

**PRESENTATION OF ONE OF THE RESULTS RELATED TO RISK
PREVENTION UNDER THE EUROPEAN PROJECT —“HARMONIA”
(HARMONIA -№ 101003517) UNDER THE EU PROGRAMME – “HORIZON
2020”**

**PROJECT TITLE "HARMONIA" - Development of a Support System for
Improved Resilience and Sustainable Urban areas to cope with Climate
Change and Extreme Events based on GEOSS and Advanced Modelling
Tools (Building a low-carbon, climate resilient future: climate action in
support of the Paris Agreement)**

**PRESENTATION OF A DEVELOPED APPLICATION – MONITORING OF TRENDS TOWARDS CHANGES IN THE
NORMATIVE INDICATORS FOR GREEN AREAS IN FUNCTIONAL URBAN ZONES, BASED ON REMOTE EARTH
SENSING (EO)**

As mentioned in the “NEWS” and “PROJECTS” sections, AURE-ECOREGIONI and the MUNICIPALITY OF THE CAPITAL CITY – DIRECTORATE “EMERGENCY ASSISTANCE AND PREVENTION” – are partners in the “HARMONY” project, bringing together 22 partners led by POLITECNICO DI MILANO (POLIMI). Its results include a list of innovative solutions integrated into Decision Support Systems (DSS). Designed to improve urban resilience and risk management, HARMONY’s innovative solutions and the advanced tools of the Integrated Risk Assessment Platform (IRAP) aim to help cities like Sofia better prepare for and respond to natural hazards. In a series of publications, AURE-ECOREGIONI intends to present some of the project’s results that are directly relevant to sustainable urban management, as well as emerging risks.

In this short publication, we present an analysis of trends in changes in the indicators of the state of the green system, for the urban “functional zones”, according to the Sofia Municipality’s Master Plan.

A practical tool has been developed for rapid assessment of trends in the percentage of potentially open and designated for greening areas in the so-called “functional zones” (FZ), defined as elements of urban planning, as well as for signaling potential discrepancies, using remote sensing and regularly updated geo-data sets. The satellite-based analysis should allow a quick overview of the area in the city where potential problems with the prescribed percentage of green areas can be expected. The results should be cross-checked with field data and discussed with experts from the city administration to ensure a correct interpretation and possible explanation of the observed trends, as well as to identify possible gaps. The approach is based on the [Verification by Monitoring \(CbM\)](#) concept developed by the Joint Research Centre of the European Commission and uses products from the [Copernicus Earth Monitoring Service \(CLMS\)](#) developed by the European Environment Agency.

The basis of the analyses carried out is as follows:

- The normative indicators for the mandatory minimum percentage of free areas for landscaping, inherent in the so-called “functional zones”, under the General Development Plan (GDP) of Sofia Municipality were used as a starting point; in accordance with the mandatory indicators, under the ZTA and in accordance with REGULATION No. 7 of December 22, 2003, on rules and norms for the development of individual types of territories and development zones, upgraded in 2015, 2020, and 2022. As recorded in the web portal <https://sofiaplan.bg/portfolio/oup-sofia/> - the current GDP was approved in 2007 and was upgraded and supplemented with regard to the green system and transport with the amendment of 2009. There have also been a number of subsequent partial amendments. Therefore, we assume that there may be changes in the published data.
- To analyze trends in the state of the green system and the indicators of the functional areas of the OUP, specific indices extracted from data from the SENTINEL constellation, more precisely the SENTINEL-2 optical satellites provided under the European COPERNICUS Program, were used. To assess the trends, data from 2017

to 2023 were analyzed. Since the optical data from SENTINEL-2 used have a resolution of 10 m, the analyses are based on generalized statistical indicators and take into account the correspondence of free areas/green cover within the individual “functional areas” of the OUP. The approach uses vegetation and phenological indices to detect potential trends – increase or decrease – in the change in the percentage of potentially undeveloped and green areas within the individual functional area. A comparison was also made with the observed percentage of green areas for 2023 with the one prescribed by regulation (minimum threshold). It is one of the main sustainability indicators used in the approved functional areas under the Sofia Municipality's Master Plan.

- The analytical data is in tabular format, with statistics on open/green areas for all functional areas under the Master Plan, and for each of the observed years. Maps have also been prepared to visualize the results of the trends in the change in the percentage of open and green areas.

The results of the analysis for the Sofia Master Plan are visualized on the map below.

