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Sentinel-3 Urban Heat Island Monitoring and analysis for Kyiv Based on Vector Data

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***Abstract*— Satellite data is one of the best sources of information to monitor and analyze the city state and the impact of urbanization on environmental aspects such as soil, water, land, and air pollution within the city. Urban Heath Island (UHI) is a zone in the city with the highest land surface temperature. These zones have a negative impact on the inhabitants comfort, ecological and energetic essential variables. One of the most common ways of detecting and analyzing thermal islands is based on the use of evening and night surface images and the difference in surface temperature in urban areas and adjacent areas. The research in this work is being primed using land surface classification maps, satellite LST products Sentinel-3 and the population density of Global Human Settlement Layer. Kyiv was chosen as study area and for this city urban heat island temperature dependence on building density, tree density and population density were analyzed.**

Keywords*— *Sentinel-3, Land Surface Temperature, Urban Heat Island, Urban Atlas, Global Human Settlement Layer, Land Cover Map

I. INTRODUCTION

High building density and low vegetation in the city are the source of many problems. The term Urban Heath Island [1] was introduced, and determinate as zones in a city with a high land surface temperature. UHI's creates discomfort for the inhabitants of the city during the day and night of the day, decreasing water, air and soils quality. If we consider the problem from the perspective of the Nexus approach, then urban development has a negative impact on all three components of the ecosystem Food-Water-Energy [2,3].

Satellite data is the best source of information for land surface temperature monitoring. Satellite missions make it possible to accurately calculate land surface temperature, and to investigate it in the time series. For the Landsat mission, satellite monitoring data that includes the thermal channel exists since 1978. In 2016, a new mission of the European Space Agency for monitoring the terrain surface of the Sentinel-3 began. Satellites of Sentinel-3 family in some parts of the world revisit one and the same point of the surface 2 times a day (in the morning and in the evening). Also, these satellites contain thermal channels that make it possible to calculate land surface temperature using split-winds algorithm [4,5]. To monitor such a phenomenon as UHI's, the evening land surface temperature is a very important source of information. At this time, they can best be recognized, because these objects are the most heated in the day and emit the most thermal energy at night.

EPA-Planet SMURBS project [6] implement innovative technologies based on use of satellite data to monitor and analyze Smart Cities. The city of Kyiv is one of the project's pilots. The main tasks of the project are the use of satellite data in city growth, city planning and disaster monitoring. UHI [7,8] is a bad sign that it is necessary to introduce planning changes in certain zones, for example, greening the territory or artificially lowering the temperature with other means. The Sentinel-3 mission does not allow possibility to analyze a large time series of data, but has great prospects for the future, which should be used already for achieving sustainable development goals.

As essential parameters for which analysis and relevance was conducted were global population dataset Global Human Settlement Layer [9,10], land cover map [11-13] for Kyiv city and Sentinel-3 land surface temperature product [14].

The main goal for use this satellite data is development of Smart City infrastructure for urbanization, city growth and city state monitoring. In this reason, four main characteristics are defined: land cover map, population density map and land surface temperature maps. Positive and negative changes in this urbanization characteristics can show sustainable zones and problem areas in which city planning must be changed.

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II. STUDY AREA MATERALS

Study area for this work is Kyiv city , the capital of Ukraine. The area of the city is 847.6 square kilometers and 2 millions 949 thousands of population. This city was chosen because the SMURBS project should become a pilot city for which the developed services will be implemented.

As land surface temperature information data source was chosen Sentinel-3 L2 Land Surface Temperature product with sensing date 27 august 2018 year and sensing time 17.38. Product provided by ESA in pre-operational mode and built using split-window algorithm based on atmosphere parameters and NDVI. This data have 1 km spatial resolution. Average Sentinel-3 LST product size equal 65 MB.

As population information for Kyiv was chosen Global Human Settlement Layer available in 250 meters spatial resolution for 2015 year. This dataset was built by European Commission and depicts the distribution and density of population, expressed as the number of people per cell (Fig.1)

