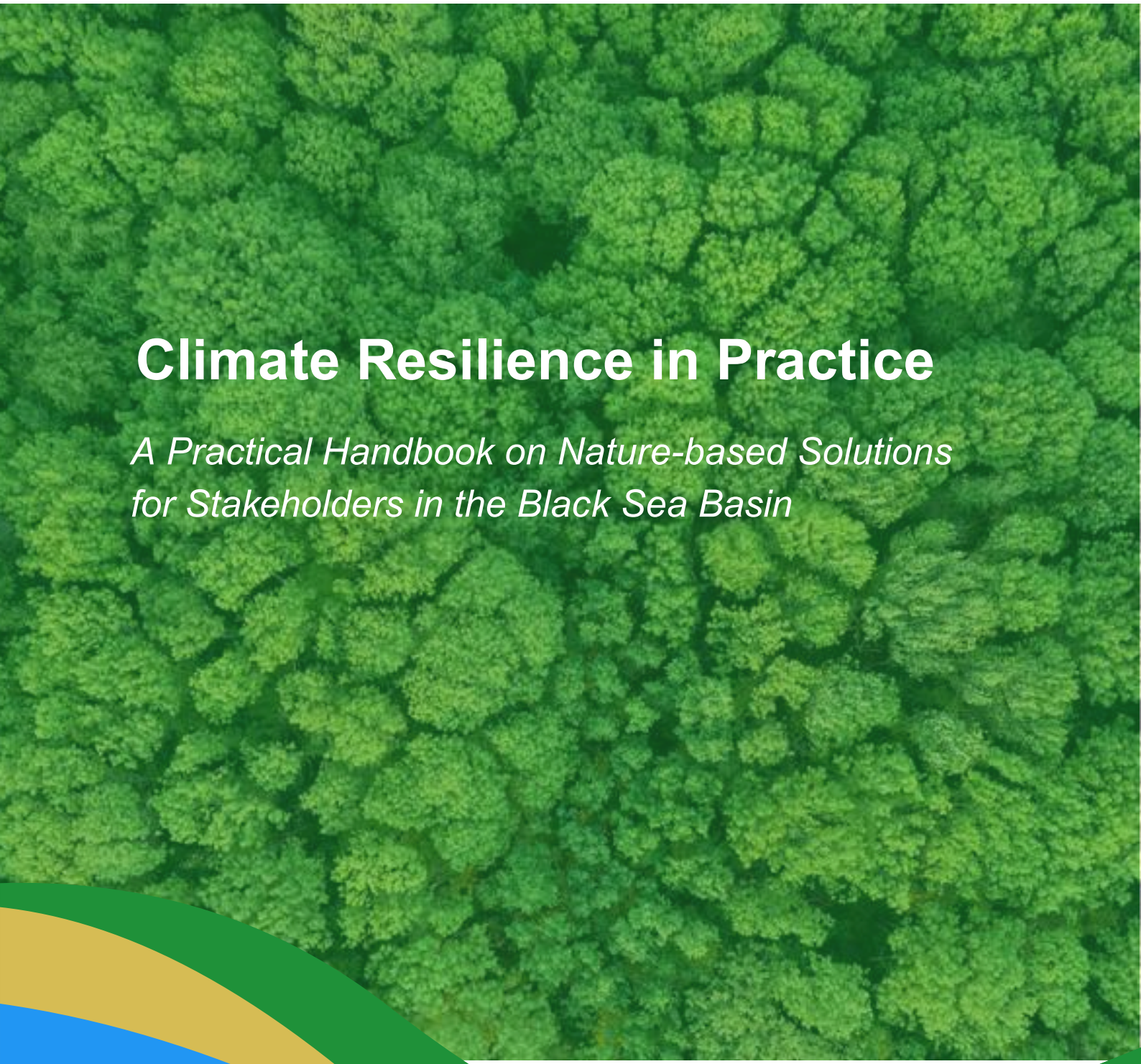
Interreg

Co-funded by the European Union

NEXT Black Sea Basin

MORE ADAPT BSB
LESS VULNERABILITY, MORE ADAPTABILITY



# Climate Resilience in Practice

*A Practical Handbook on Nature-based Solutions for Stakeholders in the Black Sea Basin*

PUBLICATION INFORMATION

Title:
Climate Resilience in Practice

Subtitle:
A Practical Handbook on Nature-based Solutions for Stakeholders n the Black Sea Basin

Project title:
Less vulnerability, more adaptability – pilot remote sensing assisted restoration of green spaces in coastal and urban areas within the Black Sea region

Project acronym and ID: MoreAdaptBSB – BSB00479

Programme: Interreg NEXT Black Sea Basin Programme 2021–2027

Activity 1.1 – Joint development of a remote-sensing-based methodology for the assessment of the resilience and vulnerability of coastal and urban areas to climate change-related hazards

Material editor:
Chamber of Chalkidiki, on behalf of the MoreAdaptBSB partnership

Contact:
E-mail: euprograms@epihal.gr
Telephone: +30 23710 24200
Website: https://www.epihal.gr/

Publishing date: September 2026

Version: Version 1.0

PROGRAMME DISCLAIMER
The responsibility for the content of this material is that of the author(s). The content of this material does not necessarily represent the official position of the European Union.
Reproduction is authorized, provided the source is acknowledged, and any changes are indicated.

# Authors

Petar Petrov, Yana Daskalova, Veneta Stefanova, Stanimira Ivanova, Iva Stamenova-Yordanova, Ina Agafonova, Georgi Kostadinov, Raluca Trandafir, Dimitra Mitka, Lyuba Zheleva, Savina Dimova, Dukena Koemdzhieva, Myhkailo Broshkov, Andrii Maiev, Daria Bulysheva

© 2026 MoreAdaptBSB Partnership
The reuse permission stated in the Programme disclaimer applies only to material for which the MoreAdaptBSB Partnership and/or the authors hold the necessary rights.

The European Union and Interreg emblems, partner logos and trademarks, as well as third-party photographs, illustrations, maps, datasets, icons and other materials, are not covered by the above reuse permission unless expressly indicated otherwise.
Permission to reuse such material must be obtained directly from the respective rights holder and is subject to the applicable licence terms.

Photographs: © MoreAdaptBSB Partnership, unless otherwise indicated.
Illustrations and graphic elements: authors / MoreAdaptBSB partnership, unless otherwise indicated.
Third-party images are credited individually where applicable.

# Table of Contents

Why Adapt, and Why Nature-based Solutions?.....5

How Climate Vulnerability Was Assessed.....11

Catalogue of Nature-based Restoration Measures...29

Choosing the Right Nature-based solution.....37

Nature-based Solution Selection Matrix.....47

From Planning to Implementation:
A Practical Guide for Municipalities.....52

Monitoring, Evaluation and Adaptive Management...57

# Why Adapt, and Why Nature-based Solutions?

## *The Black Sea Basin at a Climate Crossroads*

The Black Sea Basin is one of Europe's most environmentally and socio-economically important regions, hosting densely populated coastal settlements, productive agricultural land, wetlands, forests, ports and tourism destinations. These landscapes provide essential ecosystem services, including climate regulation, biodiversity conservation, water retention and coastal protection. However, they are increasingly exposed to climate-related hazards that threaten both ecosystems and local communities.

According to the MoreAdaptBSB project analysis, the region is facing increasingly frequent and intense climate extremes, including droughts, floods, heatwaves, sea-level rise, storms, and wildfires. Combined with rapid urbanisation and intensive land use, these hazards make coastal and urban areas particularly vulnerable.

The original project proposal further highlights that the Black Sea Basin is particularly vulnerable to coastal erosion, landslides, flooding, storms, heatwaves, droughts and new climate-related pest outbreaks. One of the most alarming findings is that approximately 19% of the Black Sea coastline (around 800 km) is currently experiencing erosion rates exceeding 1 metre per year, while flooding events across the basin have increased as a consequence of climate change.

These challenges are shared across the participating countries (Romania, Greece, Bulgaria and Ukraine) and require coordinated, science-based adaptation measures that can be applied across different territorial contexts.

## Understanding Vulnerability Before Taking Action

Climate adaptation begins with understanding where the greatest risks exist and why some areas are more vulnerable than others.

Within MoreAdaptBSB, vulnerability is understood as the interaction of three interconnected components:

**Exposure** the degree to which an area is subjected to climate hazards such as floods, droughts, extreme temperatures, storms, coastal erosion or sea-level rise.

**Sensitivity** the characteristics of ecosystems, infrastructure and human activities that determine how severely they are affected.

**Adaptive Capacity** the ability of natural ecosystems, institutions and communities to respond, recover and adapt to changing climatic conditions.

Building on the IPCC framework, the MoreAdaptBSB methodology combines climate scenarios, remote sensing, GIS, field verification and expert assessment to deliver a harmonised climate vulnerability assessment for the Black Sea Basin.

To support this assessment, project partners compiled an extensive transnational database containing spatial, climatic, environmental and socio-economic datasets for all four participating countries. These include land cover, protected areas, vegetation indices (NDVI), Net Primary Production (NPP), climate variables, flood hazard maps, coastal erosion data, population density, transport infrastructure and future climate scenarios.

## From Data to Action

One of the key innovations of MoreAdaptBSB is the integration of multiple sources of information into a common assessment framework.

The methodology combines:

- Satellite imagery from the Copernicus Sentinel missions,
- Geographic Information Systems (GIS),
- Regional climate models,
- Spatial and socio-economic databases,
- Expert assessment,
- field verification.

Satellite observations were used to identify land cover, vegetation condition, urban expansion and temperature anomalies, while regional climate models (including EURO-CORDEX, WRF and PRECIS) were applied to evaluate future climate scenarios for **2050 and 2100**. Spatial modelling was carried out using QGIS, ArcGIS Pro, Google Earth Engine, Python, R and TerrSet/IDRISI to identify areas with higher climate vulnerability and adaptation potential.

The resulting Environmental Vulnerability Index (EVI) combines environmental, climatic, socio-economic and institutional indicators through a Multi-Criteria Analysis and the Analytic Hierarchy Process (AHP), ensuring a transparent, reproducible and scientifically robust assessment of vulnerability.

## Why Nature-based Solutions?

Understanding vulnerability is only the first step. The ultimate objective is to identify adaptation measures that strengthen resilience while delivering long-term environmental and societal benefits.

The MoreAdaptBSB project promotes Nature-based Solutions (NbS) as the preferred adaptation approach because they restore ecosystem functions while simultaneously reducing climate risks.

Instead of relying exclusively on conventional engineering solutions, Nature-based Solutions use natural processes to address climate challenges. Healthy ecosystems can reduce flood risk by increasing water retention, stabilise coastlines against erosion, lower urban temperatures through vegetation, improve biodiversity and enhance carbon storage. These measures also generate social and economic co-benefits by improving public spaces, supporting tourism and reducing long-term maintenance costs.

Consequently, the overall objective of MoreAdaptBSB is to strengthen regional preparedness and adaptive capacity through the combined application of Nature-based Solutions and innovative remote sensing technologies, enabling municipalities and regional authorities to prioritise restoration measures based on scientific evidence.

## Evidence-Based Adaptation

Consequently, the overall objective of MoreAdaptBSB is to strengthen regional preparedness and adaptive capacity through the combined application of Nature-based Solutions and innovative remote sensing technologies, enabling municipalities and regional authorities to prioritise restoration measures based on scientific evidence.

A defining feature of MoreAdaptBSB is that adaptation measures are not selected solely on expert judgement but are supported by a comprehensive evidence base.

The project integrates:

- harmonised datasets from four countries;
- remote sensing indicators such as NDVI and Net Primary Production (NPP);
- climate variables including temperature, precipitation and wind;
- flood and wildfire risk;
- land use and socio-economic indicators;
- future climate projections;
- and systematic field verification.



The field validation phase demonstrates the reliability of this approach. A total of **157 verification points** were assessed across the Bulgarian and Ukrainian pilot areas. The comparison between spatial modelling and field observations showed **100% agreement within one vulnerability** class in Bulgaria and **94.7% agreement** (exact or adjacent class) in Ukraine after calibration of the model. These results confirm that the methodology provides a reliable basis for identifying priority areas for climate adaptation and ecosystem restoration.

## Key Messages

- Climate change is already increasing the vulnerability of coastal and urban areas throughout the Black Sea Basin.
- Approximately 800 km (19%) of the Black Sea coastline is affected by erosion rates exceeding 1 metre per year.
- Effective adaptation requires robust evidence combining satellite observations, climate modelling, GIS analysis and field verification.
- Nature-based Solutions provide a sustainable pathway to reduce climate risks while restoring ecosystem functions and improving quality of life.



