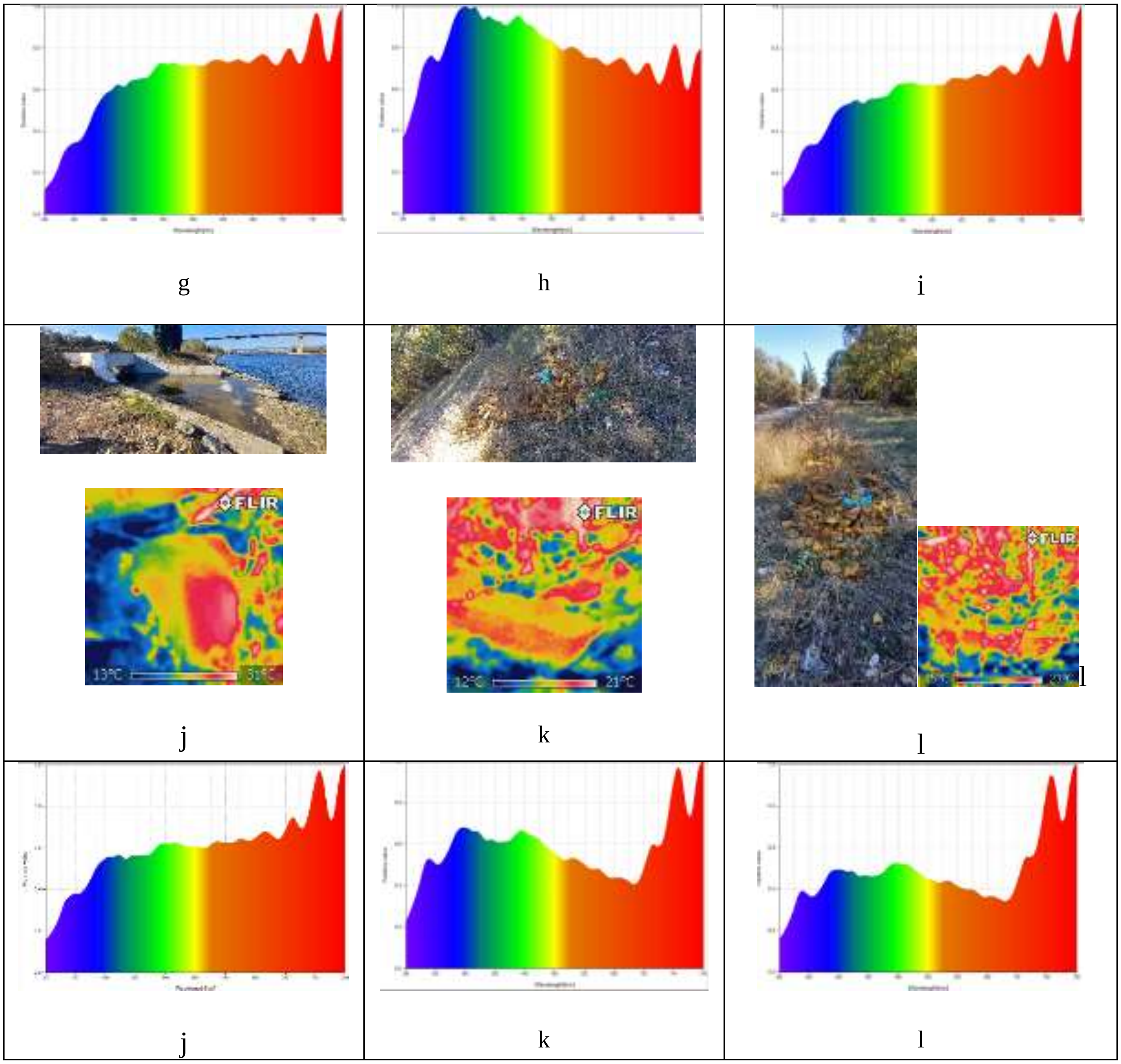


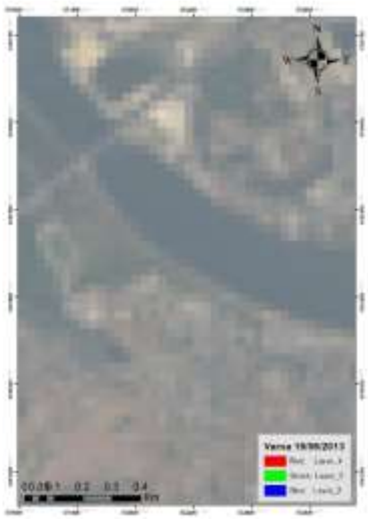
Figure 10 Images of the area of interest, thermal images and spectral curves of the objects by mobile spectrometer , 06/11/2023