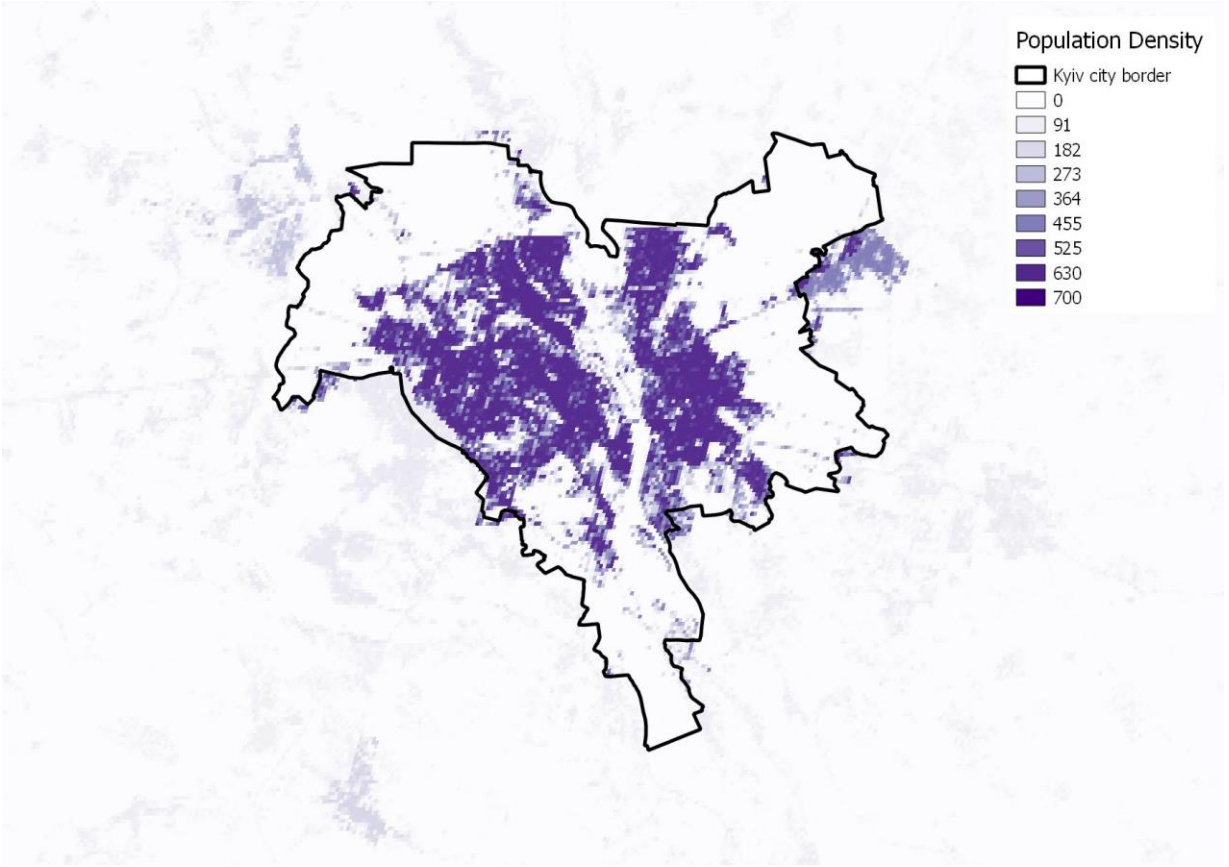

Fig. 1 Kyiv city population Global Human Settlement Layer

Land cover classification map built using time series of Sentinel-1 and Sentinel-2 images with 10 meters spatial resolution. Kyiv Space Research Institute will produce this maps for Kyiv Smart city ones for year.

To conduct geospatial analysis of this characteristics with different spatial resolution and meaning it is important to use high quality city's segmentation vector layer. For European city's to solve this problem usually use Copernicus Urban Atlas [18], but for city's with population less than 100000 of people or not European city's don't have their own Urban Atlas.. Using this vector layer it is possible to produce deep city analysis within fusion of geospatial data with different spatial, temporal resolution and meaning.

III. KYIV CITY URBAN HEAT ISLAND ANALYSIS

To estimate UHI it is necessary to select reference points which are close to the city but which do not have built area. To do this, was used land cover classification map. In general for this purpose can be used any relevant city's land cover map, the most relevant open data is ESA CCILC, for our research we used our own classification map. There were 20 points selected based on this criterion: the points are on the pixel LST in which there is no or the minimum number of artificial objects, the selected pixel should not be related to a class of water objects, the pixel should be adjacent to the pixel with high density of development. After that, on the basis of all these points, the average temperature is calculated. This is the average temperature of the zones adjacent to the city without urban areas. The next step is to calculate the difference between the temperature of land surface on image and the average temperature of the land surface adjacent to the city. The result

is shown on figure 2. It is very easy to see that urban area have very high land surface temperature if compare with adjacent areas. This image shows Kyiv Urban Heat Island with high LST zones.

