

# REGIONAL GUIDANCE DOCUMENT ON SOIL SAMPLING AND MONITORING DESIGN AND PARAMETERS

Deliverable 2 of WP1-11 Depollution Soil: Monitoring of diffuse soil pollution

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## ABBREVIATIONS

ALB	Albania
BIH	Bosnia and Herzegovina
EC	European Commission
EPA	Environmental Protection Agency
EUROSOLAN	European and Eurasian Soil Laboratory Network
GLOSOLAN	Global Soil Laboratory Network
JRC	Joint Research Centre of the European Commission
LUCAS	Land Use and Coverage Area frame Survey
MKD	North Macedonia
MNE	Montenegro
SML	EU Soil Monitoring and Resilience Law
SOP	Standard Operating Procedure
SRB	Serbia
WB	Western Balkans
WB6	Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, Serbia
WP	Work package
XXK	Kosovo

# 1. EXECUTIVE SUMMARY

The Western Balkans economies (WB6) stand at a crucial point in their alignment with the European Union's environmental acquis, particularly concerning the protection and monitoring of soil resources. Currently, soil degradation is extensive across the region, driven primarily by severe erosion, which affects approximately 40 % of the total land area, historical industrial and mining legacies resulting in widespread contamination, and diffuse agricultural pollution.<sup>1</sup> This challenge is accompanied by a lack of comprehensive, up-to-date field data and fragmented national monitoring structures.<sup>2, 8</sup>

The enactment of the Directive (EU) 2025/2360 on Soil Monitoring and Resilience (EU Soil Monitoring Law) on December 16, 2025<sup>3</sup>, mandates a fundamental shift toward a scientifically rigorous and harmonized monitoring framework across all Member States.

Participation in the upcoming Land Use/Cover Area frame statistical Survey (LUCAS) Soil survey in 2027 would represent the most effective and critical mechanism for the WB6 to establish a baseline that is already compliant with the statistical and methodological requirements of the EU Soil Monitoring Law. The revised LUCAS methodology, which incorporates advanced parameters such as increased sampling depth (0–30 cm), bulk density measurements, and biological sampling (DNA extraction), directly addresses the physical, chemical, and biological descriptors mandated by the Directive.<sup>4</sup>

## Recommendations for WB6:

1. **Institutional Alignment:** delineation of statistically sound Soil Districts and homogeneous Soil Units based on criteria established in the Directive (soil type and land use). This institutional clarity would be a prerequisite for designing the statistically sound sampling grid required for compliance with the Directive.<sup>3</sup>
2. **Methodological Transition:** adoption of the advanced LUCAS 2027 sampling protocol, prioritizing dedicated deep soil profile surveys and improving the capacity for soil monitoring where existing national capacity is severely lacking as identified during the collaboration in EU4Green.<sup>8</sup>
3. **Capacity Building and Standardization:** request technical support by the Joint Research Centre (JRC) and the regional coordination platform of the Western Balkans Soil Partnership (WBSP)<sup>7</sup> to improve the technical capacity on soil monitoring and standardize analytical methods (SOPs) and upgrade environmental laboratories.

Each economy has a unique set-up and so specific recommendations are provided to ensure possible alignment. Given that the Directive requires the first comprehensive reporting and assessment of soil health by Member States by December 16, 2031<sup>3</sup>, enabling fully prepared participation in LUCAS Soil survey 2027 would be essential, especially for those accession candidates planning for entry in the EU within this window (MNE, ALB). Specific next steps

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<sup>1</sup> Index numbers refer to numbers in chapter 5 References

for preparation of alignment may contain harmonizing soil unit delineation and investment in capacity building and will require significant financial support, technical assistance and technical standardization. Failure to establish a compliant monitoring baseline during this window may risk significant delays in fulfilling fundamental legal obligations necessary for the EU accession process.

## 2. SOIL MONITORING AT EUROPEAN LEVEL

### 2.1. LUCAS Soil surveys

#### 2.1.1. Description and organisation of LUCAS Soil surveys

The Land Use/Cover Area frame statistical Survey (LUCAS) Soil module is recognized as the definitive, harmonized, and regular collection of soil samples for the entire territory of the European Union (EU). Since its inception in 2009, the LUCAS Soil survey has provided a crucial, comparable baseline of soil properties across all major land cover types.<sup>9</sup> The LUCAS survey's design is based on a statistically rigorous master sample grid, comprising 400,000 geo-referenced points in 2022 laid over the entire EU territory, from which specific points are selected for detailed field observation and soil sampling.<sup>10</sup>

The fundamental purpose of LUCAS Soil is to provide evidence-based scientific data to support EU policy requirements, particularly those stemming from the EU Soil Thematic Strategy and, more recently, the European Green Deal. Key policy issues that the survey aims to address include mitigating specific threats to soil functions, such as the loss of soil organic matter, erosion, pollution, and the decline of soil biodiversity.<sup>9</sup> By collecting soil data, LUCAS serves as an essential foundation for modeling soil degradation processes and assessing soil condition across the continent.

#### 2.1.2. The LUCAS 2015 Survey and Western Balkans extension

The LUCAS 2015 survey represented a critical extension of the EU monitoring framework, carrying out sampling across all EU-28 Member States and expanding coverage to five economies in the Western Balkans.<sup>4</sup>

##### *Organisation and scope:*

In the Western Balkans, a total of 1,015 soil samples were collected.<sup>11</sup> The distribution across the participating economies was:

- Serbia: 412 points (40%)
- Bosnia and Herzegovina: 243 points (24%)
- Albania: 120 points (12%)
- Montenegro: 120 points (12%)
- North Macedonia: 120 points (12%)

Critically, Kosovo\*<sup>2</sup> was not included in the LUCAS 2015 campaign, resulting in a notable lack of a harmonized baseline dataset for this economy.