# How Climate Vulnerability Was Assessed

*From Climate Hazards to Evidence-Based Decisions*

Understanding climate vulnerability is a prerequisite for effective climate adaptation. Without a systematic assessment of environmental conditions, municipalities risk investing in measures that fail to address the most pressing climate threats or overlook areas where intervention is most urgently needed.

The MoreAdaptBSB methodology was developed to provide local and regional authorities with a scientifically robust yet practical framework for assessing climate vulnerability in coastal and urban environments. Rather than focusing on a single hazard, the methodology considers the complex interactions between climate processes, environmental characteristics and human activities, recognising that vulnerability emerges from the combined influence of multiple natural and socio-economic factors.

Developed specifically for the Black Sea Basin, the methodology enables comparable assessments across Romania, Greece, Bulgaria and Ukraine while remaining sufficiently flexible to accommodate local environmental conditions and data availability. The approach serves as the scientific foundation for identifying priority intervention areas, selecting appropriate Nature-based Solutions and monitoring their effectiveness over time.

## 2.1 A Common Framework for Four Countries

One of the principal challenges addressed by MoreAdaptBSB was the lack of a harmonised methodology capable of comparing climate vulnerability across different national contexts. Although the participating countries share many common environmental challenges, they differ considerably in landscape characteristics, data availability, institutional structures and planning practices.

## 2.2 Understanding the Three Dimensions of Vulnerability

The MoreAdaptBSB methodology defines vulnerability as a dynamic characteristic that reflects not only the intensity of climate hazards but also the ability of ecosystems and communities to withstand and recover from them.

### Exposure

Exposure represents the degree to which a territory is affected by climate-related hazards. Within the methodology, exposure is assessed through indicators describing flood susceptibility, wildfire risk, climatic conditions, land use patterns and the spatial distribution of population and infrastructure.
Areas located along coastlines, river systems or densely urbanised zones generally experience higher levels of exposure because they are more frequently affected by extreme weather events and climate-related processes.

The exposure map (Figure 1.2) shows the spatial degree to which territories are exposed to climatic and environmental risks. The exposure of **Romania's** coastal areas exhibits pronounced spatial contrasts.

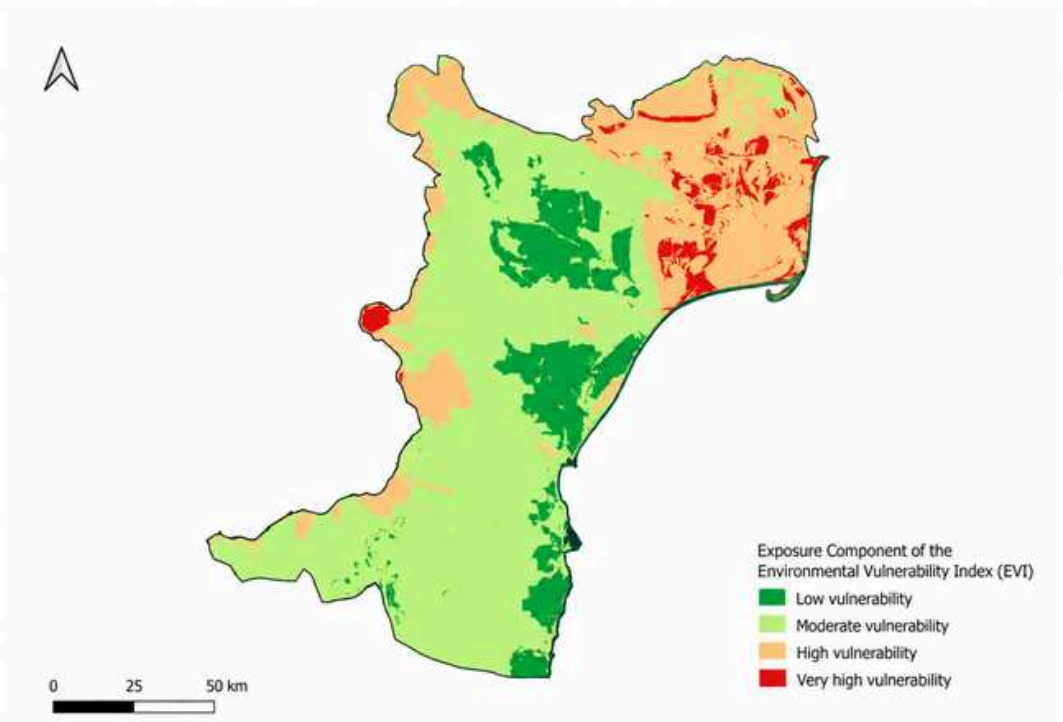



***Figure 1.2.*** *Exposure map of Constanța and Tulcea counties, Romania*

The highest exposure is found in the Danube Delta and along the northern coast, driven primarily by high flood risk. Inland areas and the southern coast show mostly low-to-moderate exposure, with an isolated peak near the Hârșova lagoon.

The highest exposure (Figure 2.2) is concentrated in the eastern part of the region, particularly around Alexandroupolis and the Evros area, due to sea-level rise, flooding, strong winds, and coastal erosion, with an additional localized hotspot near Kavala linked to higher precipitation and temperatures. Western and central areas, including Thessaloniki, together with inland mountainous areas, show the lowest exposure.

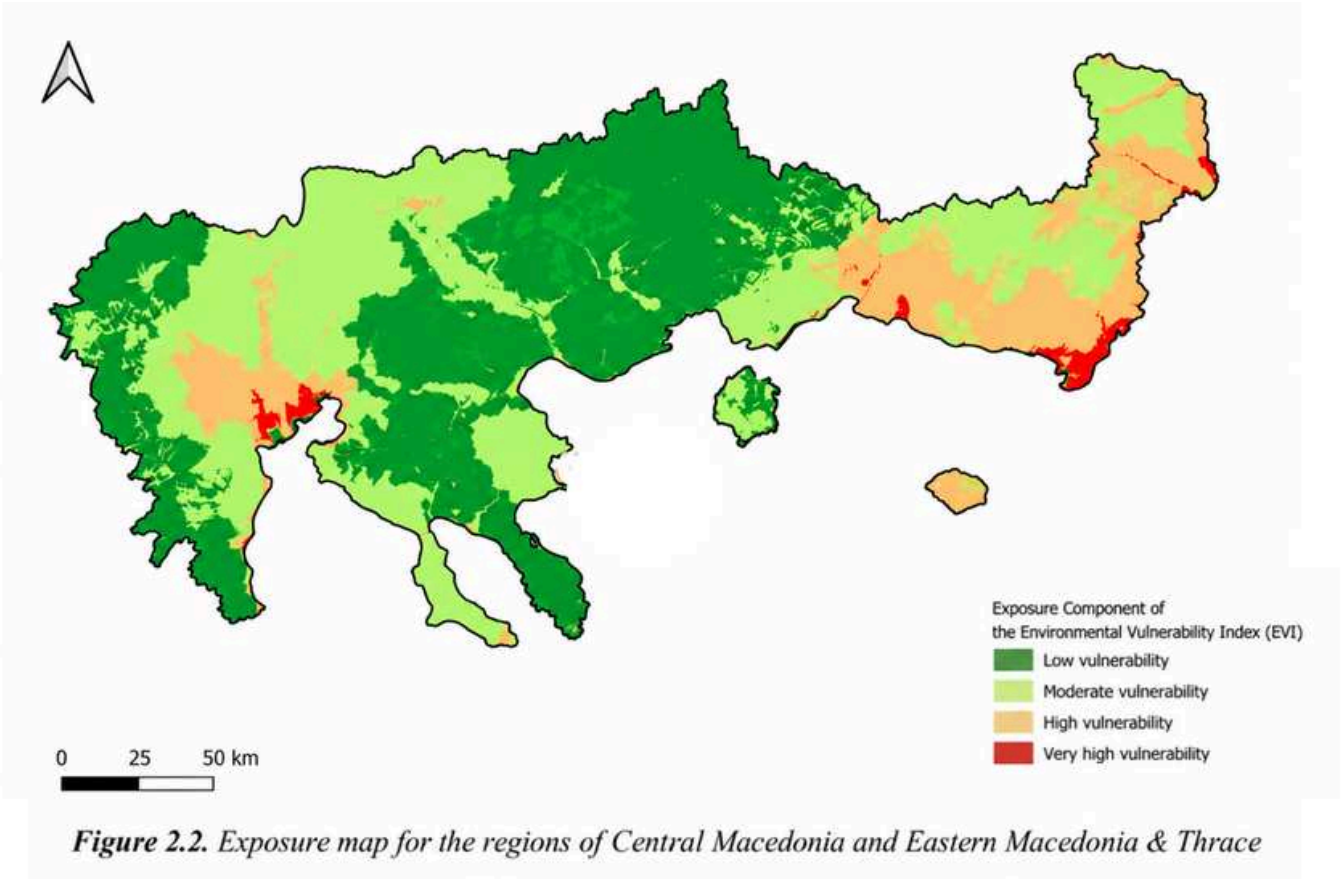



***Figure 2.2.*** *Exposure map for the regions of Central Macedonia and Eastern Macedonia & Thrace*

Exposure is low across the western and central regions and rises sharply toward the east, especially around Alexandroupolis, due to sea-level rise, flooding, and coastal erosion. A further localized hotspot occurs near Kavala, linked to elevated precipitation and temperature. Mountainous inland areas remain the least exposed, reflecting lower human pressure and more moderate climatic conditions.

The exposure map (Figure 3.2) of Bulgaria shows a clear contrast between the eastern and western parts of the country. Lower exposure is observed in the northeastern regions (Shumen and Targovishte), where higher elevation, more moderate climatic conditions, and lower risks of floods and wildfires contribute to reduced exposure.

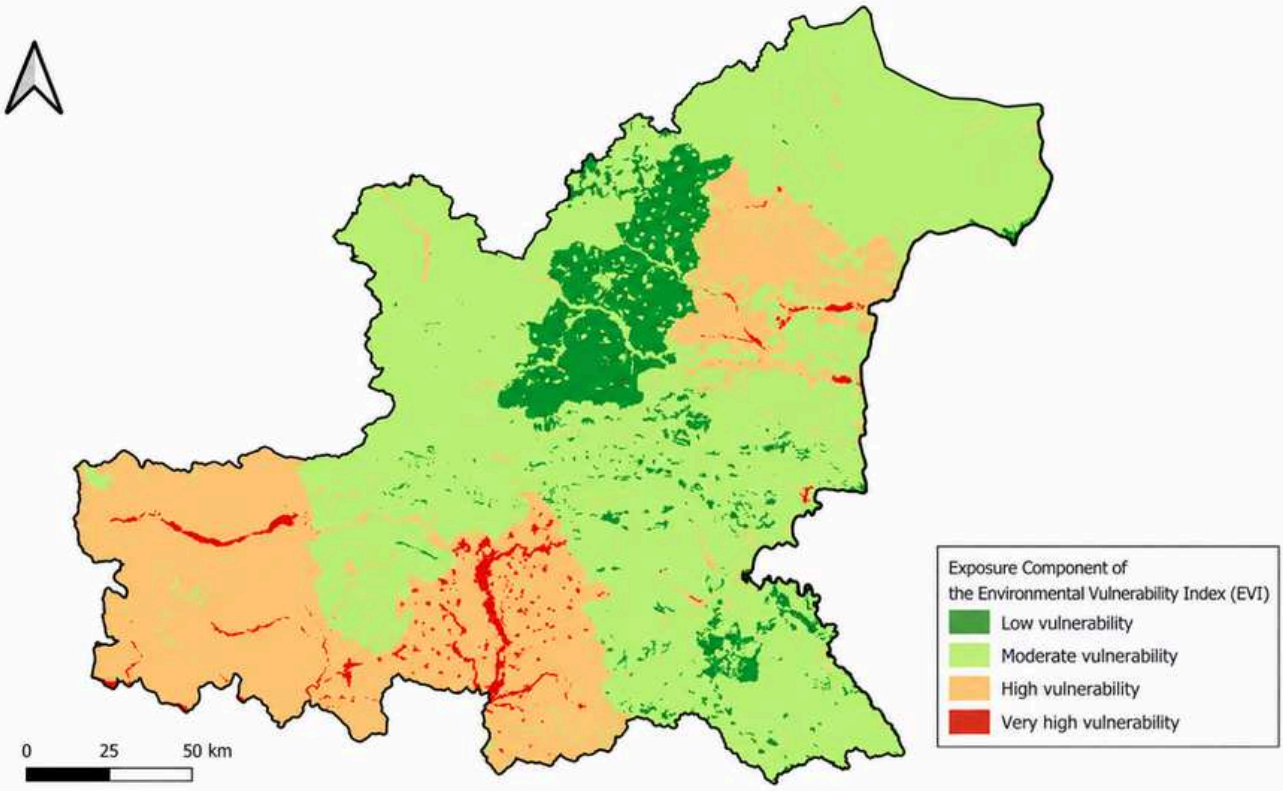



***Figure 3.2.*** *Map of exposure for the provinces of Varna, Burgas, Stara Zagora, Yambol, Sliven, Targovishte, Shumen, and Dobrich in Bulgaria*

Moderate exposure is found in Dobrich, Varna, and Sliven, while the highest exposure occurs in Stara Zagora, Yambol, and the coastal areas of Burgas and Varna due to drought, floods, wildfires, and sea-level rise.