The satellite data have a sufficiently large temporal and spatial resolution to track the dynamics in the territories around Varna. For the 10-year database, it would be difficult to summarize the data for the area of interest, due to the fact that the Asparuhov Bridge falls into the so-called critical infrastructure. When we have such sites, they are covered with a mask (fig 11). It is clearly seen that from 2020 the mask covers the coast as well. This makes it difficult to monitor the areas we are interested in.

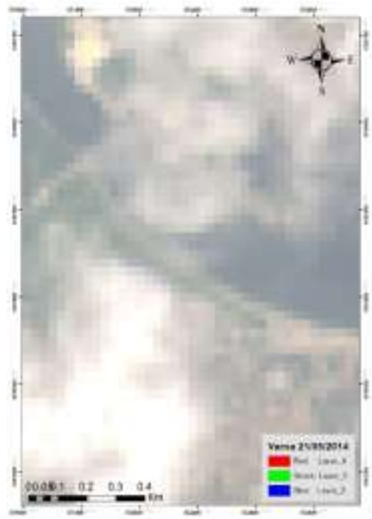
On the other hand, through the sufficient information available from Corine, the presence of dumps in several places along the canal before and after the Asparuhov Bridge has been mapped (fig. 7).

For the area, there is the availability of high value data, such as the Environmental Executive Agency's monitoring stations for radiological control, a monitoring station that monitors air quality and temperature. (fig. 9a, b).

Meanwhile, the use of Orthophoto (2022) is an option that could be used in validating the territories, as it has a resolution of 40 cm (fig. 6). Of course, it should be known that the Orthophoto image could verify these data. The bad thing is that it is filmed every 3 years in Bulgaria.