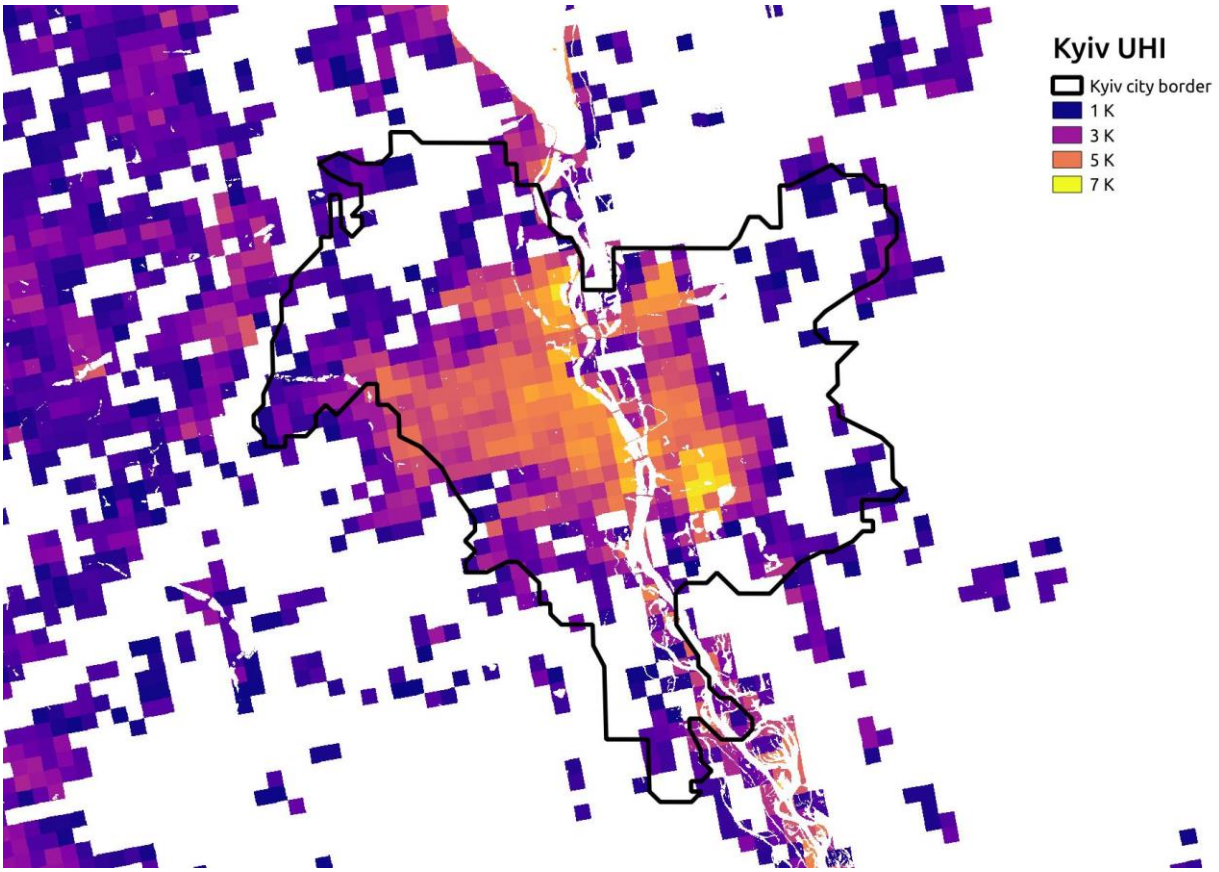

Fig. 2 Kyiv city Urban Heat Island

City land cover classification map built on Sentinel-1 and Sentinel-2 data using neural network classification approach developed in Space Research Institute SAU-NASU [15-17] and provide bigger accuracy then global land cover products that can be used for this task.

In order to carry out a qualitative analysis of the obtained geospatial results, it is necessary to switch from raster to vector form, for this purpose the task is to segment the city into rather homogeneous zones with respect to the type of land use. For European cities, such analysis can be carried out with the help of Copernicus Land Monitor Services Urban Atlas [18], but this service does not apply to Ukrainian cities. The solution to this problem is the formation of a vector layer based on open data. We developed new methodology for Urban Atlas building using open access satellite data of Sentinel mission and Open Street Map. First using Sentinel-1 and Sentinl-2 satellite images within supervised neural network classification approach was built land cover classification map. After this using Opens Street map infrastructure layers area with similar land use, building density, tree density and similar building features were joined in separate polygons.

