User-friendly Methodology and Prototype for Operational Deployment of a Satellite-based Monitoring System for EU – for More Resilient Territorial Management with Less Impact on Environment and Climate

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Abstract: The integration of Satellite Data in local Spatial Data Infrastructures (SDIs) and AI-driven analytical solutions is of strategic importance, supporting territorial management and decision making on national, regional, and municipal level. EO Copernicus can be a disruptive source of knowledge to improve territorial and environmental management and delivery of effective public policies and risk prevention services. However, due to the lack of resources and competences at organizational and individual level, as well as low awareness among political decision makers, the uptake of existing satellite data and services is challenging. Their integration in added-value services for local and regional administrations is far from optimal. Complex scientific studies and services exist, but they require high expertise also do not effectively help the widespread use of innovative solutions combating CC and risk prevention. There are gaps to bridge to achieve the vision.

The aim is to develop a user-friendly municipal expert system on risk prevention and strengthening resilience. We propose an in-house developed operational solution, combining so-called Exposure and Loss databases and the SmartCover Databases. It combines three main tools – the description of land cover through Land Cover Meta Language – LCML (ISO 19144-2); local master plans legal nomenclature and associated spatial data (functional zones) – "urban/functional bricks" concept; and satellite-based algorithms for automatic data interpretation, developed by Stalker-KM LTD (upgraded ASDE-ECOREGIONS).

Keywords: risk prevention; AI; EO; in situ; CbM; land cover; land use.

1 Introduction

Our study and solution are based on long user-oriented experience on sustainable and resilient territorial management. Thus, we are trying to integrate the combined EO remote and in-situ monitoring mechanisms, with efficient, objective, legally justified, mandatory, and easy to understand services results. One of the main targets is the application of automatic assessment of data from various sources and risk prevention analysis, using a simplified "traffic light" approach.

The proposed solution may be applied on urban, agricultural and nature territories, covering all main types on Earth environmental coverage. The use of the new world standard ISO 1944-2 allows the application of the monitoring package not only in the EU, but also worldwide.

The paper is a follow-up action of the research work of experts of Stalker-KM LTD, during a period of ten years, extracting best experience from real-life projects, assigned by different municipalities in Bulgaria. The succession work of ASDE-ECOREGIONS has upgraded the developed tools, with exchange of knowledge and high expertise with EC-mainly DG JRC Food Security unit and collaborative territorial monitoring projects, financed by UN-FAO and state administration. One of our major aims is to harmonize and orient towards user needs, the land cover/land use monitoring methods among the countries from the South-East European region.

2 Materials and methods

Because of the conference requirements, our study is limited to the Sofia Municipal urban area. Integrated EO remote data from Sentinel 2 satellite images and in-situ various data from the Sofia Master plan sources are used. On other side our solution is much oriented towards supporting the EU policies, such as the LULUCF" (Milenov et al. 2022). To obtain much better efficiency, accuracy and land cover/land use description, the following main tools are used:

- Land cover/Land use semantic model, using hierarchical manner, using the LCML, based on the principles laid down in the LCCS classification system by UN-FAO (ISO 19144-2:2023).
- Combined remote and in-situ data interpretation, applying COPERNICUS (Sentinel 2) data and services, including the monitoring framework of DG JRC – Change by Monitoring (CbM, Loudjani et al. 2023).
- Risk prevention resilience concept - Combined semi-automatic and (in future) AI-supported algorithm, assessing urban, agricultural or nature units, which are mandatory defined by local state or municipal legal system ("tegon" Devos et al. 2014, "urban bricks" Ordinance No. 7, 2003).

When using Sentinel 2 images for assessing urban areas, a problem is the relatively low spatial resolution – 20 and 10 at the most. Results are not usable at local administrative and business end-user's level. This means that we had to apply another mechanism of efficient data use, different than the traditional one, based on area mapping. Here comes the proposed application of the urban-brick as basic reference element for analysis (Figure 1). The "urban

bricks" are 3-dimensional land cover units, which spatial extent matches with the functional zones, which are units of land with stable and monitorable boundaries, with homogeneous type of land use, as prescribed by the City Master Plan (Figure 2). The main advantage is that with the "urban brick" concept we are not trying to depict the detailed areas occupied of the individual physical objects, but we are assessing the land cover status by derived statistical metrics from the satellite signal at the level of the functional zone, as our reference unit. Another argument in favour of such approach is that the functional zones are legally defined and approved by the local administration and adhere to specific facility and construction rules and regulations, including risk management and change monitoring, established by law in Bulgaria – The Territory Development/Management Law/Act–(ZUT).