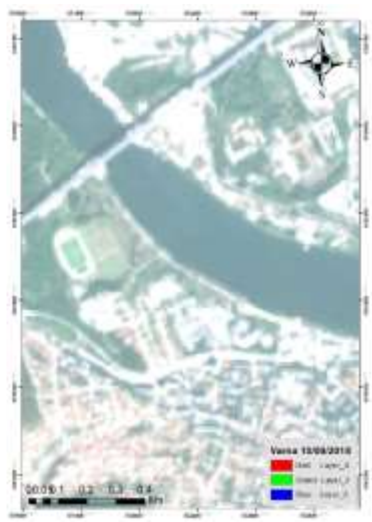
19/06/2013, Landsat 8



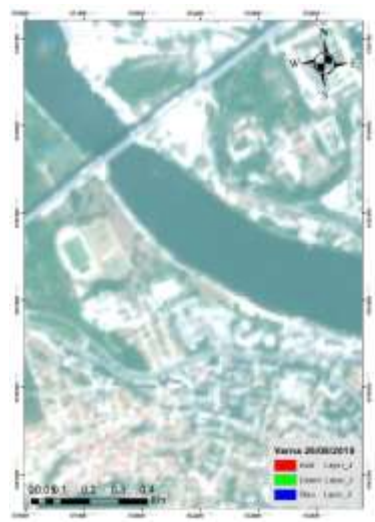
21/05/2014, Landsat 8

16/08/2016, Sentinel 2

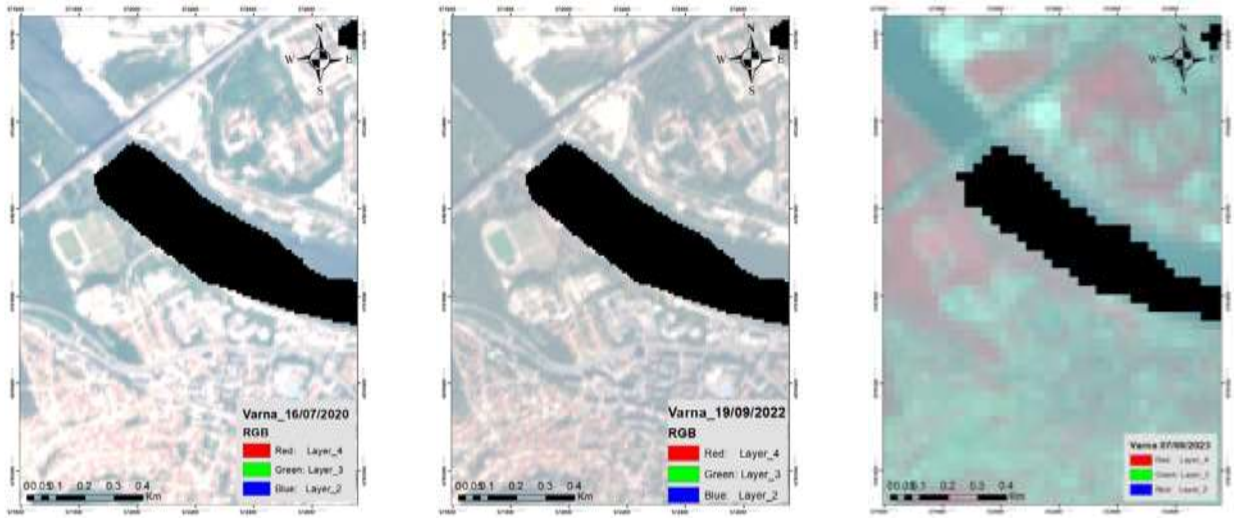
10/09/2017, Sentinel 2



10/09/2018, Sentinel 2



26/08/2019, Landsat 9

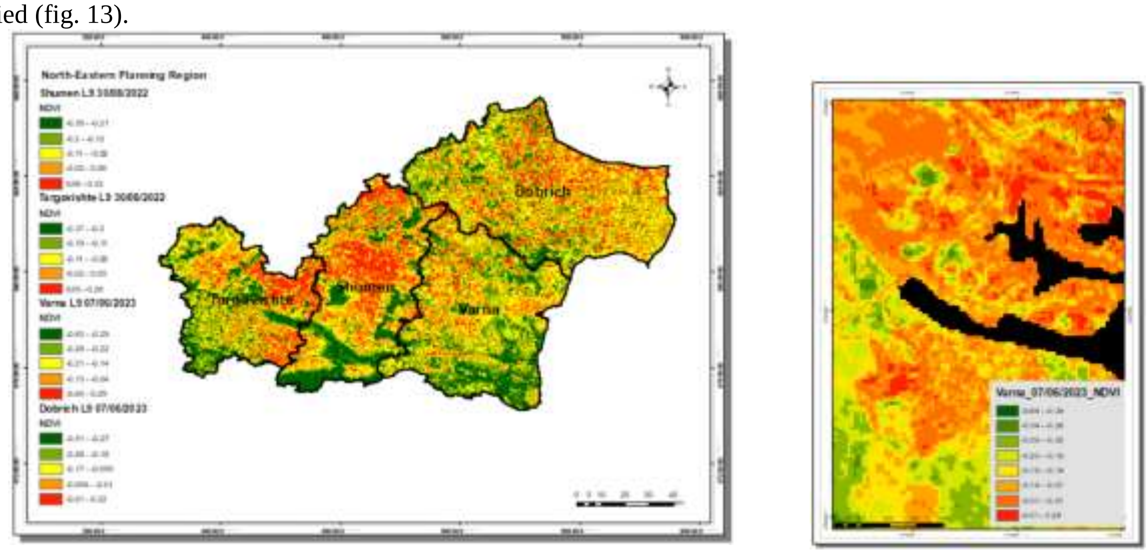


16/07/2020, Sentinel 2 | 19/09/2022, Sentinel 2 | 07/06/2023, Landsat 9

Figure 11 Optical images (2013 – 2023), Landsat 9 OLI-2/TIRS-2 and Sentinel 2MSI

Varna region is characterized by lower positive NDVI values compared to the other 3 regions of the economic region (fig. 12a). When analyzing the negative values of the index, the highest values were measured for Varna, reaching -0.65, which may indicate areas with little vegetation or potentially degraded lands.

The area of interest shows high NDVI values in 2023(fig. 12 b). The same is observed in 2020 and 2022, which were also studied (fig. 13).