#### *Geographical context and sampling methodology:*

The sampled locations reflected the region's complex geography, including the Dinaric Arc mountain range and the low-altitude Pannonian Valley. Over half of the points (53.5%) were found below 500 m, particularly in the Pannonian region, with 16.7% in the 1,000 m to 1,500 m range. Points located above 1,500 m were minimally represented, with only four points recorded at such elevations in Albania. The land cover was predominantly forest and semi-natural areas (55.5%), followed by agricultural areas (40.0%), though national land use patterns varied significantly, e.g., Montenegro with 79.2% forest, Serbia with 55.1% agriculture.<sup>11</sup>

#### *Soil parameters considered:*

In 2015, the standard LUCAS sampling procedure involved collecting a composite sample of topsoil, consisting of five subsamples taken with a spade from a depth of 0-20 cm. Vegetation residues and stones were removed prior to homogenization and air-drying.<sup>4</sup>

The laboratory analysis focused on key physical and chemical parameters relevant to soil function and degradation modeling:

- pH (CaCl) and pH (H<sub>2</sub>O)
- Soil Organic Carbon (OC) content
- CaCO<sub>3</sub>
- Particle size distribution (texture: sand, silt, clay) and coarse fragments
- Electrical conductivity (EC).<sup>5</sup>

### **2.1.3. Methodological advancements in LUCAS 2022**

The LUCAS 2022 Soil module introduced substantial technical revisions driven by the evolving requirements of the European Green Deal, particularly the Climate Law and the Biodiversity Strategy. These changes mark a definitive move from basic soil status description toward quantifying dynamic soil functions and ecosystem services, which is vital for assessing soil resilience.<sup>9</sup>

#### **Key innovations in LUCAS 2022<sup>4</sup>:**

- **Increased sampling depth:** The standard sampling depth was increased from 0-20 cm to 0-30 cm. This change was necessary for achieving more accurate and statistically

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robust assessments of Soil Organic Carbon (SOC) content in arable soils, supporting improved carbon stock accounting for climate mitigation strategies and LULUCF reporting.

- **Soil biodiversity assessment:** A doubling of the collection of fresh samples (1,410 locations) was undertaken to extract DNA from the soil, enabling the assessment of soil biodiversity, a critical descriptor for soil health.
- **Physical properties and structure:** Repeat assessments of bulk density (BD) were made at multiple depths (0-10 cm, 10-20 cm, and 20-30 cm) at a subset of locations (2,655). BD measurements are crucial for calculating accurate SOC stocks (moving from concentration to volumetric stock) and assessing soil compaction.
- **Expanded coverage and protocol refinement:** The survey included collection of samples from high elevations (>1500 m) to address previous underrepresentation in vulnerable areas. Protocols were revised for woodland sites, including the mandatory collection of litter samples.
- **Extended chemical analysis:** Measured properties systematically covered macronutrients (Nitrogen (N), Phosphorus (P), Potassium (K)) and extended extractable nutrient analysis, along with Electrical Conductivity (EC).<sup>9</sup>

The methodological shift toward 0-30 cm sampling, the incorporation of biodiversity assessment, and the routine measurement of bulk density confirm that the EU monitoring paradigm now prioritizes the quantification of **dynamic soil functions and ecosystem services** (such as carbon sequestration, water regulation, and biological resilience).<sup>9</sup> For the WB6, this means that compliance with future EU standards demands not just routine chemical monitoring, but significant investment in advanced analytical capabilities and a pedological understanding of functional change, moving beyond simple topsoil chemistry.

*Table1: Comparison of core parameters: LUCAS 2015 vs. LUCAS 2022*

Parameter/Feature	LUCAS 2015	LUCAS 2022
Sample Depth	0-20 cm (topsoil only)	0-30 cm
Core parameters analysed	pH, SOC, CaCO <sub>3</sub> , texture, EC	All 2015 parameters + N, P, K, extractable nutrients/metals
Biological Assessment	Not systematically included	Fresh samples collected for DNA analysis/soil biodiversity
Bulk Density Measurement	Limited assessment	Repeat assessment at various depths (0-10, 10-20, 20-30 cm)

## 2.2. EU Soil Monitoring Law

The Directive (EU) 2025/2360 on Soil Monitoring and Resilience, which entered into force on December 16, 2025, represents the first binding legislative framework dedicated to achieving healthy soils in the EU by 2050. Member States are required to transpose the Directive into national law by December 16, 2028.<sup>3</sup>

### 2.2.1. Aim of Soil Monitoring Law and legislative context

The primary aim of the Directive is to establish a legal framework for monitoring and assessing the health of soils across all land cover types, including agricultural land, forests, and urban areas. The legislation is intended to ensure a high level of environmental and health protection by addressing key soil threats, such as erosion, loss of organic matter, contamination, compaction, salinisation, and loss of soil biodiversity. Ultimately, the Law seeks to reduce contamination to levels that no longer pose risks to human health or the environment, continuously improve soil resilience, and put in place a solution for managing contaminated sites.