Exposure (Figure 4.2) of the southern **Ukrainian** regions to climatic and anthropogenic stressors shows significant territorial differences driven by a combination of climatic parameters, geomorphology, and human presence.

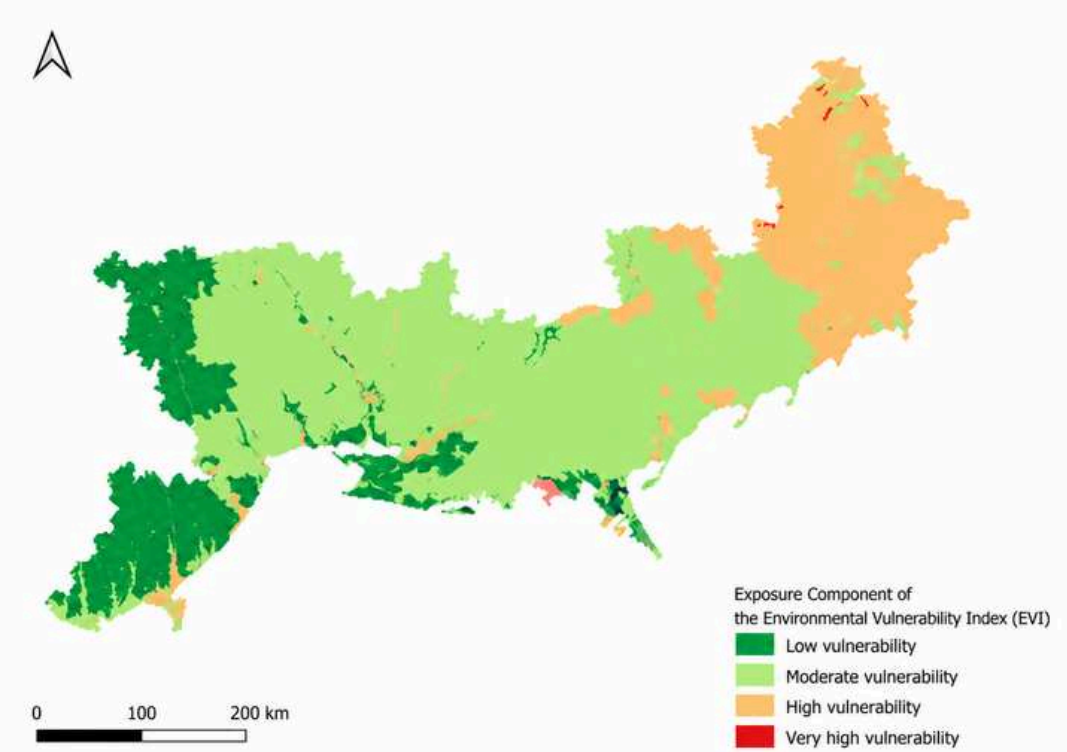



*Figure 4.2. Exposure map for the Odesa, Mykolaiv, Kherson, Zaporizhzhia, and Donetsk regions of Ukraine.*

Disclaimer: Key statistical and spatial sources used for the Zaporizhzhia and Donetsk regions date from the period shortly before the full-scale invasion of 24 February 2022

Exposure is lowest in Odesa Oblast, moderate across the central belt toward Kherson, Zaporizhzhia, and parts of Mykolaiv, and sharply higher in Donetsk Oblast and around coastal lagoons, driven by temperature extremes, precipitation deficit, coastal flood risk, and stronger winds. Major cities such as Odesa, Mykolaiv, and Mariupol carry additional exposure from high population and infrastructure density.

## Sensitivity

Sensitivity reflects the intrinsic characteristics that determine how severely an ecosystem or territory responds to climate stress.

The methodology evaluates sensitivity through indicators describing soil degradation processes and environmental pollution. Degraded ecosystems generally possess lower resilience and recover more slowly following disturbances such as droughts, floods or erosion.

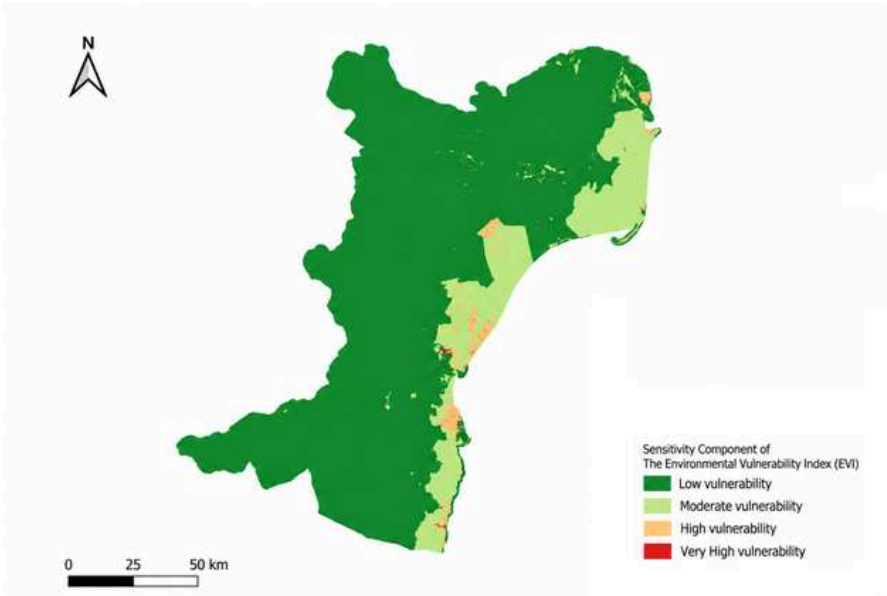



***Figure 1.3.** Sensitivity map of Constanța and Tulcea counties,*

The map (Figure 1.3) shows the sensitivity of coastal systems to external stressors, determined by soil-degradation processes, coastal erosion, and the presence of burnt areas.

Sensitivity is highest along the coastal strip — in the urban areas around Constanța, between Eforie and Mangalia, and in the Danube Delta — where coastal erosion, ground motion, and ecological stress are most intense. Inland agricultural areas show lower sensitivity due to more stable land use and fewer environmental pressures.

Sensitivity is generally low across northern and inland Greece, reflecting resilient ecosystems and stable soils. Higher sensitivity occurs in isolated coastal areas — around Halkidiki, the Gulf of Kavala, and the islands — where ground motion and shoreline erosion increase the exposure of infrastructure and settlements.

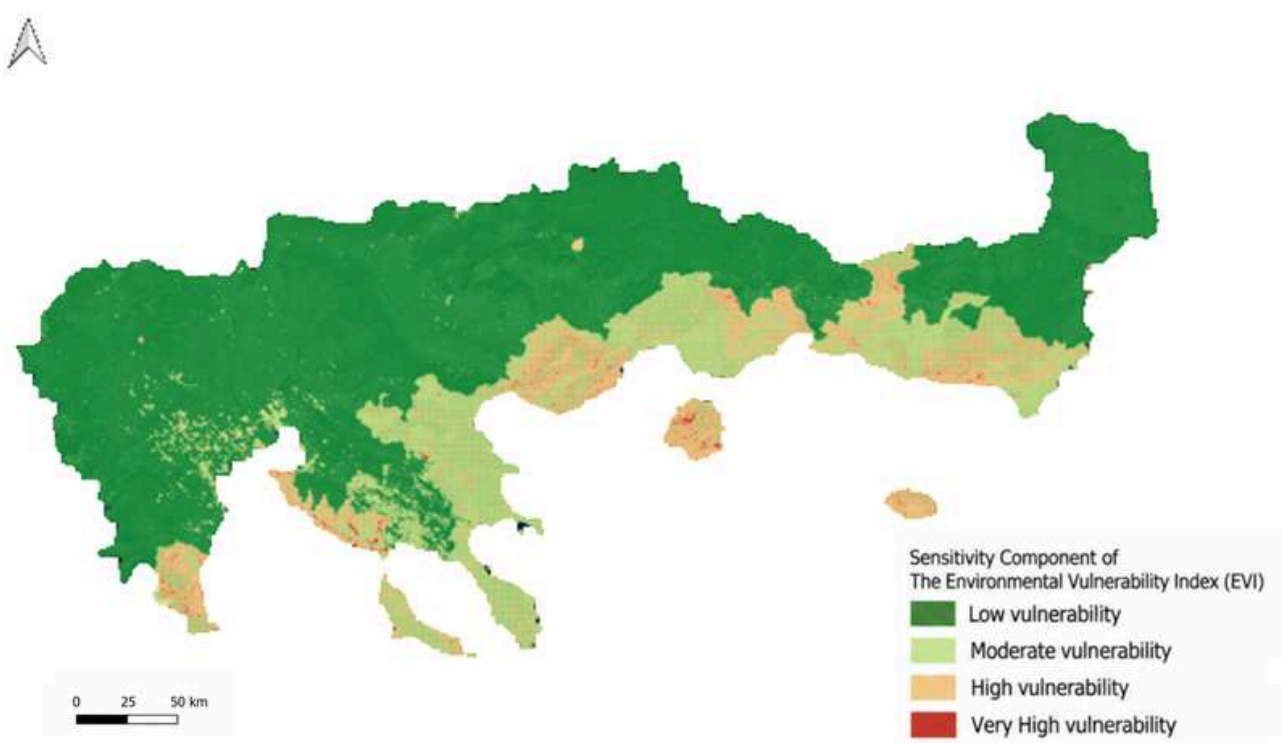



***Figure 2.3.*** *Sensitivity map for the regions of Central Macedonia and Eastern Macedonia & Thrace, Greece*

The highest sensitivity is found in coastal and urban areas, particularly in Halkidiki, Kavala, and Alexandroupoli, due to coastal erosion, ground movement, and ecological disturbances. Inland mountainous and agricultural areas show lower sensitivity and greater resilience.

Sensitivity (Figure 3.3) is assessed based on the following criteria: erosion, rockfalls, swelling of construction soils, soil liquefaction, loess, pollution, and unregulated dumpsites.

