GENERAL MONITORING APPROACH ON NATURE-BASED SOLUTIONS (NBS), including green and blue infrastructure, reducing climate-related risks while providing environmental, social and economic benefits and contributing to critical infrastructure resilience integrated into risk management and urban planning.

INTRODUCTION

In this document, we, ASDE-ECOREGIONS, present, to state and local authorities, a proposal regarding the necessity for **continuous monitoring of land cover and land use, integrated with the national mandatory legal base for sustainable territorial, resources and critical infrastructure management** . Such monitoring is crucial for prevention and managing the risks associated with natural and human-induced disasters, as well as for identifying vulnerable areas, environmental behavior, resources, and critical infrastructure—particularly within urbanized territories. The attached example focuses on the Municipality of Ruse; however, the approach is equally applicable to other municipalities across Bulgaria. This work aligns with the requirements set forth in European directives, regulations (as EU legal acts), and various guidelines and manuals used—directly or indirectly—in the assessment and management of natural disaster risks. In this context, we invite all stakeholders to review a publication by the European Environment Agency: https://www.eea.europa.eu/en/newsroom/news/what-2026s-climate-extremes-teach-europe-about-resilient-infrastructure.

As declared in the EEA publication –"According to the European Climate Risk Assessment (EUCRA), Europe's critical infrastructure, such as transport (land, sea and air), energy, communication and water infrastructure, is increasingly exposed to extreme weather events. This threatens the services that the infrastructure provides. Moreover, EUCRA highlights that climate risks do not affect sectors in isolation (see Figure 1). Hazards can trigger cascading impacts across interconnected systems, with water acting as a cross-cutting dependency linking ecosystems, food, infrastructure, health and the economy."

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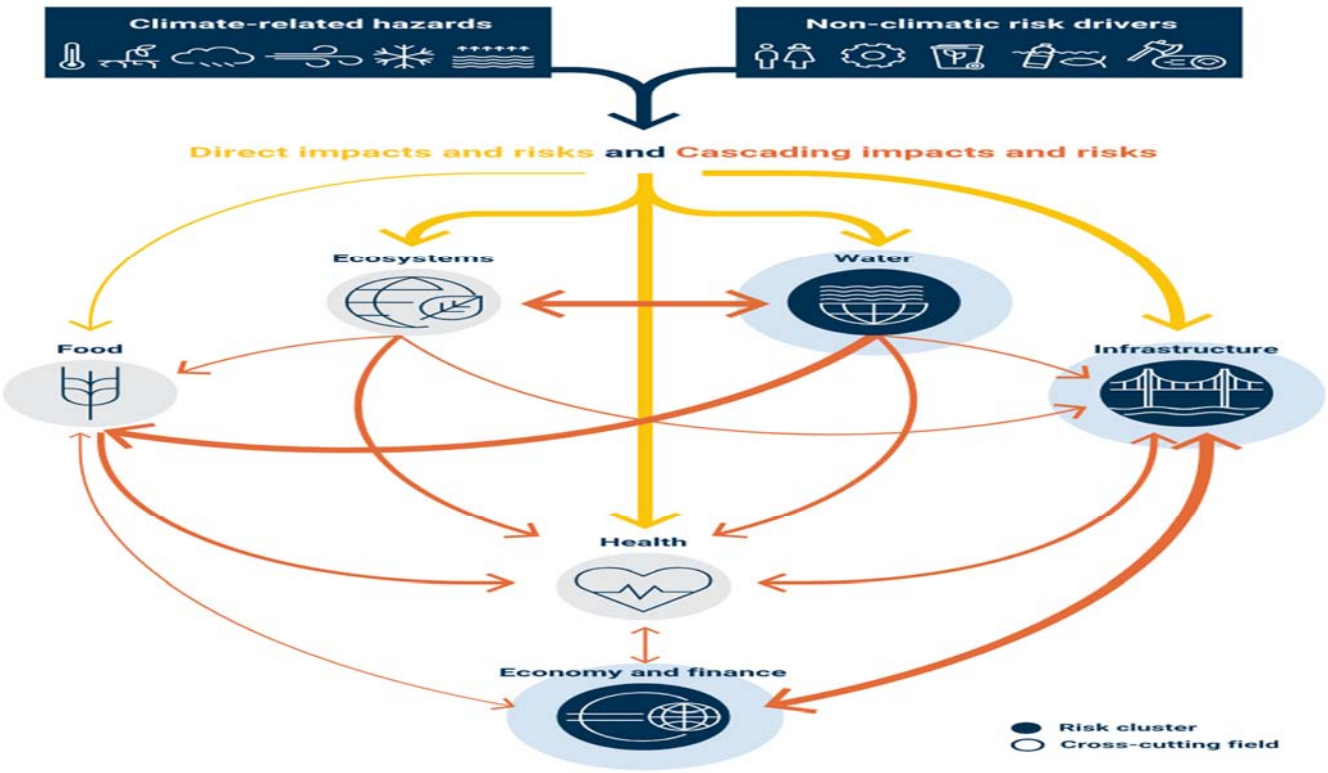


