Neural network model for monitoring of landfills using remote sensing data

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***Abstract*—The stockpiling and retention of waste is an actual problem for Ukraine today. Count of illegal dumps increases every day because many landfills are full. Special services of waste monitoring provide only partial information about the current state of waste dumps all over the country. They can't analyse landfills' size information and their changes over time. Authors create an efficient algorithm for waste monitoring that uses historical and actual satellite data. It provides information about the current area of landfills and makes it possible to analyse changes in landfills over time. The authors found success resolving the main problem of separating landfills from a quarry and artificial objects. This solution is based on mixed using pixel-based and object-based classification.**

***Index Terms*—machine learning, neural network, data science, landfills, satellite data, geospatial maps, vegetation indices, validation**

I. Introduction

Actual satellite information of every point for Earth land cover is available due to the Copernicus program. It was started in the 2016 year and allows using satellite data of the European Space Agency. These satellite images have a spatial resolution of 10 meters and provide ample opportunity for scientists and researchers to investigate and resolve many actual problems and tasks. Ukraine has a list of problems that connect with waste. The major of them is stockpiling, waste disposal, and creating many illegal dumps. Pollution of huge areas and land degradation is the result of these problems. Therefore, providing waste monitoring and detecting illegal dumps are crucial steps in resolving these issues in separate amalgamated territorial communities and Ukraine overall. Exploration of landfills and waste dumps in the Donetsk region was the main objective of this study. The authors created a map of landfills classification and information tool for analysing changes over time in landfills for four amalgamated territorial communities in the Donetsk region under this project.

II. Research methods

Different technologies that use satellite information and artificial intelligence approach are used for landfill monitoring. We have analyzed several works [1] – [4] and can say that all methods have cons and pros. Pixel-based methods have positive results in detecting artificial objects but aren't so good in separating landfills from a quarry or sand. Object-based methods use spectral information and identify some parts of cities as landfills because they have similar spectral indicators. The main problem of our investigation was separating landfills from artificial objects. We resolved this challenge by using a mixed approach for classification that implies using pixel-based [5] and object-based methods [6] in tandem. In that

way, we achieved better accuracy for the waste dumps class identification. Also were used methods of statistical analysis, comparison method, and summarization.

III. Process and Results

A. In-situ and satellite-based datasets creation for landfills classification

After analyzing east territories in the Donetsk region, we defined several amalgamated territorial communities that may have enough landfills for investigation and place near each other. They are Olhinska amalgamated territorial community (11 villages and urban-type settlements), Mirnohradska (4 municipal councils), Kurahivska (7 municipal councils), Pokrovska (10 municipal councils). Data about existing landfills in selected areas we received from open sources and consists of 82 objects (Figures 1-2). We added more objects on the map for analyzing spectral characteristics and defining headline items for the landfills class. They are artificial objects, agricultural areas, woods, fields, water, quarries, and swamps.

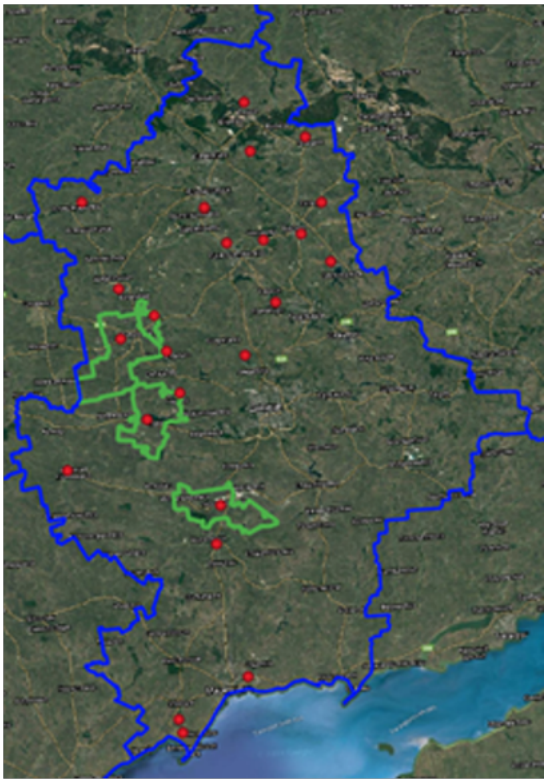

Fig. 1. Open data of landfills location in the Donetsk region

All Sentinel images we download using an open platform Copernicus Open Access Hub (https://scihub.copernicus.eu/) and processed by Sentinel Application Platform (SNAP).