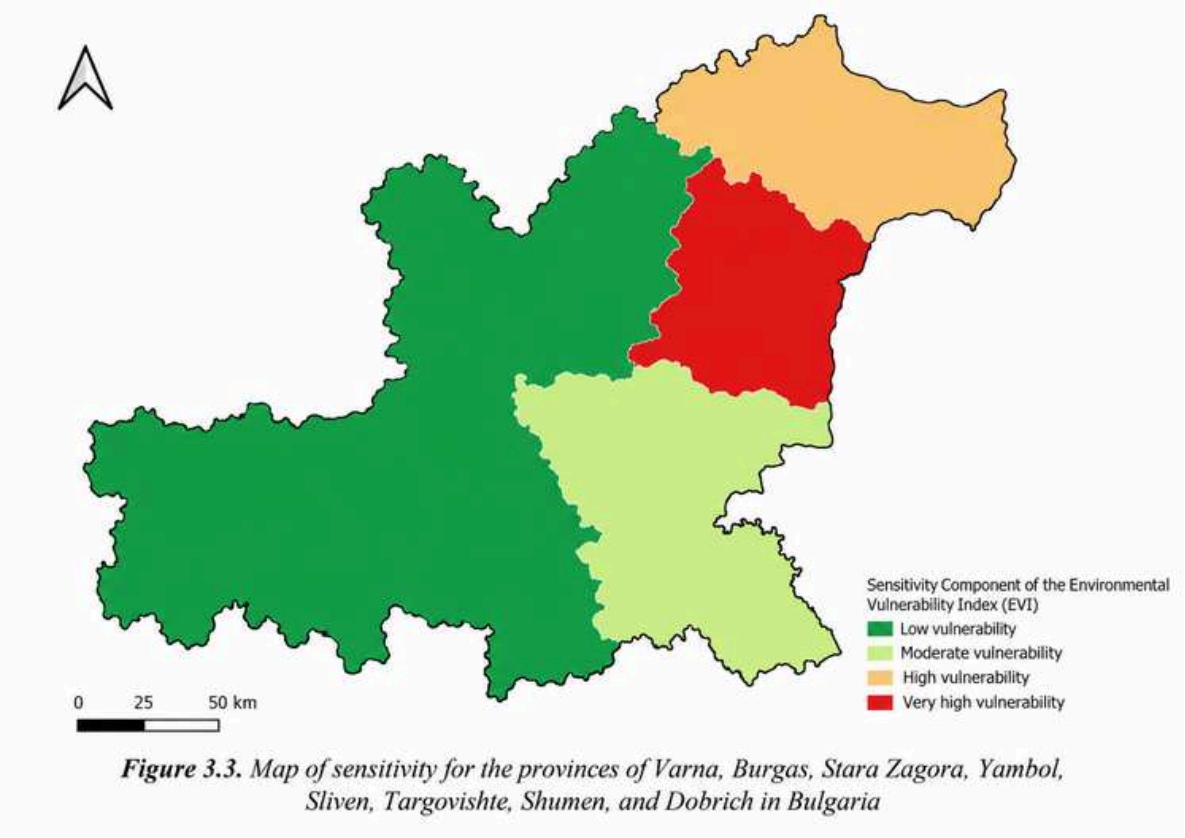



***Figure 3.3.*** *Map of sensitivity for the provinces of Varna, Burgas, Stara Zagora, Yambol, Sliven, Targovishte, Shumen, and Dobrich in Bulgaria*

Sensitivity is highest in Varna and Dobrich, where loess terraces and urbanization drive pronounced erosion and landslide risk, with additional erosion pressure on the Strandzha, Sredna Gora, and Sliven Balkan slopes. Lower sensitivity is observed across Burgas, Stara Zagora, Yambol, Shumen, and Targovishte, where land use is more stable.

The sensitivity map (Figure 4.3) highlights the ecological vulnerability of southern Ukraine based on air and water pollution, erosion, landslides, and soil degradation, reflecting the ability of ecosystems to respond to climate and human pressures.

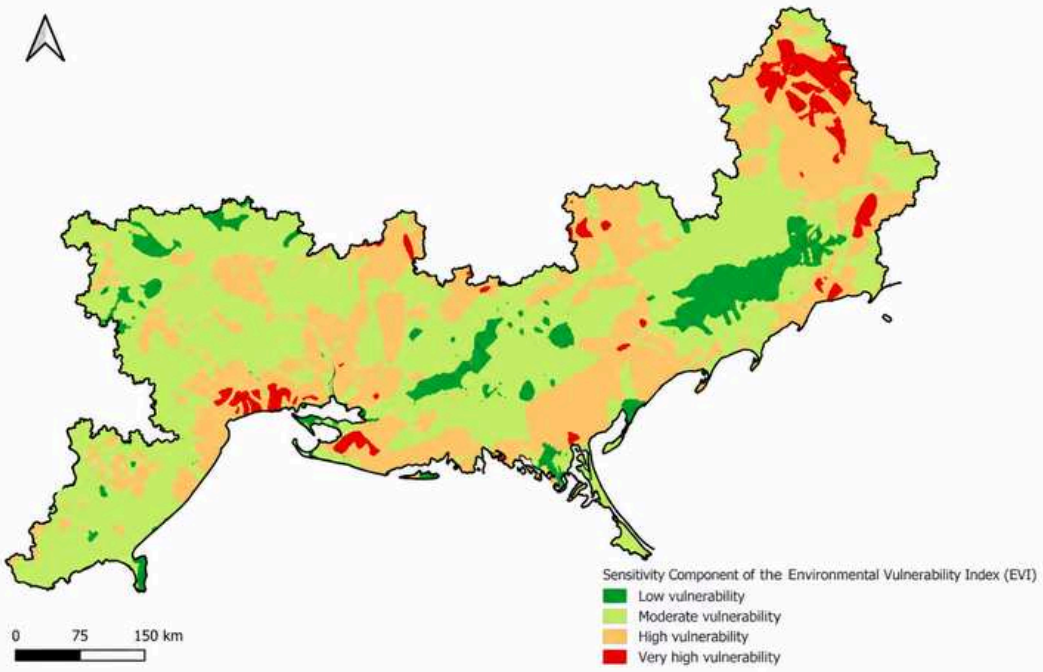



***Figure 4.3.*** *Sensitivity map for the Odesa, Mykolaiv, Kherson, Zaporizhzhia, and Donetsk regions of Ukraine*

Disclaimer: Key statistical and spatial sources used for the Zaporizhzhia and Donetsk regions date from the period shortly before the full-scale invasion of 24 February 2022.

The highest sensitivity is observed in the coastal and industrial regions of Odesa, Kherson, Donetsk, and Zaporizhzhia due to air and water pollution, coastal erosion, soil degradation, and landslides. Central parts of Zaporizhzhia and Mykolaiv are also sensitive because of intensive agriculture and erodible soils. Inland areas generally show moderate to low sensitivity, with sensitivity concentrated in economically active zones.

## Adaptive Capacity

Adaptive capacity measures the ability of ecosystems, institutions and communities to adjust to changing climatic conditions.

Unlike exposure and sensitivity, adaptive capacity reflects positive characteristics that reduce vulnerability. The methodology therefore incorporates indicators describing vegetation condition (NDVI), ecosystem productivity (Net Primary Production), protected areas and socio-economic resilience. Territories with healthier ecosystems and stronger institutional capacity are generally better equipped to adapt to future climate pressures.

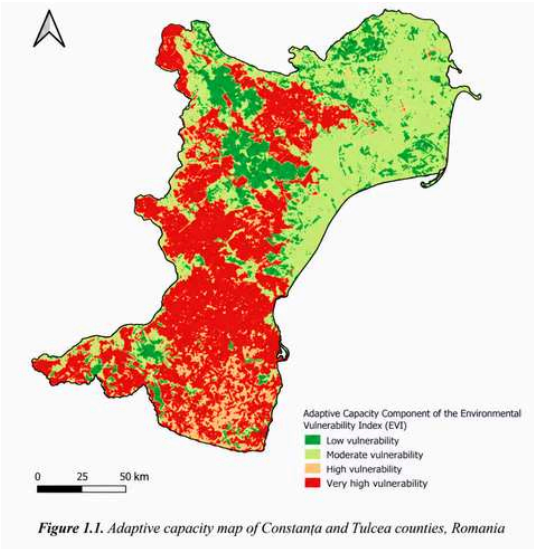



*Figure 1.1. Adaptive capacity map of Constanța and Tulcea counties, Romania*

The adaptive capacity map shows the ability of Romania's coastal regions to respond to climate change. It is assessed using protected areas, Net Primary Production (NPP), and the Normalized Difference Vegetation Index (NDVI), which reflect ecosystem health, productivity, and resilience.

The highest adaptive capacity is found in the northern coastal areas, especially around the Razim–Sinoe Lagoon, due to extensive protected areas and healthy vegetation. Lower adaptive capacity is observed around Constanța and Mangalia, where urbanization and fragmented vegetation reduce ecosystem resilience.

The adaptive capacity map (Figure 2.1) for Northern Greece shows predominantly high and very high vulnerability values. Only limited sections in the northwestern and northeastern periphery, as well as the mountain ranges, display lower vulnerability, indicating better institutional and infrastructural capacity for adaptation.

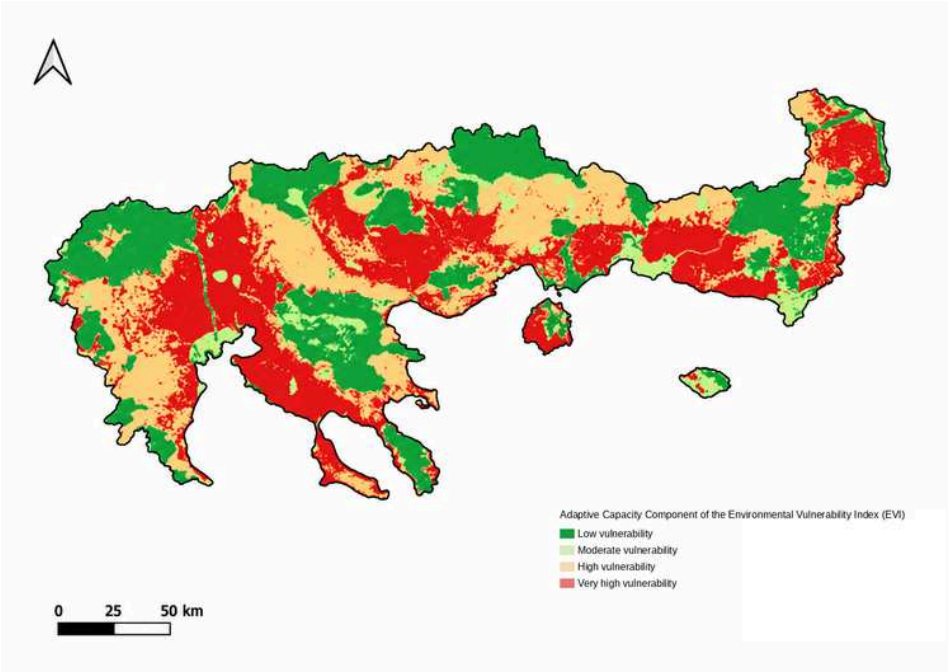



***Figure 2.1.*** *Adaptive capacity map for the regions of Central Macedonia and Eastern Macedonia & Thrace, Greece*

Adaptive capacity is lower in the coastal and lowland areas of Thessaloniki, Serres, and Xanthi due to high population density, intensive agriculture, and urban pressure. Mountainous areas, including the Rhodope and Central Macedonia ranges, show higher adaptive capacity due to forests, lower urbanization, and more sustainable land use.

Bulgaria shows significant regional differences in adaptive capacity, with low capacity observed in Burgas, Sliven, Yambol, Targovishte, Shumen, and Dobrich due to limited protected areas, lower vegetation productivity (NDVI/NPP), and weaker socio-economic conditions.

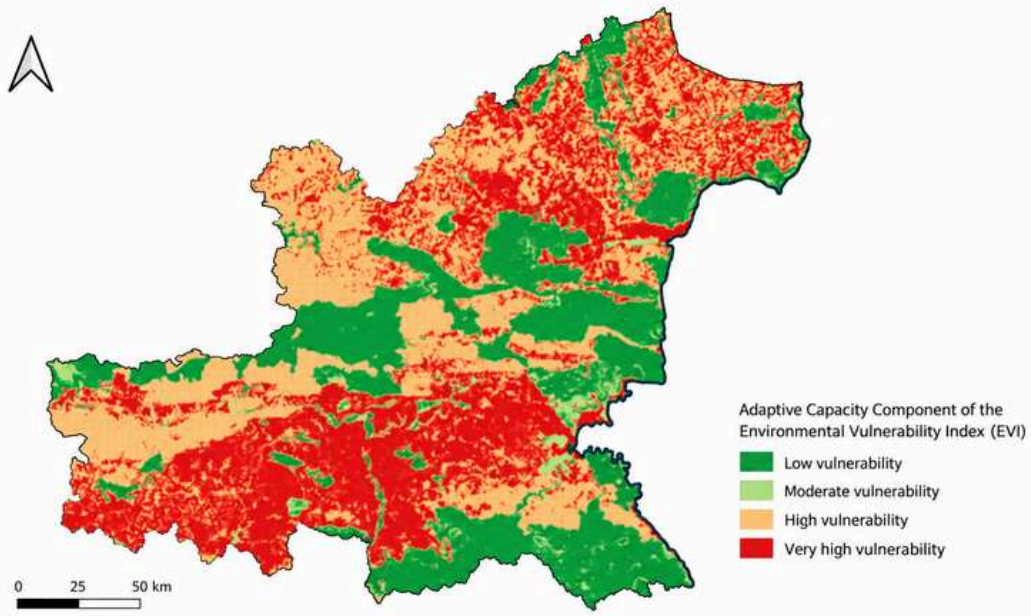



***Figure 3.1.*** *Map of the adaptive capacity of the provinces of Varna, Burgas, Stara Zagora, Yambol, Sliven, Targovishte, Shumen, and Dobrich in Bulgaria*

Moderate to high vulnerability is observed in Stara Zagora and parts of Burgas and Sliven, reflecting limited protected areas and lower vegetation productivity. Varna stands out as an exception, with higher adaptive capacity due to protected areas, healthier vegetation, and stronger economic conditions. Elsewhere, capacity remains low across most of the country, with higher-capacity pockets confined to protected, forested areas rather than following any single coastal or regional pattern.