The cornerstone of the Directive is the requirement for Member States to submit their first comprehensive report on the implementation and assessment of soil health to the European Commission by December 16, 2031.<sup>3</sup> This establishes a clear timeline for the WB6 to develop capacities and implement compliant monitoring systems in relation to the ambitions becoming members of the EU.

### 2.2.2. Monitoring Approach: Soil Districts and Soil Units

The monitoring framework mandated by the Law adopts a nested, hierarchical governance and statistical approach centered on Soil Districts and Soil Units.<sup>3</sup>

**Soil Districts:** These serve primarily as the geographical and administrative units for governance. Member States are required to appoint one or more competent authorities for each Soil District to ensure the monitoring and assessment activities are properly undertaken. Monitoring soil health within the Law occurs at the level of the Soil Unit, which falls under the purview of the designated Soil District authorities.

**Soil Units:** The Soil Unit is the fundamental assessment unit of the Directive. Soil Units must be established across the entire territory of the Member State, defined to reflect a certain degree of homogeneity in soil characteristics, including soil type, climatic conditions, and land use. Crucially, a Soil Unit may consist of non-adjacent areas due to the spatial variability of soil properties.

**Definition Criteria:** To ensure sufficient harmonization across the EU, the minimum criteria for defining Soil Units must be defined at the European level, taking into account at least the following characteristics<sup>3</sup>:

1. **Soil type:** Utilizing resources like the map of soil regions of the European Union and Adjacent Countries (which builds on the World Reference Base for Soil Resources).
2. **Land use:** Using harmonized land use categories (e.g. those defined in Regulation (EU) 2018/841 for reporting).

Member States may also incorporate additional factors such as climatic and environmental conditions, including environmental zones or river basins. The institutional requirement to appoint competent authorities for specific Soil Districts implies that political clarity and administrative capacities must be established before technical monitoring can begin

effectively. This is particularly relevant for the WB6, especially in contexts such as Bosnia and Herzegovina, where monitoring is currently fragmented across administrative entities.

### 2.2.3. Requirements for sampling design and field work

The EU Soil Monitoring Law mandates a monitoring design that achieves a high degree of statistical certainty, moving beyond the regional statistical assessments typical of previous LUCAS campaigns.<sup>3</sup>

**Statistical rigor:** The grid of sampling points must be determined using geostatistical methods and must be sufficiently dense to provide an estimation of the area of degraded soils throughout the Member State's territory within an uncertainty of not more than 5% at the Soil Unit level. This 5% uncertainty rule is one of the most demanding technical requirements, forcing a significant increase in sampling density compared to the sparse LUCAS 2015 network (1,015 points spread across the entire WB region).<sup>11</sup> This transition necessitates expert geostatistical modeling to optimize the placement of sampling points efficiently within each newly defined Soil Unit.

**Sample collection in the field:** While the EU methodology will guide sampling, the general approach requires sampling points to be representative of their respective Soil Units. Standard practice, as adopted by LUCAS 2022, emphasizes composite sampling and, critically, the collection of soil cores for repeated Bulk Density measurements at various depths (0-10 cm, 10-20 cm, 20-30 cm).<sup>4</sup> The monitoring design should also integrate existing data from national surveys and EU-level initiatives, such as the LUCAS Soil campaigns.<sup>3</sup>

**Soil archiving:** Member States are encouraged, though not strictly obliged, to preserve a representative subset of soil samples in physical archives for at least two monitoring cycles (10 to 12 years). This long-term archiving supports future research and trend analysis, potentially reducing long-term monitoring costs.<sup>3</sup>

### 2.2.4. Soil Descriptors and Threats (Annex I, Part A, B, C, D)

The Directive mandates Member States to monitor a set of common descriptors covering the physical, chemical, and biological dimensions of soil health, aligning these indicators with the seven major threats to soil.<sup>3</sup>

**Part A** (soil descriptors with criteria for healthy soil condition established at Union level): Descriptors in this area address threats such as salinisation, loss of soil organic carbon, and compaction. Monitoring involves basic parameters like soil organic carbon concentration, electrical conductivity (ec) and soil texture but relies heavily on field and laboratory assessments of bulk density and soil structure.

**Part B** (soil descriptors with criteria for healthy soil condition established at Member State level): This dimension addresses threats including erosion, contamination, reduced water retention and infiltration capacity and excess of nutrients. Core parameters include Soil Organic Carbon (SOC) stocks, water holding capacity, saturated hydraulic conductivity, air capacity, phosphor and metals.

Contamination monitoring is greatly strengthened. The Commission will establish an indicative watch list of soil contaminants within 18 months of the law entering force (by mid-2027), including relevant PFAS substances (Per- and Polyfluoroalkyl substances) and pesticides.<sup>3</sup> The focus on emerging contaminants (PFAS, POPs, pharmaceuticals) necessitates significant analytical upgrades across the WB6, due to novelty of the subject.<sup>2</sup>

**Part C** (soil descriptors without criteria): This addresses the excess of nutrients, acidification, compaction, loss of soil biodiversity and soil contamination by pesticides and PFAS. Monitoring may be supported by LUCAS, in particular through its focus on DNA extraction and the development of new biological indicators.<sup>4</sup>

**Part D** (soil sealing and soil removal indicators): The Law explicitly requires the monitoring of soil artificialisation, which is subdivided into **soil sealing** (covering soil with impermeable materials) and **soil removal** (removal of soil for construction or mining).<sup>3</sup>

*Tab. 2: Soil Monitoring Law descriptors (Annex I) and required monitoring dimensions*