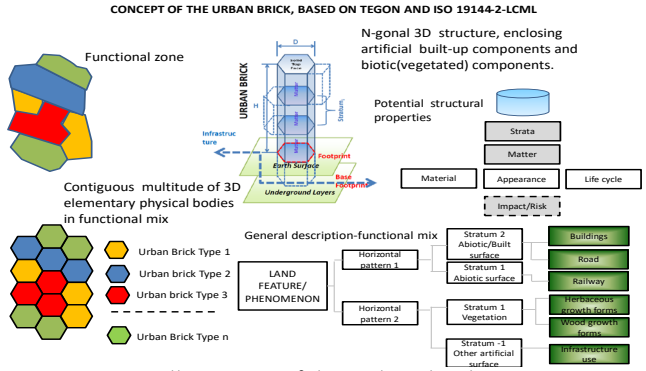

Figure 1. Illustration of the "urban-brick" concept.

Figure 2. Illustration of the "urban-brick" (in blue contour), representing a contiguous piece of land with specific biophysical characteristics and functional purpose (ex. residential). The spatial extent of the "urban bricks" matches with the outlines of the functional zones. The background image is from Google Earth.

As example, for the urban-brick UB1 Residential Functional zone, the end-user (local administration, auditors, public organizations, etc) may monitor the following indicators, territorial device parameters, which are mandatory for sustainable territorial management and risk resilience (Figure 3):

- maximum building density – %;
- maximum intensity factor – ratio between the unfolded built-up area and the area of the landed property;
- minimum green area;
- maximum elevation/high of buildings.

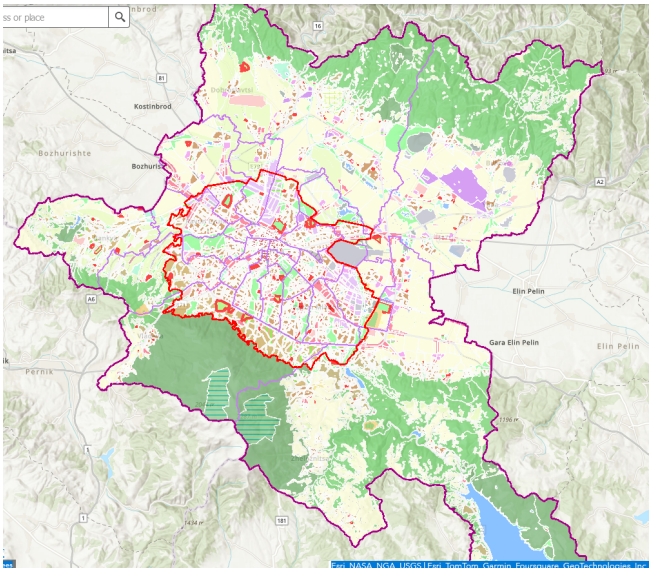

Figure 3. Sofia Municipality Master Plan.

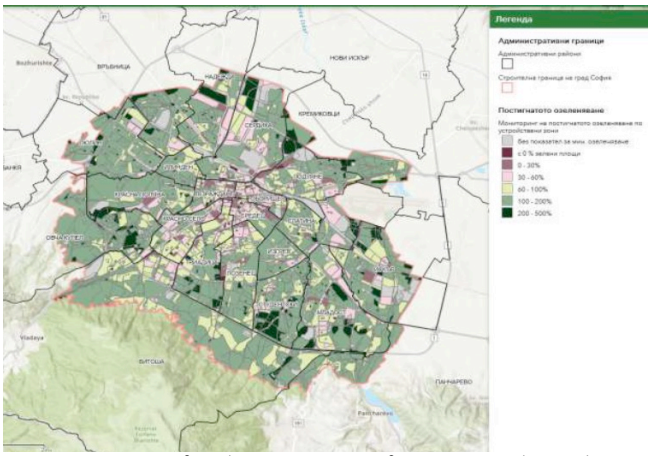

Figure 4. Sofia Thematic map of Grassing achieved.

It must be underlined that sometimes, monitoring green indicator is confused with monitoring green mass increase (Figure 4). A mandatory free from sealing area for the urban units, to be used for vegetation, must be maintained without being replaced by another parameter.

The satellite-based method uses the HR-VPP product developed by the European Environment Agency (EEA) as part of the Copernicus Land Monitoring Service (CLMS), to assess the percentage of potential green spaces within the functional zones, on yearly basis. The obtained values are compared with the prescribed minimum percentages for

green spaces for each functional zone. Linear regression analysis is performed to detect negative trends with respect to the share of green spaces (Figure 5).