The adaptive capacity map of southern Ukraine shows predominantly high and very high vulnerability, indicating limited ability of ecosystems and communities to adapt. Only small areas demonstrate lower vulnerability and greater adaptive potential.

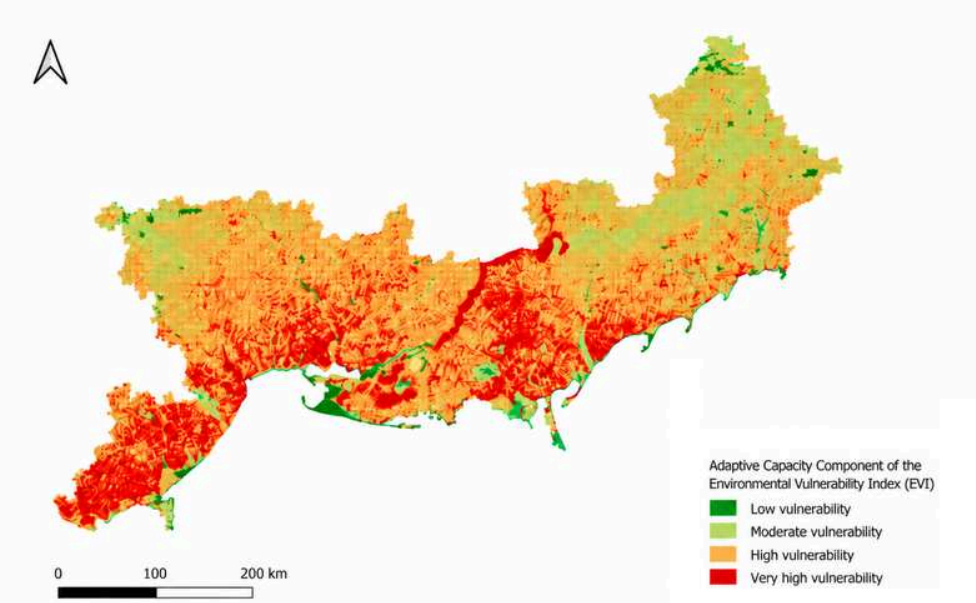



***Figure 4.1.*** *Adaptive capacity map for the Odesa, Mykolaiv, Kherson, Zaporizhzhia, and Donetsk regions of Ukraine.*

Disclaimer: Key statistical and spatial sources used for the Zaporizhzhia and Donetsk regions date from the period shortly before the full-scale invasion of 24 February 2022.

Higher adaptive capacity is observed in riverine and protected coastal areas, particularly around the Dnipro Delta lagoons in Kherson Oblast, due to healthier ecosystems. Inland and drought-affected parts of Odesa and the steppe interior show lower capacity due to soil degradation. Overall, southern Ukraine has predominantly low adaptive capacity, with higher capacity limited mainly to narrow protected coastal strips.

## 2.3 Building the Environmental Vulnerability Index

Rather than analysing each environmental variable independently, the methodology combines multiple indicators into a single Environmental Vulnerability Index (EVI), providing an integrated picture of climate vulnerability.

The index consists of four equally weighted thematic components:

| Component | Examples of Indicators |
|---|---|
| Exposure | Flood risk, fire risk, land use, population density, road density, climatic variables |
| Sensitivity | Soil degradation, pollution |
| Adaptive Capacity | Protected areas, NDVI, Net Primary Production, Socio-Economic conditions |
| Climate Scenarios | BIO5, BIO6 and BIO13 climatic projections |

## 2.4 Data Sources

The reliability of the methodology depends on the quality and diversity of the underlying datasets.

To support the assessment, project partners collected and harmonised environmental, climatic, spatial and socio-economic information from multiple sources. These datasets were standardised and integrated into a common geospatial database, allowing consistent analysis across the four participating countries.

The assessment incorporates:

- Copernicus Sentinel-1 & Sentinel-2 satellite imagery
- CORINE Land Cover
- Digital Elevation Models
- Protected areas
- Temperature, Precipitation & Wind Datasets
- Flood hazard maps
- Demographic information
- Wildfire risk
- Net Primary Production (NPP)

## 2.5 Remote Sensing and Spatial Analysis

Remote sensing technologies form one of the methodological pillars of MoreAdaptBSB.
Satellite imagery was processed to derive indicators describing vegetation condition, land cover, urban expansion and temperature anomalies. Geographic Information Systems (GIS) enabled the integration of these observations with climatic and socio-economic information, producing spatially explicit vulnerability maps.

Regional climate models, including EURO-CORDEX, WRF and PRECIS, were subsequently used to simulate future climate conditions for 2050 and 2100, allowing municipalities to anticipate future changes rather than responding only to current environmental conditions.

## 2.6 Spatial Modelling

Once all datasets had been harmonised, spatial modelling techniques were applied to calculate vulnerability across the project territories.

The methodology combines Multi-Criteria Analysis with GIS-based modelling to integrate environmental, climatic and socio-economic indicators into a common analytical framework. The resulting Environmental Vulnerability Index identifies areas characterised by high exposure, elevated sensitivity and limited adaptive capacity, highlighting priority zones for intervention.

The analyses were performed using QGIS, ArcGIS Pro, Google Earth Engine, Python, R and TerrSet/IDRISI, ensuring reproducibility and compatibility with widely used planning tools.

## 2.7 Field Verification

Scientific models require validation against real-world conditions.

For this reason, MoreAdaptBSB complemented remote sensing and spatial modelling with systematic field verification. Using a common technical guide and standardised field checklist, experts evaluated vegetation condition, erosion processes, flooding, soil characteristics, geomorphology and human pressures across selected pilot sites.

Overall, **157 verification points** were assessed. In Bulgaria, the model achieved **71.4% exact agreement** with field observations and **100% agreement within one vulnerability class.** Following calibration of indicator weights and classification thresholds, the Ukrainian assessment reached **94.7% agreement** between spatial modelling and field observations, confirming the robustness and reliability of the methodology*.

*Disclaimer: Some of the underlying statistical and spatial sources for Ukraine predate the full-scale invasion of 24 February 2022 and do not reflect subsequent changes on the ground; results should be interpreted accordingly.

# Chapter 3

# Catalogue of Nature-based Restoration Measures

## Nature-based Solutions for Climate Adaptation

The MoreAdaptBSB vulnerability assessment identifies areas with the highest climate-related risks and supports the selection of effective adaptation measures. The project promotes Nature-based Solutions (NbS) as sustainable approaches that protect, restore, and manage ecosystems while providing environmental, social, and economic benefits. NbS contribute to climate adaptation, biodiversity conservation, carbon storage, and improved water management. Combined with remote sensing and spatial monitoring, they offer an evidence-based pathway to enhance ecosystem resilience and support sustainable development of coastal and urban areas.

## Selecting the Right Solution

Nature-based Solutions should be adapted to local climate risks, environmental conditions, and ecosystem needs. MoreAdaptBSB supports municipalities in selecting suitable restoration measures based on the Environmental Vulnerability Index and the main challenges of the Black Sea Basin.

## 3.1 Reducing Urban Heat Islands

### Climate challenge

Urbanisation replaces natural vegetation with impermeable surfaces such as asphalt, concrete and buildings. These materials absorb and retain solar radiation, creating significantly higher temperatures than surrounding rural areas.

Increasing summer temperatures and more frequent heatwaves intensify this phenomenon, affecting human health, energy consumption and urban liveability.

### Recommended Nature-based Solutions

- Urban tree planting
- Green walls
- Urban forests
- Green corridors
- Pocket parks
- Green roofs
- Permeable public spaces

## Expected benefits

- Lower surface temperatures
- Reduced heat stress
- Improved air quality
- Carbon sequestration
- Increased biodiversity
- Improved public health

## Suitable locations

- Residential neighbourhoods 
- Urban centres 
- Schools 

- Commercial districts 
- Industrial zones 
- Hospitals 


## Indicators to monitor

- Land Surface Temperature
- NDVI
- Air temperature
- Surface albedo
- Tree canopy cover

# 3.3 Addressing Drought and Water Scarcity

## Climate challenge

Longer dry periods reduce soil moisture, weaken vegetation and increase pressure on agriculture, forests and urban green infrastructure.

Climate projections included in the MoreAdaptBSB methodology indicate changing precipitation patterns and increasing climatic stress throughout the project area.

### Recommended Nature-based Solutions

- Native drought-resistant vegetation
- Rainwater harvesting
- Sustainable irrigation
- Soil restoration
- Agroforestry
- Mulching

### Benefits

- Reduced irrigation demand
- Improved soil moisture
- Water conservation
- Increased resilience

### Indicators

- Vegetation productivity
- Soil moisture
- Precipitation
- NDVI

# 3.4 Combating Coastal Erosion

## Climate challenge

The Black Sea coastline is increasingly threatened by erosion and sea-level rise.

According to the MoreAdaptBSB project proposal, approximately 19% of the Black Sea coastline (around 800 km) experiences erosion rates exceeding 1 metre per year, making coastal adaptation one of the project's primary priorities.

## Recommended Nature-based Solutions

- Coastal vegetation planting
- Wetland conservation
- Saltmarsh restoration
- Living shorelines
- Dune restoration
- Native grasses

## Benefits

- Biodiversity enhancement
- Natural wave attenuation
- Reduced erosion
- Carbon storage

## Indicators

- Sediment accumulation
- Shoreline change
- Vegetation cover
- Habitat quality

# 3.5 Restoring Degraded Ecosystems

## Climate challenge

Soil degradation, pollution and habitat fragmentation reduce ecosystem resilience and biodiversity.

These factors are included within the sensitivity component of the MoreAdaptBSB methodology.

## Recommended Nature-based Solutions

- Invasive species management
- Native species planting
- Ecological restoration
- Ecological corridors
- Pollinator habitats
- Reforestation

## Benefits

- Increased ecosystem resilience
- Better habitat connectivity
- Improved biodiversity
- Carbon sequestration

## Indicators

- Habitat fragmentation
- Species diversity
- Protected areas
- NDVI



# 3.6 Increasing Adaptive Capacity

## Climate challenge

Climate resilience depends not only on environmental conditions but also on the capacity of communities and institutions to prepare, respond and recover.

The MoreAdaptBSB methodology therefore evaluates adaptive capacity through ecological and socio-economic indicators, including vegetation productivity, protected areas and socio-economic resilience.

## Recommended Nature-based Solutions

- Ecosystem restoration programmes
- Citizen participation initiatives
- Green infrastructure planning
- Protected area management
- Urban green networks
- Community gardens



## Benefits

- Improved environmental governance
- Better ecosystem services
- Community engagement
- Increased resilience

| Climate Challenge | Recommended NbS | Main Benefits |
|---|---|---|
| Urban Heat | Urban trees, green roofs, parks | Cooling, air quality, biodiversity |
| Flooding | Wetlands, bioswales, rain gardens | Water retention, flood reduction |
| Drought | Native vegetation, agroforestry | Soil moisture, resilience |
| Coastal | Dunes, coastal vegetation, living shorelines | Shoreline protection |
| Ecosystem Degradation | Ecological restoration, reforestation | Biodiversity, carbon storage |
| Low Adaptive Capacity | Green infrastructure, community gardens | Resilience, participation |

# Chapter 4

# Choosing the Right Nature-based Solution

## From Vulnerability Assessment to Practical Decision-Making

Nature-based Solutions are most effective when tailored to local vulnerabilities, climate risks, and ecosystem conditions. The MoreAdaptBSB methodology provides an evidence-based framework that combines vulnerability assessment with environmental and socio-economic indicators, helping municipalities select the most suitable solutions for long-term resilience.

### 4.1 Step 1 – Identify the Main Climate Risk

The first step is to identify the dominant climate challenge affecting the area. The vulnerability assessment distinguishes four main components: Exposure, Sensitivity, Adaptive Capacity, and Future Climate Projections, each highlighting different aspects of climate vulnerability. Together, they reveal where ecosystems and communities are most at risk and where intervention should be prioritised.