<b>Aspect of soil degradation</b>	<b>Relevant threats addressed</b>	<b>Key descriptors/ parameters</b>	<b>Recommendation for WB implementation</b>
Part A	Salinisation, soil organic carbon, compaction	Soil organic carbon concentration, electrical conductivity (EC), texture, bulk density	Rigorous field sampling (BD) in particular subsoils
Part B	Erosion, contamination, nutrient imbalance, water retention	SOC stock, P, heavy metals, water holding capacity, saturated hydraulic conductivity, air capacity	Laboratory capacity upgrade, nutrient and contamination assessment
Part C	excess of nutrients, acidification, compaction, loss of biodiversity, contamination	N, pH, BD, DNA/biological Indicators, pesticides and PFAS (watch list)	Establishing protocols for fresh sample handling, contaminant screening, and advanced analytics
Part D	Soil sealing and soil removal	Soil sealing and soil removal, de-sealing and net-sealing	Provide remote sensing data and investigate soil removal

### 2.2.5. Operational Trigger Values (OTVs) and Sustainable Target Values (STVs)

The criteria used to assess soil health are divided into two essential categories, both of which are defined and applied by the Member States, based on their specific soil units and local context<sup>3</sup>:

- **Sustainable Target Values (STVs):** These are non-binding, aspirational long-term objectives intended to reflect the vision of achieving healthy soil by 2050. They guide Member States in promoting sustainable soil management practices.
- **Operational Trigger Values (OTVs):** These represent thresholds for healthy soil condition of certain soil descriptors. Exceedance of OTVs indicates that support for soil health and soil resilience is needed.

The definition of these OTVs and STVs is a national responsibility, allowing Member States the flexibility to tailor compliance measures to their unique local challenges such as naturally elevated background levels of heavy metals or the specific pedological characteristics of unique soil types. However, the definition of these values demands high scientific confidence, which should be supported by the robust, standardized baseline data for WB6 provided by LUCAS 2027.

### 2.2.6. How LUCAS Soil supports the EU Soil Monitoring Law

The Directive explicitly acknowledges the role of LUCAS, noting that the Commission will revise its LUCAS Soil sampling programme to provide direct support for the Law's implementation. LUCAS serves three critical functions in supporting the new legal framework:

1. **Establishing a harmonized baseline:** LUCAS provides comparable, high-quality, standardized data across the EU, which is essential for EU-wide assessments and comparisons.<sup>9</sup>
2. **Informing national network design:** Member States are encouraged to build upon the LUCAS methodology and data to refine their national systems, utilizing the LUCAS sample locations and protocols to meet the stringent statistical requirements for Soil Unit delineation.<sup>3</sup>
3. **Developing and validating methodologies:** The Joint Research Centre (JRC) and the Mission 'A Soil Deal for Europe' platform with its research projects are developing harmonized methods, tools, and datasets that directly support the implementation of the Law. These methodological innovations (e.g. new descriptors or digital sampling tools) should be incorporated into upcoming rounds of the LUCAS Soil survey.

## 2.3. Future LUCAS Soil surveys

The next iteration of the LUCAS Soil survey should be fundamentally adapted from the previous campaigns to align with the statistical and thematic requirements of the EU Soil Monitoring Law.

### 2.3.1. Comparison with and adaptation from LUCAS 2022

While LUCAS 2022 introduced crucial methodological enhancements such as the 0-30 cm depth, bulk density measurement, and biodiversity sampling, its core statistical stratification was still largely designed to provide robust assessments at the NUTS 2 (regional) or NUTS 0 (country) level for key variables like SOC.<sup>5</sup>

The EU Soil Monitoring Law, however, requires monitoring networks to demonstrate statistical confidence (uncertainty less than 5%) at the much finer geographical scale of the **Soil Unit**.<sup>3</sup> This discrepancy necessitates a complete redesign of the sampling strategy of LUCAS Soil surveys. The WB6 should ensure that their participation fully embraces these adaptations to achieve legislative compliance.

### **2.3.2. Necessary adaptations for LUCAS 2027**

Discussions within expert forums, such as the EUSO Technical Working Group on Monitoring<sup>12</sup>, and subsequent JRC planning documents discuss adjustments to the LUCAS design:

#### *Statistical stratification and density:*

The future LUCAS campaign will need to move away from a uniform, regular grid approach toward a stratified, geostatistical design on the basis of the spatial distribution of soil properties, land cover and climate. For the inclusion of the Western Balkans, it would be helpful if the JRC applies its expertise in geostatistical modeling to generate a specific, compliant sampling plan tailored to the WB6.

#### *Subsoil and profile monitoring:*

A major deficiency of previous surveys was the focus solely on topsoil (0-20 cm or 0-30 cm). Many crucial soil functions, such as carbon sequestration potential, deep nutrient cycling, water storage capacity, and contaminant filtering, depend heavily on subsoil properties.<sup>6</sup> Therefore, the 2027 survey plans must incorporate a dedicated soil profile survey module at a subset of reference points. This will involve collecting samples and analyzing physico-chemical parameters at depths below 30 cm. For the Western Balkans, which experiences increasing intensity of droughts and floods due to climate change<sup>1</sup>, subsoil data on water regulation capacity is vital for developing effective climate adaptation strategies.

#### *Contaminants:*

To align with the chemical descriptors of the Directive, the LUCAS survey must systematize and expand its pollutant analysis. This involves a strategic transition from periodic screening of heavy metals to systematic monitoring of the emerging pollutants identified in the EU watch list, notably PFAS, Persistent Organic Pollutants (POPs), and specific pesticide residues.<sup>9</sup> This necessitates refined laboratory analytical methods and procurement of specialized equipment, which is a major area of required investment for the WB6.