Fig.1. Cascading effects from one system to another due to climate extremes (copyright-EEA)

The proposed methodology for monitoring land cover/land use comprises three steps: preliminary interpretation/classification of land cover and land use, including the assessment of changes; the development of hazard and risk maps; and the creation of natural disaster risk management plans, alongside measures to ensure the resilience of territories, infrastructure, assets, and resources, as well as the protection of the population.

This document covers the first stage: a methodology for the interpretation and classification of land cover and land use, and the assessment of changes and trends that have occurred. Parallel thematic maps assessing Ruse Municipality are presented.

The work was developed by the ASDE-ECPREGIONS expert team, supported by Ruse Municipality representatives, under "a pioneering European initiative funded by the EU, focused on advancing Nature-Based solutions (NBS) to safeguard critical urban infrastructure against both natural and human-induced hazards" - https://nbsinfra.eu/

Schematic approach on Monitoring trends in land cover/land use, based on ISO 19144 and national legal base

Important Note: The following version incorporates two mandatory elements for territorial planning/management monitoring:

1. Copernicus Sentinel-2 satellite data as the core Earth Observation data source for land-cover monitoring.
2. Functional zones as a required spatial-planning basic framework elements for stratifying, interpreting and reporting land-cover and land-use trends.

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Sentinel-2 provides 13 multispectral bands, with spatial resolutions of 10 m, 20 m and 60 m. The Copernicus Data Space Ecosystem (https://dataspace.copernicus.eu/) provides access to the imagery, with 2-3 days revisit frequency, including atmospherically corrected Level-2A surface-reflectance products.

The mandatory status of functional zones should be established by the national applicable territorial-planning legislation, regulation or project specification (in Bulgarian this is the TERRITORIAL PLANNING LAW - https://www.lex.bg/laws/ldoc/2135163904); it is not a requirement imposed by ISO 19144 family itself.

1. Mandatory methodological requirements

Component	Proposed requirement
Classification standard	Use ISO 19144-2:2023 to describe and harmonize land-cover classification systems.
Satellite data	Use Copernicus Sentinel-2 Level-2A as the primary optical remote-sensing dataset.
Temporal coverage	Use comparable annual or seasonal composites for every monitoring period.
Spatial framework	Maintain an official GIS layer of functional zones, including unique zone IDs and zone types.
Land-use evidence	Integrate planning documents, cadastral information and other relevant datasets; do not infer all land uses from satellite imagery alone.
Change detection	Produce land-cover transition matrices and change maps for the entire study area and for each functional zone.
Quality assurance	Validate classifications and changes using independent reference data and document uncertainty.
Reporting	Report indicators at both territorial and functional-zone levels.

2. Sentinel-2 data processing procedure

Step 1 — Data acquisition

Obtain Sentinel-2 Level-2A imagery from the Copernicus Data Space Ecosystem.

Official access: Copernicus Data Space Ecosystem (https://dataspace.copernicus.eu/)

Select cloud-screened images for the study area and the relevant monitoring dates. Record acquisition dates, processing baselines and data coverage.

Step 2 — Pre-processing

Apply cloud and cloud-shadow masking, consistent projection and grid alignment, and appropriate seasonal compositing. Use the native spatial resolution of each band appropriately; resampling a 20 m band to 10 m does not create additional spatial detail.

Step 3 — Derive land-cover information

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Use spectral bands, temporal signatures and appropriate indices, such as NDVI for vegetation, alongside a documented classification algorithm. Produce a consistent land-cover map for each monitoring year.

Step 4 — Validate results

Use independent reference samples, field observations or suitable high-resolution reference imagery. Report the confusion matrix, overall accuracy, user's accuracy and producer's accuracy, including class-specific uncertainty.