SNAP is an open-source product of the European Space Agency (ESA) [7]. Processing of satellite data was done in automation mode. So, we download input data in SNAP and receive output data that are ready for classification. Processing of satellite data was done in automation mode. So, we download input data in SNAP and receive output data that are ready for classification.

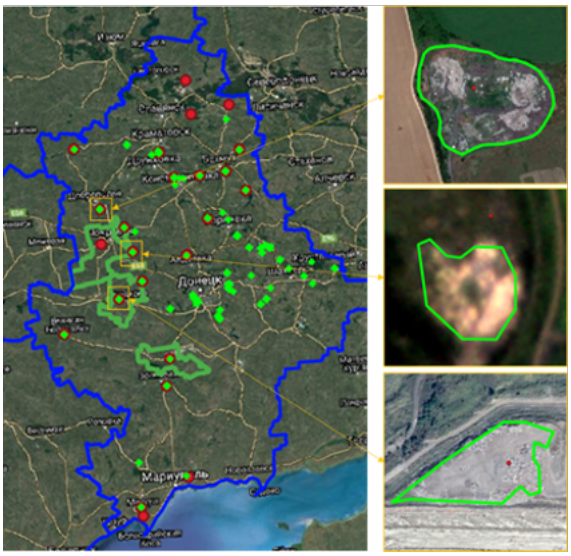

Fig. 2. Creation data set for testing and studying of the network for landfills identification

A lot of vegetation indexes were calculated for better separating different classes of land cover and landfills [8]. They are included different thematical groups such as vegetation, water, and soil. We analyzed the calculation results of 19 indexes in different studying sets for various classification classes. After that, we removed all indexes which provide non-harmonized and invisible spectral relationships, because they are a cause of mixed classification. As a result, we identified 3 thematical indexes and included them as additional levels of landfills classification. They are NDVI, SAVI, NDWI2. We discovered that additional layers based on these indexes can improve classification accuracy. We can get information about thermal channels from satellite data. Methods that are based on such information are widely used for the identification and monitoring of dumps. It is because exists a suggestion that the temperature of landfill areas is higher than other types of land cover. Using temperature data Land Surface Temperature (LST) was investigated in this studying. This information was received from data of satellite Landsat-8. We used channels B10, B4, and B5 for the calculation of the NDVI index. Results of the investigation show that the temperature of landfills is similar to the temperature of artificial objects. But also, it was found that fields, particularly plow fields, have a higher temperature than dumps.

The separation of artificial objects (buildings, roads, etc.) from landfills is a more complicated task than the separation of agricultural areas. So, we can use this index as additional data during the studying of our neural network. However, it should be noted, that if we used data with a high spatial resolution, for example, Planet (spatial resolution 3 meters), using information about temperature can add additional inaccuracy with a spatial resolution of 30 meters.

After comparing, we can say, that using data with higher spatial resolution, for example, Sentinel-2 (spatial resolution 10 meters) with Planet (spatial resolution 3 meters), Google digital substrate (spatial resolution 0,4 meters) allows us to improve classification accuracy.

But using Google digital substrate isn't a good idea because we often don't know if this data were created on a specified date.

B. Developing of artificial intelligence model using neural network based on landfills data

To deliver classification map we used two approaches: pixel-based [9] and object-based classification [10]. After providing of analysis, we see that all methods have cons and pros. Examples of classification results are shown in Figure 3. The pixel-based method has a high accuracy of classification for main classes of land cover (artificial objects, water, wood, soil, and others). But often, landfills are included in the class of open soils (sand, quarries). It is because the spectral characteristics of these objects are similar. We used the U-Net segmentation model as an object-based method. The accuracy of this method for landfills recognition isn't so good because misrecognition of artificial objects. So, we try to use a mixed approach that consisted of the association of output results from different methods according to probability for each class. Classification in our method is based on time series of satellite data. We use the merge method on the level of making decisions and consider the posterior probability of identity for each pixel to a certain class. We use vectorization for obtained a raster map of landfills using the open-source library GDAL. Therefore, the final output has a vector format and is used for publishing results.

C. Validation and visualization of obtained results

Validation of land cover classification map was done for calculation of the accuracy of obtained landfills locations in the Donetsk region. Confusion matrix and several metrics (overall accuracy, kappa coefficient, producer accuracy, user accuracy) were used for comparison of results from different classification methods and map filtration for land cover.