#### *Biological descriptors and fresh sample handling:*

The collection and standardized handling of fresh samples for DNA extraction must be formalized and integrated into routine operations to satisfy the biological descriptor requirements (Annex I, Part C). The expertise and methodologies developed under the Mission Soil projects should be integrated in the future to ensure that the biological data collected is scientifically robust and policy-relevant.

*Integration with National Networks:*

A core objective for future LUCAS planning is to improve integration with national monitoring initiatives.<sup>12</sup> The WB6 should seize this opportunity to align their existing national monitoring protocols (e.g. related to the Nitrates Directive or local pollution monitoring) with the standardized LUCAS methodology. This alignment facilitates data interoperability, strengthens the overall regional dataset, and helps Member States reduce the administrative burden associated with parallel reporting schemes.

*Table 3: Required adaptations for LUCAS Soil 2027*

<b>Requirement of EU Soil Law</b>	<b>LUCAS 2022 Standard</b>	<b>Adaptation required for LUCAS 2027</b>
Robust assessment at Soil Unit level (5% uncertainty)	Statistical design for NUTS 0/2 level	Geostatistical stratification based on spatial distribution of soil properties, land cover and climate
Assessment of multiple soil functions	Topsoil (0-30 cm) focus for SOC	Inclusion of a systematic soil profile survey component (sampling deeper layers) in a subset of points
Monitoring of emerging contaminants	Increased measurement of metals and plant protection residues in a subset	Systematically target contaminants listed in the EU watch list; formalize analysis of POPs and PFAS
Integration of existing data and national networks	Limited involvement, focus on EU-wide harmonisation	Increased collaboration mechanisms for integration with national soil monitoring data

## 3. RECOMMENDATIONS FOR SOIL MONITORING IN WB6

### 3.1. Region Western Balkans

The participation of the WB6 in the next LUCAS Soil survey must be viewed as a cohesive regional effort, strategically aligned under the Green Agenda for the Western Balkans (GAWB) and secured through dedicated EU support mechanisms. The overview of the status of soil monitoring, focusing particularly on diffuse soil pollution in agricultural land, confirms that while several institutions collect soil data, the fragmented legal frameworks and varying stages of implementation necessitate a unified approach through LUCAS Soil.

#### **Technical and Financial Support Mechanisms:**

The **Joint Research Centre (JRC)** is the primary technical and scientific partner, providing the ancillary environmental data necessary for the 2015 baseline.<sup>11</sup> The JRC, through the EU4Green project, has supported regional workshops to discuss LUCAS requirements and enhance regional analytical capacities. The JRC could provide the pedological and geostatistical expertise needed to design the monitoring networks in WB6 that satisfy the 5% uncertainty criterion stipulated by the EU Law.

The **Western Balkans Soil Partnership (WBSP)**, established under the FAO Global Soil Partnership, is regarded as the dedicated regional platform for coordinating technical exchange and ensuring that soil actions are integrated within the GAWB framework. The WBSP's role is essential for facilitating cross-border harmonisation, particularly for future Soil Unit delineation and soil sampling in WB6.

Financial support could be secured through targeted allocations from the Instrument for Pre-accession Assistance (IPA III), specifically leveraging the priority area for environment and climate resilience. Given the acute nature of degradation in the WB6 with high rates of soil erosion and severe industrial contamination impacting public health the region should frame its LUCAS participation as essential for risk mitigation and public health protection, thereby strengthening the case for securing necessary EU resources.

### 3.2. Albania

**Current status & challenge:** Albania has established a localized network of 26 monitoring sites, but resource constraints severely limit the scope and intensity of its soil monitoring efforts. The monitoring network, part of the National Environmental Monitoring Programme (EMSA), tracks parameters like fertility, salt content, heavy metals, hydrocarbons (near point sources), and erosion rates. This monitoring, however, is not continuous due to budget limitations<sup>8</sup>.

#### **Recommendations based on the collaboration within EU4Green:**

- **Thematic Focus:** Prioritize monitoring descriptors related to water retention capacity and soil organic matter stability, in particular in coastal and mountainous soil units. Participation in the new subsoil sampling module would be essential to gather the data required for evidence-based climate adaptation planning.<sup>1</sup>
- **Methodology:** Ensure comprehensive sampling of high-altitude mountain zones (elevations above 1500 m), improving the minimal representation seen in the 2015 survey (only four points recorded).<sup>11</sup>
- **Institutional set-up:** The existing 26 sites should be standardized and integrated as high-confidence reference points within the new LUCAS-aligned soil monitoring network.
- **Data Leverage:** The extensive, ongoing domestic programme, the Agriculture Land Inventory of Albania Programme, has already covered 62% of the agriculture land and produced a detailed GIS database of soil characteristics (including EC, CEC, SOC, and erosion risk). LUCAS Soil survey results should be included in this GIS database and the EMSA system.

**LUCAS 2027:** The primary goal is to secure external funding to be able to participate in LUCAS Soil survey to expand the soil monitoring network density to satisfy the 5% uncertainty rule of the SML in future.