For the EO objective for monitoring of open and green space trends for Sofia Municipality, the HR_VPP – total productivity (TPROD) for Sofia Municipality, using based on Sentinel 2 data (2017-2023) is used. Data is incorporated into a new semi-automatic tool for monitoring changes (CbM) – Risk prevention algorithm – RiskMON. It starts with precise application on selected pilot area and after finalising this preliminary stage it will be applied on the whole territory in future. Further enhancement with AI-based methods is foreseen at later stage. Further development of the expert system to assess the

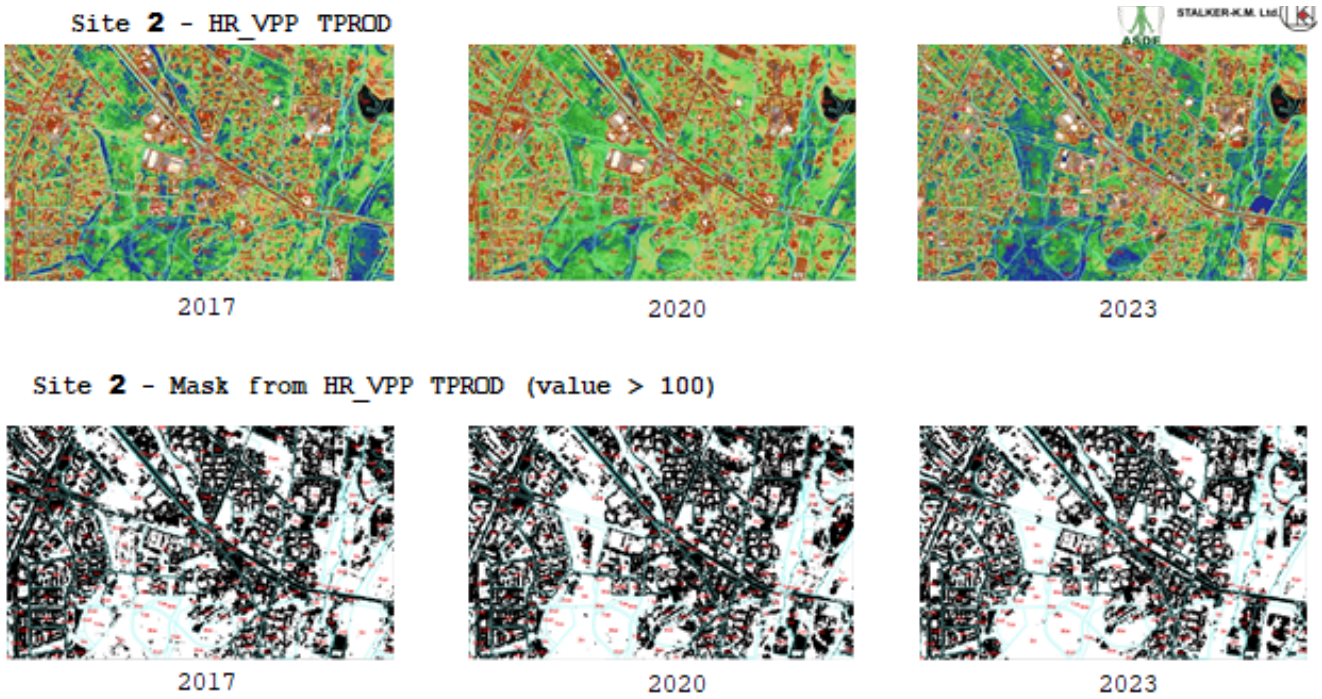

Figure 5. EO objective Monitoring of Grassing tendencies - HR_VPP – total productivity (TPROD), Sentinel 2 – 2017-2023.

vulnerability (flooding) of the so-called "urban bricks" – "functional units" (FM) will be done in the context of a Proposal of Algorithm on flood risk prevention.

Scope: The assignment deals with the annual update of the information on the percentage of the area potentially covered with green vegetation, within the functional units of the city master plan. The collected data allows for the update of the values of attributes "Min Green Area (Mg)", Max Allowed residential /public area (Ra) and Min area of recreational space (Mr) of the Asset score of the table on "Risk Assessment".

Method: Overlay the geometries of the functional units with a gridded (raster) dataset reflecting vegetation phenology, as derived from satellite data. Extract the zonal statistics (count, sum and mean) of the pixels value distributions within each polygon of the functional unit.

Expected output: A new vector (polygon-based) file with the geometries of the functional units, with additional set of attributes reflecting the distribution of the green vegetation and artificial surfaces within each functional unit. The update is produced once per year with data for the precedent year (Figure 6). It covers all the years from 2017 until 2022/23. The assignment is developed using data from the Master Plan of the Sofia Municipality.

3 Results and discussion

Providing Basic solution SEE countries resilience**.** The aim of ASDE-ECOREGIONS is together with colleagues from EU countries (priority South-East Europe), to develop a user-friendly locally objective/effective/efficient/economic monitoring system on assessing the resilience and vulnerability/natural hazards, air pollution, flooding, landslides, earthquake, using EO COPERNICUS services and mandatory territorial units – the so-called "tegon" and "urban bricks".