Typical questions include:

- Is the area prone to flooding or coastal inundation?
- Are high summer temperatures creating urban heat islands?
- Is coastal erosion threatening infrastructure or habitats?
- Are drought and water scarcity affecting vegetation?
- Are ecosystems degraded due to pollution, soil erosion or habitat fragmentation?
- Is adaptive capacity limited because of poor vegetation cover or insufficient green infrastructure?

### 4.2 Step 2 – Understand Local Conditions

The same Nature-based Solution may perform differently depending on local environmental conditions. Before selecting an intervention, municipalities should assess the physical and ecological characteristics of the site.

Key considerations include:

- Proximity to rivers or the coastline
- Topography and slope
- Existing vegetation
- Existing infrastructure
- Soil type and stability
- Protected area status
- Biodiversity value
- Hydrological conditions
- Land ownership

The MoreAdaptBSB database integrates these variables through spatial datasets and remote sensing, enabling local authorities to evaluate site suitability before implementation.

### 4.3 Step 3 – Prioritise Areas with the Highest Vulnerability

Municipal resources are often limited. For this reason, interventions should first target areas where climate risks are greatest and where adaptation measures are expected to have the highest impact.

The Environmental Vulnerability Index (EVI) developed by MoreAdaptBSB classifies territories according to their overall vulnerability by combining exposure, sensitivity, adaptive capacity and future climate scenarios. Areas classified as high or very high vulnerability should generally receive priority for restoration and adaptation measures.

#### Priority hierarchy

| Vulnerability Class | Recommended Action |
|---|---|
| Very High | Immediate intervention |
| High | Short-term implementation |
| Moderate | Monitoring and targeted improvements |
| Low | Preventive management & monitoring |

### 4.4 Step 4 – Match the Nature-based Solution to the Risk

The choice of intervention should directly address the identified climate challenge while considering available space, expected environmental benefits and maintenance requirements.

| Climate Challenge | Priority Nature-based Solutions |
|---|---|
| Flooding | Rain gardens, wetlands, bioswales, retention ponds |
| Heatwaves | Urban forests, street trees, green roofs, pocket parks |
| Coastal erosion | Dune restoration, living shorelines, coastal vegetation |
| Drought | Native vegetation, rainwater harvesting, agroforestry |
| Soil degradation | Ecological restoration, reforestation, grassland restoration |
| Biodiversity loss | Habitat restoration, ecological corridors, pollinator habitats |

Municipalities should also consider combining several Nature-based Solutions within the same area to maximise ecosystem services and increase resilience.

## 4.5 Step 5 – Assess Feasibility

Before implementation, municipalities should evaluate whether the selected intervention is technically, environmentally and economically feasible.

Important questions include:

### Technical feasibility

- Is sufficient land available?
- Are there underground utilities?
- Can the intervention be integrated into existing infrastructure?

### Environmental feasibility

- Will biodiversity benefit?
- Are protected habitats affected?
- Are invasive species likely to become a problem?

### Financial feasibility

- What are the construction costs?
- What maintenance will be required?
- Are funding opportunities available?

### Social feasibility

- Will local communities support the intervention?
- Can stakeholders participate in implementation and maintenance?
- Are there opportunities for educational or recreational use?

## 4.6 Step 6 – Plan for Long-Term Monitoring

Nature-based Solutions are living systems that evolve over time. Monitoring is therefore essential to determine whether interventions continue to deliver the expected environmental and social benefits.

The MoreAdaptBSB methodology demonstrates how remote sensing, field observations and environmental indicators can be combined to monitor ecosystem recovery and adaptation performance over time.

Suggested monitoring indicators include:

- vegetation cover (NDVI)
- ecosystem productivity (NPP)
- land surface temperature
- shoreline position
- flood frequency
- biodiversity indicators
- soil stability
- community use of green spaces



## 4.7 Municipal Decision Checklist

- Have the main climate risks been identified?
- Has the vulnerability map been consulted?
- Are local environmental conditions understood?
- Is the proposed Nature-based Solution appropriate for the site?
- Have maintenance needs been considered?
- Are stakeholders involved?
- Is long-term monitoring planned?
- Can the intervention be integrated into existing spatial planning strategies?

## Municipality Decision Dashboard

| Criterion | High | Medium | Low |
|---|---|---|---|
| Flood Risk | ● | | |
| Heat Stress | ● | ● | |
| Vegetation | | ● | |
| Biodiversity | | | |
| Infrastructure | ● | | |

The municipality immediately sees where intervention is needed.

STEP 1

Identify the Main Climate Risk



Flooding



Heatwaves



Coastal Erosion



Drought



Vegetation Degradation



Biodiversity Loss

STEP 2

Consult the Vulnerability Assessment

*Exposure Sensitivity Adaptive Capacity Climate Scenarios*

STEP 3

Is the Area Classified as High or Very High Vulnerability?

*Yes*

Prioritise Intervention

*No*

Continue Monitoring

STEP 4

Select the Appropriate Nature-based Solution



Urban Forests



Wetlands



Rain Gardens



Living Shorelines



Habitat Restoration



Native Vegetation

STEP 5

Evaluate Feasibility

*Technical, Environmental, Financial, Social*

STEP 6

Implement • Monitor • Adapt

*Use remote sensing, field verification and monitoring indicators to evaluate long-term performance.*

***Decision Principle**: Prioritise interventions where vulnerability is highest and select Nature-based Solutions that best match local environmental conditions and long-term resilience objectives.*

## *Key Messages*

- Base decisions on evidence rather than assumptions.
- Prioritise interventions where vulnerability is highest.
- Select Nature-based Solutions that match local environmental conditions.
- Combine multiple measures whenever possible to maximise ecosystem services.
- Integrate monitoring from the beginning to evaluate long-term effectiveness.
- Embed Nature-based Solutions within broader municipal planning, climate adaptation and biodiversity strategies.

## *Monitoring Dashboard*

NDVI

Surface temperature

Shoreline change

Public use

Water retention

Ecosystem recovery

## *The "5 Questions" Page*

- What is the main climate risk?
- What do the vulnerability maps show?
- Which Nature-based Solution addresses that risk?
- Can it be maintained over time?
- How will success be monitored?

# Chapter 5

## Nature-based Solution Selection Matrix

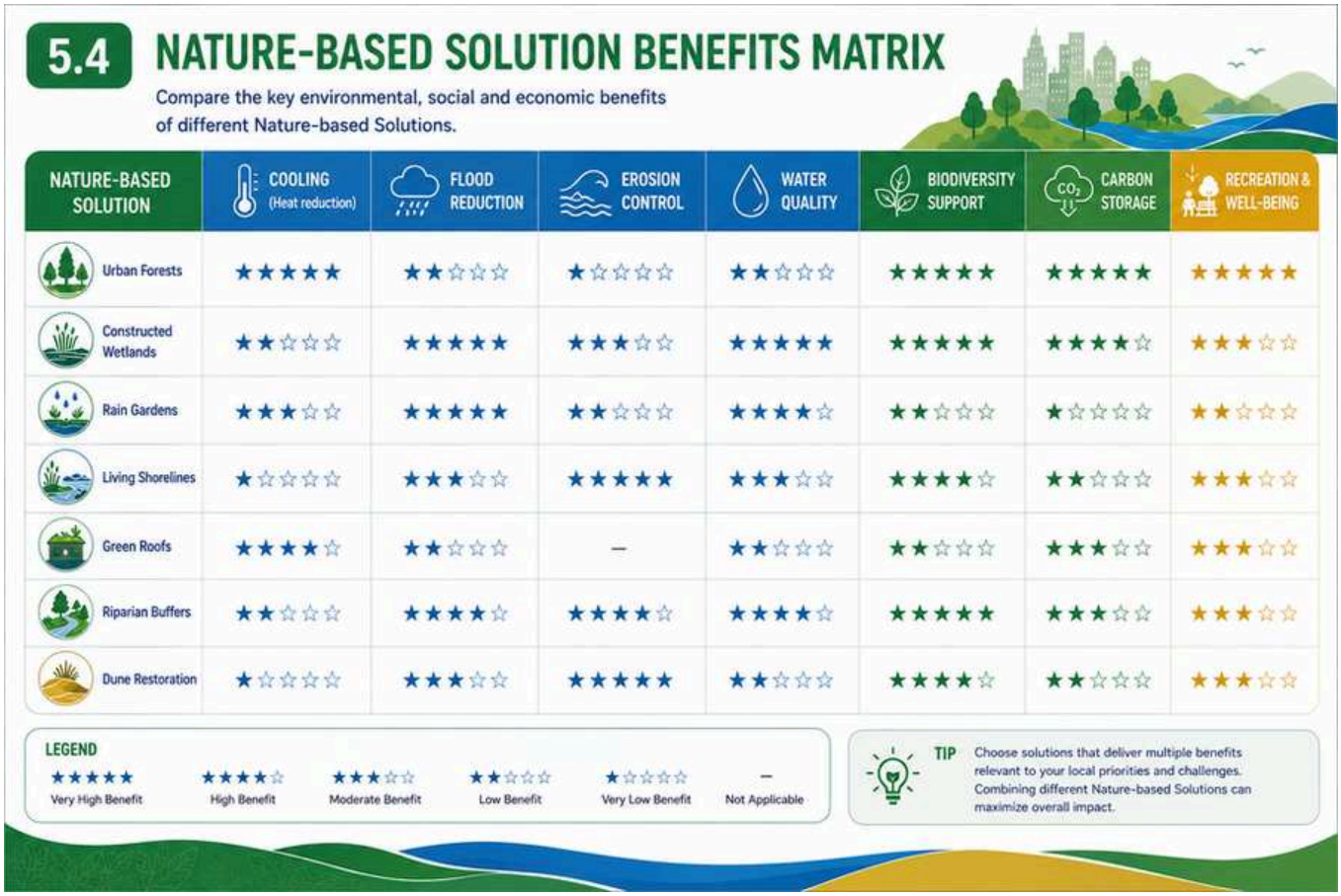


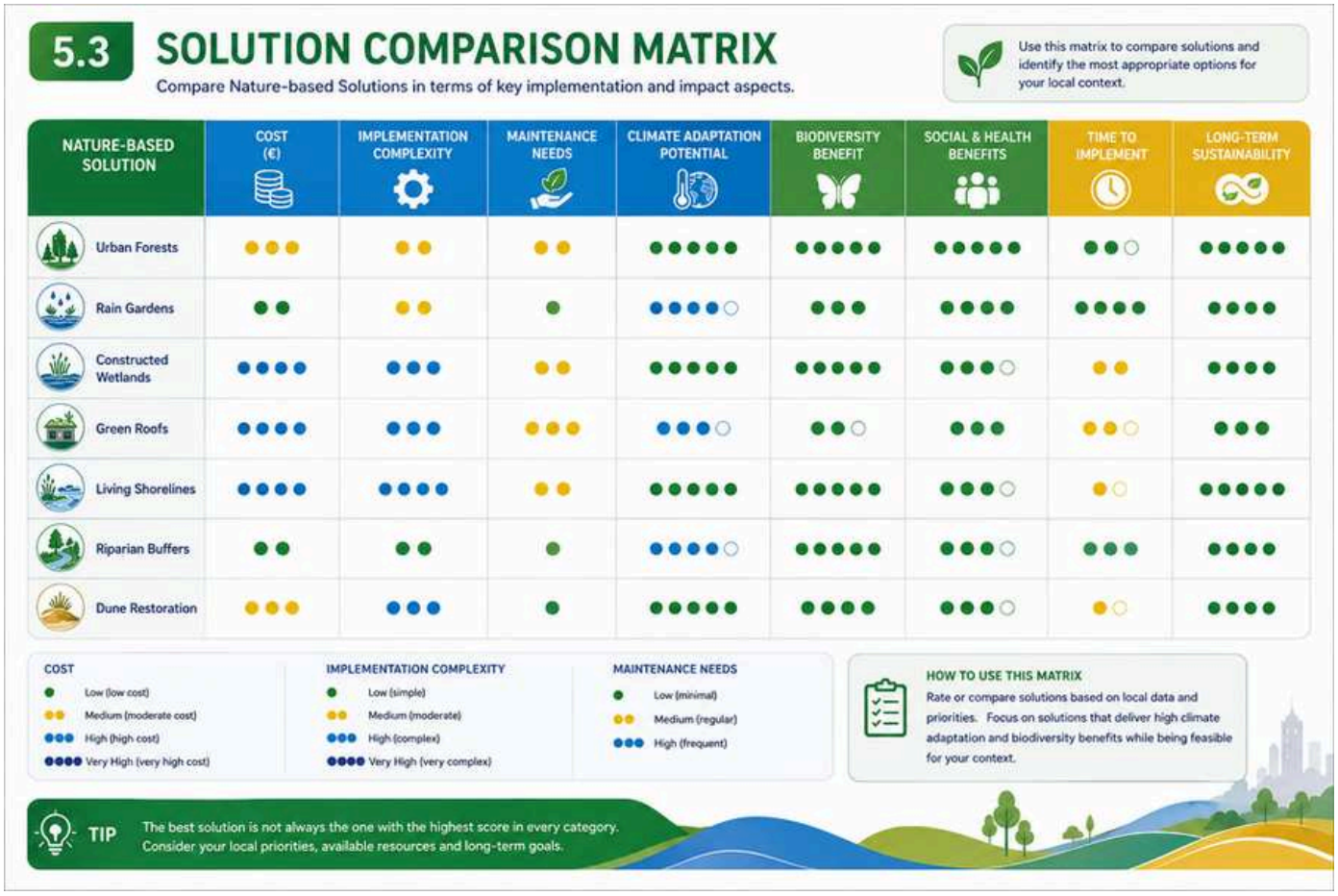
## 5.2 SITE SUITABILITY MATRIX

Identify the most suitable Nature-based Solutions according to the type of area.