### 3.3. Bosnia and Herzegovina

**Current status & challenge:** Bosnia and Herzegovina faces a critical challenge of institutional fragmentation, with soil management and monitoring responsibilities split between the Federation of Bosnia and Herzegovina (FBiH) and Republika Srpska (RS), as no state-level law regulates the issue.<sup>8</sup> Despite this, BiH contributed a substantial number of points to the 2015 LUCAS campaign (24%).<sup>11</sup> Legacy contamination from historical mining and industrial activities poses a major threat to soil health.<sup>1</sup>

#### **Recommendations based on the collaboration within EU4Green:**

- **Thematic Focus:** The LUCAS sampling design should be stratified to ensure adequate representation across known industrial and mining risk zones.<sup>1</sup> Special focus should be given to monitoring heavy metals to assess potential problems in the economy.
- **FBiH Integration:** The Federal Institute for Agropedology already conducts continuous monitoring of agricultural land contamination, aiming for 500 sampling points in a four-year cycle (first cycle completed in 2023). This existing data on heavy metals and organic pollutants should be directly mapped and linked to new LUCAS Soil survey results to maximize efficiency.
- **RS Implementation:** The RS must prioritize the adoption of the Rulebook of soil monitoring methodology, which is currently missing, despite the Law on Agriculture

Land prescribing monitoring. The RS has collected over 7,000 samples for soil fertility control since 2014 on a project basis.

- **Institutional set up:** In relation to a future implementation of the SML it is necessary to enforce a unified sampling protocol and establish a central, transparent data repository for soil monitoring data, overcoming administrative barriers. The technical requirement for coherent reporting within defined Soil Districts can be leveraged to drive necessary institutional consolidation.
- **Data Leverage:** The substantial 2015 LUCAS soil dataset should be used to inform preliminary geostatistical analysis, helping to define the Soil Units and minimizing the cost and complexity of defining homogeneity.

**LUCAS 2027:** In case external funding to participate in LUCAS Soil survey is secured, the standardized EU methodology should be utilized as a mandate for achieving functional and technical unification of soil monitoring protocols across administrative entities.

### 3.4. Kosovo

**Current status & challenge:** Kosovo\* was excluded from the LUCAS 2015 campaign, resulting in a critical lack of harmonized soil health baseline data.<sup>11</sup> No soil monitoring has been established up to now, and the Hydro-Meteorological Institute's responsibility for soil quality control is not yet activated due to lack of resources.<sup>8</sup>

#### **Recommendations based on the collaboration within EU4Green:**

- **Thematic Focus:** Mandate comprehensive chemical monitoring (Annex I, Part B), specifically targeting heavy metals, PAH, and POP residues in industrial and urban-influenced soil units.<sup>1</sup>
- **Strategic Planning:** Full JRC/WBSP support would be helpful for the initial Soil Unit delineation and subsequent geostatistical design to ensure the new sampling points are highly representative and meet the demanding 5 % uncertainty rule.
- **Data alignment:** Integrate the planned actions of the domestic Agriculture Land Inventory of Western Kosovo (which includes a 300 x 300 m grid sampling, analysis of physical-chemical parameters, heavy metals, organic pollutants, and soil biology) with the LUCAS methodology to avoid duplication and ensure standardization.
- **Capacity Building:** focus should be on personal for the soil sampling in the field for LUCAS 2027 and training and equipping of laboratories to handle complex parameters (bulk density and specialized contaminant analysis) required by the Directive for the future implementation of the SML.
- **SML alignment:** The absence of a legacy dataset offers a strategic advantage, allowing Kosovo\* to align directly with the EU Soil Monitoring Law without the need to reconcile older data infrastructures, potentially enabling faster alignment with the Directive's 2028 transposition deadline.

**LUCAS 2027:** Kosovo\* should establish a fully compliant, statistically sound soil health baseline from scratch adopting the most advanced LUCAS protocols and apply for external funding to participate in LUCAS Soil survey.

### 3.5. Montenegro

**Current status & challenge:** Montenegro is characterized by its mountainous terrain and possesses the largest proportion of forest and semi-natural areas in the region (79.2 %).<sup>11</sup> The terrain is highly susceptible to severe soil erosion, which is identified as the most prevalent degradation process in the region.<sup>1</sup> State-funded annual monitoring of hazardous and harmful materials in soil is being realized in the vicinity of industrial zones, roads, landfills, and populated places.<sup>8</sup>

#### **Recommendations based on the collaboration within EU4Green:**

- **Thematic Focus:** Utilize the revised LUCAS 2022 protocol for woodland sites, focusing on the collection of litter samples and accurate measurement of organic layer thickness.<sup>4</sup> Prioritize the monitoring of biological descriptors (Part C) through DNA extraction in forested units to establish a soil biodiversity baseline.<sup>3</sup>
- **Contaminant Integration:** The national monitoring has improved by introducing analysis of long-term organic pollutants (POPs).<sup>8</sup> These specific local monitoring parameters should be integrated with the EU watch list requirements and considered in the LUCAS survey 2027 if carried out in Montenegro as well.
- **Methodology:** Maximize the collection of samples in the underrepresented high-altitude mountain zones (the Alpine biogeographical region).<sup>11</sup> Implement the new LUCAS gully erosion assessment across the economy to characterize the most severe degradation threat.<sup>1</sup>
- **Policy Linkage:** Ensure the SOC stock data feeds directly into national LULUCF reporting and climate mitigation strategies.<sup>13</sup>
- **SML alignment:** Given the high forest coverage, Montenegro's monitoring strategy should strategically emphasize ecosystem service monitoring over purely agricultural concerns, utilizing the most complex technical modules of the LUCAS survey (DNA, multi-depth BD).