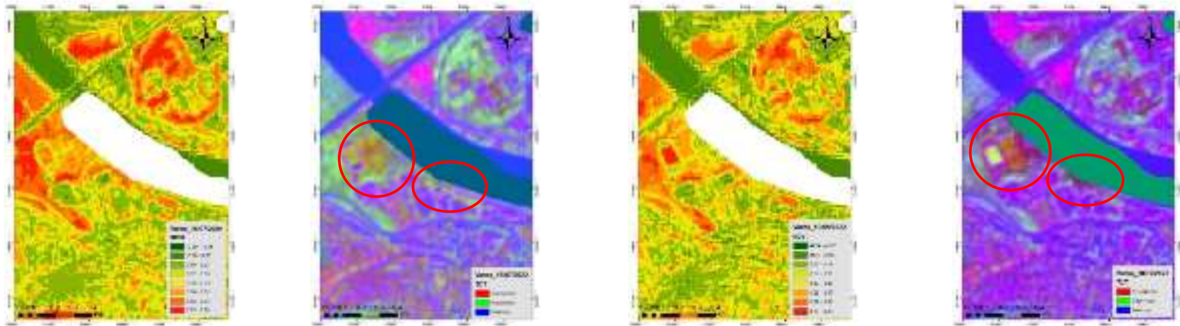
a | b

Figure 12 Mosaic of NDVI images, Landsat 9 OLI-2/TIRS-2, 07/06/2023; 30/08/2022;a)North-East region b)Varna

Significant changes are observed in the NDVI and TCT right in the area of interest for the two years selected for presentation (fig. 13).

The NDGI data provided a clear representation of vegetation greenness trends for the entire Varna District (fig. 14a) as well as for the specific area of interest (fig. 14b). This comprehensive approach demonstrates the spatial and temporal variability in vegetation health and cover within the region.

This comprehensive approach demonstrates the spatial and temporal variability in vegetation health and cover within the region. The notable changes in NDVI and other vegetation indices over the analyzed period emphasize the need for continuous monitoring to understand the underlying causes, which may include climatic factors, land use changes, and anthropogenic activities. The integration of high resolution satellite data, ground-based monitoring stations, and periodic Orthophoto imagery can significantly enhance the accuracy and effectiveness of environmental monitoring and management strategies in the Varna region.

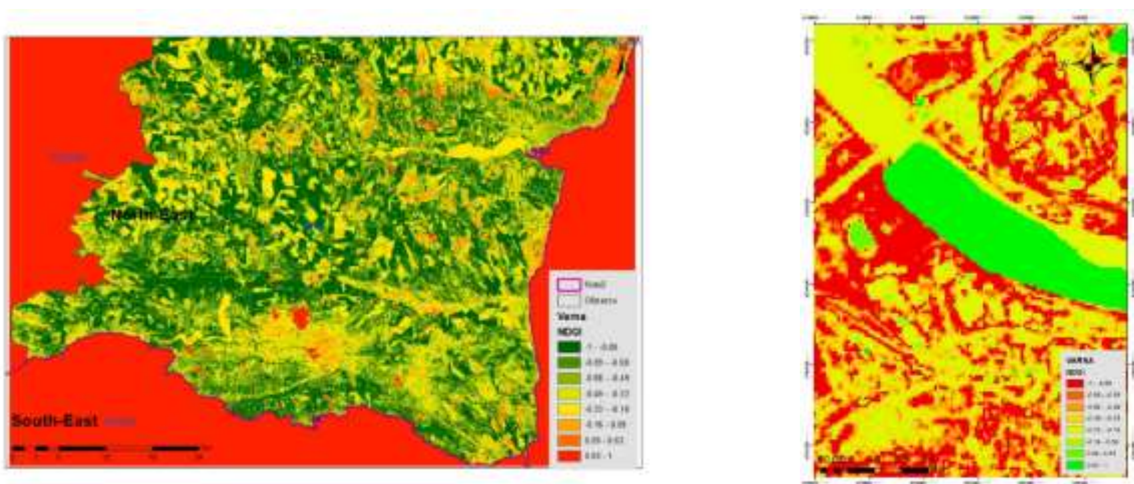


NDVI 16/07/2020 TCT 16/07/2020 NDVI 19/09/2022 TCT 19/09/2022

Figure 13 NDVI and TCT, Area of interest, Sentinel 2MS

NDGI is made from the two TCT images used which are 16/07/2020 and 19/09/2022. The changes for the whole area are with positive values (fig. 14 a) and not so big changes in the area of interest (fig. 14 b) are very clearly visible, excluding the water channel on which a mask was previously applied by the Copernicus programme.