Using this approach, formatting vector segmentation of the city and zonal statistics on satellite products by vectors give a greater opportunity to analyze and visualize data than raster approaches.

The result this approach use shown on figure 3. With this method of segmentation of the city and the calculation of zonal statistics using geospatial raster and vector layers, it is possible to create products necessary for the analysis of the city. The first useful product is the Urban Atlas vector layer with a built area density for the city. It gives an opportunity to evaluate urbanization and its growth, to identify zones with very dense buildings and to make smart urban planning.

The second product is the density of green areas based on the Urban Atlas and classification map. This product helps to identify zones with insufficient greening and monitor the state of green plantations in time. On the basis of this product, it is also possible to provide city planning and first of all, city's greenery planning. This is a serious problem for Kyiv, because there is a clear shortage of green plantations in the central part and in some residential areas, which leads to an increase in the temperature of the earth's surface and the formation of thermal islands.

Using this tool it is possible also better explore the UHI of Kyiv and identify the most critical areas. Having constructed a vector map of UHI (fig. 4) it is immediately visible in which areas of the city it is necessary to perform redevelopment and landscaping. The maximum average differential temperature between the LST of the city and the LST of the adjacent areas may reach 7 Kelvin degree for this image. This is a very significant difference.

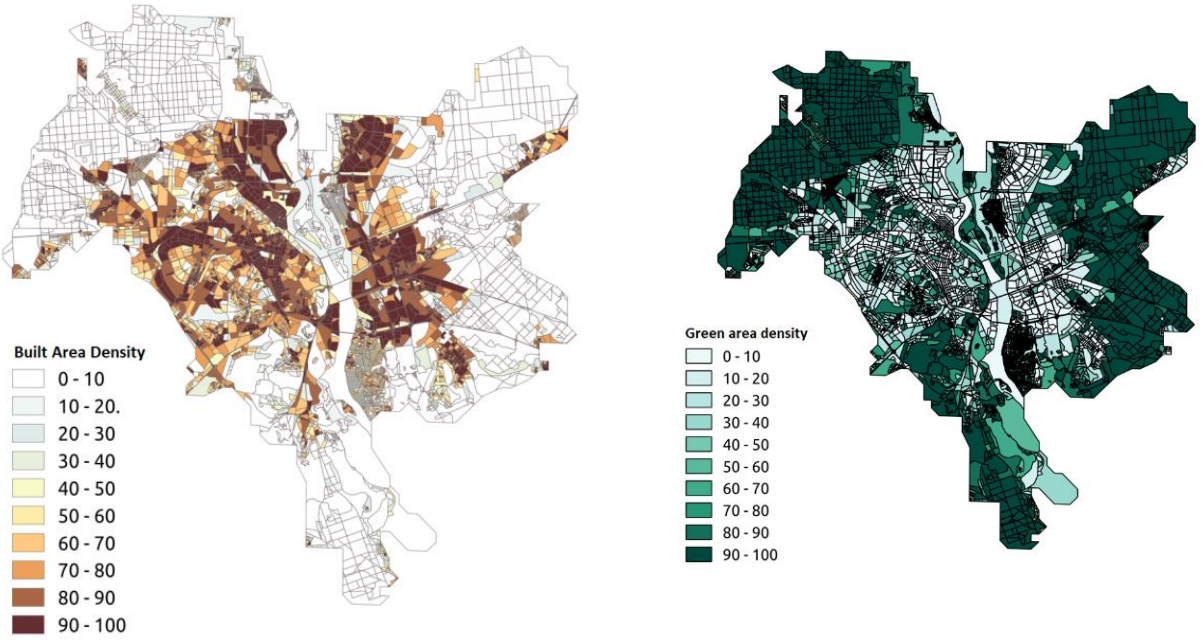

Fig. 3 Kyiv city Urban Atlas with built area density and Green area density

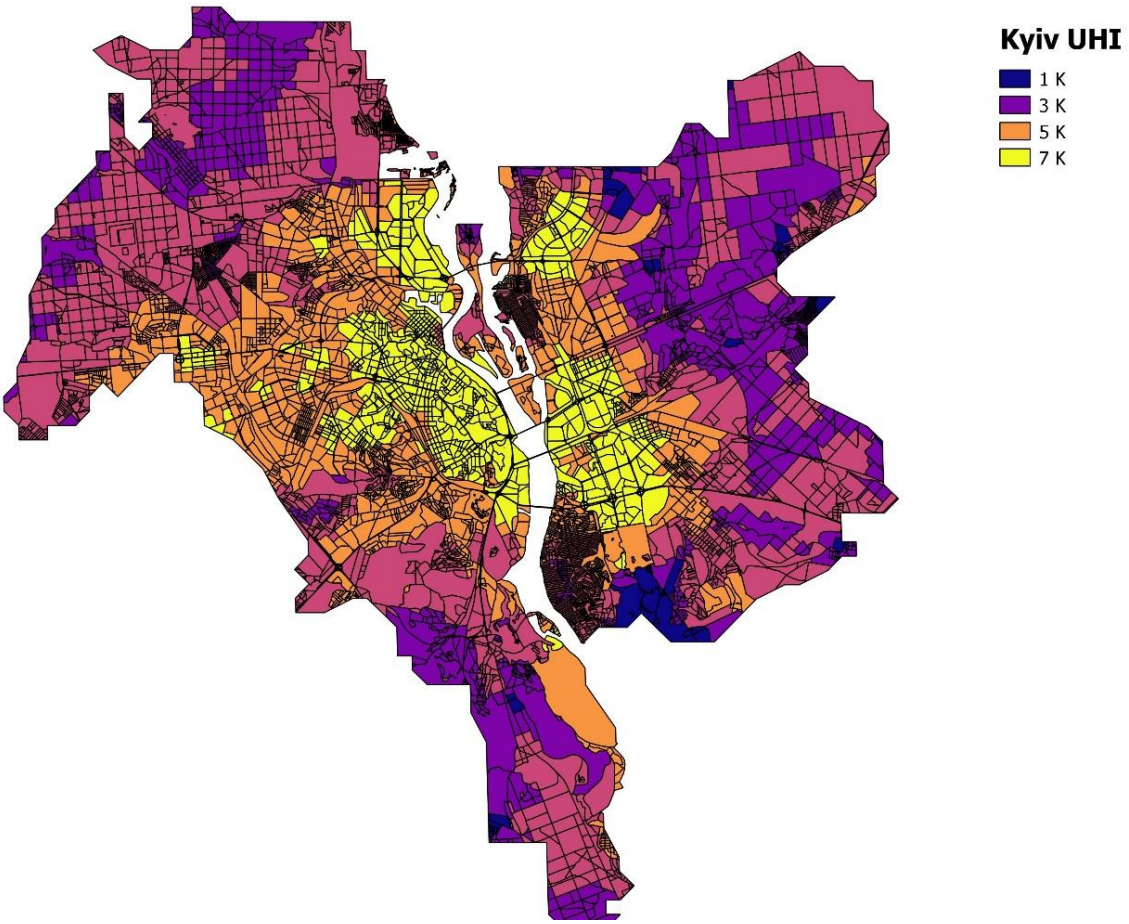

Fig. 4 Kyiv city Urban Heat Island vectorized using Urban Atlas