**LUCAS 2027:** The focus should be on accurately quantifying Soil Organic Carbon (SOC) stocks and establishing baselines for soil biodiversity, leveraging the advanced LUCAS protocols designed for non-agricultural and high-altitude land.

### 3.6. North Macedonia

**Current status & challenge:** The development of a law on soil protection and a soil strategy is planned under the project Promoting Sustainable Land Management (SLM). However, no systematic soil monitoring is conducted so far.<sup>8</sup> The economy contains large agricultural

areas dominated by unique soil types, particularly Smonitsa (Chromic Vertisols). These clay-rich, highly dynamic soils are prone to specific degradation challenges, including salinization, sodicity, and compaction.<sup>1</sup> The economy's soil is vulnerable to diffuse pollution from neighboring thermal power plants (acid rain) and heavy metal contamination (lead, cadmium, zinc) from mining areas (Zletovo, Toranica, Sasa) and the Veles smeltery.<sup>2</sup>

#### **Recommendations based on the collaboration within EU4Green:**

- **Thematic Focus:** Monitoring must prioritize chemical descriptors related to nutrient balances, salinization, and sodicity, especially in agricultural soil units.<sup>9</sup> Results must be tightly linked to policies such as the implementation of the Nitrates Directive.
- **Contamination Mapping:** Utilize the LUCAS stratification to systematically map pollution alongside highways and in regions impacted by mines/smelters, particularly those areas where soils are not protected against floods from contaminated rivers (e.g. Zletovo, Kamenica, Toranica).
- **Methodology:** Implement rigorous field protocols for measuring physical descriptors, specifically bulk density, in Smonitsa soil units.<sup>4</sup> The high shrink-swell capacity of these Vertisols requires specialized training for surveyors to ensure accurate data collection.<sup>1</sup>
- **Legislative alignment:** The development of the planned law on soil protection and a soil strategy must be closely linked to the LUCAS methodology to establish a national sampling system that enables direct comparison of results.
- **Institutional:** Ensure Soil Unit delineation accurately captures the unique pedo-climatic heterogeneity, including concentrations of cold semi-arid climate (BSk) zones.<sup>11</sup>

**LUCAS 2027:** The priority should be to generate standardized functional data, particularly physical properties and SOC, to inform climate adaptation strategies (NAP) and ensure representative monitoring across pedologically complex agricultural units.

### **3.7. Serbia**

**Current status & challenge:** Serbia possesses the largest existing LUCAS dataset (412 points, 40 % of the WB6 total) and the largest proportion of agricultural areas (55.1 %).<sup>11</sup> Soil monitoring legislation (Law on Soil Protection) is in place, and the National Soil Monitoring Programme has been adopted in Sept. 2025. Systematic control of agricultural soil fertility is extensive: over 23,878 agricultural soil samples were tested in central Serbia, more than 3,000 in Vojvodina.<sup>8</sup> The main monitoring challenge involves addressing diffuse agricultural pollution (e.g. nutrients and pesticides) and achieving updated contamination estimates.<sup>2</sup>

#### **Recommendations based on the collaboration within EU4Green:**

- **Thematic Focus:** Prioritize monitoring of chemical descriptors in agricultural zones, specifically pesticide residues (including those on the EU watch list) and ensuring balanced nutrient inputs to support Farm2Fork sustainability objectives. <sup>2</sup>
- **Methodology:** Implement repeat sampling at a significant subset of the 2015 sites to establish a temporal trend analysis for SOC and heavy metals. This will provide robust evidence required for the first EU reporting cycle in 2031.
- **Data Validation:** The existing extensive fertility and chemical data (including a project on diffuse pollution from pesticides and fertilizers) and the 2015 LUCAS dataset should be used to conduct preliminary geostatistical analysis for delineating Soil Unit boundaries and optimizing the placement of new, denser LUCAS monitoring points.
- **Legislative Finalization:** Prioritize the establishment of the National Soil Monitoring Network which should incorporate the LUCAS 2015 points as a historical baseline.
- **SML alignment:** Serbia's substantial existing baseline is a crucial strategic asset that can significantly reduce the complexity and cost of initial Soil Unit stratification, allowing resources to be focused on targeted monitoring in high-risk agricultural pollution areas.

**LUCAS 2027:** Leveraging the existing data richness, the priority with the next LUCAS soil survey should be to establish robust temporal trends for key indicators in intensive agricultural areas.

## 4. OUTLOOK - NEXT STEPS FOR WB6 PARTICIPATION IN LUCAS 2027

The successful participation of the Western Balkans economies in the LUCAS 2027 survey and subsequent alignment with the EU Soil Monitoring Law asks for decisive action in the future (2026-2027). The timeline is constrained: the Directive is now in force (December 2025), requires transposition by 2028, and mandates the first soil health assessment by 2031. Involvement in the LUCAS Soil sampling survey is envisaged as the key mechanism to support the WB6's endeavor to understand the status of their soil resources and identify areas for protection from diffuse soil pollution.