In figure 14a, which covers the entire region characterized by positive NDGI values are prominently visible. These changes indicate areas experiencing varying degrees of vegetation greenness over the analyzed period. Conversely, figure 14b focuses specifically on the area of interest. Here, although changes in NDGI values are observed, they appear less pronounced compared to the broader region depicted in figure 14a. This suggests relative stability or minor fluctuations in vegetation greenness within the specific area under scrutiny. It is important to note that the water channel, previously masked by the Copernicus programme, remains evident as an exclusion in both figures. This masking ensures that only valid land areas are included in the analysis, thereby enhancing the accuracy of vegetation monitoring assessments. Overall, the application of NDGI facilitates is a detailed examination of vegetation dynamics, highlighting spatial and temporal variations in vegetation health and greenness across the study area. These findings contribute to a deeper understanding of environmental changes and can inform decision-making processes related to land management and conservation.

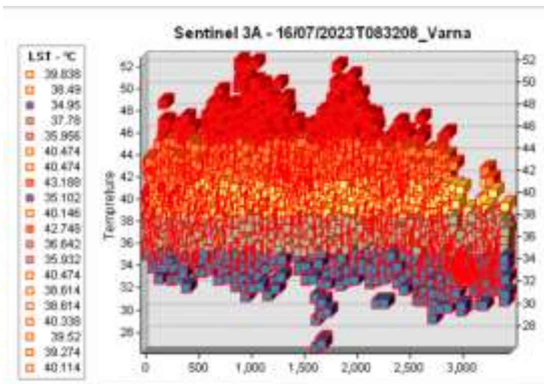


a b

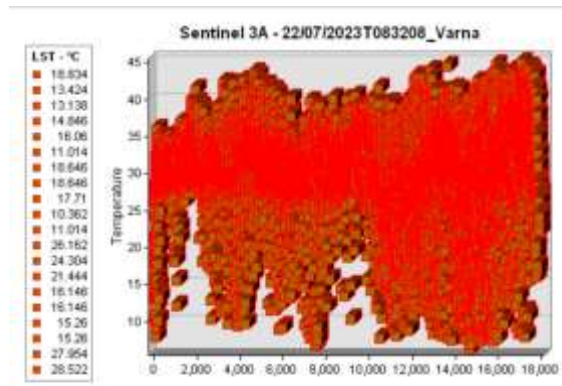
Figure 14 Normalized Differential Greenness Index (NDGI), a) District Varna b) Area of interest, Sentinel 2MSI

LST shows change even within two weeks (fig.15). A serious temperature amplitude was noticed on 22/07/2023, when there are values from 15 degrees to 45 degrees (fig 15b).

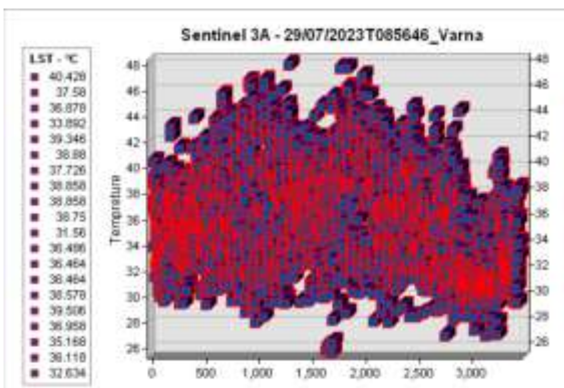
The LST distribution data for the North - East region (fig. 15d) show approximately the same distribution. Like this one from 22/07/2023. Individual values up to 15 degrees are observed. Average values are around 40 degrees.
The fact is that it is because of the high temperatures in the Varna region and the entire North - East region that a heat island is forming. The high values are not only from the daytime LST temperatures, but also from the evening images where the reflectance from the objects is even much higher (fig. 15d).
This dual effect emphasizes the impact of local environmental conditions on temperature dynamics and underscores the need for effective urban heat island mitigation strategies in the region.