3. Functional zones as a mandatory planning layer

"Functional zones" must be treated as a separate spatial-planning layer, based on the national mandatory territorial planning units, in support to the accepted land-cover/land use classes. In our case (Bulgaria) such layer is based on the national legal documents - the Territorial Planning Law (in Bulgarian - ЗУТ -https://www.lex.bg/laws/ldoc/2135163904) and the attached Ordinance No. 7 of 22 December 2003 – on rules and standards for the spatial development of specific types of territories and spatial development zones (https://www.mrrb.bg/bg/naredba-7-ot-2003-g-za-pravila-i-normativi-za-ustrojstvo-na-otdelnite-vidove-teritorii-i-ustrojstveni-zoni/). Each mapped land-cover polygon or pixel is spatially related to the applicable "functional zone" through a GIS overlay. On one side - the dimensions of these functional zones are highly suitable for utilizing data from the SENTINEL constellation to analyze the state of land cover and land use; on other – the results from such analysis provides information on trends which are directly related to the sustainable territorial management on local and national level. It is mandatory that the exact zone categories must follow the applicable national and local planning framework. As example, depending on that framework, the "functional zones" may include in general:

- Urban / settlement zones
- Built-up expansion, land sealing, conversion of open space.
- Agricultural zones
- Cropland extent, abandonment, conversion to built-up land or other cover.
- Forestry and ecological zones
- Forest-cover loss and gain, fragmentation, vegetation change.
- Water, flood-risk and conservation zones
- Water extent, wetland changes, vegetation condition and land-cover changes relevant to protection objectives.
- Industrial, transport and infrastructure zones/networks
- Expansion of impervious surfaces, waste sites, degraded areas, critical infrastructure development and land conversion.

These are illustrative categories, not a substitute for the legally defined functional zones in the relevant planning system. A specific example is provided in the attached maps.

Required GIS operation

For every reporting period:

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1. Intersect the land-cover map with the functional-zone boundaries.
2. Calculate the area of each land-cover class within each zone.
3. Compare the results between monitoring dates.
4. Identify transitions that are relevant to the zone's planning objectives.
5. Flag changes requiring further investigation, planning review or field verification.

Where a functional zone changes its boundary or designation, retain the previous version and put the effective date. This avoids confusing change in planning designation with an actual change in land cover.

4. Mandatory monitoring indicators

Let $A_{z,c,t}$ denote the area of land-cover class c, within functional zone z, at time t.

Indicator	Calculation or interpretation
Class area	$A_{z,c,t}$, hectares or km²
Percentage of zone	$100 A_{z,c,t}/A_z$, where A_z is the zone area
Net area change	$A_{z,c,t_2}-A_{z,c,t_1}$
Annualized net change	$(A_{z,c,t_2}-A_{z,c,t_1})/(t_2-t_1)$
Relative change	$100(A_{z,c,t_2}-A_{z,c,t_1})/A_{z,c,t_1}$, when baseline area is nonzero
Transition area	Area converted from class i to class j between dates
Planning-zone change flag	Change that meets a predefined planning threshold or requires investigation

Net change alone is insufficient: simultaneous gains and losses can cancel each other out. Therefore, transition matrices and gross gains and losses should also be reported.

5. Final outputs

The monitoring system should deliver:

- Annual or periodic Sentinel-2-derived land-cover maps.
- Functional-zone maps with documented source, date and legal or planning status.
- Land-cover and land-use trend statistics for each functional zone.
- Change-detection maps and transition matrices. Accuracy and uncertainty reports.
- A GIS database with versioned maps, metadata and reproducible processing records.
- Planning report identifying significant changes, potential conflicts + functional-zone objectives.

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6. Standards clarification

The official ISO page describes ISO 19144-2 (2023) as a common meta-model for describing and comparing land-cover classification systems, rather than a complete monitoring specification. Accordingly, the proposed procedure combines that classification framework with Copernicus Sentinel-2 data and a functional-zone GIS overlay. If this is to become a legally binding methodology, the mandatory use of Sentinel-2, the required functional-zone categories, reporting frequency and acceptance thresholds should be explicitly adopted in the applicable planning regulation or technical specification.

Proposed scheme: Monitoring trends in land cover / land use

1. **Define territorial planning objectives and study area**
Area of interest · reference period · monitoring frequency · indicators

2. **Establish "functional zones" GIS layer**
According legally approved local Master Plan/Overall Territorial Management Municipal Plan

3. **Acquire CopernicusSentinel-2 Level-2A data**
Use the existing EU services as: COPERNICUS services, EEA services

4. **Pre-process imagery and create seasonal composites**
Geometric and atmospheric correction · cloud masking · spatial and temporal harmonization, etc..

5. **Classify land cover using ISO19144-2:2023 / LCML**
Apply consistent class definitions at each monitoring date; integrate land-use evidence where available

6. **Integrate land-use evidence and planning document**

7. **Validate classifications and change detection**
Independent reference samples · confusion matrix · class-specific accuracy · change validation

8. **Calculate change indicators by functional zone**

9. **Assess/Analyse trends, conflicts and planning implications**
Spatial and temporal patterns · drivers of change · uncertainty · metadata · monitoring report

10. **Publish maps, statistics and update monitoring database**

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