Our interpretation of land cover classification maps we based on a few guesses:

- Reference data is statistically authentic (for example, test set for calculation of the accuracy of classification map);
- Reference data accurately correlates with map (geo-referenced, projection);
- Every pixel of the map is well-defined and corresponds to one of the real land cover classes;
- If the period between performing classification and obtaining reference data is long, we suggest that land cover didn't change during this period.

As a testing result, we obtained the next general accuracy for landfills class: F1-score = 86% with Kappa coefficient = 0.91.

Also, our results were approved by residents of selected areas. New two locations with landfills were found in Olhinska amalgamated territorial community and one unknown location was found in Pokrovska amalgamated territorial community.

D. Developing of software web-interface and posting geospatial program for landfills monitoring

The dashboard was created and based on obtained maps for four amalgamated territorial communities in the Donetsk region. Administrative borders and landfills maps dated 27.07.2021 and 15.09.2021 were used for the creation of the user's information panel. These programs allow analyzing changes in landfills over time. Data with different spatial resolutions were used for investigation. Open-source data Sentinel-2 has 10 meters spatial resolution and paid data Planet with 3 meters spatial resolution. Also, we provided images for all amalgamated territorial communities and calculated the square for all identified landfills. All products are shown on an interactive map from Google for users. Also, it included information about the project, contributors, and developers. Figure 4.

The dashboard is located by link http://inform.ikd.kiev.ua/ldms/ and is open-source for use.

IV. Conclusions

Landfill maps were developed and this data was used for the creation information dashboard for four amalgamated territorial communities in the Donetsk region. All needed information, such as administrative borders and landfills maps is dated 27.07.2021 and 15.09.2021. Was created landfill identification method with high accuracy and this information can help to analyze changes in landfills over time. As a result of our study, we can say that idea of using mixed methods can improve the accuracy of landfill identification methods.

V. Acknowledgment

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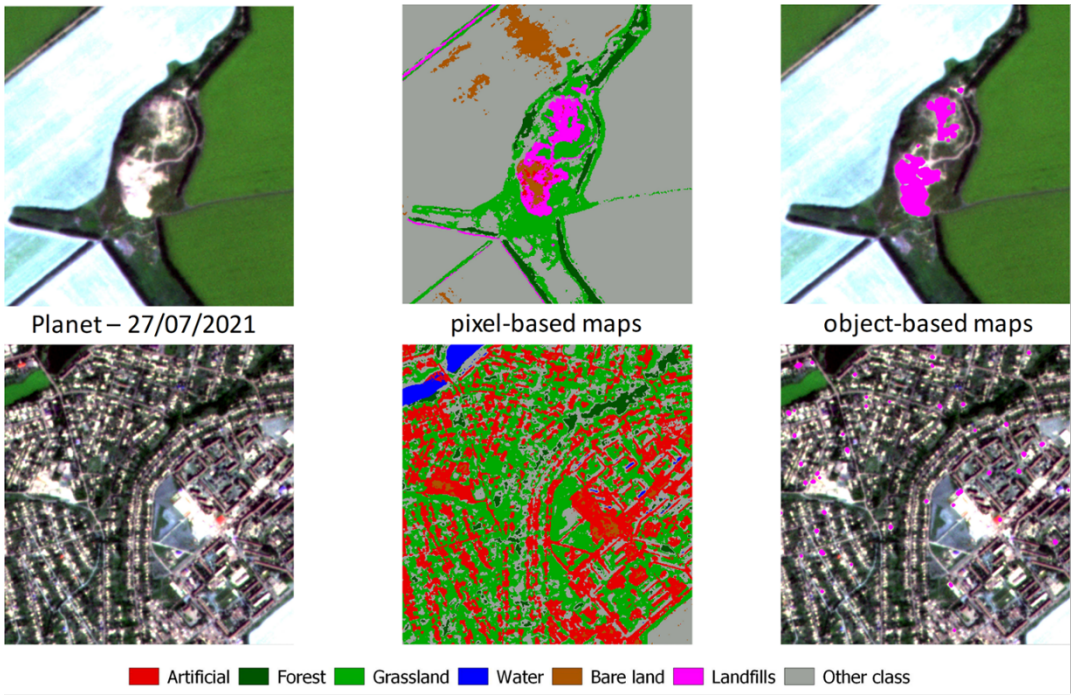

Fig. 3. Results of pixel-based and object-based classification

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