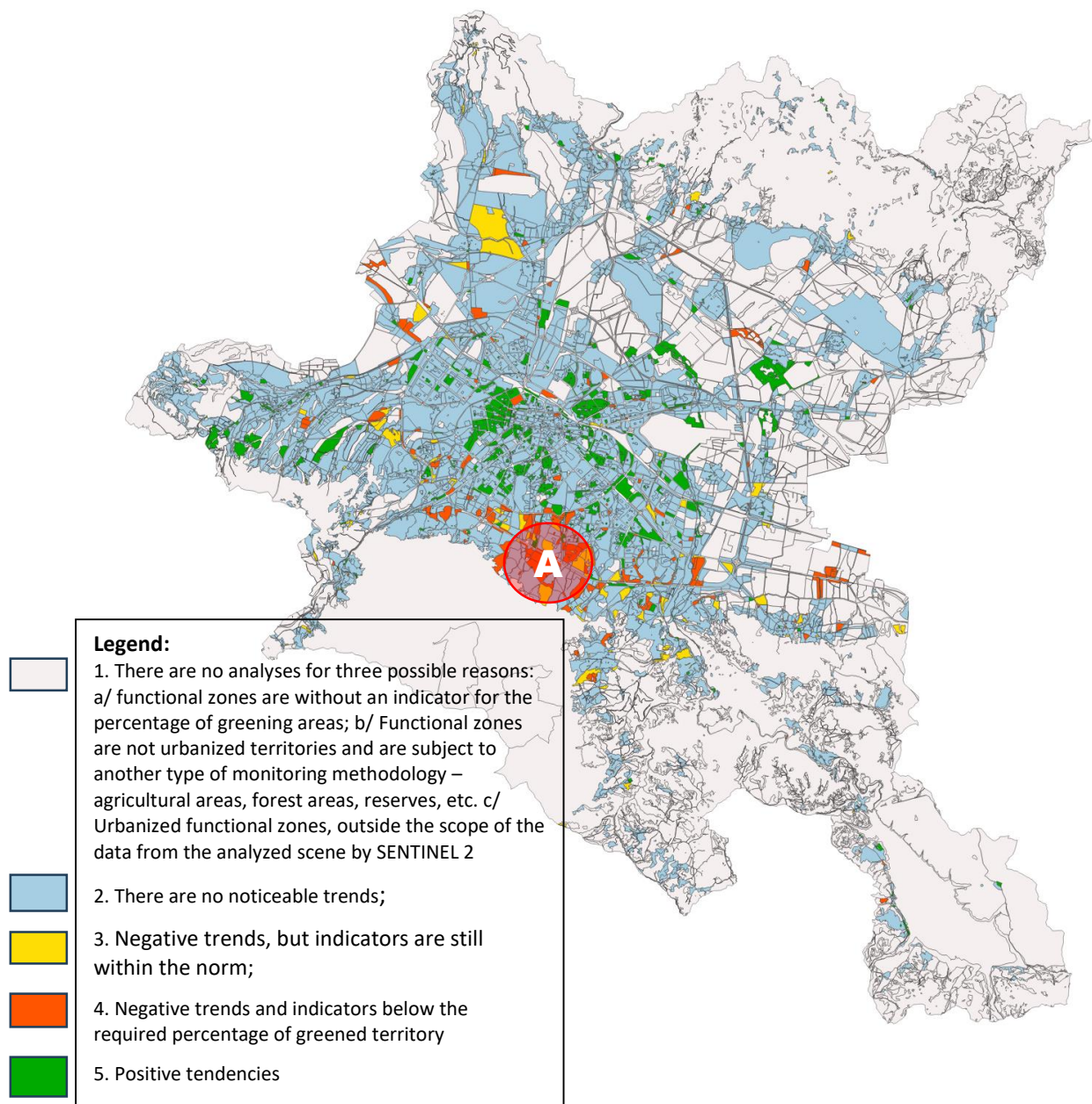


Fig. 1. Map of assessment of changes in the green space index in the urbanized functional zones under the 2019 Master Plan, for the period 2017-2023. Agricultural areas and natural environment (forests) are not included in the analysis.

Some general indicators:

Table 1. Statistics of the results obtained for the trends in the index of mandatory percentages of green spaces for urban "functional areas":

Categories	Number functional zones in the category	Average area in hectares of the functional zones in the category
Functional zones with negative tendency, over the minimum threshold (code 1)	162	8.62
Functional zones with negative tendency, under the minimum threshold (code 2)	285	5.91
Functional zones with positive tendency of the percentage green areas (code 3)	651	4.44
Functional zones without changes of the index for green areas (code 4)	4901	7.15

It was also made a quality assessment according to the following principle methodology:

- Division of functional areas into separate groups by type of assessment result (Code 1, 2, 3 and 4);
- Analysis of each group separately (based on a representative sample):
 - o Performing a quick review to detect functional areas with potentially erroneous results ("candidates"). Visual comparison of images only between Sentinel-2 time series is used.
 - o Performing a detailed visual assessment using historical images from Google Earth Engine. Confirming or rejecting the "candidates" from the quick scan.

The achieved accuracy is expressed by the F-score parameter and is 0.9.

Below are examples of the visual assessment:



Maps Data: Google © 2025 CNES/Astrium, Maxar Technologies, Airbus, Landsat/Copernicus

Fig. 2. Quality assessment. Left: Visual analysis of Sentinel-2 images between 2017 and 2023 with observed visible change in the condition of green areas. Right: Confirmation of the observed change using very high-resolution archival images in Google Earth Engine.