| TYPE OF AREA | MOST SUITABLE NATURE-BASED SOLUTIONS | | | | |
|---|---|---|---|---|---|
| **DENSE URBAN AREAS**<br>High population density, limited green space | Urban forests | Green roofs | Green walls | Pocket parks | Permeable surfaces |
| **RESIDENTIAL AREAS**<br>Neighbourhoods, streets and public spaces | Rain gardens | Street trees | Bioswales | Permeable pavements | Community gardens |
| **INDUSTRIAL AREAS**<br>Industrial zones, business parks, logistics areas | Green roofs | Green buffers | Permeable surfaces | Stormwater wetlands | Tree planting |
| **RIVER CORRIDORS**<br>Rivers, streams and riparian zones | Riparian buffers | Wetlands | Floodplain restoration | Bank revegetation | Sediment traps |
| **AGRICULTURAL LAND**<br>Farmland, orchards and rural landscapes | Agroforestry | Hedgerows | Cover crops | Rainwater harvesting | Soil conservation |
| **COASTAL AREAS**<br>Coastlines, beaches, dunes and lagoons | Living shorelines | Dune restoration | Coastal vegetation | Salt marsh restoration | Beach nourishment |
| **PROTECTED AREAS**<br>Parks, nature reserves and conservation areas | Habitat restoration | Native vegetation | Ecological corridors | Wetland restoration | Pollinator habitats |
| **BROWNFIELD SITES**<br>Abandoned or degraded land and vacant lots | Ecological restoration | Urban forests | Native planting | Green roofs | Community green spaces |

**TIP** Consider local conditions, space availability, land ownership and community needs when selecting the most appropriate Nature-based Solutions.


5.4
NATURE-BASED SOLUTION BENEFITS MATRIX
Compare the key environmental, social and economic benefits of different Nature-based Solutions.
NATURE-BASED SOLUTION
COOLING (Heat reduction)
FLOOD REDUCTION
EROSION CONTROL
WATER QUALITY
BIODIVERSITY SUPPORT
CARBON STORAGE
RECREATION & WELL-BEING
Urban Forests ★★★★★ ★★☆☆☆ ★☆☆☆☆ ★★☆☆☆ ★★★★★ ★★★★★ ★★★★★
Constructed Wetlands ★★☆☆☆ ★★★★★ ★★★☆☆ ★★★★★ ★★★★★ ★★★★☆ ★★★☆☆
Rain Gardens ★★★☆☆ ★★★★★ ★★☆☆☆ ★★★★☆ ★★☆☆☆ ★☆☆☆☆ ★★☆☆☆
Living Shorelines ★☆☆☆☆ ★★★☆☆ ★★★★★ ★★★☆☆ ★★★★☆ ★★☆☆☆ ★★★☆☆
Green Roofs ★★★★☆ ★★☆☆☆ – ★★☆☆☆ ★★☆☆☆ ★★★☆☆ ★★★☆☆
Riparian Buffers ★★☆☆☆ ★★★★☆ ★★★★☆ ★★★★☆ ★★★★★ ★★★☆☆ ★★★☆☆
Dune Restoration ★☆☆☆☆ ★★★☆☆ ★★★★★ ★★☆☆☆ ★★★★☆ ★★☆☆☆ ★★★☆☆
LEGEND
★★★★★ Very High Benefit
★★★★☆ High Benefit
★★★☆☆ Moderate Benefit
★★☆☆☆ Low Benefit
★☆☆☆☆ Very Low Benefit
– Not Applicable
TIP
Choose solutions that deliver multiple benefits relevant to your local priorities and challenges. Combining different Nature-based Solutions can maximize overall impact.


5.3
SOLUTION COMPARISON MATRIX
Compare Nature-based Solutions in terms of key implementation and impact aspects.
Use this matrix to compare solutions and identify the most appropriate options for your local context.
NATURE-BASED SOLUTION
COST (€)
IMPLEMENTATION COMPLEXITY
MAINTENANCE NEEDS
CLIMATE ADAPTATION POTENTIAL
BIODIVERSITY BENEFIT
SOCIAL & HEALTH BENEFITS
TIME TO IMPLEMENT
LONG-TERM SUSTAINABILITY
Urban Forests
Rain Gardens
Constructed Wetlands
Green Roofs
Living Shorelines
Riparian Buffers
Dune Restoration
COST
Low (low cost)
Medium (moderate cost)
High (high cost)
Very High (very high cost)
IMPLEMENTATION COMPLEXITY
Low (simple)
Medium (moderate)
High (complex)
Very High (very complex)
MAINTENANCE NEEDS
Low (minimal)
Medium (regular)
High (frequent)
HOW TO USE THIS MATRIX
Rate or compare solutions based on local data and priorities. Focus on solutions that deliver high climate adaptation and biodiversity benefits while being feasible for your context.
TIP
The best solution is not always the one with the highest score in every category. Consider your local priorities, available resources and long-term goals.


5.5
DECISION SUPPORT TOOL
Selecting the Right Nature-Based Solution for Your Area
Follow this step-by-step guide to identify and select the most appropriate Nature-based Solution based on your local context.
Use local data, stakeholder knowledge and this matrix to make informed decisions and build climate resilience through nature.
1 IDENTIFY THE CLIMATE CHALLENGE
What is the main climate challenge in your area?
Urban Heat Islands
Flood Risk
Coastal Erosion
Drought & Water Scarcity
Vegetation Degradation
Biodiversity Loss
Riverbank Instability
Landslide-Prone Slopes
OUTPUT
Selected climate challenge(s) for your area
2 ASSESS VULNERABILITY AND SITE CONTEXT
What are the key vulnerability factors and site characteristics?
CONSIDER:
Exposure to climate hazards (e.g., heat, floods, drought)
Sensitivity of people, ecosystems and infrastructure
Existing environmental conditions (green cover, soil, water, biodiversity)
Land use and spatial characteristics
Available space and resources
Stakeholder and community needs
OUTPUT
Summary of vulnerability factors and site context
3 EXPLORE SUITABLE NATURE-BASED SOLUTIONS
Which Nature-based Solutions are suitable for your area?
Use the Nature-based Solution Selection Matrix (5.1) to explore options
Check site suitability (see Matrix 5.2)
Compare options using the Solution Comparison Matrix (see Matrix 5.3)
Review the benefits using the Benefits Matrix (see Matrix 5.4)
OUTPUT
List of suitable Nature-based Solutions for your site
4 EVALUATE AND PRIORITIZE OPTIONS
Which options are most appropriate and feasible?
Assess each option based on benefits, feasibility, cost, maintenance and risks
Consider social acceptance and stakeholder support
Check potential funding and resources
Prioritize solutions that deliver multiple benefits and are implementable in your context
OUTPUT
Prioritized list of Nature-based Solutions with justification
5 PLAN, IMPLEMENT AND MONITOR
Put your solution into action and track results.
Develop an implementation plan (design, partners, timeline, budget)
Implement the selected solution(s)
Monitor and evaluate performance and benefits
Adapt and improve based on monitoring and feedback
OUTPUT
Implementation plan and monitoring framework
TIP
Engage stakeholders and local communities at every step.
Local knowledge is essential for effective and sustainable solutions.
REMEMBER
Nature-based Solutions are most effective when they are locally relevant, ecosystem-based and people-centered.

# Chapter 6

## From Planning to Implementation: A Practical Guide for Municipalities

### *Purpose*

Provide local authorities with a practical roadmap for moving from vulnerability assessment to the implementation and long-term management of Nature-based Solutions.
Unlike the previous chapter, this one should combine short explanatory text (30%) with practical checklists, timelines, and diagrams (70%).

## 6.1 The Municipal Implementation Cycle



## 6.2 Stakeholder Engagement

Municipal implementation depends on cooperation among multiple actors.

| Stakeholder | Main Role |
|---|---|
| Municipality | Technical guidance |
| Environmental agencies | Technical guidance |
| Universities | Scientific support |
| Local communities | Co-design and stewardship |
| NGOs | Awareness raising |
| Businesses | Investment and maintenance |
| Citizens | Monitoring and feedback |

## 6.3 Municipal Readiness Checklist

A one-page checklist that local authorities can complete before implementation.

### Governance

- Climate adaptation included in municipal strategy
- Political commitment secured
- Cross-department coordination established

### Technical

- Vulnerability assessment completed
- Priority areas identified
- Site surveys available

### Financial

- Budget identified
- Funding opportunities explored
- Maintenance budget available

### Social

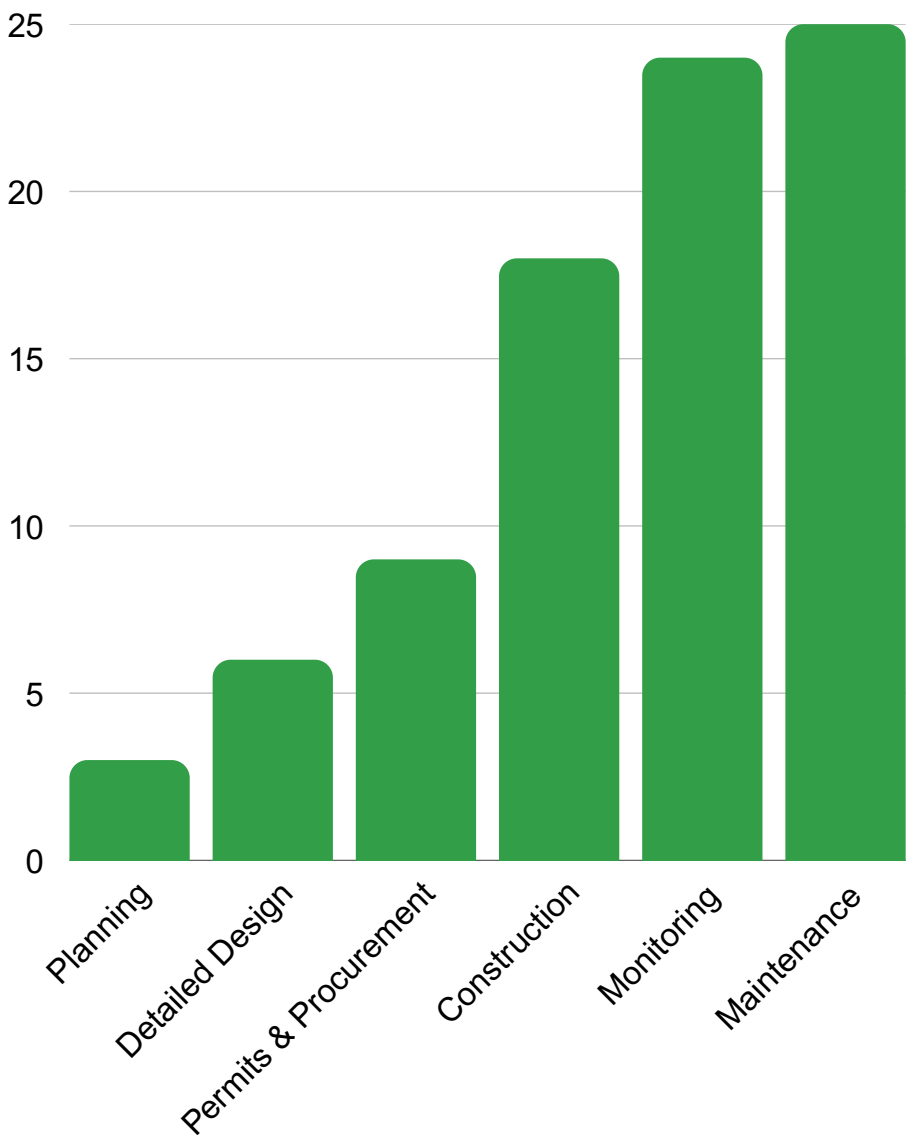
- Citizens consulted
- Landowners informed
- Communication plan prepared

## 6.4 Funding Opportunities

- European Regional Development Fund (ERDF)
- Interreg Programmes
- LIFE Programme
- Horizon Europe
- CAP Rural Development
- National climate adaptation funds
- Municipal budgets
- Public-private partnerships

## 6.5 Typical Implementation Timeline

A Gantt-style timeline.