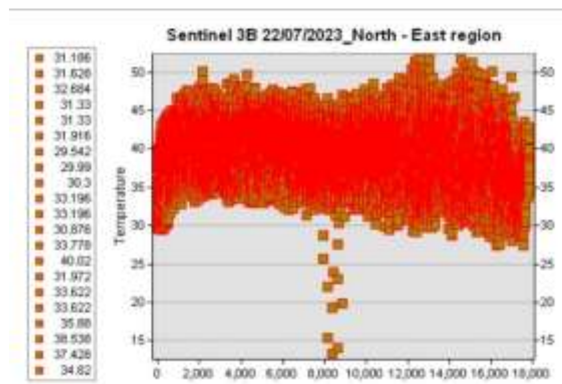
a



b



c



d

Figure 15 Distribution of LST (°C), District Varna and Nort - East Planning region of Bulgaria

5. CONCLUSION

Based on the analyzed data, it can be concluded that during the summer season, high temperatures significantly influence the thermal reflectance of various waste materials along the coastline. Even in the autumn month of November, thermal reflectance remain high, highlighting the necessity for proper waste management and control of unregulated dumping. These high temperature from waste materials emphasize the environmental impact and the urgent need for effective waste management strategies.
Landsat and Sentinel data are also sufficient to analyze the areas around the landfill. There is enough LST data that gives a clear idea of the climate changes in the Varna region and the entire North-East region. The area around the canal falls in one of the country's heat islands, which is an important factor in the accumulation of landfills (unregulated or regulated).
The selected satellite scenes were taken during the summer season, when the vegetation in the area is well represented and there is a presence of high temperatures, as evidenced by the Sentinel -3 SLTRS data (fig. 5). The morning LST data used for at least a 5-year period in July show highs reaching over 52 degrees. A cumulative effect from different anthropogenic activities is observed. The area is industrial and mapped with landfills according to data from Corine Land cover 2018, a thanks to open data it has been analyzed in detail. Unfortunately, the images right in the area of the landfill cannot be used after 2016 because a mask was made on an infrastructure object (fig. 11). Without in situ data, this sprawling illegal landfill

could not be traced in detail. From the optical indices used, it can be seen that according to NDGI there are no significant changes in the area except in the water, but this is not the case because a mask has been made there and it's colored green (fig. 14b).

As a data validator, the Orthophoto image can be used due to its high resolution of 40 cm, although it's taken 3 years ago. Values from a mobile spectrometer can be matched with satellite data in the visible range for objects such as nylon, plastic and building materials. The same can be confirmed for the data from the thermal camera, because it has already been proven in a previous study that the differences in the temperatures of the thermal camera and LST are about 1-2 degrees during the day[31].

These integrated data validation approaches enhance the robustness of environmental monitoring and assessment efforts, providing insights into material composition and thermal dynamics critical for informed decision-making and policy formulation.

The insights gained from this study can inform targeted interventions aimed at promoting sustainable land use and mitigating environmental degradation.

The data generated helped create a registry and its use by various stakeholders.

ACKNOWLEDGEMENTS

This work was supported by the Bulgarian Ministry of Education and Science under the National Research Programme „Young scientists and postdoctoral students -2" approved by DCM 206 / 07.04.2022.

REFERENCES

[1] https://consulthub.bg/pniidit

[2] https://www.ekonovini.bg/bg/karta-na-nezakonnite-smetishta-v-balgariya/

[3] https://www.varna24.bg/novini/varna/Zapochvat-proverki-za-nezakonni-smetishta-vuv-Varnensko-i-Dobrichko-1585921

[4] https://www.varna.bg/bg/1310

[5] https://varna.news/nyakolko-nezakonni-smetishta-razkriti-kraj-asparuhovo/

[6] https://www.oe.org/environment/plastics/Policy-Highlights-Cost-and-financing-for-a-future-free-from-plastic-leakage.pdf?utm_source=Adestra&utm_medium=email

[7] https://bg.wikipedia.org/wiki/%D0%A1%D0%B5%D0%B2%D0%B5%D1%80%D0%BE%D0%B8%D0%B7%D1%82%D0%BE%D1%87%D0%B5%D0%BD_%D1%80%D0%B0%D0%B9%D0%BE%D0%BD_%D0%B7%D0%B0_%D0%BF%D0%BB%D0%B0%D0cd%BD%D0%B8%D1%80%D0%B0%D0%BD%D0%B5

[8] https://www.varna24.bg/novini/varna/Pravyat-novo-smetishte-pod-Asparuhov-most-781022

[9] Kaplan G., U. and Avdan U., "Mapping and monitoring wetlands using Sentinel – 2 imagery, ISPRS Annals ofthe Photogrammetry," Remote Sensing and Spatial Information Sciences 4 (4) W4 (2017).[2] Important Bird Areas – Straldja Complex (2023).