Proposal for Trans-border collaboration on common solution for Development of methodology and prototype for operational deployment of a satellite-based system for EU wide agri-ecological zoning for the purpose of more effective agricultural management with less impact on environment and climate.

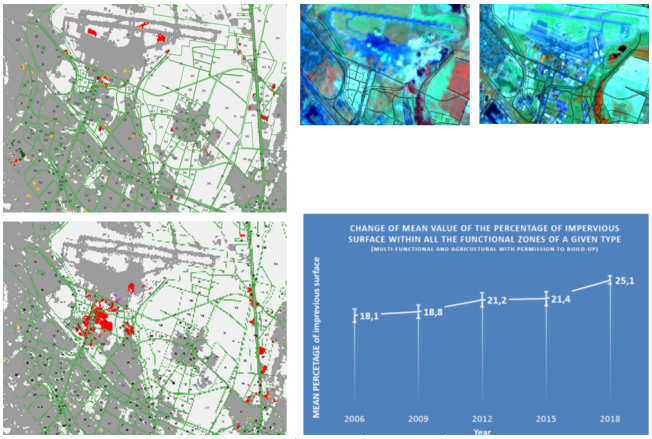

Figure 6. Assessing trends in urbanised territories using Copernicus HRLs.

Proposal for Trans-border collaboration on common solution for Development of methodology and prototype for operational deployment of a satellite-based system for EU wide urban-resilient zoning for the purpose of more effective territorial, natural resources, and critical infrastructure management with less impact on environment, climate, and economy (Figure 7).

It should also support the Carbon Border Adjustment Mechanism (*CBAM)* – Reg. (EU) 2023/956 and „EU Fit for 55").

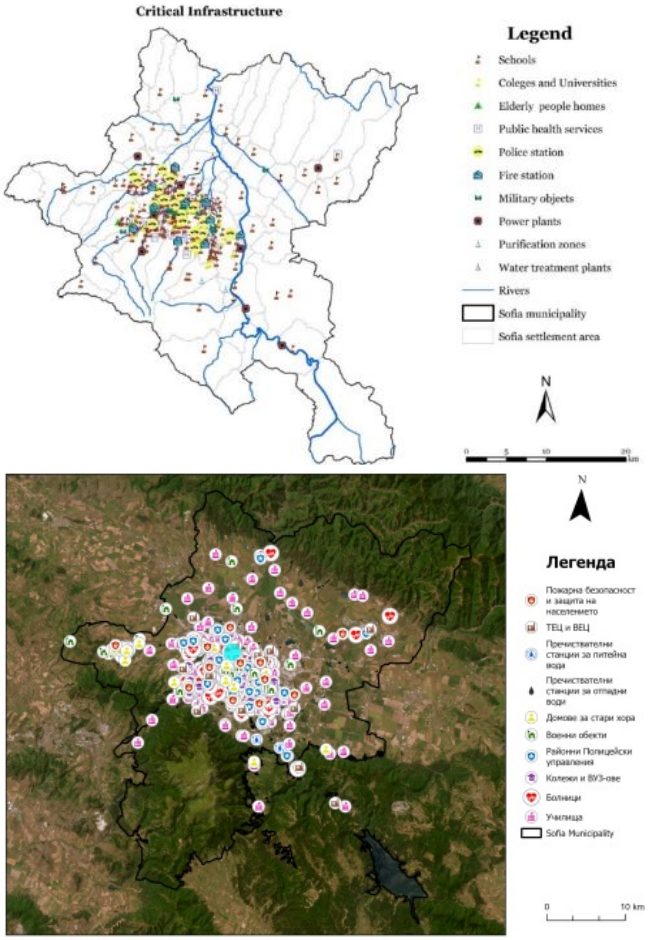

Figure 7. Sofia Assets and Critical infrastructure – Exposure (top) and Loss data (bottom) sets.

4 Conclusions

Our efficient solution: A Trans-national/Trans-border Bottom-up APPROACH from EU guidelines, R&D projects, EU (RRF) (RRPs) towards local operational capacity from post-event recovery towards risk prevention/resilience policy. Considering climate impact, but also negative human impact – lack of efficient management, neglecting surveillance measures, etc. Operational solution, combining the so-called Exposure and Loss databases/SmartCover Databases with three main tools – the ISO 19144-2/3; local mandatory nomenclature; the AI/ML algorithm on satellite data interpretation.

We propose collaborative projects under the HORIZON 2020, INTERREG, Danube Program, ESA-PECS program for South-East Europe**.**

1. Network of Risk Prevention Regional centers network (an up-grading of the EC supported concept from 2010–2011)
2. Methodology and prototype for operational deployment of a satellite-based system for EU wide agri-ecological zoning for more effective urban/agri-management with less impact on environment and climate.
3. Prototype for satellite-based detection and mapping of photovoltaic installation in agricultural areas. Assessment of their typology in relation to their impact on soil health.

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