Maps Data: Google © 2025 CNES/Astrium, Maxar Technologies, Airbus, Landsat/Copernicus

Fig. 3. Example of confirmed correct detection of detailed changes in green systems (based on Google Earth Engine)

As a more representative example of the analysis of trends in the index for green areas in functional zones of the urbanized territory of Sofia, below we present a sample of the results for Sofia Municipality. The results were analyzed by the Sentinel-2 satellite constellation, from the observed percentage of potential green areas in functional zones of the type "JM" - "residential zone with low or low-rise development" for the period 2017-2023. Only those functional zones that are defined with a negative trend (Codes 1 and 2 from Table 1 above, and corresponding to the orange and red contours in the picture below) were selected. The study area is the southeastern part of the city of Sofia - **Fig. 4** and the area outlined with a red circle - **A**, from **Fig. 1**.



Fig.4. Trends in the reduction of potential “green areas” in a sample of the Master Plan of the Sofia Municipality – part of the so-called “Southern Arc” of Sofia; **Blue** – ne negative tendencies for the last 7 years; **Orange** – Negative tendencies the last 7 years; **Red** – negative tendencies below the minimum percentage of green areas;

The statistically significant trend of lowering the percentage of potential green areas is clearly visible – **Fig.5**

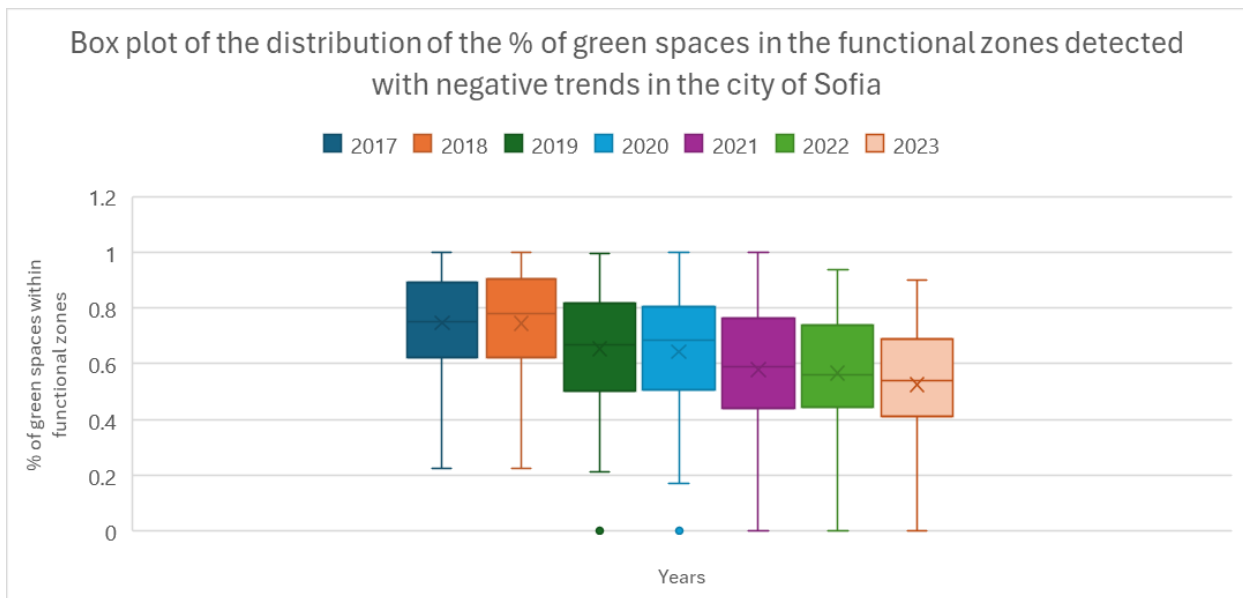


Fig.5. “Box-plot” graph of the distribution of % of green areas in the functional zones, found to have negative trends in the city of Sofia (according to Regulation No. 7 of December 22, 2003)

Conclusions:

- 1. There is a general negative trend in the reduction of the percentage of mandatory green areas, according to the adopted normative indices for landscaping the functional zones of the urbanized territory of Sofia Municipality (Regulation 7, of 2003);**
- 2. The results, at this stage, are preliminary and should be discussed with specialists from Sofia Municipality, the Union of Architects, civil organizations and urbanists who are included in current changes to the Master Plan of Sofia Municipality, in order to discuss and adopt the applied methodology, assessment of the visible changes, based on satellite information, as well as possible explanations;**

It is necessary to make a preliminary reservation that the analyses and the presented results are indicative and are only based on data from the SENTINEL-2 satellite constellation (under the European COPERNICUS Program) and indicators published on the web pages of Sofia Municipality, municipal enterprise SOFIAPLAN - <https://sofiaplan.bg/portfolio/oup-sofia/>. It would be good to hold a discussion with experts from Sofia Municipality - SofiaPlan and to clarify some important issues, such as: changes in the characteristics of certain "functional zones", partial amendments and new parcel plans that have not yet entered into force and have not been published, possible other interpretations of the remote sensing data, etc. Therefore, we consider the results presented above as an opportunity for the citizens and the administration of Sofia Municipality to provoke such a discussion and clarify the presence of negative trends in the management of the green system of the capital.