[10] https://scihub.copernicus.eu

[11] Ivanova I., Stankova N., Borisova D.,Spasova T. and Dancheva A., "Dynamics and development of Alepumarsh for the period 2013-2020 based on satellite data," Proc. SPIE 11863, 1186315 (2021) doi:10.1117/12.2597726

[12] Dimitrova, M., Gochev, D., and Trenchev, P., "A Comparison of the Reflective Characteristics of Basic Objects,Obtained from the Data from the TM, ETM+, OLI and SENTINEL-2," Proceedings SES2016, 199-208 (2017)

[13] https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-3slstr/overview/geophysicalmeasurements/land-surface-temperature

[14] https://step.esa.int/main/download/snap-download

[15] https://sekonic.com/

[16] Temenuzhka Spasova, Daniela Avetisyan; Synchronized Remote sensing monitoring approach in the Livingstone island region of antarctica, RSCY 2023, Ayia Napa - Cyprus., CYPRUS, APRIL, 2023

[17] https://inspire.egov.bg/en

[18] .https://sdi.eea.europa.eu/catalogue/copernicus/api/records/71c95a07-e296-44fc-b22b-415f42acfdf0?language=all

[19] https://land.copernicus.eu/en/map-viewer?dataset=0407d497d3c44bcd93ce8fd5bf78596a

[20] https://eea.government.bg/kav/reports/air/qReport/189/01#

[21] https://eea.government.bg/kav/reports/air/qReport/325/01#param-data
[22] https://data.egov.bg/
[23] https://remap.jrc.ec.europa.eu/Advanced.aspx
[24] Rouse, J. W., R. H. Haas, J. A. Schell, and D. W. Deering (1973). Monitoring vegetation systems in the Great Plains with ERTS, Third ERTS Symposium, NASA SP-351 I, 309-317
[25] Kauth, R. J., Thomas, G. S. (1976). The Tasselled cap - A graphic description of the spectral-temporal development of agricultural crops as seen by Landsat. Proceedings of the Symposium on Machine Processing of Remotely Sensed Data, West Lafayette, Indiana, U.S.A, 29 June-1 July 1976, 41–51
[26] Crist E., Cicone R., 1984: A physicaly-based transformation of Thematic Mapper data – the TM Tasseled Cap. IEEE Transactions on Geoscience and Remote Sensing, 22, 256 – 263. doi: http://dx.doi.org/10.1109/TGRS.1984.350619.
[27] Nedkov, R., "Normalized differential greenness index for vegetation dynamics assessment," Comptes Rendus L'acad'emie Bulg.Des Sci., 70, 1143–1146, (2017)
[28] Stankova, N., Post-fire recovery monitoring using remote sensing: A review. Aerospace Research in Bulgaria, 35, 2023, 192-200; https://doi.org/10.3897/arb.v35.e19
[29] Stankova, N., Assessment of post-fire ecological impacts using remote sensing methods: a review, Ecological engineering and environmental protection, 3-4, 2023, 44-51.
[30] Avetisyan, D., & Spasova, T. (2023). Copernicus data utilization for polar research and monitoring purposes. Proceedings of 3rd National Workshop with International Participation Under the EU Copernicus Programme, 28–38. https://doi.org/10.5281/zenodo.10438977
[31] Temenuzhka Spasova, Adlin Dancheva, Daniela Avetisyan, Iva Ivanova, Iliyan Popov, and Boris Shirov "Monitoring of renewable energy sources with remote sensing, open data, and field data in Bulgaria", Proc. SPIE 12733, Image and Signal Processing for Remote Sensing XXIX, 1273311 (19 October 2023); https://doi.org/10.1117/12.2680495