### 4.1. Strategic and institutional preparation (2026)

1. **Formalize EC/WBSP support:** The WB6 will depend on technical and financial support agreements with the European Commission and the WBSP to secure assistance for the geostatistical sampling design and methodological standardization for the participation in the LUCAS survey 2027 and the future implementation of the EU Soil Monitoring Law. To prepare for this, regional EU4Green workshops were held in Nov. 2024, in Sarajevo, BiH, and in Nov. 2025 in Skopje, MKD, to discuss the requirements regarding monitoring design, soil sampling, and parameters to be analysed for LUCAS Soil, and compare them with the EU Soil Monitoring Law requirements.
2. **Harmonized Soil Unit delineation:** For the alignment with the EU Soil Monitoring Law, it should be envisaged to achieve a harmonized regional delineation of Soil Units and Districts. This preparatory step should utilize existing and forthcoming JRC mapping products and harmonized land use data to ensure compliance with the statistical requirements for the new EU soil monitoring grid.
3. **Capacity building investment:** Dedicated IPA III funds should be utilized for capital investment in upgrading environmental laboratory capabilities. This includes procuring specialized field equipment (e.g. bulk density sampling rings) and high-end analytical instruments necessary for processing complex samples (e.g., DNA sequencing, persistent organic pollutant and PFAS detection).

### 4.2. Technical and methodological standardisation (2027)

1. **Finalize sampling design:** The JRC-supported geostatistical sampling design must be implemented, finalizing the exact coordinates for the LUCAS 2027 points. This design should explicitly account for oversampling in high-risk contamination zones and in currently underrepresented areas, e.g. high-altitude regions.
2. **Implement GLOSOLAN/EUROSOLAN Quality Control (QC/QA):** Opportunities for cooperation with the European and Eurasian Soil Laboratory Network (EUROSOLAN), part of the Global Soil Laboratory Network (GLOSOLAN), should be explored.

- Rigorous Standard Operating Procedures (SOPs) should be established and enforced across all WB6 economies for both field sampling and laboratory analysis.
- Soil material from the LUCAS samples could be analyzed in WB6 laboratories according to national standards and, if possible, according to the Standard Operating Procedures (SOPs) of GLOSOLAN.
- This harmonisation would be helpful for the comparison of economy, EU, and global standards. Furthermore, deriving transfer functions from this comparative analysis would enable the comparison of new data with previously generated data from past soil investigations, allowing for the assessment of potential changes in soil status over time.

Successful preparation for and participation in LUCAS 2027 is the necessary action for the WB6 to acquire the compliant, standardized baseline data required by the EU Soil Monitoring Law. Failure to prepare fully for this survey window will critically delay the WB6's ability to meet these new legal obligations and may threaten their overall environmental alignment with EU accession criteria.

## 5. REFERENCES

- 1 Belis, C., Djatkov, D., Dobricic, S., De Meij, A., Kolarević, S., Arias Navarro, C., Wojda, P., Jones, A., Lamy, M.-C., Porcel Rodriguez, E., Marinov, D. And Lettieri, T., Status of Environment and Climate in the Western Balkans, Second edition, Publications Office of the European Union, Luxembourg, 2024, <https://data.europa.eu/doi/10.2760/1865356>, JRC140061.
- 2 Arias Navarro, C., Vidojević, D., Zdruli, P., Yunta Mezquita, F., Jones, A. And Wojda, P., Soil pollution in the Western Balkans, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/21207, JRC138306
- 3 European Parliament, Soil Monitoring Law - Consolidated Text Directive (EU) 2025/2360, 2025.
- 4 Jones, A., Orgiazzi, A., Panagos, P., Scarpa S., Havenga, C. & Van Eynde, E. LUCAS 2022 Soil Module. An Overview, JRC Technical Reports, 2024.
- 5 JRC-ESDAC, LUCAS, <https://esdac.jrc.ec.europa.eu/projects/lucas>
- 6 Fernández-Ugalde O., Jones A., Tóth G., Orgiazzi A., Panagos P., Eiselt B. LUCAS Soil Component: proposal for analysing new physical, chemical and biological soil parameters, JRC Technical Reports, 2016, EUR28038.
- 7 FAO, Western Balkans Soil Partnership, <https://www.fao.org/global-soil-partnership/regional-partnerships/europe/western-balkans-soil-partnership/en/>
- 8 Huber, S., Friesl-Hanl, W., Report on Status of Soil Monitoring in WB6. EU4Green, IPA/2021/429-949, Umweltbundesamt GmbH, Austria, 2024.
- 9 Jones, A., Fernandez Ugalde, O., Scarpa, S. and Eiselt, B., LUCAS Soil 2022, EUR 30331 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-21079-5, doi:10.2760/74624, JRC121253.
- 10 Ballin, M., Barcaroli, G., Masselli, M., New LUCAS 2022 sample and subsamples design: Criticalities and solutions, 2022 edition, Eurostat statistical working papers, ISBN 978-92-76-53401-3, ISSN 2315-0807, doi: 10.2785/957524, 2022.
- 11 Arias Navarro, C., Vidojević, D., Zdruli, P., Yunta Mezquita, F., Jones, A. and Wojda, P., Lucas Soil 2015 in the Western Balkans, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/071913, JRC138305.
- 12 JRC, EU Soil Observatory, WG Soil Monitoring, [https://esdac.jrc.ec.europa.eu/euso/TWG\\_MONITORING](https://esdac.jrc.ec.europa.eu/euso/TWG_MONITORING)

13 RCC, 2024 Report on the Implementation of the Green Agenda for the Western Balkans Action Plan (GARI), 2024.

14 Vidojevic, D., Zdruli, P., Čivić, H., Marković, M., Milić, St., Mukaetov, D., Knežević, M., Sharku, A. Soil management in the Western Balkans – gaps and recommendations. Standing working group for regional rural development (SWG), Skopje, 2022, ISBN 978-608-4760-41-2.