## 6.6 Common Challenges and Recommended Solutions

| Challenge | Recommended Action |
|---|---|
| Limited funding | Combine multiple funding instruments |
| Limited technical expertise | Collaborate with universities and experts |
| Public resistance | Early stakeholder engagement |
| Land ownership conflicts | Establish cooperation agreements |
| Long maintenance needs | Develop long-term management plans |
| Climate uncertainty | Apply adaptive management principles |

## 6.7 Key Messages

Successful Nature-based Solutions are not defined only by good design. Their long-term effectiveness depends on evidence-based planning, stakeholder participation, adequate financing, continuous monitoring, and adaptive management. Municipalities that integrate these elements into their decision-making processes are better positioned to build resilient, sustainable and climate-adapted communities.

# Chapter 7

# Monitoring, Evaluation and Adaptive Management

## *Purpose*

Help municipalities establish a practical monitoring framework to assess the effectiveness of Nature-based Solutions over time and support evidence-based adaptive management.

## *7.1 Why Monitoring Matters*

**Monitoring Cycle**



## 7.2 Monitoring Framework

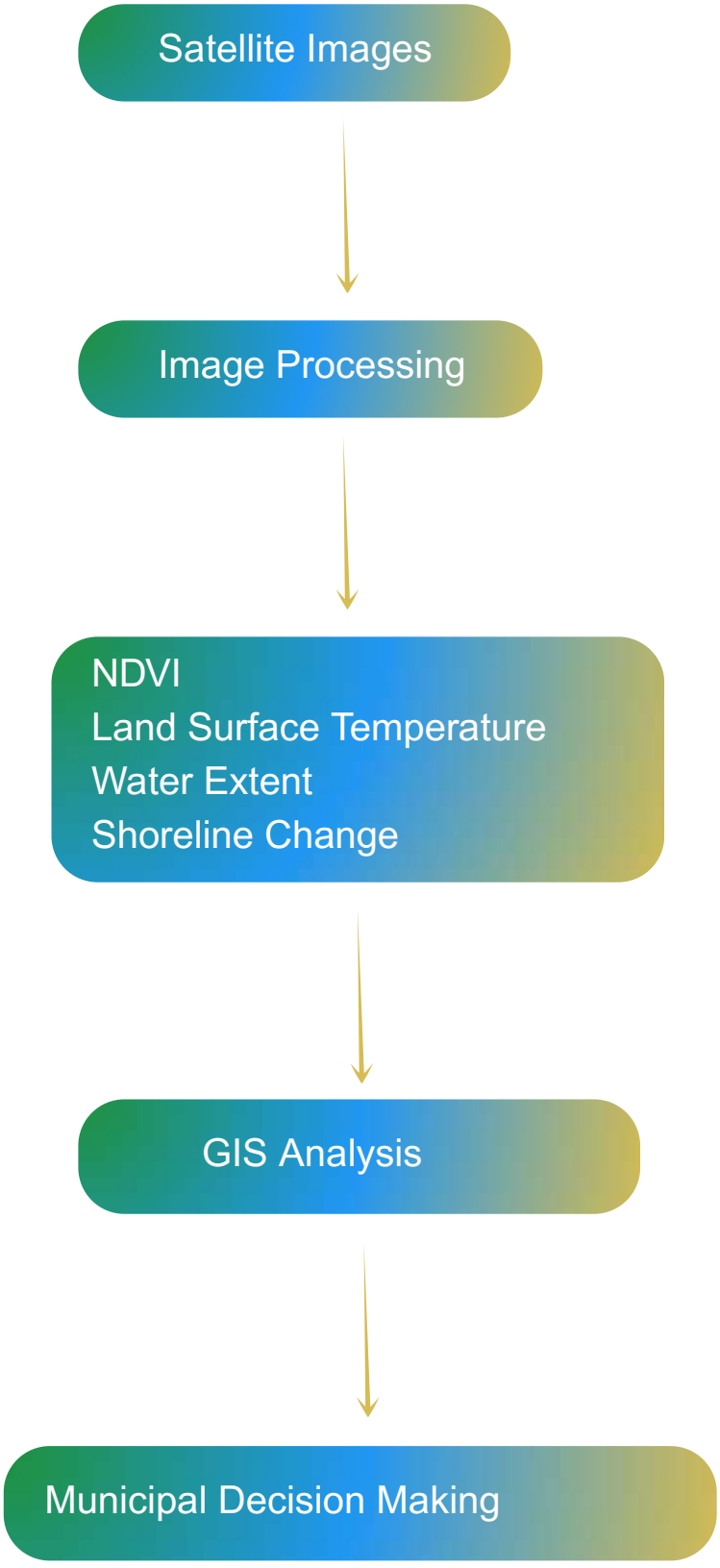
| Step | Description |
|---|---|
| Establish baseline | Record initial conditions before intervention |
| Select indicators | Environmental, social and economic |
| Collect data | Remote sensing and field surveys |
| Analyse trends | Compare with baseline |
| Report results | Annual municipal reports |
| Adapt management | Modify interventions where needed |

## 7.3 Key Performance Indicators (KPIs)

| Indicator | Method | Frequency |
|---|---|---|
| Vegetation cover (NDVI) | Sentinel-2 | Annual |
| Surface temperature | Satellite imagery | Summer |
| Flooded area | Remote sensing | After major events |
| Shoreline position | UAV/Satellite | Annual |
| Habitat condition | Field surveys | Annual |
| Species richness | Ecological surveys | Annual |
| Carbon storage | Vegetation assessment | Every 3–5 years |
| Public satisfaction | Questionnaires | Annual |

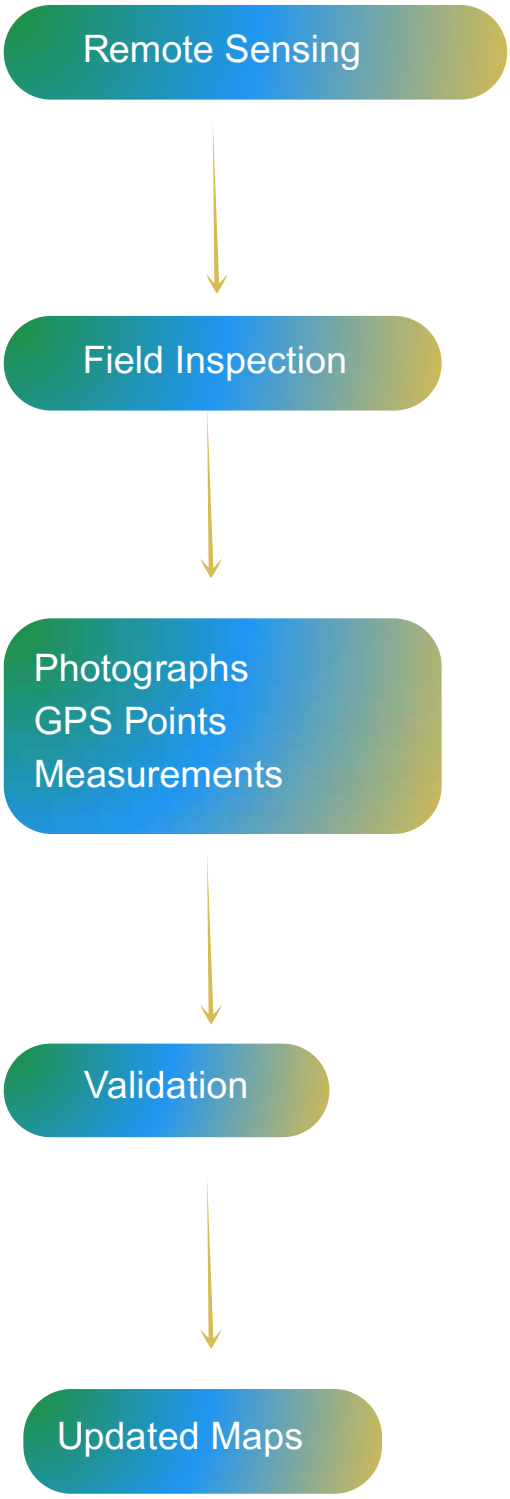
## *7.4 Remote Sensing Dashboard*

MoreAdaptBSB monitoring approach

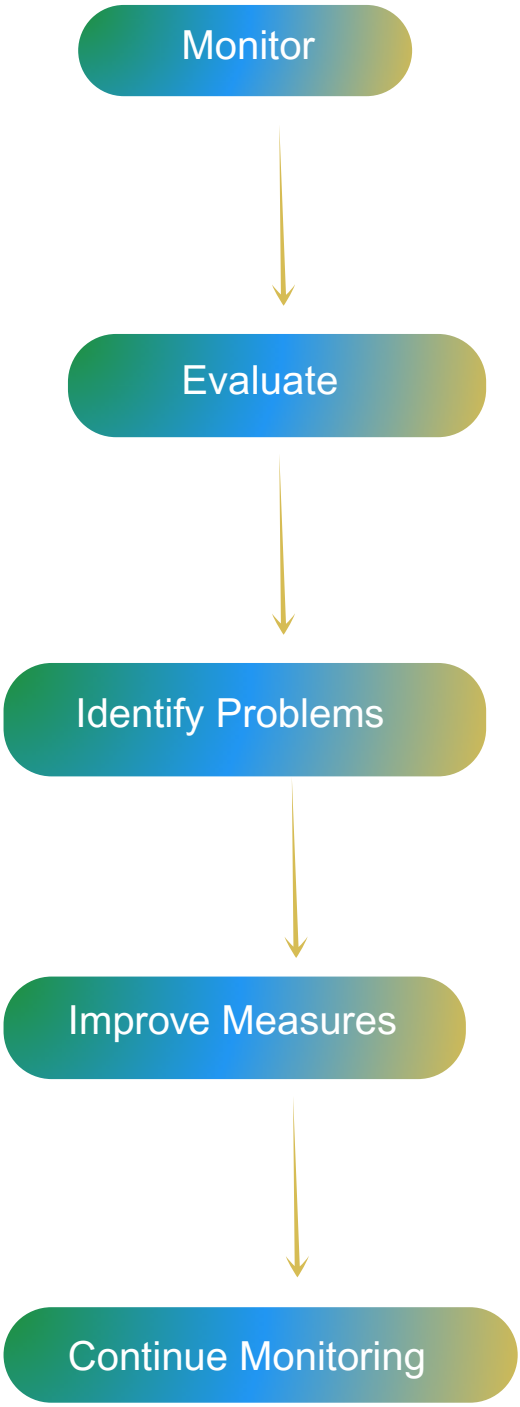


## 7.5 Field Verification

Illustrate how satellite observations are validated.




## 7.6 Adaptive Management




This emphasises that Nature-based Solutions are dynamic and require ongoing adjustment rather than one-time implementation

## *7.7 Traffic-Light Performance Dashboard*

A visual dashboard suitable for annual municipal reporting.

| Indicator | Status |
|---|---|
| Urban cooling |  |
| Flood reduction |  |
| Flood reduction |  |
| Vegetation recovery |  |
| Biodiversity |  |
| Public satisfaction |  |
| Public satisfaction |  |

Include a legend:

 Target achieved

 Requires attention

 Corrective action needed

## *7.8 Practical Recommendations*

Effective monitoring is essential for ensuring that Nature-based Solutions continue to deliver climate adaptation benefits over time. Municipalities should combine remote sensing technologies, field verification, and locally relevant indicators within an adaptive management framework. Continuous evaluation enables informed decision-making, supports efficient resource allocation, and strengthens long-term climate resilience.

**Building resilient coastal communities starts today. Explore the MoreAdaptBSB methodology and implement Nature-based Solutions for a more climate-resilient Black Sea Region.**

## Partners

## Website

## Discover More