The correlation analysis as and visual analysis shows big correlation between UHI's temperature and built, built area density and population density for Urban Atlas polygons. In physical aspect built up area absorb more sun radiation and heat more than area covered by vegetation, it explain high land surface temperature in area with high building density. Heated built up area have less cooling from evaporation and plant transpiration if compare with other land cover zones. That why we can easily definite Urban Heat Island using evening and night images, on which vegetation is already cooled while urban area radiate heat energy. The third relation is relation between population density and building density. In Ukraine we have a lot of urban areas with high building density but low population density, so this correlation is not so strong, but usually areas with high population density have high building density.

IV. Conclusion

The UHI problem is serious and for its solution is a necessary tool that can detect and analyze their cells. Satellite data makes it possible to solve this problem. The data of the satellite Sentinel-3 in spite of the distinction of 1 km is applicable in the needs of a smart city. It provides the opportunity to monitor and analyze UHI. The vector layers of the city are also an important geospatial analysis tool. Copernicus Land Monitor Service provides access to the Urban Atlas service for European cities. For cities that do not have the Urban Atlas, you can use the construction methodology developed in the SMURBS Era-Planets project and use it to conduct geospatial analysis.

This research shows how Sentinel-3 data and other geospatial products can be used within Urban Atlas vector data to provide deep geospatial city's analysis in terms of land use and land surface temperature. This products and technologies can be effectively used for Smart city monitoring and urbanization monitoring in order to achieve Sustainable Development Goals and Sustainable City's.

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